Attachment A

Disturbed area runoff characteristics

A.1 Introduction and purpose

This attachment to the revised water management report (WMR PIR-RTS) (Appendix J to the PIR-RTS) describes the approach and results of disturbed area runoff and wet weather monitoring undertaken as part of the baseline water quality monitoring for Snowy 2.0. These results have been used to characterise the expected quality of untreated stormwater runoff from areas that will be disturbed by construction phase 1 activities (see WMR PIR-RTS for a description of construction phase 1 activities). The water quality profile of treated stormwater discharge from proposed construction phase 1 stormwater management systems is also established based on the water quality of untreated runoff and the treatment benefits of the proposed controls.

A.2 Background

Results from two rounds of disturbed area samples from Lobs Hole were documented in the water characterisation report (WCR) (Annexure A to the water assessment). These results were applied to inform estimates of project level water quality characteristics of discharges from construction phase 1 stormwater water management systems. The water quality characteristics were presented in the water management report (WMR EIS) (Annexure D to the water assessment) and were applied to assess residual impacts associated with stormwater discharges.

Following the submission of the EIS, in November 2019 additional disturbed area runoff monitoring was undertaken near proposed disturbance areas at Marica and Tantangara, increasing the spatial coverage of the data set. The project level water quality characteristics were revised using this updated data set and are documented in this attachment. These revised profiles are applied to the updated assessment of residual impacts that is described in the WMR PIR-RTS.

A.3 Disturbed area monitoring

A.3.1 Monitoring approach

Runoff samples were collected from existing access tracks and areas disturbed by historic construction and mining activities. These areas are referred to as existing disturbed areas as they were constructed/disturbed prior to activities associated with the project. Samples were typically collected from roadside drainage or areas where minor to moderate concentrated runoff from a disturbed area occurred. Typical disturbed area monitoring locations are shown in Photograph A.1.

Additional samples were collected from minor watercourses located downstream of disturbed areas and larger watercourses such as the Yarrangobilly River. These sample locations are referred to as receiving waters in this attachment. Receiving water samples provide a snapshot of water quality when runoff from disturbed areas is occurring. Typical receiving water monitoring locations are shown in Photograph A.2.

Photograph A.1 Examples of disturbed area runoff monitoring locations

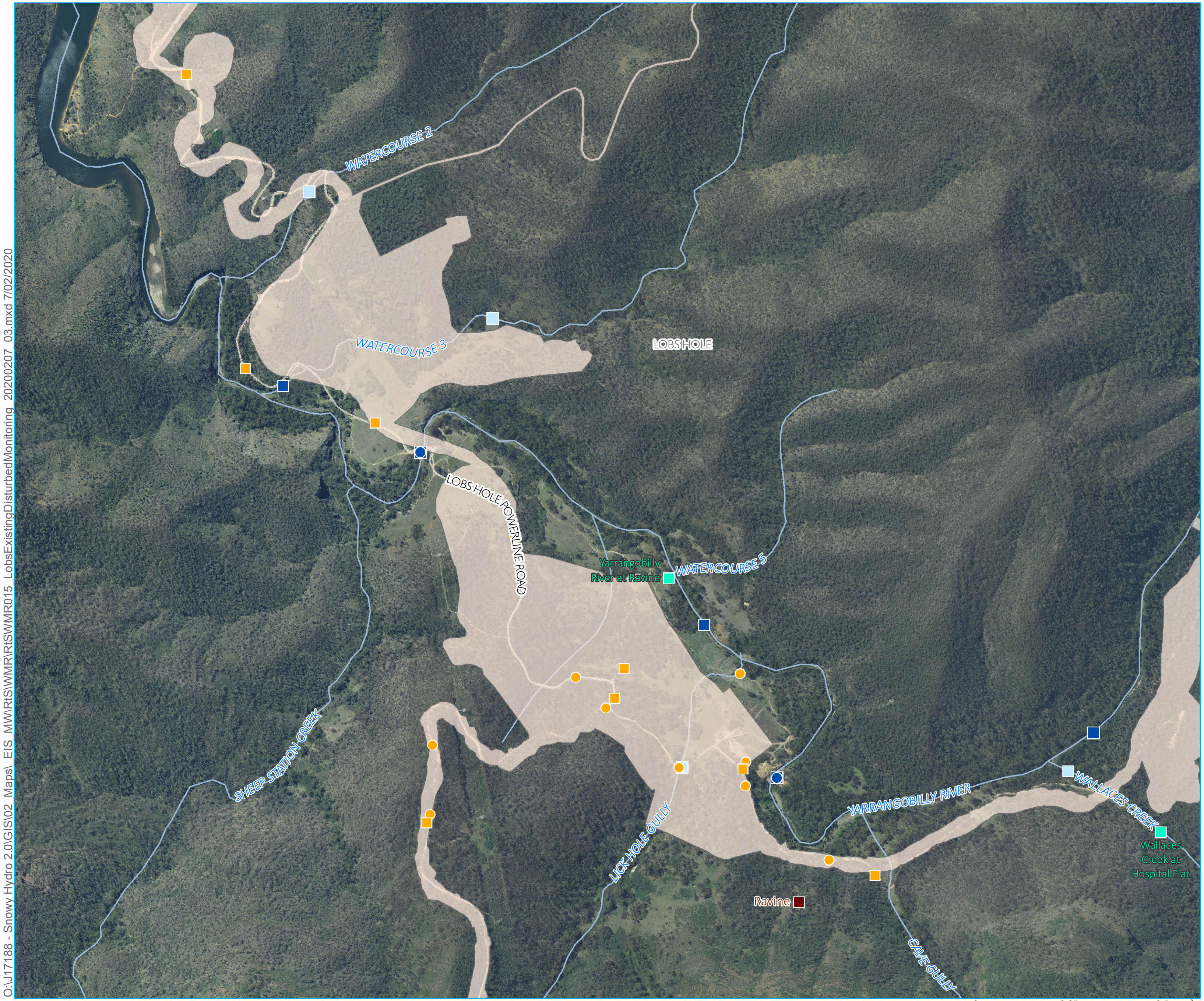
Photograph A.2 Examples of minor watercourse and receiving water monitoring locations

A.3.2 Monitoring events and locations

Disturbed area runoff monitoring was undertaken during three independent wet weather events. Table A.1 provides a summary of each event, describing the sampling locations and rainfall and streamflow context for each event. Sampling locations are shown in Figure A.1 to Figure A.3.

Table A.1 Monitoring summary

Event	Date	Sampled Locations	Rainfall and streamflow context
Event 1	22 March 2019	**Lobs Hole**: • 9 x disturbed area runoff samples • 1 x receiving water sample from a minor watercourse • 2 x receiving water samples from the Yarrangobilly River Refer to Figure A.1 for sampling locations	• Approximately 15mm of rainfall was recorded at the SHL operated gauge at Lobs Hole prior to and shortly after sampling. • Moderate runoff from disturbed areas was occurring during sampling. • There was a minor increase in streamflow in the Yarrangobilly river (stream gauge 410474) due to the rainfall.
Event 2	3 May 2019	**Lobs Hole**: • 8 x disturbed area runoff samples • 4 x receiving samples from minor watercourses • 5 x receiving water sample from the Yarrangobilly River Refer to Figure A.1 for sampling locations	• Approximately 49 mm of rainfall was recorded at the SHL operated gauge at Lobs Hole prior to and shortly after sampling. • Moderate runoff from disturbed areas was occurring during sampling. • Streamflow in the Yarrangobilly river (stream gauge 410474) increased from 0.5 to 8 m^3/s due to the rainfall.
Event 3	3 November 2019	**Marica Trail** • 4 x disturbed area runoff samples • 1 x receiving water samples from minor watercourses • 2 x receiving water samples from the Eucumbene River Refer to Figure A.2 for sampling locations **Tantangara Compound** • 9 x disturbed area runoff samples • 3 x receiving samples from minor watercourse • 2 x receiving water samples from Kellys Plain Creek Refer to Figure A.3 for sampling locations.	• Approximately 20 to 60 mm of rainfall was recorded at regional gauges prior to and shortly after sampling. • Moderate runoff from disturbed areas was occurring during sampling. • A moderate streamflow response occurred in regional watercourses due to the rainfall. For example, streamflow in the Murrumbidgee River (410535) increased from 1.3 to 8.7 m^3/s. • Sampling was undertaken on the rising limb of the runoff hydrographs.



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

0 0.25 0.5 km
GDA 1994 MGA Zone 55
N

KEY

- Streamflow gauge
- Weather station

Disturbed area runoff monitoring location

- Disturbed area (March)
- Disturbed area (May)
- Receiving water (minor watercourse) (March)
- Receiving water (major watercourse) (March)
- Receiving water (minor watercourse) (May)
- Receiving water (major watercourse) (May)
- Disturbance area
- Local road
- Watercourse

Existing disturbed area monitoring locations - Lobs Hole

Snowy 2.0
Water management report
Preferred infrastructure report and response to submissions
Main Works
Figure A.1

snowy 2.0
EMM creating opportunities

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

0 0.5 1 km

GDA 1994 MGA Zone 55

N

KEY

Disturbed area runoff monitoring locations

- Disturbed area
- Receiving water (minor watercourse)
- Receiving water (major watercourse)
- Disturbance boundary
- Main road
- Local road
- Watercourse
- Waterbodies

Existing disturbed area monitoring locations - Marica Trail

Snowy 2.0
Water management report
Preferred infrastructure report and response to submissions
Main Works
Figure A.2

snowy 2.0

EMM creating opportunities

KEY

Disturbed area runoff monitoring locations
- Disturbed area
- Receiving water (minor watercourse)
- Receiving water (major watercourse)
- Weather station
- Disturbance area

Existing environment
- Local road
- Watercourse
- Waterbodies

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

0 0.25 0.5 km
GDA 1994 MGA Zone 55
N

Existing disturbed area monitoring locations - Tantangara Compound

Snowy 2.0
Water management report
Preferred infrastructure report and response to submissions
Main Works
Figure A.3

snowy 2.0
EMM creating opportunities

A.3.3 Monitoring methods

At each location, field data was collected using a calibrated, portable water quality meter, and representative water samples were collected for lab analysis. The data collected included the analytes presented in Table A.2. Sample collection followed standard quality assurance and quality control (QA/QC) procedures to establish accurate, reliable and precise results, which included:

- calibration of equipment;
- submitting laboratory samples within holding times;
- keeping samples chilled;
- wearing fresh disposable nitrile gloves during sampling at each location; and
- collection of field duplicate samples.

Table A.2 Analytical suite

Category	Monitoring analytes	Analysis method
Physico-chemical properties	pH, electrical conductivity, turbidity, dissolved oxygen, temperature, oxidation reduction (redox) potential	Measured insitu using a hand-held water quality meter
	Total suspended solids, total alkalinity, total hardness	Analysis undertaken by a NATA certified laboratory
Nutrients	total nitrogen, ammonia, oxidised nitrogen and total kjeldahl nitrogen	
	total phosphorus and reactive phosphorus	
	total organic carbon, dissolved organic carbon	
Inorganics	cyanide	
Metals (0.45µm field filtered)	Al, As, Ag, B, Ba, Be, Cd, Cr (total), Co, Cu, Fe, Hg, Mn, Ni, Pb, Se, V and Zn	

A.4 Results

A.4.1 Disturbed area results

The interpretation of the water quality of disturbed area runoff is informed by 30 samples that were collected from disturbed areas at Lobs Hole, Marica and Tantangara. The results indicate that water quality was similar across the project area. General water quality characteristics include:

- The pH was generally mildly acidic, ranging from 5.0 to 7.4. This is interpreted to be due to naturally acidic soils.
- Turbidity and suspended solids were variable but were high to very high at most sample locations, indicating the presence of highly erodible and/or dispersive soils.

- Total nitrogen and phosphorus concentrations were variable but were generally elevated relative to WQO values. Nitrogen was primarily in organic form (ie total kjeldahl nitrogen (TKN)). Organic nitrogen is less bioavailable than inorganic forms of nitrogen (oxidised nitrogen and ammonia). Phosphorus was primarily in non-reactive form. Non-reactive phosphorus is less bioavailable than reactive forms.

- Aluminium (0.45 µm field filtered) was consistently elevated relative to the WQO value, with concentrations ranging from 2 to 100 times the WQO value. This is interpreted to be due to naturally high concentrations of aluminium in soils. Aluminium is also elevated in most watercourses during winter/spring baseflow conditions (WCR). The concentrations refer to laboratory analysis of 0.45 µm field filtered samples. Some of the metal concentration may be mineral or organic bound and may have lower eco-toxicology risks than similar concentrations of dissolved metals.

- Copper (0.45 µm field filtered) was generally elevated relative to the WQO value but was highly variable. 4 out of the 30 samples returned concentrations greater than 0.3 mg/L (300 x WQO value) indicating that there are localised copper 'hot spots' that are likely to be associated with areas of copper rich geology. The remaining 26 samples returned concentrations ranging from below detection to 0.037 mg/L (<40 x WQO value). The concentrations refer to laboratory analysis of a 0.45 µm field filtered samples. Some of the metal concentration may be mineral or organic bound and may have lower eco-toxicology risks than similar concentrations of dissolved metals.

- WQO values for arsenic, chromium (total), cobalt, iron, lead, and zinc were occasionally exceeded. Exceedances were generally less than 10 x WQO values.

Table A.3 provides a summary of key disturbed area sample results, providing the 10th, median and 90th percentile concentrations from Lobs Hole, Marica, Tantangara and all combined samples. The WQO values are provided for context. Results are also presented in box and whisker charts in Figure A.4 to Figure A.6 (discussed further in the following section).

Table A.3 Disturbed area sample results summary

			Lobs Hole				Marica Trail				Tantangara compound				All data			
Key analyte	Units	WQO value[1]	# samples/ Exceedances[2]	Min/10P[3]	Median	Max/90P[3]	# samples/ Exceedances[2]	Min/10P[3]	Median	Max/90P[3]	# samples/ Exceedances[2]	Min/10P[3]	Median	Max/90P[3]	# samples/ Exceedances[2]	Min/10P[3]	Median	Max/90P[3]
pH		6.5-8	17/12	**4.9**	**5.8**	7.4	4/0	7.0	7.2	7.4	9/9	**4.8**	**5.7**	**6.4**	30/21	**5.0**	**5.9**	7.4
Turbidity	NTU	25	17/17	**119**	**974**	**2,520**	0/0	-	-	-	4/2	6	**94**	**740**	21/19	**34**	**740**	**1,993**
Total suspended solids	mg/L	-	17/0	97	390	1,200	4/0	320	1,027	2,620	9/0	8	662	5,710	30/0	71	447	2,053
Nitrogen (total)	mg/L	0.25	17/17	**1.02**	**2.00**	**4.74**	4/3	0.20	**0.36**	**0.53**	9/6	0.13	**0.94**	**2.57**	30/26	0.22	**1.40**	**3.12**
Phosphorus (total)	mg/L	0.020	17/17	**0.17**	**0.52**	**1.06**	4/4	**0.02**	**0.14**	**0.45**	9/7	0.01	**0.05**	**0.09**	30/28	**0.03**	**0.21**	**0.88**
Aluminium (dissolved)	mg/L	0.027	17/17	**0.106**	**0.310**	**0.830**	4/4	**0.132**	**0.302**	**0.601**	9/9	**0.050**	**0.729**	**2.590**	30/30	**0.120**	**0.357**	**1.182**
Copper (dissolved)	mg/L	0.001	17/12	0.001	**0.004**	**0.441**	4/4	**0.005**	**0.019**	**0.027**	9/9	**0.002**	**0.012**	**0.021**	30/25	0.001	**0.007**	**0.325**

1. The WQO values for field parameters and nutrients 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 are for the protection of 99% of aquatic species.
2. An exceedance refers to any result that is above detection limit and exceeds the WQO value. Where a range is given for the WQO value, exceedances are determined in relation to the lower and upper limit for pH.
3. If less than 10 samples are available, the minimum value is reported instead of the 10th percentile value and the maximum value is reported instead of the 90th percentile value.

Bold denotes WQO value is exceeded.

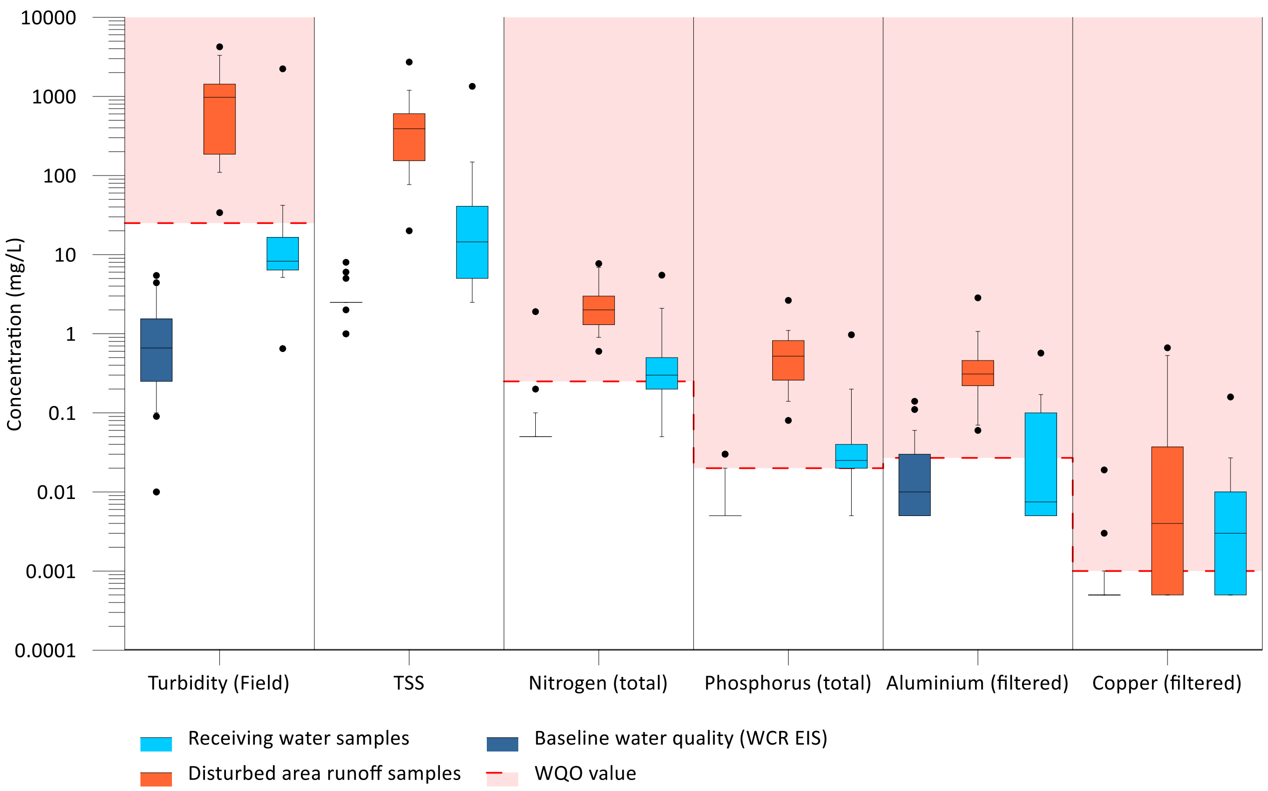
A.4.2 Receiving water results

As described in Section A.3, as part of the disturbed area monitoring program, samples were collected from minor watercourses located downstream of disturbed areas and larger watercourses such as the Yarrangobilly River. These receiving water samples provide a snapshot of water quality when runoff from disturbed areas is occurring.

The water quality in minor watercourses near access tracks was variable, with elevated turbidity, suspended solids and aluminium, copper and other metals detected at some locations. When elevated water quality parameters were detected, the concentrations were typically 1 to 2 orders of magnitude lower than disturbed area samples. The water quality in major watercourses (ie Yarrangobilly River, Eucumbene River and Kellys Plain Creek) was generally better than minor watercourses, but worse than the baseline water quality described in the WCR, which is predominantly based on dry weather sampling.

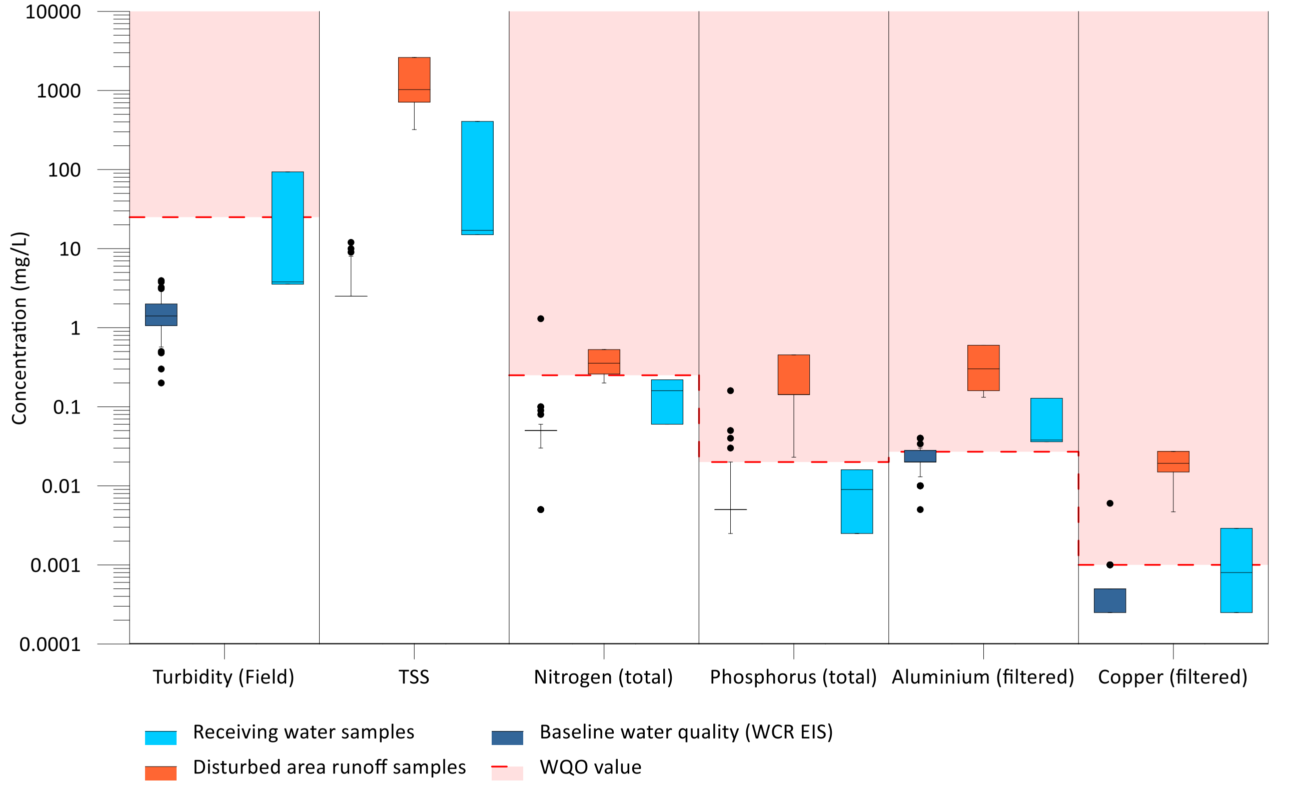
Box and whisker plots compare the key disturbed area sample results, the receiving water results and the baseline water quality results that are presented in the WCR. WQO values are also included for context. The box (the rectangle) represents the data range for the middle 50% of values (ie the data between the first and third quartiles). The horizontal line in the middle of the box represents the median value. The whiskers represent the minimum and maximum values, excluding outliers. Outliers are taken as any value outside of the 10th and 90th percentile values are also indicated.

Figure A.4 presents results from Lobs Hole, Figure A.5 results from Marica and Figure A.6 results from Tantangara.



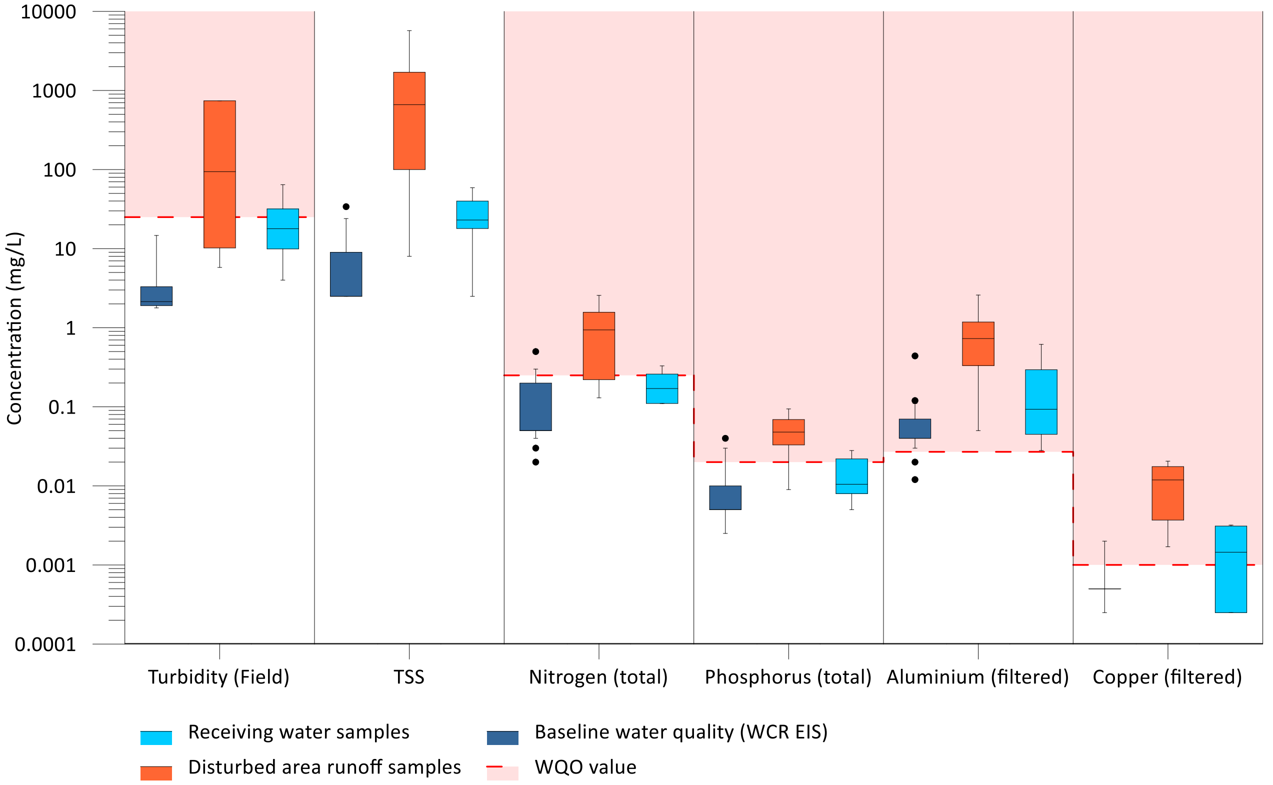
Note: Turbidity units in NTU, all other analytes in mg/L
Points represent outliers, considered here to be data outside the 10th and 90th percentiles
Baseline water quality statistics were calculated from all baseline water quality data from relevant major watercourses that is presented in the WCR EIS

Figure A.4 Lobs Hole – Comparison of disturbed area runoff, receiving water and baseline receiving water results



Note: Turbidity units in NTU, all other analytes in mg/L
Points represent outliers, considered here to be data outside the 10th and 90th percentiles
Baseline water quality statistics were calculated from all baseline water quality data from relevant major watercourses that is presented in the WCR EIS

Figure A.5 Marica trail – Comparison of disturbed area runoff, receiving water and baseline receiving water results



Note: Turbidity units in NTU, all other analytes in mg/L
Points represent outliers, considered here to be data outside the 10th and 90th percentiles
Baseline water quality statistics were calculated from all baseline water quality data from relevant major watercourses that is presented in the WCR EIS

Figure A.6 Tantangara compound – Comparison of disturbed area runoff, receiving water and baseline receiving water results

A.5 Application to residual impact assessment

The following approach has been applied to characterise the water quality profile of treated stormwater discharge from proposed construction phase 1 stormwater management systems:

- The disturbed area runoff monitoring results that are documented in this attachment have been applied to characterise the water quality profile of untreated runoff from proposed construction disturbance areas.
- The benefits of proposed controls (which are described in WMR PIR-RTS Chapter 3) have been estimated considering the physical and chemical processes provided by the controls and the results of limited jar testing of four disturbed area samples that were collected from Lobs Hole during sampling Event 2. The jar tests simulate the water quality response to sedimentation processes by allowing samples of disturbed area runoff to settle in a jar. Samples were collected after 1 hour and 1 day of settling and were analysed for a range of analytes. The results were compared to the water quality of fresh samples to provide an indication of the water treatment benefit of sedimentation processes for the key analytes.

WMR PIR-RTS presents the water quality of discharges as:

- Likely ranges – describes the likely water quality range for each project level water management category. The likely range considers variable factors that influence water quality such as spatial variation in soil types and variation in rainfall intensities and depths for different events.
- Value applied to the residual impact assessment (referred to as the RIA value) – These values represent a conservative estimate of typical or median discharge water quality from a project level water management category.

Table A.3 applies describes the assumptions and logic applied to establishing the likely range and RIA values for discharges from the construction phase 1 water management categories. The Lobs Hole jar test results are provided in Figure A.8 to Figure A.14 (after Table A.3).

Table A.4 Discharge characteristics for construction phase 1 water management categories

Key analyte	Units	WQO Value	Untreated runoff quality from disturbed areas (results from all samples in Table A.3) 10th percentile	Median	90th percentile	Discharge characteristics (after treatment) Likely range	RIA value	Comments
pH	NTU	6.5–8.0	5.0	5.9	7.4	4.0–8.0	4.5	**Proposed controls[1] - pH** No pH adjustment is proposed for construction phase 1. **Summary of water quality and treatment processes** Mildly acidic runoff may occur in areas that have naturally acidic soils. Jar test results (Figure A.7) indicate that the pH declines from the 5.0 to 5.5 range (from four fresh samples) to 4.0 to 5.2 range after 20 hours of settling or aging. This is interpreted to be due to gaseous carbon dioxide from the atmosphere dissolving into the water (forming Carbonic Acid) and / or minerals leaching into the water column from suspended solids. **Adopted values** The RIA and likely range values were established based on the balance of evidence.
Turbidity	NTU	2–25	34	740	1,993	100–1000	250	**Proposed controls[1] - turbidity** The proposed controls are expected to provide significant reductions in turbidity, primarily through managing soil loss rates and treatment in sedimentation dams (WM 1.3 major works only). **Summary of water quality and treatment processes** Elevated turbidity is expected to occur in areas that have highly erodible and/or dispersive soils. Jar test results (Figure A.8) indicates that turbidity will generally increase (relative to untreated levels) after 1 hour of settling, but will reduce to the 150 to 400 NTU range after 1 day of settling. **Adopted values** • RIA value - the approximate median concentration from the four jar test results was considered to be appropriate for typical discharge conditions when > 1 day of residence time in sedimentation basins can be expected prior to overflows occurring. • Likely range – the range allows for expected variation in soil risk and the variable effectiveness of proposed controls during different discharge scenarios (ie the controls will be less effective during significant intense rainfall).

Table A.4 Discharge characteristics for construction phase 1 water management categories

Key analyte	Units	WQO Value	Untreated runoff quality from disturbed areas (results from all samples in Table A.3): 10th percentile	Median	90th percentile	Discharge characteristics (after treatment): Likely range	RIA value	Comments
Total suspended solids	mg/L	-	71	447	2,053	25–300	50	**Proposed controls[1] – total suspended solids** The proposed controls are expected to provide significant reductions in total suspended solids, primarily through managing soil loss rates and the capture of most coarse sediment. **Summary of water quality and treatment processes** Jar test results (Figure A.9) indicate that total suspended solids will reduce to approximately 50 mg/L after 1 day of settling. The recorded range in concentrations was 30 to 60 mg/L from four tests. **Adopted values** • RIA value - proposed controls are expected to effectively manage coarse sediment. As such the value applied to RIA (50 mg/L) is the approximate median concentration from the jar tests and is also the value recommended in *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom 2004). • Likely range - the range allows for expected variation in soil risk and the variable effectiveness of proposed controls during different discharge scenarios (ie the controls will be less effective during significant intense rainfall).
Nitrogen (total)	mg/L	0.25	0.22	1.40	3.12	0.1–5.0	0.8	**Proposed controls[1] – Total nitrogen** The proposed controls are expected to provide a beneficial reduction in total nitrogen, primarily through managing soil loss rates and the capture of some organic bound nitrogen. **Summary of water quality and treatment processes** If total nitrogen is elevated it is expected to be primarily in organic form (ie TKN) which is less bioavailable than non-organic forms. Jar test results (Figure A.10) indicate that moderate reductions of total nitrogen will occur after 1 day of settling. The recorded range in concentrations was 0.4 to 2.1 mg/L from four tests. **Adopted values** • RIA- proposed controls are expected to provide some beneficial reduction of total nitrogen concentrations. Hence, the median concentration from jar test results is applied. • Likely range – the range allows for expected variation in soil risk and the variable effectiveness of proposed controls during different discharge scenarios (ie the controls will be less effective during significant intense rainfall).

Table A.4 Discharge characteristics for construction phase 1 water management categories

Key analyte	Units	WQO Value	Untreated runoff quality from disturbed areas (results from all samples in Table A.3) 10th percentile	Median	90th percentile	Discharge characteristics (after treatment) Likely range	RIA value	Comments
Phosphorus (total)	mg/L	0.02	0.03	0.21	0.88	0.01–1.00	0.15	**Proposed controls[1] – Total phosphorus** The proposed controls are expected to provide a beneficial reduction in total phosphorus, primarily through managing soil loss rates and the capture of some mineral or sediment bound phosphorus. **Summary of water quality and treatment processes** If total phosphorus is elevated it is expected to be primarily in non-reactive form, and less bioavailable than reactive forms. Jar test results (Figure A.11) indicate that moderate reductions of total phosphorous will occur after 1 day of settling. The recorded range in concentrations was 0.1 to 0.3 mg/L from four tests. **Adopted values** • RIA- proposed controls are expected to provide some beneficial reduction of total phosphorus concentrations. Hence, the median concentration from jar test results is applied. • Likely range – the range allows for expected variation in soil risk and the variable effectiveness of proposed controls during different discharge scenarios (ie the controls will be less effective during significant intense rainfall).

Table A.4 Discharge characteristics for construction phase 1 water management categories

Key analyte	Units	WQO Value	Untreated runoff quality from disturbed areas (results from all samples in Table A.3) 10th percentile	Median	90th percentile	Discharge characteristics (after treatment) Likely range	RIA value	Comments
Aluminium (field filtered)[3]	mg/L	0.027[2]	0.120	0.357	1.182	0–50 x WQO value	10 x WQO value	**Proposed controls[1] - Aluminium** The proposed controls are expected to provide a beneficial reduction in aluminium, primarily through managing soil loss rates and the capture of some mineral or sediment bound aluminium. **Summary of water quality and treatment process** Most soils and geology within the project area are known to have naturally high concentrations of aluminium. This can unavoidably result in elevated concentrations of aluminium in stormwater that contacts disturbed soils. Source controls that minimise soil loss rates are expected to provide some mitigation relative to runoff from disturbed areas that have no controls. Jar test results (Figure A.12) indicate that slight to moderate reductions of aluminium will occur after 1 day of settling. The recorded range in concentrations was 0.1 to 0.6 mg/L from four tests. **Adopted values** • RIA – The RIA value (10 x WQO or 0.27 mg/L) is moderately below the median value from untreated runoff to account for some beneficial reduction from the proposed controls. • Likely range – the broad range allows for expected variation in soil risk and the variable effectiveness of proposed controls during different discharge scenarios (ie the controls will be less effective during significant intense rainfall).

Table A.4 Discharge characteristics for construction phase 1 water management categories

			Untreated runoff quality from disturbed areas (results from all samples in Table A.3)			Discharge characteristics (after treatment)		
Key analyte	**Units**	**WQO Value**	**10th percentile**	**Median**	**90th percentile**	**Likely range**	**RIA value**	**Comments**
Copper (field filtered[3]	mg/L	0.001[2]	0.001	0.007	0.325	0–500 x WQO value	7 x WQO value	**Proposed controls[1] - Copper** The proposed controls are expected to provide a beneficial reduction in copper, primarily through managing soil loss rates and the capture of mineral or sediment bound copper. **Summary of water quality and treatment process** Most soils and geology within the project area are known to have naturally high concentrations of copper, with potential for localised copper hot spots (see section A.3). This can unavoidably result in elevated concentrations of copper in stormwater that contacts disturbed soils. Source controls that minimise soil loss rates are expected to provide some mitigation relative to runoff from disturbed areas that have no controls. Jar test results from lower concentration samples (Figure A.13) indicate that slight to moderate reductions of copper will occur after 1 day of settling. Results from a higher concentration sample (Figure A.14) indicate that no material reduction of copper will occur after 1 day of settling. **Adopted values** • RIA – The RIA value (7 x WQO or 0.007 mg/L) is similar to median values from untreated runoff. This accounts for some beneficial reduction in copper loads from the proposed controls but allows for some contingency for higher loads in runoff from localised copper hot spot areas. • Likely range – the broad range allows for expected variation in soil risk and the variable effectiveness of proposed controls during different discharge scenarios (ie the controls will be less effective during significant intense rainfall).

Table A.4 Discharge characteristics for construction phase 1 water management categories

			Untreated runoff quality from disturbed areas (results from all samples in Table A.3)			**Discharge characteristics** (after treatment)		
Key analyte	**Units**	**WQO Value**	**10th percentile**	**Median**	**90th percentile**	**Likely range**	**RIA value**	**Comments**
Other metals and toxicants[3]	mg/L	Note 2	< WQO	< WQO		WQO values occasionally exceeded	< WQO values	**Proposed controls[1] – other metals and toxicants** The proposed controls are expected to provide a beneficial reduction in metals, primarily through managing soil loss rates and the capture of mineral or sediment bound metals. **Summary of water quality and treatment processes** Disturbed area runoff monitoring (see Section A.3) identified that concentrations of some metals such as arsenic, chromium (total), cobalt, iron, lead, and zinc will occasionally exceed WQO values. However, typical or median concentrations are expected to be less than WQO values. As with aluminium and copper, the proposed controls are expected to provide a beneficial reduction in metal loads, relative to runoff from disturbed areas that have no controls. **Adopted values** • RIA – A < WQO value was adopted as disturbed area runoff monitoring that median concentrations in untreated runoff (at a project level) will be less than WQO values. • Likely range – A > WQO value was adopted as disturbed area runoff monitoring results indicate that WQO values will occasionally be exceeded in untreated runoff.

Notes: 1. Refer to WMR PIR-RTS Chapter 3 for information on proposed controls.
2. Default trigger values for 99% level of species protection apply. Refer to the water assessment for WQOs.
3. Concentrations refer to laboratory analysis of a 0.45 µm field filtered sample. Some of the metal concentration may be mineral or organic bound and may have lower eco-toxicology risks than similar concentrations of dissolved metals.

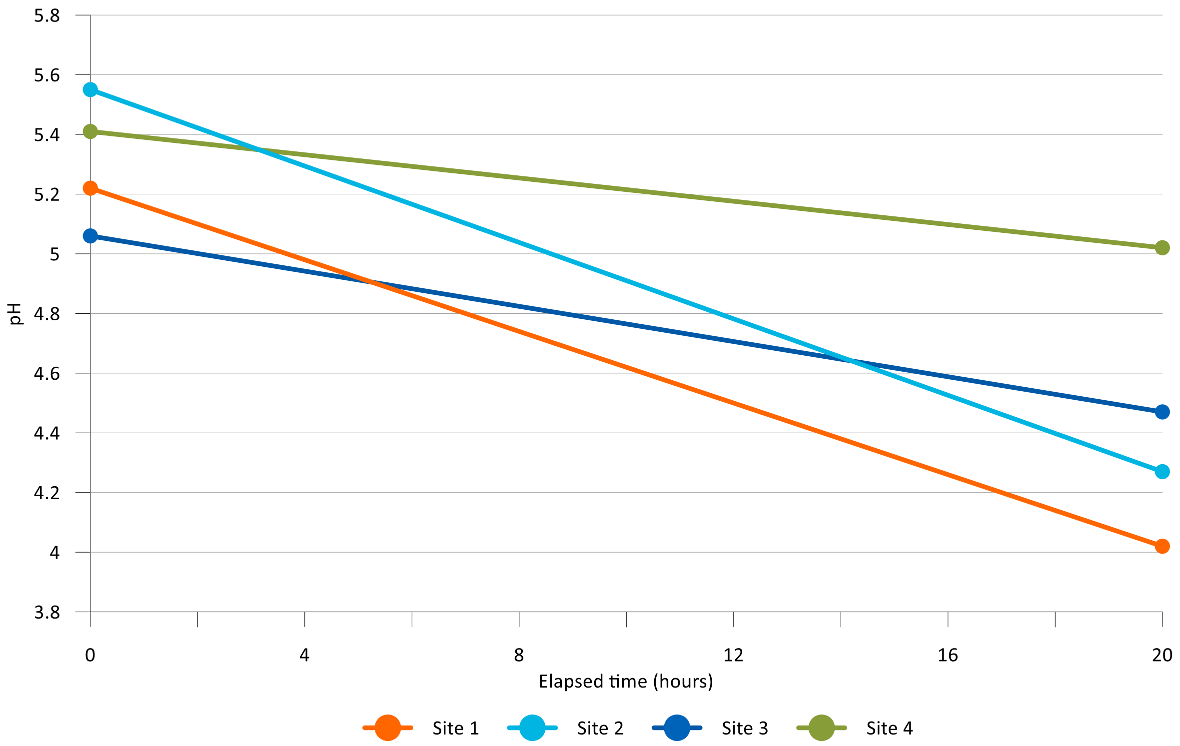


Figure A.7 Lobs Hole jar test results - pH

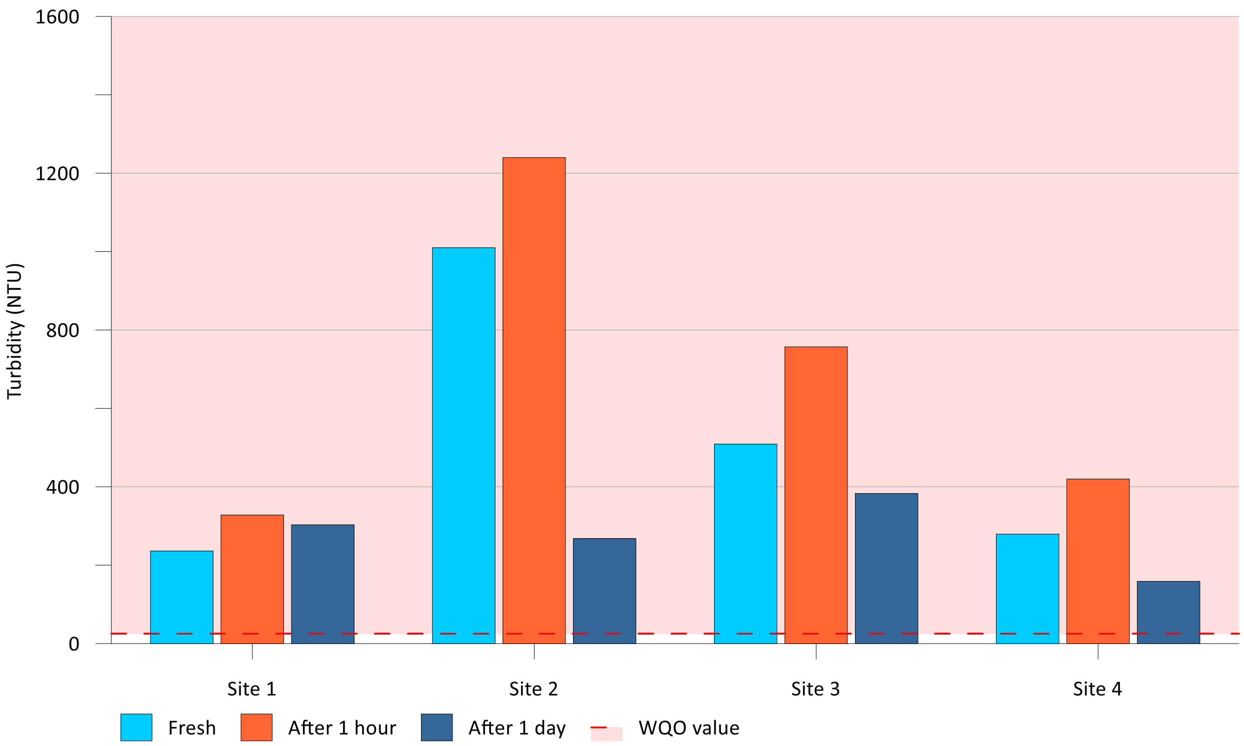


Figure A.8 Lobs Hole jar test results - turbidity

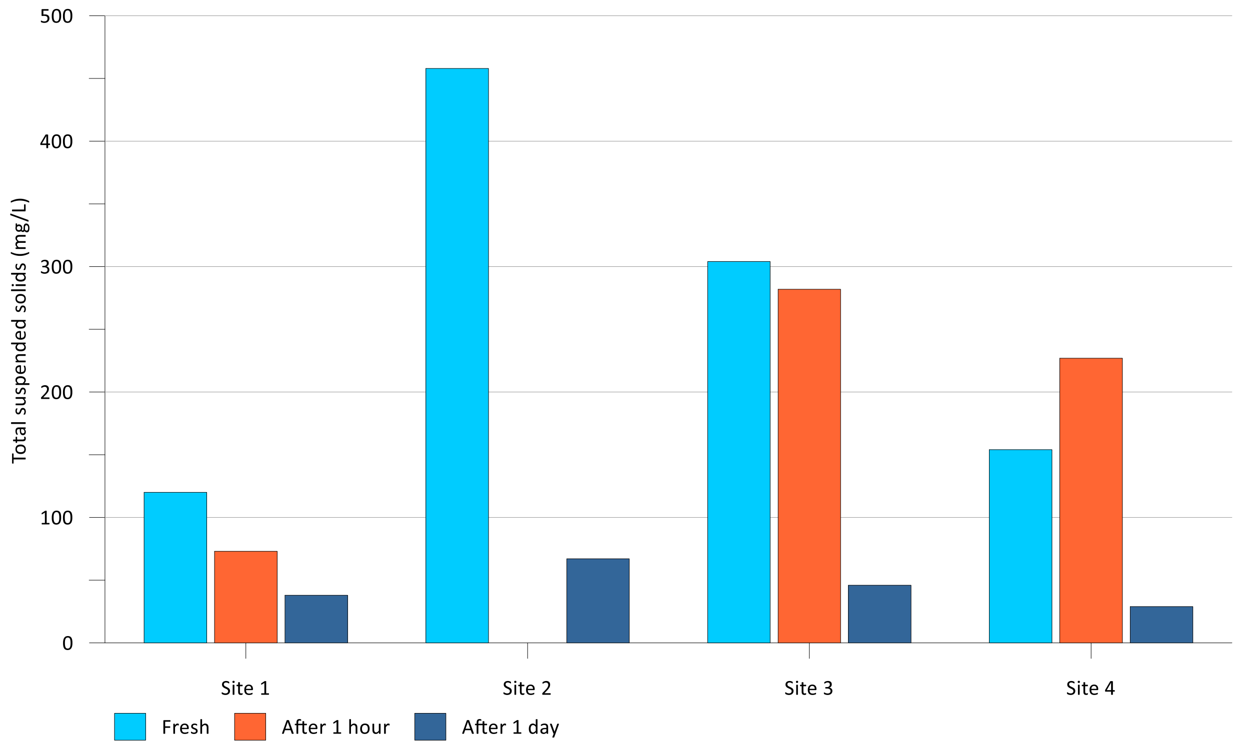


Figure A.9 Lobs Hole jar test results – total suspended solids

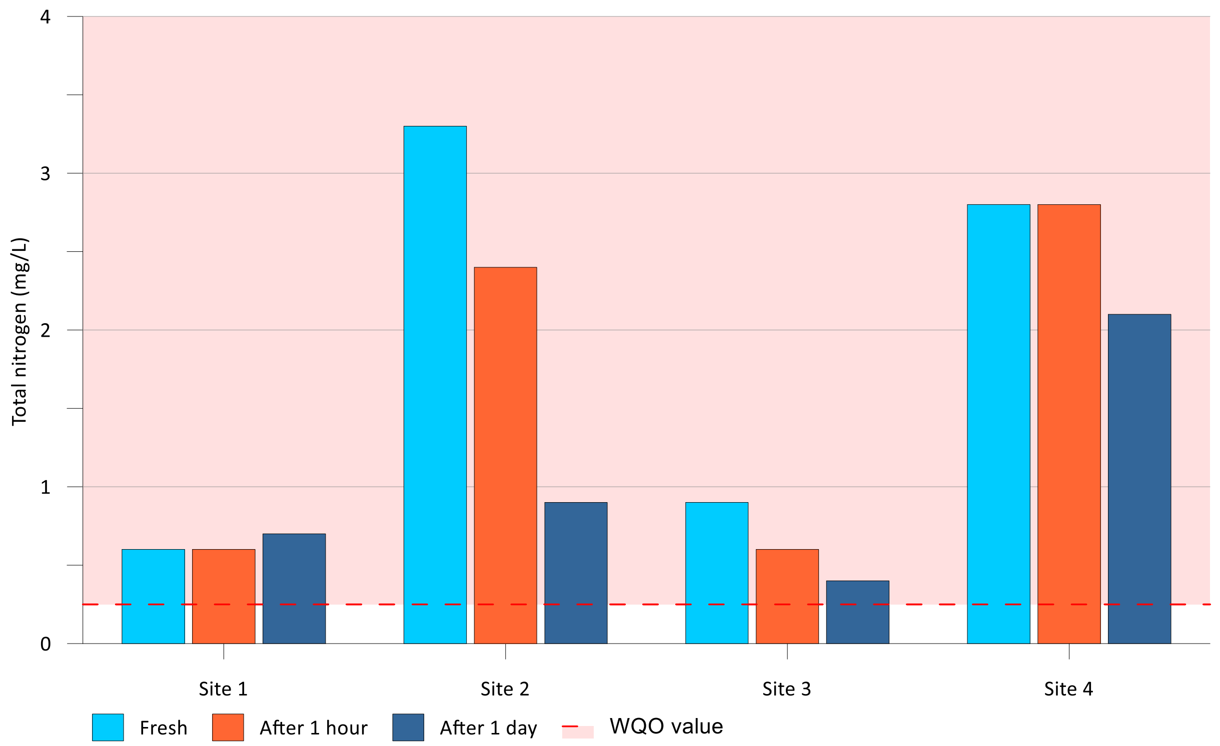


Figure A.10 Lobs Hole jar test results – total nitrogen

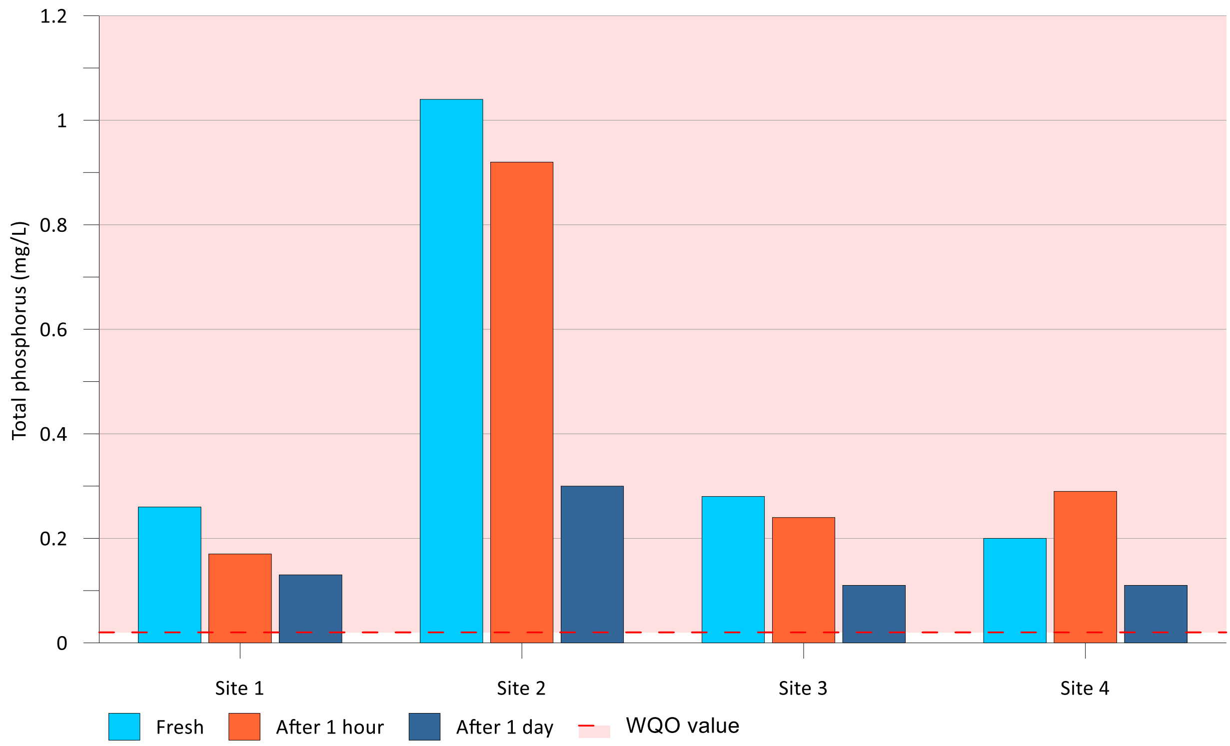


Figure A.11 Lobs Hole jar test results – total phosphorous

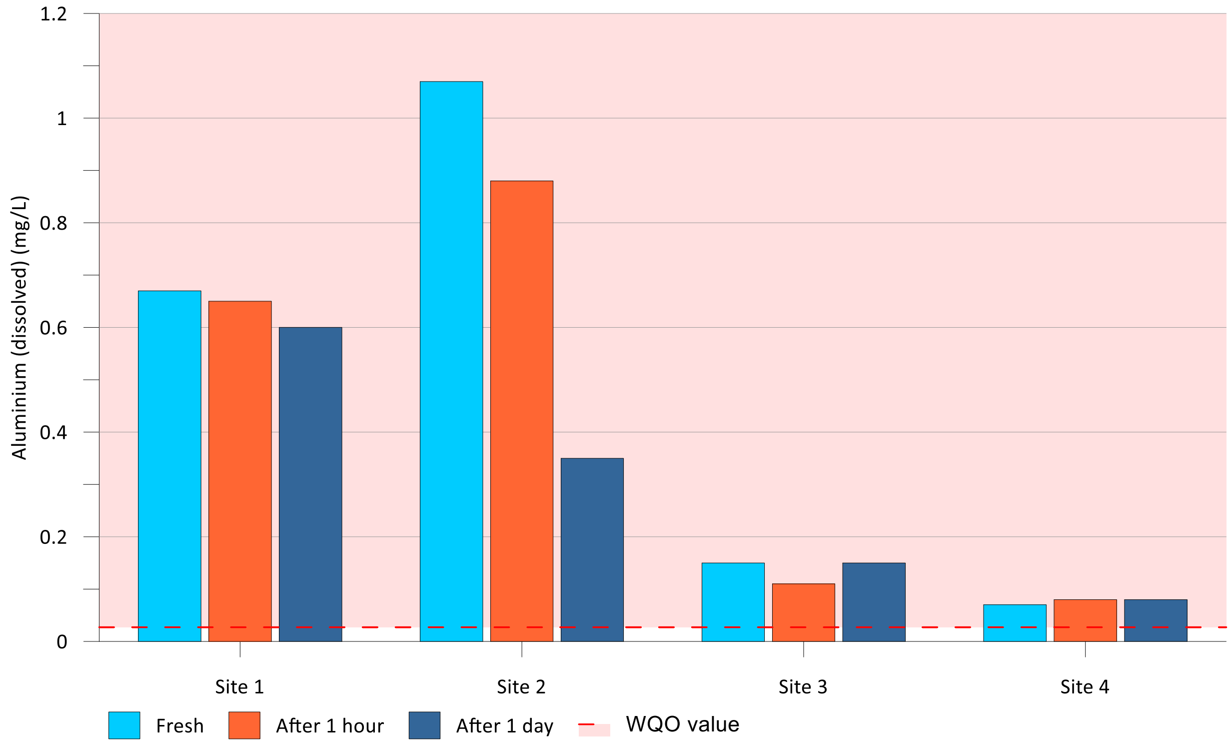


Figure A.12 Lobs Hole jar test results – aluminium (filtered)

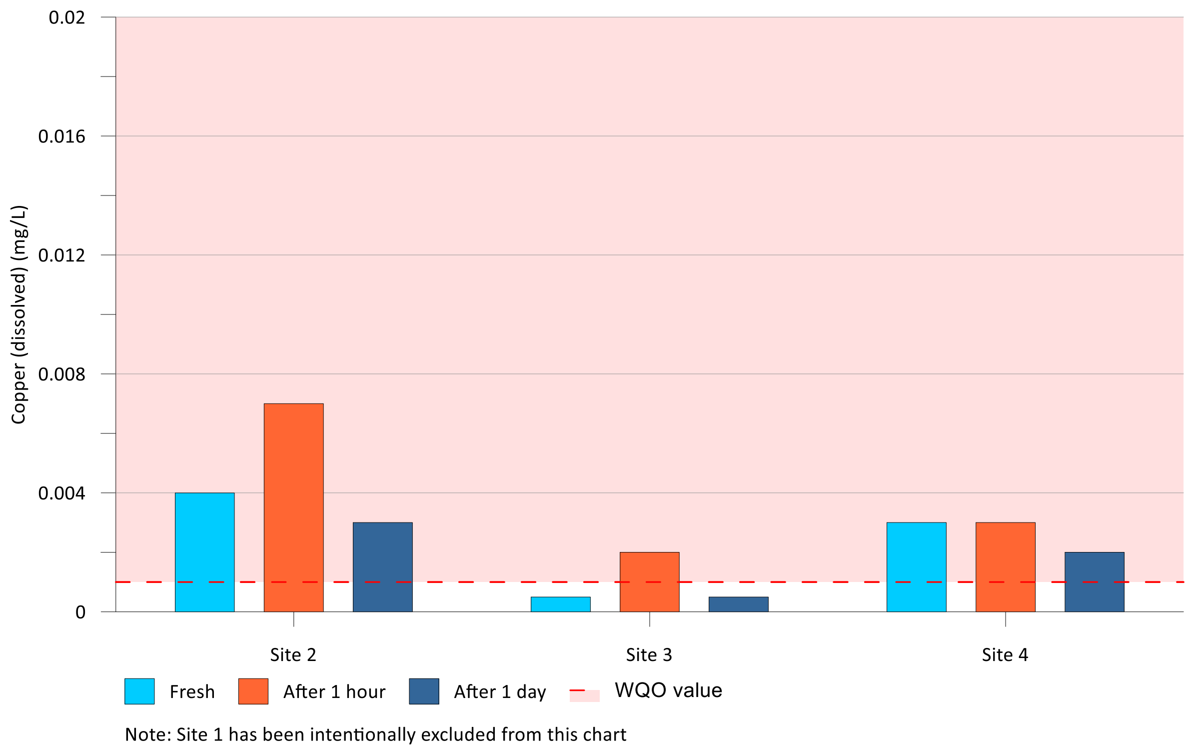


Figure A.13 Lobs Hole jar test results – copper (filtered) – lower concentration samples

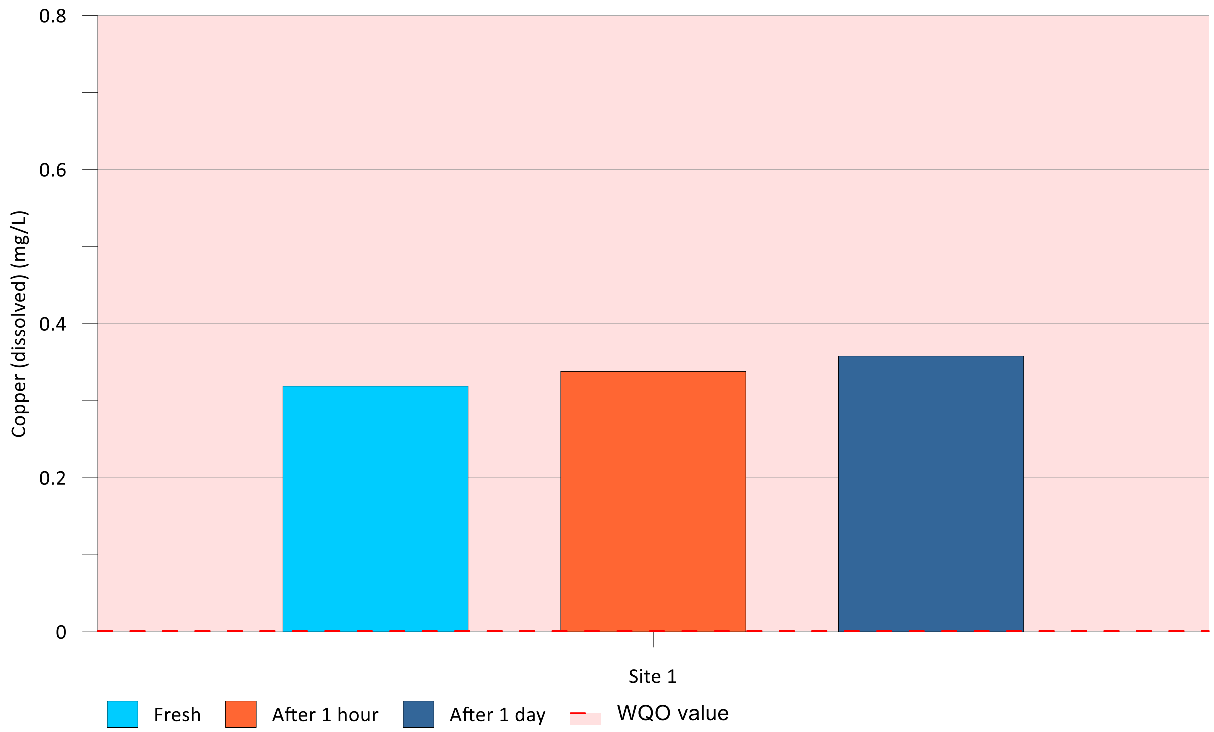


Figure A.14 Lobs Hole jar test results – copper (filtered) – higher concentration sample

Attachment B

Stormwater management areas

B.1 Introduction and purpose

This attachment to the water management report (WMR) (Appendix J of the PIR-RTS) describes the methods and assumptions applied to calculate disturbance profiles for each stormwater management category established in the WMR. The disturbance profiles are used to calculate stormwater discharge profiles that were applied to assess residual impacts associated with stormwater discharges. Residual impacts are also documented in the WMR.

B.2 Water management categories

The WMR describes stormwater approaches separately for the following project phases:

- Construction – refers to the construction of Snowy 2.0 Main Works, including the following phases:
  - Construction phase 1 – Construction of surface infrastructure – refers to the construction of access roads, service trenches, accommodation camps, construction pads, tunnel portals and other surface infrastructure.
  - Construction phase 2 – All other construction activities – refers to the construction of subsurface infrastructure and tunnel intakes and the use of surface infrastructure such as access roads, construction pads and accommodation camps to support construction activities.

  It is noted that at a project level the two construction phases will occur concurrently during the initial years of the project schedule, but at a local level, the phases would occur sequentially.
- Operational phase (phase 3) – refers to the operational phase of Snowy 2.0.

For each phase, project level stormwater management categories have been established to describe each unique aspect of the proposed stormwater system. Table B.1 describes the stormwater categories that are relevant to each project phase and notes the approximate disturbance duration associated with each phase.

Table B.1 Project phases and water management categories

Project phase	Disturbance period	Stormwater categories
Construction phase 1 – construction of surface infrastructure	Initial 15 months of construction	• WM 1.2 – Minor works • WM 1.3 – Major works
Construction phase 2 – all other construction activities	Approximately 5 years	• WM 2.2 – Accommodation camps • WM 2.3 – Construction pads • WM 2.4 – Access roads • WM 2.5 – Large temporary stockpiles
Operational phase (phase 3)	For perpetuity following construction	• WM 3.2 – Permanent surface infrastructure • WM 3.3 – Permanent access roads

B.3 Data

The following data has been used to establish disturbance profiles:

- the project disturbance area;
- the conceptual layout; and
- minimum operating levels for Tantangara and Talbingo reservoirs.

B.4 Approach

The project disturbance area describes the maximum extent of surface disturbance. The actual disturbance footprint is expected to be substantially less than the project disturbance area. The following approach was applied to calculate estimated actual disturbance areas for each stormwater management category:

- Step 1 – potential disturbance areas relevant to each phase were calculated from the project disturbance area; and
- Step 2 – actual disturbance areas were estimated for each stormwater management category based on the potential disturbance areas, the conceptual layout and various actual to potential disturbance ratios.

B.5 Step 1 – Calculation of potential disturbance areas

B.5.1 Assumptions

Table B.2 describes assumptions that were applied to calculate the potential disturbance area from the project disturbance area.

Table B.2 Potential disturbance area calculation assumptions

Assumption	Description/justification
All phases – disturbance areas which are below the minimum operating level of reservoirs, or otherwise associated with on-reservoir activity (such as barging) have been excluded.	No stormwater runoff will occur from reservoir water bodies.
All phases – disturbance area associated with spoil emplacement areas have been excluded	Impacts related to spoil emplacement are not assessed in this WMR.
Phase 2 – disturbance areas associated with large excavations have been excluded	Stormwater captured in large excavations will be managed by the process water management system.
Phase 2 and 3 – the assumed disturbance is limited to the inside of the cut and fill batters of the conceptual layout.	Following construction, cut and fill batters will be stabilised and rehabilitated in accordance with the rehabilitation strategy (Appendix F to the EIS). Rehabilitated areas are not considered to be disturbed areas.
Phase 3 only – the assumed disturbance is limited to the conceptual layout of the permanent surface infrastructure and access roads.	Near the end of the construction phase of the project, temporary surface infrastructure will be decommissioned, and disturbance areas will be reprofiled and rehabilitated in accordance with the rehabilitation strategy (Appendix F to the EIS). Rehabilitated areas are not considered to be disturbed areas.

B.6 Potential disturbance areas

Table B.3 provides the calculated potential disturbance area for each phase and category.

Table B.3 Potential disturbance area by phase and category

Stormwater management category	Potential disturbance area by project phase (ha)		
	Phase 1	Phase 2	Phase 3
WM 1.2 – Minor works	347	-	-
WM 1.3 – Major works	164	-	-
WM 2.2 – Accommodation camps	-	17	-
WM 2.3 – Construction pads	-	50	-
WM 2.4 – Access roads	-	233	-
WM 2.5 – Large temporary stockpiles	-	29	-
WM 3.2 – Permanent surface infrastructure	-	-	19
WM 3.3 – Permanent access roads	-	-	202
Total potential disturbance area	**512**	**328**	**220**
Areas below reservoir minimum operating levels	58	58	58
Excluded areas	217	226	217
Assumed rehabilitated areas	0	174	292
Total disturbance area	**787**	**787**	**787**

B.7 Step 2 – Calculation of actual disturbance areas

B.7.1 Reduction factors

Reduction factors have been established to calculate the actual disturbance area from the potential disturbance areas. Table B.4 presents the applied reduction factors for each water management category with explanatory notes.

Table B.4 Reduction factors

Stormwater management category	Reduction factors	Comments
WM 1.2 – Minor works	0.9	Minor works are primarily associated with the construction of road and service corridors. The potential disturbance boundary includes some contingency for design and unforeseen local constraints. Based on the conceptual layout, approximately 90% of the potential disturbance area is expected to be disturbed.
WM 1.3 – Major works	0.95	Major works are primarily associated with the construction of accommodation camps, portals and construction pads. The potential disturbance boundary includes contingency for design and unforeseen local constraints. Based on the conceptual layout, approximately 95% of the potential disturbance area is expected to be disturbed.

Table B.4 Reduction factors

Stormwater management category	Reduction factors	Comments
WM 2.2 – Accommodation camps	1.0	The potential disturbance area digitised from the concept layout based on the internal batter extent. Hence, no further reduction is required.
WM 2.3 – Construction pads	1.0	The potential disturbance area was digitised from the concept layout based on the internal batter extent. Hence, no further reduction is required.
WM 2.4 – Access roads	-	Actual disturbance area was calculated using an alternative method – See section B.7.2
WM 2.5 – Large temporary stockpiles	1.0	The potential disturbance area was digitised from the concept layout based on the outer batter extent. Hence, no further reduction is required.
WM 3.2 – Permanent surface infrastructure	1.0	The potential disturbance area was digitised from the concept layout based on the internal batter extent. Hence, no further reduction is required.
WM 3.3 – Permanent access roads	-	Actual disturbance area was calculated using an alternative method – See Section B.7.2

B.7.2 Access roads – construction phase 2 and operational phase

Access roads are included in disturbance area calculations for construction phase 2 (WM 2.4) and the operational phase (WM 3.3). Broadly, all roads have been categorised as follows:

- Existing 4WD tracks that will have minor modifications (ie additional passing bays).
- Existing 4WD tracks that will be substantially modified to be dual lane unsealed roads.
- New dual lane unsealed roads that will be constructed as part of the project.
- Roads that will be sealed near the end of the construction phase.

The following assumptions have been applied to calculating actual disturbance areas:

- Existing 4WD tracks that will only have minor modifications are not considered to materially increase the disturbance area and are therefore not considered to be additional disturbance areas associated with the project.
- Unsealed and sealed roads are expected to have different runoff quality characteristics and are therefore separated.
- The actual disturbance area is limited to the road surface. Road drainage will be designed to have non-erosive capacity (described in Section 3 of the WMR) and road batters will be established and rehabilitated.

Table B.5 provides the following information for each road included in the project description:

- relevant phase and stormwater management category;
- construction upgrades;
- final condition;
- catchment location;

- approximate length;
- typical cross section width of road surface (excluded drains and batters); and
- estimated actual disturbance area.

Table B.5 Assumed disturbance areas – access roads

Road	Phase	Stormwater management category	Construction upgrade	Final condition	Catchment	Length (m)	Typical cross-sectional width (m)	Estimated actual disturbed area (ha)
Lobs Hole Ravine Road (south)	2 and 3	WM 2.4, WM 2.3	Significant upgrade	Sealed	Yarrangobilly River	4,064	7	3
					Other areas	10,389	7	7
Lobs Hole Ravine Road (north)	2 and 3	-	Minor modifications	4WD track	Yarrangobilly River	12,164	7	9
Mines Trail Road	2 and 3	WM 2.4, WM 2.3	Significant upgrade	Sealed	Yarrangobilly River	2,528	7	2
Lobs Hole Road	2 and 3	WM 2.4, WM 3.3	Significant upgrade	Gravel	Yarrangobilly River	3,123	7	2
Marica Trail	2 and 3	WM 2.4, WM 3.3	Significant upgrade	Gravel	Upper Eucumbene River	2,103	7	1
					Wallaces Creek	3,249	7	2
Marica West	2 and 3	WM 2.4, WM 3.3	New road	Gravel	Yarrangobilly River	5,486	7	4
					Wallaces Creek	1,685	7	1
Powerline Road	2 only	WM 2.4	New road	Gravel	Yarrangobilly River	1,409	6	1
				Gravel	Talbingo Reservoir	1,339	6	1
Pipeline Road	2 and 3	WM 2.4, WM 3.3	New road	Gravel	Yarrangobilly River	1,422	6	1
Talbingo Excavated Rock Emplacement Access Road	2 only	WM 2.4	New road	Rehabilitated	Talbingo Reservoir	3,183	7	2
Tantangara Road	2 and 3	WM 2.4, WM 3.3	Significant upgrade	Gravel	Kellys Plain Creek	2,001	6	1
					Nungar Creek	8,079	6	5
					Other areas	5,093	6	3
Tantangara Excavated Rock Emplacement Access Road	2 only	WM 2.4	Significant upgrade	Rehabilitated	Tantangara Reservoir	5,386	7	4
Quarry Trail	2 and 3	WM 2.4, WM 3.3	Significant upgrade	Gravel	Tantangara Reservoir	1,551	6	1
				Gravel	Kellys Plain Creek	1,452	6	1
Gooandra Trail/Bullock Hill Trail	2 and 3	-	Minor modifications	4WD track	Tantangara Creek	23,931	6	14

Table B.5 Assumed disturbance areas – access roads

Road	Phase	Stormwater management category	Construction upgrade	Final condition	Catchment	Length (m)	Typical cross-sectional width (m)	Estimated actual disturbed area (ha)
Total WM 2.4								**42**
Total WM 3.3								**35**

B.7.3 Actual disturbance areas

Table B.6 provides the estimated actual disturbance areas for each project phase. The areas are broken-down into regional catchments.

Table B.6 Actual disturbance areas by catchment

Stormwater management category	Reduction factors	Estimated actual disturbance area by catchment (ha)[1]											
		Lower Eucumbene River	Upper Eucumbene River	Tantangara Creek	Wallaces Creek	Yarrangobilly River	Kellys Plain Creek	Nungar Creek	Tantangara Reservoir	Talbingo Reservoir	Rock Forest	Other areas[2]	Total
WM 1.2 – Minor works	0.9	13	10	45	14	70	27	36	12	15	-	71	313
WM 1.3 – Major works	0.95	-	14	-	14	75	17	-	21	0	15	-	157
Construction phase 1 total:													**470**
WM 2.2 – Accommodation camps	1	-	-	-	2	8	7	-	-	-	-	-	18
WM 2.3 – Construction pads	1	-	-	-	2	21	5	-	5	-	16	-	51
WM 2.4 – Access roads	-	-	1	-	3	12	2	5	5	3	-	10	42
WM 2.5 – Large temporary stockpiles	1	-	12	-	7	5	-	-	5	0	-	-	30
Construction phase 2 total:													**141**
WM 3.2 – Permanent surface infrastructure	1	-	-	-	2	10	-	-	7	-	-	-	20
WM 3.3 – Permanent access roads	-	-	-	-	-	-	-	-	-	-	-	-	-
– Unsealed	-	-	1	-	3	7	2	5	1	-	-	3	23
– Sealed	-	-	-	-	-	5	-	-	-	-	-	7	12
WM 3.3 Total	-	-	1	-	3	11	2	5	1	-	-	10	35
Operational phase (phase 3) total:													**55**

Notes: 1. Values are presented to the nearest integer.

2. Other areas include: sections of Tantangara Road which flow to the lower sections of the Eucumbene River, and sections of Lobs Hole Ravine Road, Snowy Mountains Highway and the Link Road which are outside of the catchments characterised elsewhere.

B.8 Disturbance areas applied to residual impacts assessment

The area and duration of disturbance for each stormwater management category has been estimated based on the actual disturbance area, conceptual layout and project schedule. These values are applied to discharge modelling (WMR, Attachment E) to assess changes in receiving water flow regimes and water quality in the following three key catchments:

- Yarrangobilly River (including Wallaces Creek);
- Upper Eucumbene River; and
- Kellys Plain Creek.

Table B.7 provides a break-down of the disturbance areas applied to assess residual impacts.

Table B.7 Disturbance areas applied to discharge modelling

Stormwater management category	Estimated actual disturbed area by catchment (ha)[1]				
	Yarrangobilly River[2]	Upper Eucumbene River	Tantangara Compound[3]	All other areas	Total
WM 1.2 – Minor works	83	10	75	145	313
WM 1.3 – Major works	89	14	38	16	157
Construction phase 1 total					470
WM 2.2 – Accommodation camps	10	-	7	1	18
WM 2.3 – Construction pads	23	-	11	17	51
WM 2.4 – Access roads[3]	16	1	12	13	42
WM 2.5 – Large temporary stockpiles	12	12	5	1	30
Construction phase 2 total					141
WM 3.2 – Permanent surface infrastructure	12	-	7	1	20
WM 3.3 – Permanent access roads	-	-	-	-	0
– Unsealed[4]	10	1	8	3	23
– Sealed	5	-	-	7	12
WM 3.3 Total	15	1	8	10	35
Operational phase (phase 3) total					55

Notes: 1. Values are presented to the nearest integer.
2. Includes disturbance areas in Yarrangobilly River and Wallaces Creek catchments.
3. Includes disturbance areas in Kellys Plain Creek, Nungar Creek and Tantangara Reservoir catchments.
4. Refers to the surface area of access roads that will be constructed or substantially modified. The use of existing access tracks that will only be slightly modified (ie by construction of overtaking bays) is not considered to result in material additional disturbance.

Attachment C

Summary of water management measures

Table C.1 Summary of proposed management measures

Measure[1]	Description
Construction phase 1 – construction of surface infrastructure	
WM 1.1 Clean water management	
WM 1.1.1	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. Temporary clean water drainage will be designed to have non-erosive hydraulic capacity. The design event will be established based on disturbance duration and other relevant factors.
WM 1.1.2	Where practical, clean water diversions will seek to avoid increasing flow rates in adjoining watercourses.
WM 1.2 minor works	
WM 1.2.1	An Erosion and Sediment Control Plan (ESCP) will be prepared for each construction area. Each ESCP will: • apply the methods and principles provided in *Managing Urban Stormwater: Soils and Construction:* – *Volume 1 – Soils and construction* (Landcom 2004); and/or – *Volume 2A – Installation of services* (DECC 2008); and/or – *Volume 2C – Unsealed roads* (DECC 2008); unless stated below; • consider local soil characteristics, topography and environmental constraints and proposed construction methods; • apply clean water management controls as per: – WM 1.1 for clean water management during surface construction disturbance; – WM 2.1 for temporary watercourse diversions around temporary surface infrastructure; and – WM 3.1 for permanent watercourse diversions. • all temporary drainage and sediment control measures will be designed to have non-erosive hydraulic capacity and be structurally sound for a design event. The design event will be established based on the disturbance duration and other relevant factors; • consider all practical erosion control and rehabilitation methods and apply the most appropriate method; • consider all practical methods to stabilise small temporary stockpiles and apply the most appropriate method. Apply management controls as per WM 2.5 for the management of large temporary stockpiles; • apply enhanced erosion controls where significant risks are identified; and • be progressively amended as required during construction.
WM 1.2.2	The following will be implemented: • measures to manage the storage and handling of hydrocarbons and other chemicals that have potential to pollute receiving waters; and • measures to manage accidental leaks and spills.
WM 1.2.3	Suitably qualified erosion and sediment control professional(s) will be commissioned to: • oversee the development of ESCPs; • inspect and audit controls; • train relevant staff; and • progressively improve methods and standards as required.

Table C.1 Summary of proposed management measures

Measure[1]	Description
WM 1.3 major works	
WM 1.3.1	An ESCP will be prepared for each construction area. Each ESCP will: • apply the methods and principles provided in *Managing Urban Stormwater: Soils and Construction:* – *Volume 1 – Soils and construction* (Landcom 2004); and/or – *Volume 2A – Installation of services* (DECC 2008); and/or – *Volume 2C – Unsealed roads* (DECC 2008); and unless stated below; • consider local soil characteristics, topography and environmental constraints and proposed construction methods; • apply clean water management controls as per: – WM 1.1 for clean water management during surface construction disturbance; – WM 2.1 for temporary watercourse diversions around temporary surface infrastructure; and – WM 3.1 for permanent watercourse diversions. • consider all practical source control and rehabilitation methods and apply the most appropriate methods; • consider all practical methods to stabilise small temporary stockpiles and apply the most appropriate method. Apply management controls as per WM 2.5 for the management of large temporary stockpiles; • all temporary drainage and sediment control measures will be designed to have non-erosive hydraulic capacity and be structurally sound for a design event. The design event will be established based on the disturbance duration and other relevant factors; • where practical, all runoff from disturbance areas will be directed 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 proposed dewatering arrangements for each basin will be described in the ESCP. • be progressively amended as required during construction.
WM 1.3.2	The following will be implemented: • measures to manage the storage and handling of hydrocarbons and other chemicals that have potential to pollute receiving waters; and • measures to manage accidental leaks and spills.
WM 1.3.3	Suitably qualified erosion and sediment control professional(s) will be commissioned to: • oversee the development of ESCPs; • inspect and audit controls; • train relevant staff; and • progressively improve methods and standards as required.
WM 1.4 water supply system	
WM 1.4.1	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 will also likely source water from Tantangara and/or Talbingo Reservoirs provided required licences and approvals can be obtained. Extraction from watercourses is not proposed and will be avoided. The most suitable and available extraction locations and water sources will be established at detailed design stage.

Table C.1 Summary of proposed management measures

Measure[1]	Description
Construction phase 2 (all other construction activities)	
WM 2.1 temporary watercourse diversions	
WM 2.1.1	Where practical, all temporary watercourse diversions will: • be piped and/or surface drainage systems; • be designed and constructed to have non-erosive hydraulic capacity and be structurally sound for a design event that will be established by a risk assessment (described below); and • have adequate scour protection at the system inlets and outlets. During detailed design a risk assessment will be undertaken to identify risks associated with by-pass flows that may occur as a result of system blockage or an event greater than the design event. This process will establish the: • design capacity of the diversion; and • need for and capacity of overland flow paths or other measures to manage bypass flows.
WM 2.1.2	Where practical, temporary watercourse diversions will seek to avoid increasing flow rates in adjoining watercourses.
WM 2.1.3	All temporary watercourse diversions will be decommissioned following the completion of works. WM 3.1 applies to any permanent watercourse diversion or re-established watercourse.
WM 2.2 accommodation camps	
WM 2.2.1	Where practical, the following source controls will be applied: • the storage and handling of chemicals that have potential to contaminate the stormwater system will be undertaken in bunded areas. Any liquid waste stream will be disposed to an appropriate facility; • landscaped areas will be predominately vegetated with endemic native vegetation; and • runoff from road and other hardstand areas will be treated in vegetated swales.
WM 2.2.2	Runoff from accommodation camps will be managed by drainage systems that have a 20% AEP capacity. Overland flow paths will be provided as required.
WM 2.2.3	Runoff from accommodation camps will be treated in either sedimentation or bioretention basins (also referred to as raingardens). The most appropriate control will be established at detailed design with consideration of topography, soil conditions and other relevant factors. Where sedimentation basins are utilised, 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 proposed dewatering arrangements for each basin will be described in the relevant water management plan.
WM 2.2.4	Overall, the stormwater management system for accommodation camps will be designed and operated to achieve the water quality characteristics described in Table 3.12.
WM 2.3 construction pads	
WM 2.3.1	Where practical, activities that have potential to contaminate stormwater runoff will be isolated from the stormwater system by covering (ie by a building or roof) and/or bunding.
WM 2.3.2	Runoff from construction pads and upslope clean water areas will be managed by a drainage system. The design capacity will be established at detailed design. Overland flow paths will be provided as required.
WM 2.3.3	Runoff from construction pads will be directed to sedimentation basins. The sedimentation basins will be designed to capture runoff from the 85^{th} percentile 5-day rainfall event. Larger basins (ie sized to capture the 90^{th} or 95^{th} 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

Table C.1 Summary of proposed management measures

Measure[1]	Description
	• treated with appropriate water treatment chemicals and discharged. The proposed dewatering arrangements for each basin will be described in the relevant water management plan.
WM 2.3.4	Overall, the stormwater management system for construction pads will be designed and operated to achieve the water quality characteristics described in Table 3.15.
WM 2.4 access roads	
WM 2.4.1	Any existing access tracks that will no longer be required following the construction of the new access roads will be rehabilitated.
WM 2.4.2	All cut and fill batters that require stabilisation will be stabilised as soon as practical following construction.
WM 2.4.3	Roads surfaces will be constructed and maintained with aggregate material to reduce soil loss rates and water quality risks. The use of material that presents elevated water quality risks relative to other material available for road construction and maintenance will be avoided.
WM 2.4.4	Where practical access roads will grade to table drains that are designed and constructed to have non-erosive hydraulic capacity for the 10% AEP event. Transverse (or cross drainage) will be constructed to have the following non-erosive hydraulic capacities: • Primary roads – 1% AEP event; • Maintenance roads – 2% AEP event; and • Temporary access roads – 10% AEP event.
WM 2.4.5	Sediment traps or filters will be installed and maintained at all discharge locations to reduce coarse sediment in discharge.
WM 2.4.6	Temporary roads will be rehabilitated as soon as they are no longer needed.
WM 2.5 large temporary stockpiles	
WM 2.5.1	Excavated material will be characterised and identified contaminated soils or PAF material will be managed separately.
WM 2.5.2	Water management for each large temporary stockpile will be described in a ESCP that will: • apply the methods and principles provided in *Managing Urban Stormwater: Soils and Construction – Volume 1 – Soils and construction* (Landcom 2004) unless stated below; • consider local soil characteristics, topography and environmental constraints and proposed construction methods and identify risks associated with proposed activities; • apply clean water management controls as per: – WM 1.1 for clean water management during surface construction disturbance; and – WM 2.1 for temporary watercourse diversions around temporary surface infrastructure. • consider all practical temporary stabilisation methods and apply the most appropriate methods; • where practical, all runoff and seepage from each stockpile will drain to sedimentation basins designed to capture the 85^{th} percentile 5-day rainfall event. Larger basins (ie sized to capture the 90^{th} or 95^{th} 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 proposed dewatering arrangements for each basin will be described in the ESCP. • be progressively amended as required during construction.
WM 2.5.3	All large temporary stockpiles will be removed during the construction phase of the project and the disturbed area will be rehabilitated in accordance with the relevant rehabilitation strategy.
WM 2.6 large surface excavations	
WM 2.6.1	Water that accumulates in the sumps of large surface excavations will be either:

Table C.1 Summary of proposed management measures

Measure[1]	Description
	• dewatered to the process water system (WM 2.7); or • used for dust suppression.
WM 2.7 Process water	
WM 2.7.1	A process water management system will be established to: • supply water to construction activities; and • manage water that is pumped from the sumps in subsurface excavations and large surface excavations (WM 2.6). The process water system will be decommissioned once the project enters the commissioning phase and the headrace and tailrace tunnels are flooded.
WM 2.7.2	The process water system will be designed and constructed to minimise stormwater ingress into the system to reduce the volume of water that requires management.
WM 2.7.3	Where practical, the storage and handling of chemicals that have potential to contaminate the process water system will be undertaken in bunded areas. Any liquid waste streams will be disposed to an appropriate facility.
WM 2.7.4	Where practical, plant and equipment washdown will be undertaken in designated washdown bays or areas. Washdown water will be captured, treated and reused to minimise or avoid discharge into the process water system.
WM 2.7.5	Where practical, the process water system will be designed to include the system contingency measures presented in Table 4.6.
WM 2.7.6	All process water will be treated to meet the water quality specifications provided in Table 4.7.
WM 2.7.7	All treated surplus process water will be discharged to Tantangara and Talbingo reservoirs via diffuser arrangements. Indicative discharge locations are provided in Figure 2.2. Discharges to watercourses will be avoided.
WM 2.7.8	All water treatment by-products will be disposed outside of KNP to an appropriately licensed facility or by other means that are approved via the water management plan process.
WM 2.8 potable water – no management measures required	
WM 2.9 wastewater	
WM 2.9.1	All wastewater produced will be reticulated or trucked to a wastewater treatment plant. All reticulation and storages will be designed to restrict stormwater and groundwater ingress into the wastewater system.
WM 2.9.2	Water efficient fittings will be used to minimise wastewater loads.
WM 2.9.3	Low phosphorus products are to be used for washing activities controlled by site management (ie laundry services and mess hall) and encouraged (via education) for general use.
WM 2.9.4	No trade waste will be discharged to the wastewater system.
WM 2.9.5	Each wastewater treatment plant will include emergency storage for untreated wastewater. The storage volume will be calculated during detailed design based on analysis of response times for emergency measures to be implemented.
WM 2.9.6	All wastewater will be treated to meet the water quality specifications provided in Table 5.1. All wastewater treatment plants will be designed to operate during winter when sub-zero temperatures can persist for extended periods of time.
WM 2.9.7	Treated wastewater will be discharged to Talbingo and Tantangara reservoirs via diffuser arrangements. Indicative discharge locations are provided in Figure 2.2.
WM 2.9.8	All water treatment by-products will be disposed outside of KNP to an appropriately licensed facility or by other means that are approved via the water management plan process.
WM 2.10 tunnel inflows	
WM 2.10	Tunnel boring machines will be equipped with drilling machines to drill drainage holes to relieve groundwater pressures. If required, pre-excavation grouting will also be used to seal-off groundwater inflow and to improve the stability of the excavation face. Post-excavation grouting, from the segmental lining, may also be used to further consolidate the surrounding rock and/or further reduce water ingress if required.

Table C.1 Summary of proposed management measures

Measure[1]	Description
Operational phase (Phase 3)	
WM 3.1 permanent watercourse diversion	
WM 3.1.1	Any watercourse that will be permanently diverted around permanent infrastructure will: • be a piped and/or surface drainage system; • be designed and constructed to have non-erosive hydraulic capacity and be structurally sound for the 1% AEP event; and • have adequate scour protection at the system inlets and outlets. During detailed design a risk assessment will be undertaken to identify risks associated with by-pass flows that may occur as a result of system blockage or an event greater than the design event. If significant risks are identified (such as embankment failures or entrainment of materials that could pollute the receiving environment), engineered overland flow paths will be established to manage by-pass flows.
WM 3.1.2	Watercourses to be reinstated into a rehabilitated landform along either its original or an alternative alignment will be designed and constructed as a physically stable naturalised watercourse that has similar environmental values to the pre-disturbed watercourse.
WM 3.2 permanent surface infrastructure	
WM 3.2.1	Transformers and any other infrastructure that has potential for leaks or spills will be bunded in accordance with relevant guidelines.
WM 3.2.2	Runoff from permanent surface infrastructure will be managed by a drainage system that has a 1% AEP capacity. Overland flow paths will be provided as required.
WM 3.3 permanent access roads	
WM 3.3.1	Unsealed roads will be maintained with aggregate material to reduce soil loss rates and water quality risks. The use of material that presents elevated water quality risks relative to other material available for road construction and maintenance will be avoided.
WM 3.3.2	Where practical access roads will grade to table drains that are designed and constructed to have non-erosive hydraulic capacity for the 10% AEP event. Transverse (or cross drainage) will be constructed to have the following non-erosive hydraulic capacities: • Primary roads – 1% AEP event; and • Maintenance roads – 2% AEP event.
WM 3.3.3	Sediment traps or filters will be maintained at all discharge locations on unsealed roads to reduce coarse sediment in discharge.
WM 3.4 Tailrace tunnel dewatering	
WM 3.4.1	Water pumped from the tailrace tunnel to enable maintenance access will be discharged into a drainage system that will convey the water to the Yarrangobilly River. The drainage system will be designed and constructed to have non-erosive hydraulic capacity and be structurally sound for the design discharge rate and duration.
WM 3.5 Management of groundwater inflows	
WM 3.5.1	Groundwater inflows into the power station cavern, access tunnels and any other excavation that will not be flooded will be collected and pumped into the collector tunnel or tailrace surge tank.
Ancillary management measures	
Instream works 1	All permanent culverts and bridges will be designed by a suitably qualified professional in accordance with the relevant Austroads Guidelines.
Instream works 2	All service crossings of watercourses will be designed by a suitably qualified professional in accordance with best practice methods.

Notes: 1. The management measures presented are principles or design objectives, that will be further developed in the detailed design of Main Works. The measures implemented may vary from those presented but will meet the proposed discharge characteristics or other stated objectives.

Attachment D

Water balance model technical report

D.1 Purpose

This attachment to the water management report (WMR) (Appendix J of the PIR-RTS) describes the methods and assumptions applied to developing a water balance of the project's process water system. The process water system is described in Chapter 4 of the WMR.

D.2 Process water system

The process water system will supply water to, and manage water produced by construction activities. Key water uses (or system demands) include water used for subsurface construction (primarily TBM cooling and dust suppression), concrete production, grouting activities, fill conditioning and access road dust suppression. Key inflows into the system include water pumped from subsurface and large surface excavations.

The process water system will comprise separate systems at the Tantangara and Talbingo construction compounds. These systems are referred to as the Tantangara and Talbingo process water systems and will operate independently (ie they will not be connected). Each system will:

- be isolated from the stormwater management system (described in Chapter 3 of the WMR);
- discharge to a reservoir when net inflows into the system exceed net usage; and
- be toped up from the water supply system (Section 6.1 of the WMR) when net usage exceeds net inflows.

The water quality of process water will be influenced by the groundwater inflow quality, any degradation by construction activities and other factors. The water quality is expected to be variable, with potential for poor water quality to occur in some parts of the process water system. All process water will be treated to a suitable quality for re-use within the process water system and discharge to reservoirs.

Figure D.1 shows the conceptual framework of the process water system.

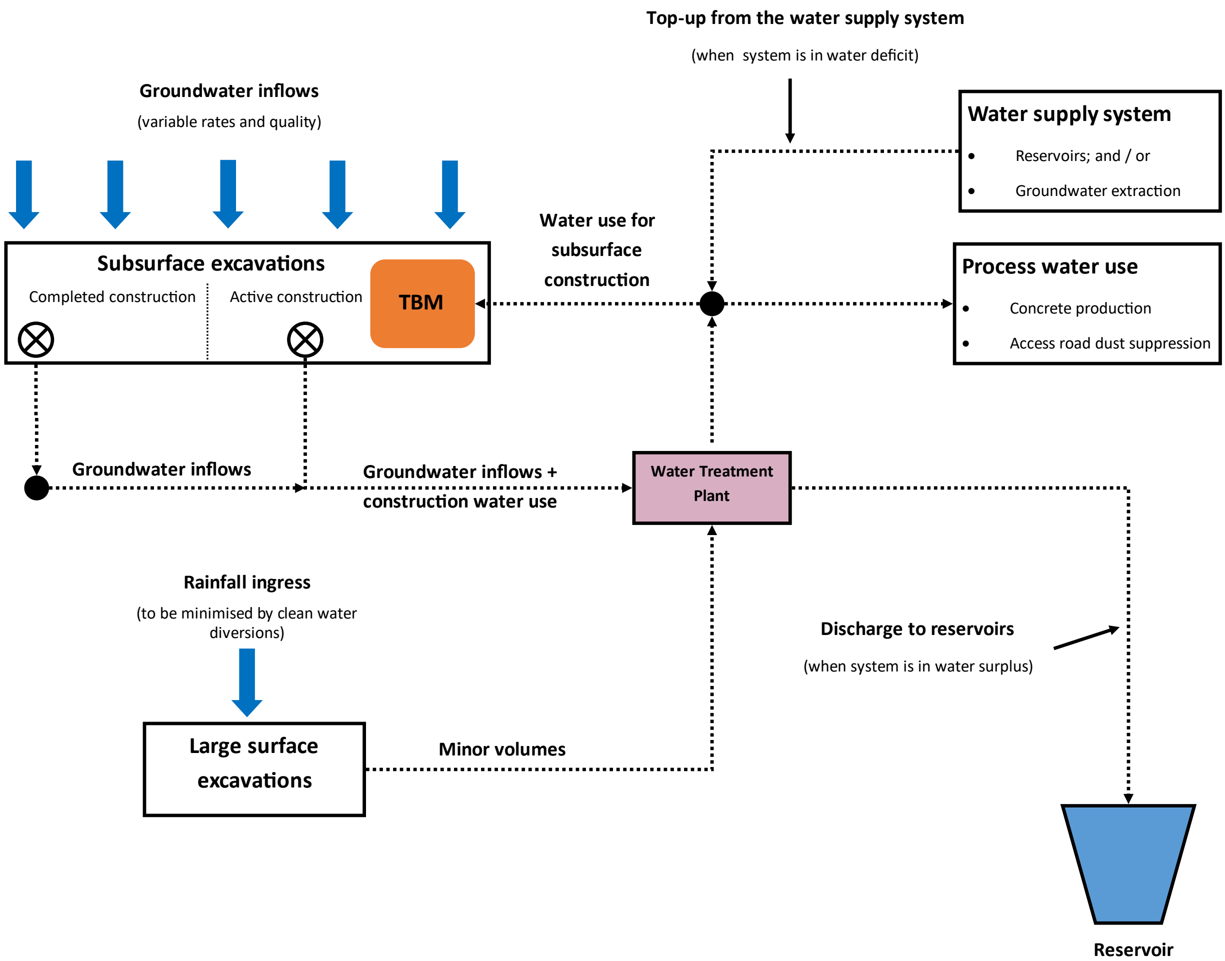


Figure D.1 Process water system – conceptual framework

D.3 Tantangara and Talbingo system extents

The Tantangara and Talbingo process water systems will manage water pumped from connected subsurface excavations. Figure D.2 shows the extent of subsurface excavations connected to each system. As the volume and water quality of groundwater inflows will be a key contributing factor to the process water system, the following groundwater quality categories have been established to collectively describe inflows from geological units that have similar groundwater quality characteristics:

- Plateau – includes the Boggy Plains Suite, Gooandra Volcanics, Kellys Plain Volcanics, Tantangara Formation and Temperance Formation geological units.
- West ravine – includes the Ravine Beds West geological unit.
- East ravine – includes the Boraig Group and Ravine Beds East geological units.

Figure D.2 shows the extent of each groundwater quality category. The groundwater quality characteristics of each category are discussed in Section 4.3.1 of the WMR. Refer to the WCR (Annexure A to the water assessment) for more information on geological units and associated groundwater quality.

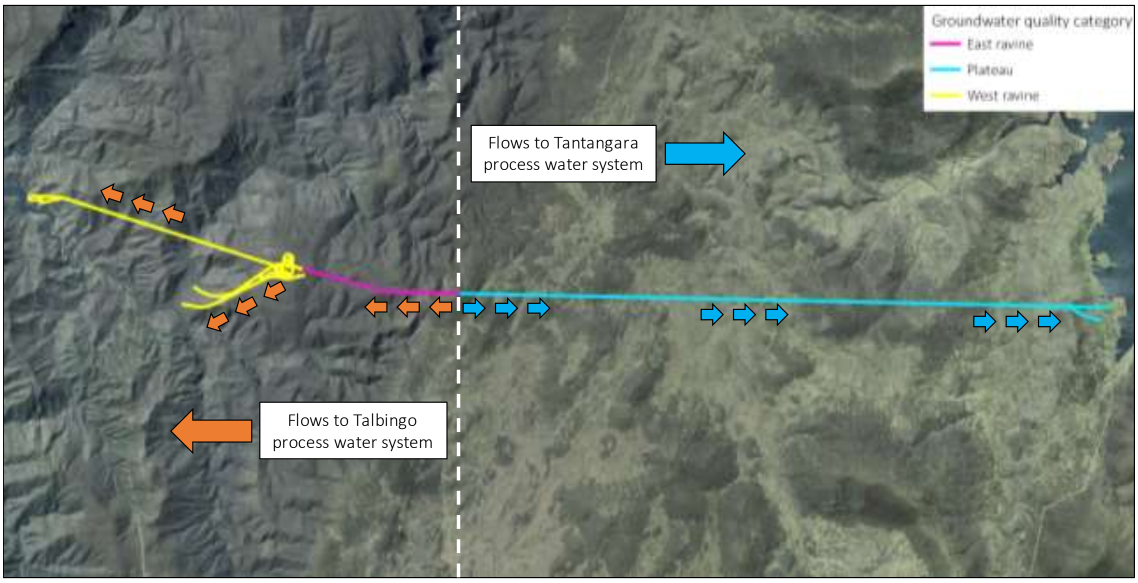


Figure D.2 Process water system extent

D.4 System inflows

As indicated in Figure D.1, the following process water system inflows will occur:

- groundwater inflows into subsurface excavations;
- water pumped from sumps of surface excavations that may have poor water quality; and
- top-up water from the water supply system.

D.4.1 Groundwater inflows

The revised modelling report (Appendix I of the PIR-RTS) provides predicted groundwater inflow volumes over the construction phase of the project. Model outputs were provided as quarterly inflow averages to each subsurface excavation component. A breakdown of the primary subsurface components is provided in Table D.1. The predicted groundwater inflows to each component are shown in Figure D.3.

Table D.1 Subsurface excavation dewatering

Subsurface component	Description	Start of inflow[1]	Maximum inflow
HRT – Tantangara side	Section of headrace tunnel (HRT) that extends approximately 15.4 km from Tantangara Reservoir in the east to the western extent of the plateau.	Month 12	3.9 ML/day
HRT – Talbingo side	Section of HRT that extends approximately 2.0 km from the power station structure in the west to the western extent of the plateau in the east.	Month 12	0.6 ML/day
TRT	Tailrace tunnel (TRT) extends 5.8 km from the power station structure in the east to Talbingo Reservoir in the west.	Month 6	0.7 ML/day
MAT, ECVT and ancillary structures.	Includes the maintenance access tunnel (MAT) and emergency egress cables and ventilation tunnel (ECVT) that each extend approximately 2.5 km from the power station structure in the east to Lobs Hole in the west, and all other underground components including, surge tanks, power station infrastructure etc.	Month 1	1.2 ML/day

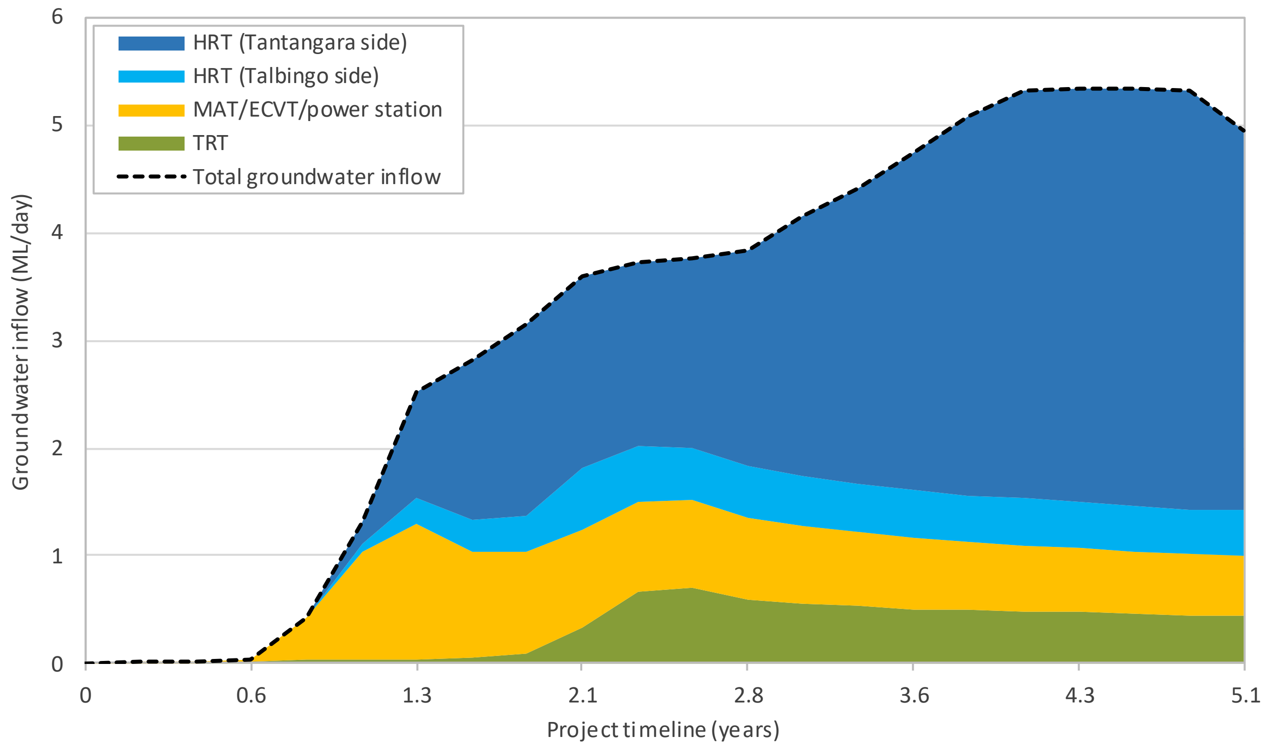


Figure D.3 Groundwater inflow predictions

D.4.2 Dewatering surface excavations

Water that accumulates in the sumps of large surface excavations such as tunnel intakes may have poor water quality due to construction activities. Accordingly, water may be dewatered to the process water system. Inflows into surface excavations will occur from direct rainfall and groundwater ingress. Estimated inflow volumes and contributing catchment areas of large surface excavations that will be connected to the process water system are described in Table D.2.

Table D.2 Large surface excavations

Large surface excavation	Contributing catchment area	Inflow volume
Tantangara intake	6 ha	36 ML/year[1]
Talbingo intake	3 ha	17 ML/year[2]

Notes: 1. Inflow volume calculated using average yearly rainfall (1,009 mm/year) for Tantangara Reservoir rainfall gauge (WCR, Annexure A to the water assessment) and a runoff coefficient (Cv) of 0.6.

2. Inflow volume calculated using average yearly rainfall (920 mm/year) for Ravine rainfall gauge (WCR, Annexure A to the water assessment) and a runoff coefficient (Cv) of 0.6.

Water dewatered from large surface excavations is not included in the water balance as the volumes are insignificant when compared to the volume of groundwater inflows.

D.4.3 Top-up from the water supply system

The process water system will be toped-up with water from the water supply system (Section 6.1 of the WMR). System top-ups will only be required when net usage exceeds net inflows.

D.5 Process water usage

Estimated process water usage for the Tantangara and Talbingo process water systems was developed as part of the concept design. Process water demands were estimated for concrete batching plants, TBMs and dust suppression. TBM demands for the Talbingo process water system were calculated separately for the Talbingo portal and MAT/ECVT portals. Process water demands were estimated for a seven-year process water timeseries (period over which process water demands occur). Process water use for the Tantangara and Talbingo process water systems is presented as stacked area charts in Figure D.4 and Figure D.5 respectively.

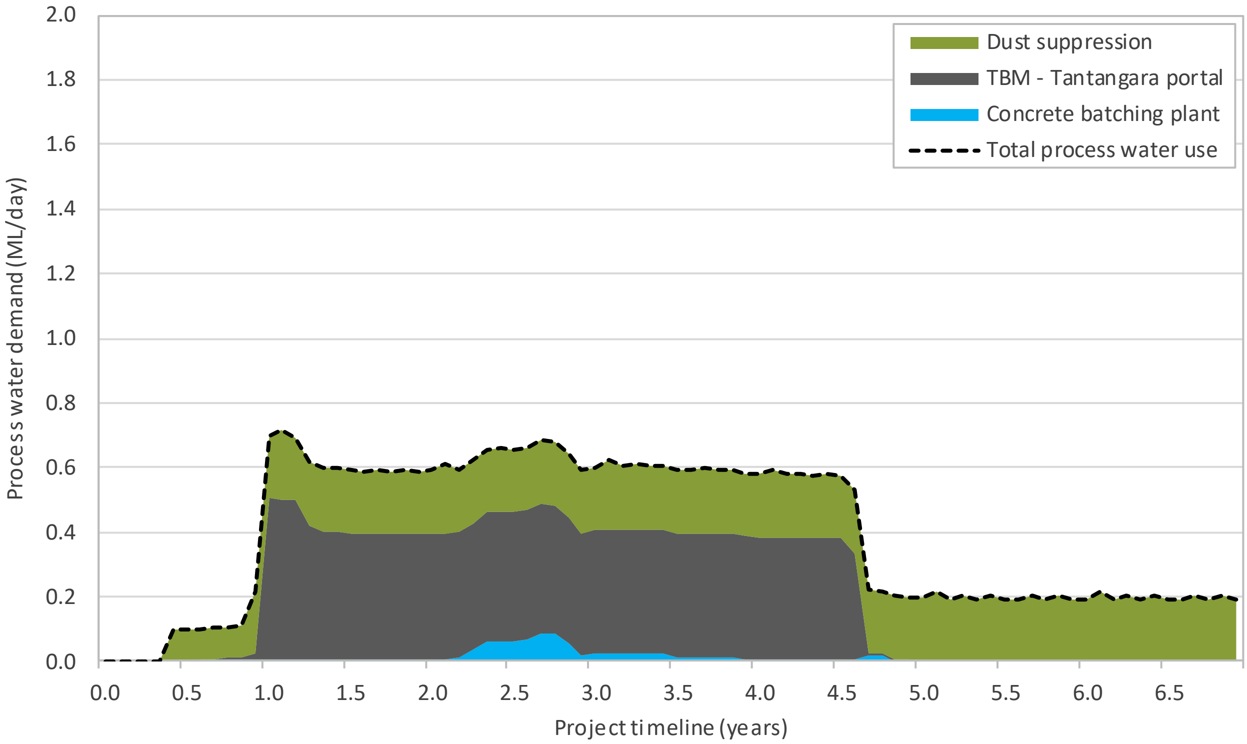


Figure D.4 Estimated process water use for the Tantangara process water system

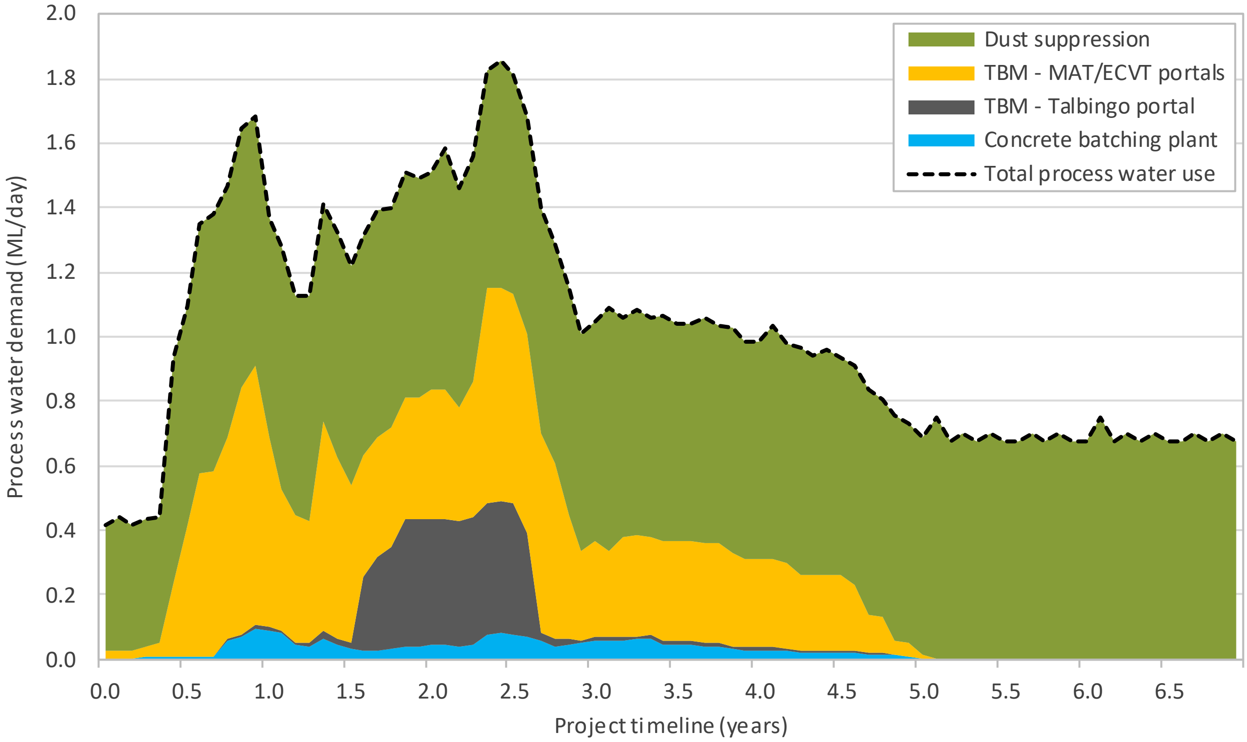


Figure D.5 Estimated process water use for the Talbingo process water system

D.6 Model assumptions

D.6.1 Groundwater inflows

The groundwater inflow dewatered to each process water system is dependent on construction timing, subsurface component and geological units intercepted. The groundwater model outputs described in Section D.4.1 have been used to define inflows to each of the process water systems.

The subsurface components assumed to contribute to each process water system are identified in Table D.3 and shown in Figure D.2. The groundwater inflow directed to each tunnel portal in the water balance model is shown in Figure D.6. Groundwater inflows for each groundwater quality category are shown in Figure D.7.

Table D.3 Breakdown of subsurface components

Process water system	Tunnel portal	Contributing subsurface components	Groundwater quality category
Tantangara	Tantangara	• HRT chainage 0 to 15,400 m	• Plateau
Talbingo	Talbingo	• TRT	• West ravine
	MAT/ECVT	• MAT and ECVT • HRT chainage 17,400 to 15,400 m • All other subsurface components including surge tanks, power station etc.	• West ravine • East ravine

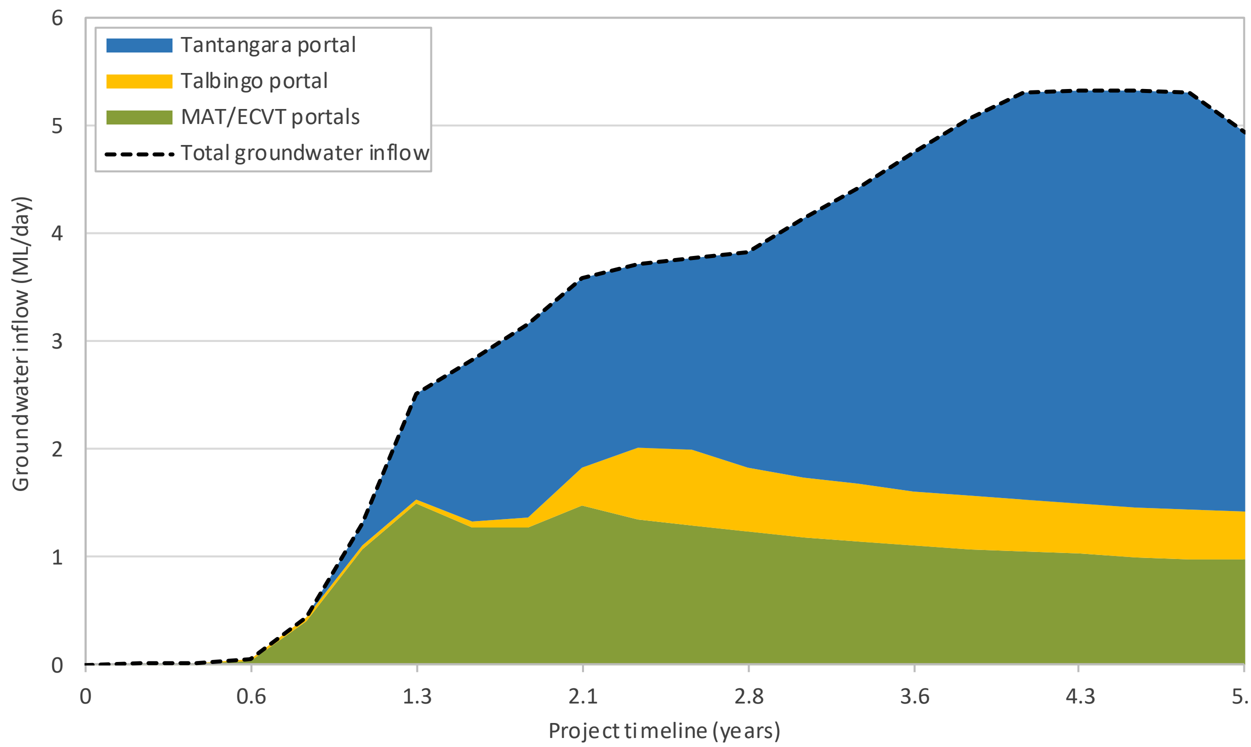


Figure D.6 Water balance model groundwater inflow – subsurface components

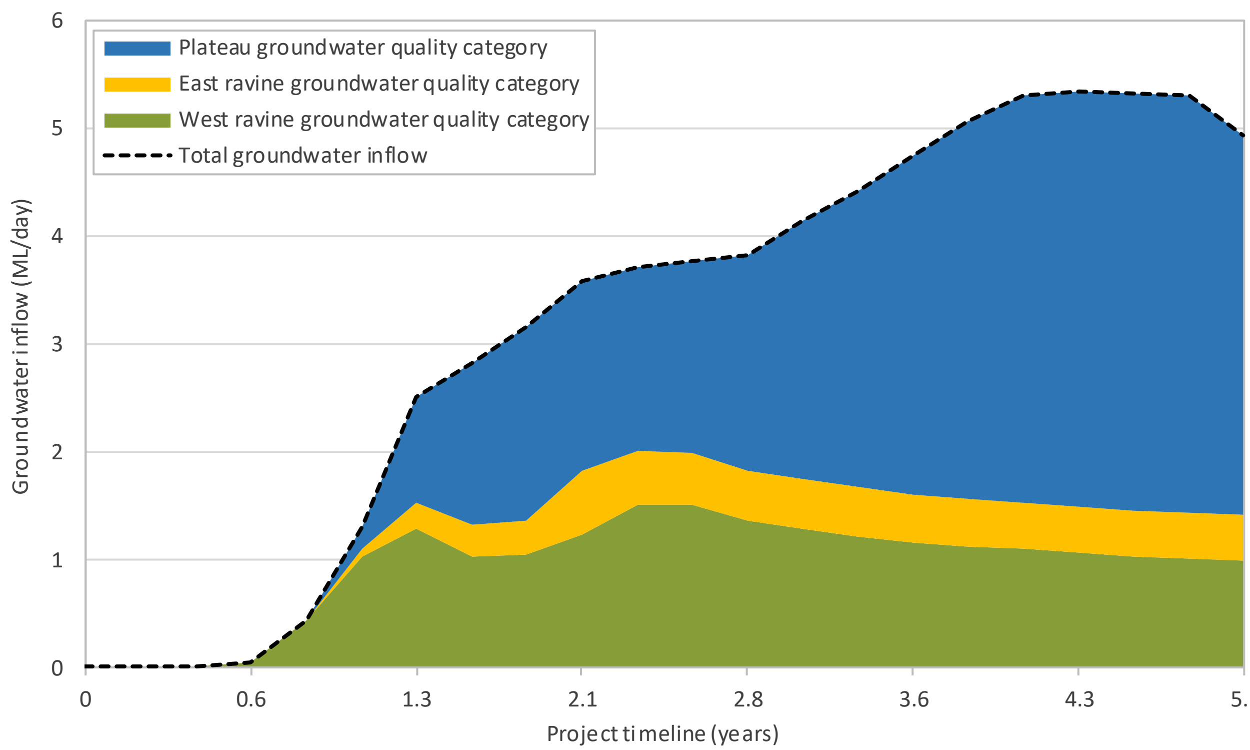


Figure D.7 Water balance model groundwater inflow – groundwater quality categories

D.6.2 Rainfall data

Direct rainfall inflows to Tantangara and Talbingo process water system surface excavations are estimated to be 36 ML/year and 17 ML/year respectively (see Section D.4.2). Subsurface excavation inflows to Tantangara and Talbingo process water systems are predicted to be up to 1,400 ML/year and 690 ML/year respectively. Hence, rainfall occurring directly onto surface excavations is negligible compared to the predicted subsurface excavation inflows.

Rainfall has not been included in the water balance model.

D.6.3 Evaporation

No water storages have been modelled. Hence, evaporation has not been included in the water balance model.

D.6.4 Site infrastructure

i Process water demands

Monthly process water demands described in Section D.5 were converted to daily values for use in the water balance model. Daily process water demands were obtained by dividing the monthly total by the number of days in each month.

Process water for concrete batching and dust suppression at the Talbingo process water system is preferentially sourced from the MAT/ECVT portal. This assumption is based on the timing of construction (construction of MAT/ECVT commences before TRT) and has been made to simplify the modelling process. During construction, process water could be preferentially sourced from either the MAT/ECVT portal or Talbingo portal as required.

Process water used by the TBM is sourced independently at each tunnel. TBM process water is recycled through the WTP for re-use. No water losses have been assumed during the recycling process.

It is noted that some stormwater captured in sedimentation basins may also be used for dust suppression. This is not expected to materially alter the results given the dust suppression water use is minor in comparison to groundwater inflows.

ii Water management basins and sumps

Daily groundwater inflows to Tantangara and Talbingo process water systems are predicted to be substantially greater than the available storage within sumps and water management basins, resulting in short residence times (less than a daily timestep) for process water that enters these storages.

Accordingly, no water management basin, portal sump or tunnel sump storages are modelled.

iii Process water treatment plant

Process water from the Tantangara and Talbingo process water systems will be treated prior to re-use or discharge. The water treatment process does not impact the water balance. It is noted that it is assumed that no clean groundwater diversions occur.

D.6.5 Water supply system

The process water system is topped up with water from the project's water supply system (Section 6.1 of the WMR) when usage exceeds groundwater inflows.

D.6.6 Reservoirs

Controlled discharge to Tantangara and Talbingo reservoirs occurs when groundwater inflows exceed net process water use.

D.7 Model representation

D.7.1 Modelling approach

The water balance model was developed in GoldSim version 12.1 (GoldSim Technology 2017). The model applied a continuous simulation methodology that simulated the performance of the system over the construction period.

D.7.2 Time step and simulation time

The water management system was modelled for the 84-month project timeline with daily time steps. The project timeline was assumed to commence at the beginning of the process water use time series and finish at the end of the process water use time series (see Section D.5).

D.7.3 Scenario

The water balance model has been used to simulate groundwater inflows for the lined but unmitigated tunnel scenario described in the revised modelling report (Appendix I of the PIR-RTS).

D.8 Model results

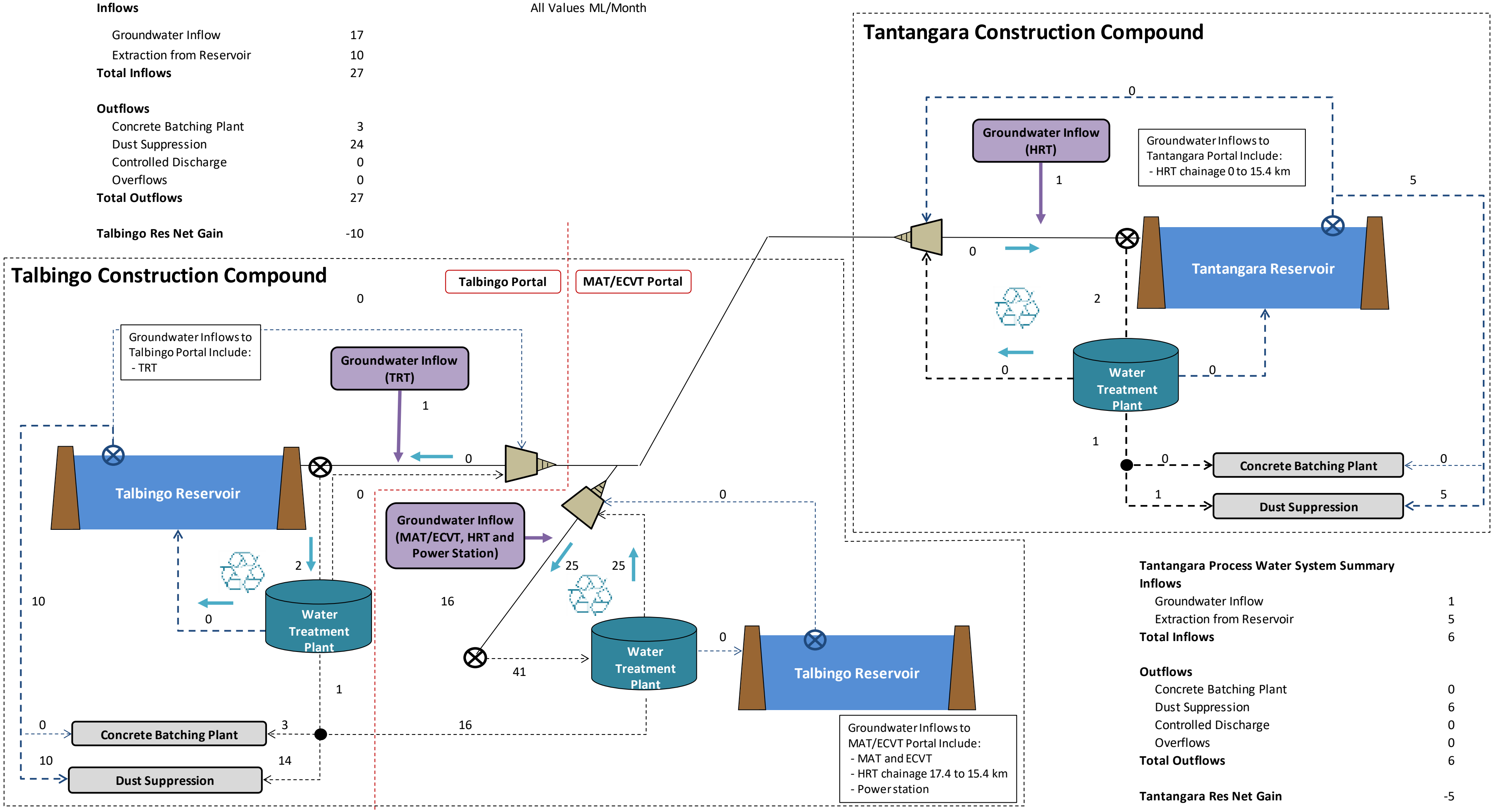
Model results are presented in Section 4.2 of the WMR. Additional results are provided in flow chart form Figure D.8 to Figure D.13. The flow charts have been prepared to describe the functionality of the process water management system for months 12, 24, 36, 48, 60 and 72 of the construction phase of the project. The flow charts show system flows for the MAT/ECVT, Talbingo and Tantangara portals separately. It is noted that the MAT/ECVT and Talbingo portals system form the Talbingo process water system and all results presented in the WMR refer to the Talbingo process water system.

Talbingo Process Water System Summary

Inflows	
Groundwater Inflow	17
Extraction from Reservoir	10
Total Inflows	27
Outflows	
Concrete Batching Plant	3
Dust Suppression	24
Controlled Discharge	0
Overflows	0
Total Outflows	27
Talbingo Res Net Gain	-10

Construction Month 12

All Values ML/Month



Tantangara Process Water System Summary

Inflows	
Groundwater Inflow	1
Extraction from Reservoir	5
Total Inflows	6
Outflows	
Concrete Batching Plant	0
Dust Suppression	6
Controlled Discharge	0
Overflows	0
Total Outflows	6
Tantangara Res Net Gain	-5

Figure D.8 Water balance results: month 12 of construction

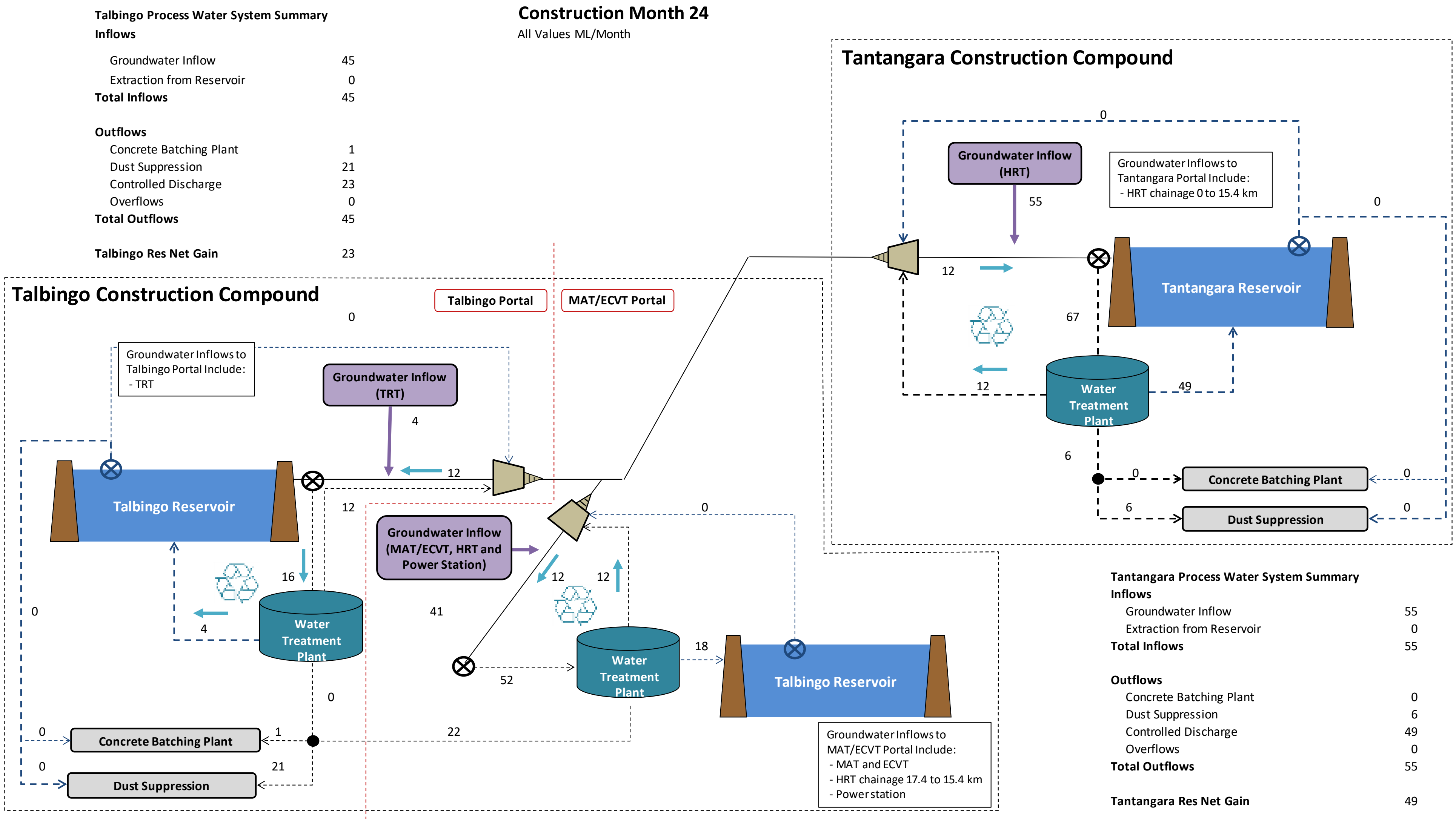


Figure D.9 Water balance results: month 24 of construction

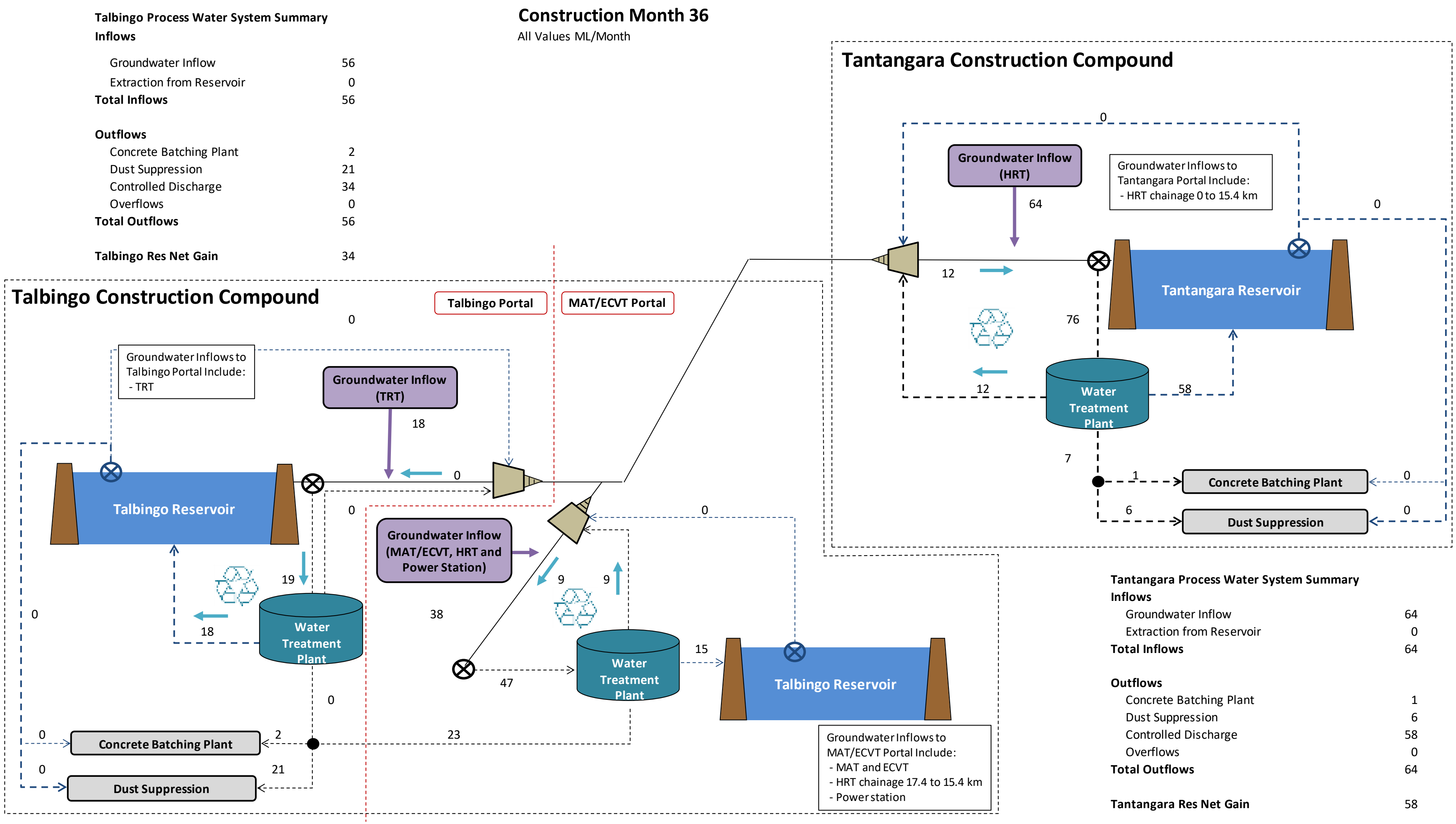


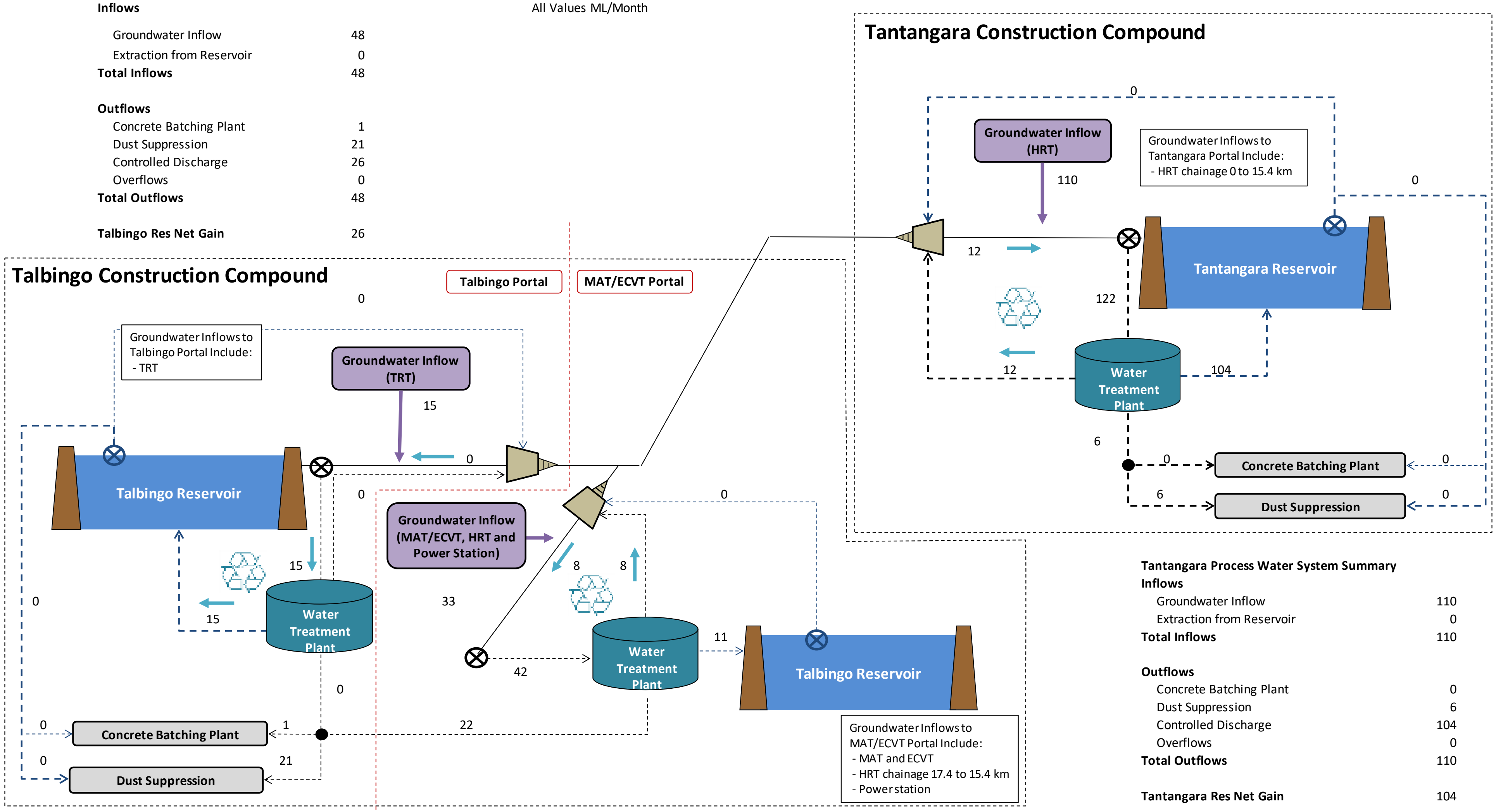
Figure D.10 Water balance results: month 36 of construction

Talbingo Process Water System Summary

Inflows	
Groundwater Inflow	48
Extraction from Reservoir	0
Total Inflows	48
Outflows	
Concrete Batching Plant	1
Dust Suppression	21
Controlled Discharge	26
Overflows	0
Total Outflows	48
Talbingo Res Net Gain	26

Construction Month 48

All Values ML/Month



Tantangara Process Water System Summary

Inflows	
Groundwater Inflow	110
Extraction from Reservoir	0
Total Inflows	110
Outflows	
Concrete Batching Plant	0
Dust Suppression	6
Controlled Discharge	104
Overflows	0
Total Outflows	110
Tantangara Res Net Gain	104

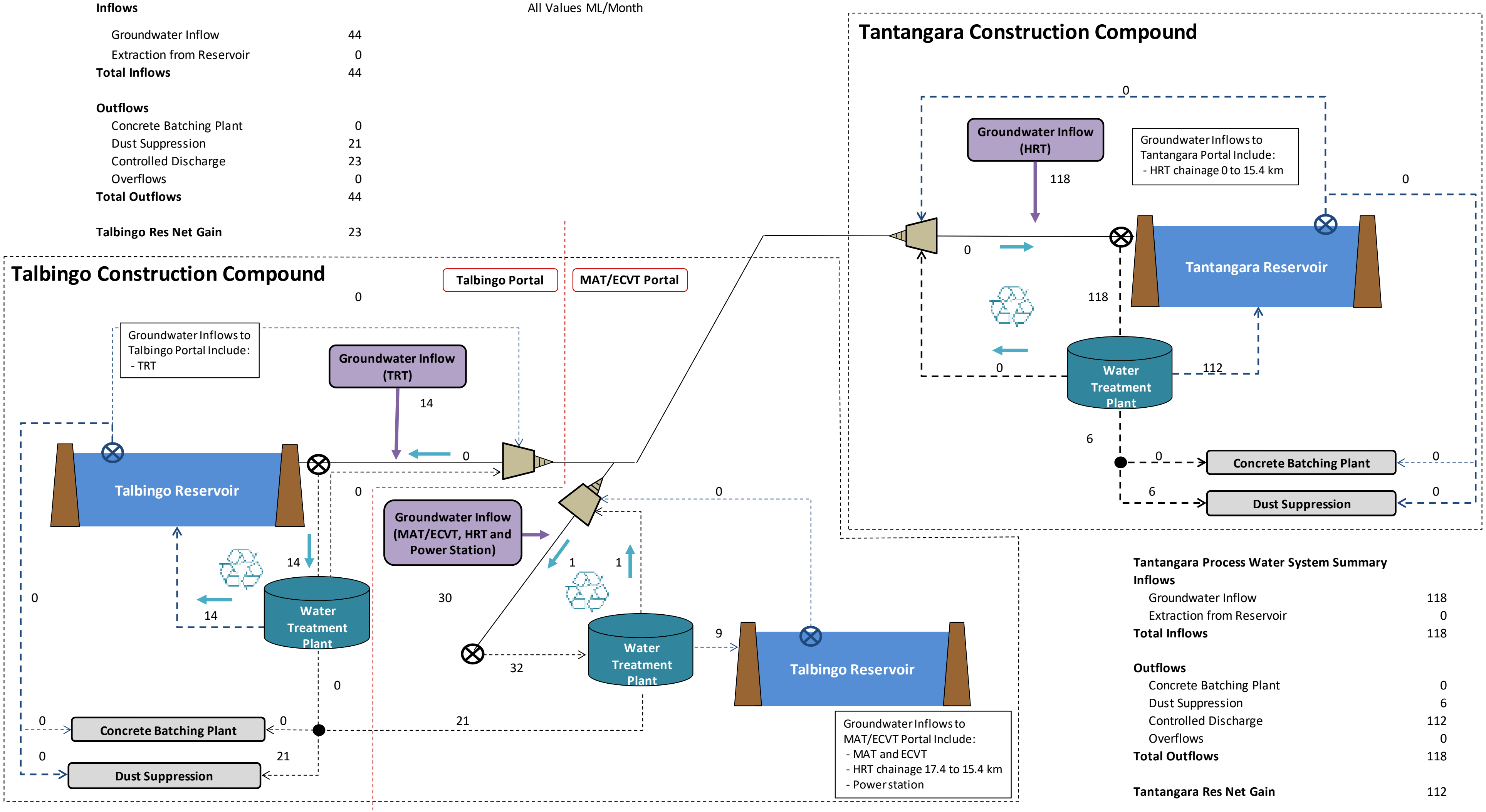
Figure D.11 Water balance results: month 48 of construction

Talbingo Process Water System Summary

Inflows	
Groundwater Inflow	44
Extraction from Reservoir	0
Total Inflows	44
Outflows	
Concrete Batching Plant	0
Dust Suppression	21
Controlled Discharge	23
Overflows	0
Total Outflows	44
Talbingo Res Net Gain	23

Construction Month 60

All Values ML/Month



Tantangara Process Water System Summary

Inflows	
Groundwater Inflow	118
Extraction from Reservoir	0
Total Inflows	118
Outflows	
Concrete Batching Plant	0
Dust Suppression	6
Controlled Discharge	112
Overflows	0
Total Outflows	118
Tantangara Res Net Gain	112

Figure D.12 Water balance results: month 60 of construction

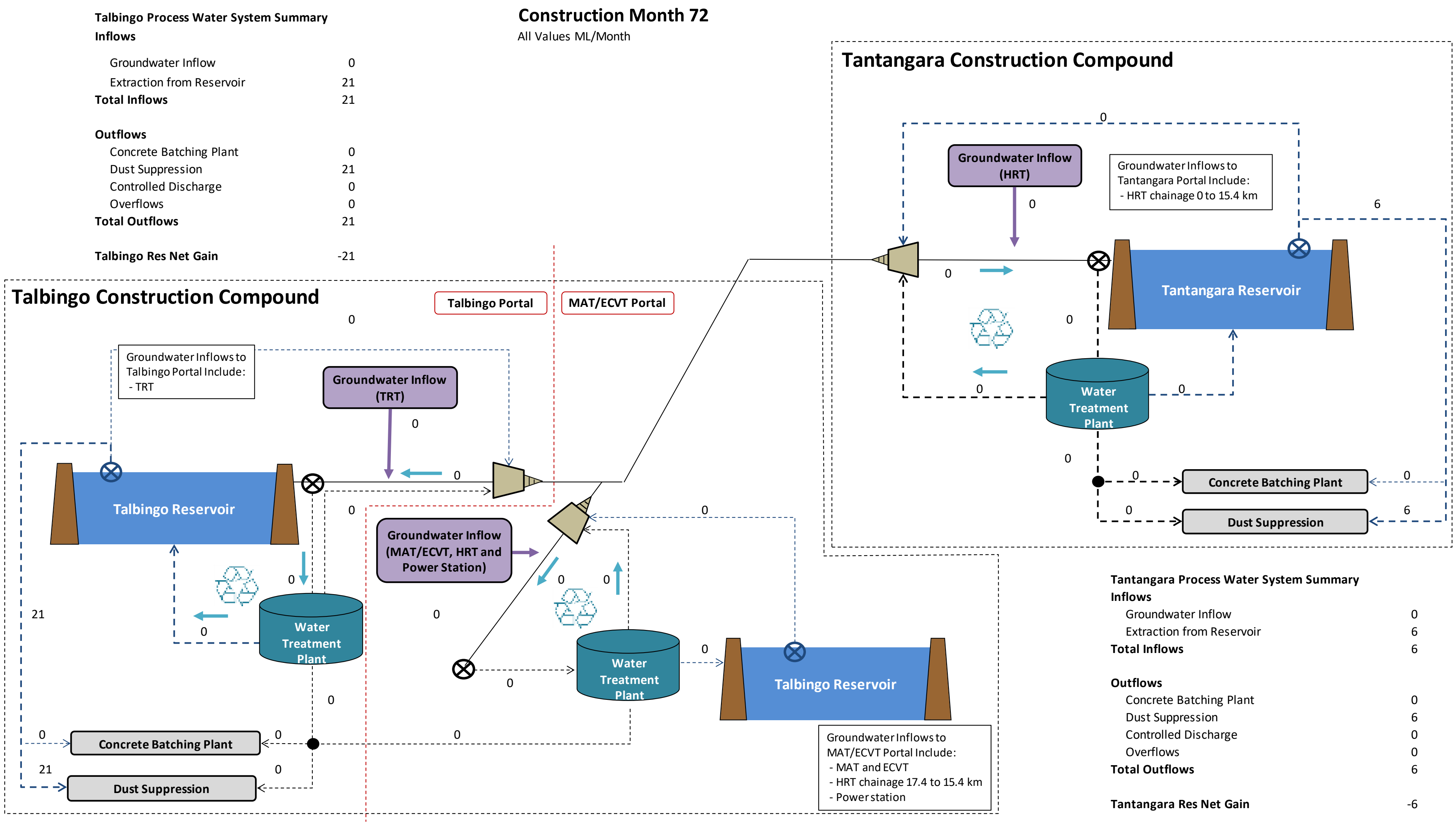


Figure D.13 Water balance results: month 72 of construction

D.9 Model sensitivity

Table D.4 describes the sensitivity of model results due to variation in the followings key water balance assumptions:

- groundwater inflows; and
- process water use.

Table D.4 Model sensitivity

Changes to assumptions	Resulting changes to model results
• Groundwater inflows lower than predicted; and/or • Process water use higher than predicted.	• Decrease in the frequency and magnitude of discharge to reservoirs. • Increase in the frequency and magnitude of top-up from the water supply system.
• Groundwater inflows higher than predicted; and/or • Process water use lower than predicted.	• Increase in the frequency and magnitude of discharge to reservoirs. • Decrease in the frequency and magnitude of top-up from the water supply system.

Attachment E

Stormwater discharge modelling

E.1 Introduction

This attachment to the water management report (WMR) (Appendix J of the PIR-RTS) describes the assumptions and methodology applied to estimate residual water quality impacts associated with stormwater runoff from the stormwater management areas described in the water management report.

This attachment is a technical account of the stormwater discharge modelling methodology, including a discussion of assumptions and limitations. Modelling results are presented and discussed in Chapter 8 of the water management report.

E.2 Model purpose

The discharge model was used to:

- estimate runoff quantity and quality from areas disturbed by the project;
- undertake dilution calculations, such that the relative impact of site runoff to receiving waterbody water quality might be estimated;
- estimate pollutant (suspended solids, nutrient and selected dissolved and suspended metals) loads entering the Talbingo and Tantangara reservoirs within stormwater runoff.

This model does not perform an engineering design function for sediment basin sizing, nor is it suitable for use for a mixing zone analysis.

E.3 Model software

The model was built using GoldSim version 12.1. GoldSim is an industry standard water systems model which has probabilistic simulation capability. The model applied a continuous simulation methodology which gave a statistical assessment of runoff regimes and residual water quality impacts.

GoldSim was used for this assessment as it provides a user-friendly interface for the simulation of complex water systems and allows for the probabilistic use of historic climate and streamflow data.

E.4 Model design

E.4.1 Overview

The model uses historical climate data and assumptions about the runoff characteristics of the stormwater management categories to estimate runoff quantity and quality from disturbed areas over three phases of the project (as described in the WMR):

- Phase 1
  - WM 1.2 – Minor works; and
  - WM 1.3 – Major works.
- Phase 2
  - WM 2.2 – Accommodation camps;

- WM 2.3 – Construction pads;
- WM 2.4 – Access roads; and
- WM 2.5 – Stockpiles (earthworks).

• Phase 3
  - WM 3.2 – Permanent surface infrastructure; and
  - WM 3.3 – Permanent access roads.

The area of each type of disturbance is documented in Attachment B of the WMR.

The model was run on a daily time scale using 40 years of climate data to generate annualised statistics about the likely runoff regimes of disturbed areas.

Dilution calculations were then undertaken, comparing the estimated runoff with gauged streamflow.

A model has been built for the Yarrangobilly River, Upper Eucumbene River, and Tantangara construction compound catchments for quantitative assessment.

E.4.2 Model input data

Table E.1 documents all data used in the model and applicable modelled catchments.

Table E.1 Model input data

Data type	Data name	Data source/comments	Modelled catchment
Rainfall record	Ravine_RF_Data	Rainfall gauge record from January 1992–June 2019 located at the Yarrangobilly River in Lobs Hole, owned and operated by Snowy Hydro (SHL). Record has been infilled with SILO patched point rainfall data from 1978–2019 where gauged data was not available (lat/long: -35.80, 148.40)	Yarrangobilly River
Rainfall record	Tant_RF_Data	Rainfall gauge record from January 1991–October 2018 located at the weather station near Tantangara Reservoir, owned and operated by SHL. Record has been infilled with SILO patched point data from 1972–2019 where gauged data was not available (lat/long: -35.80, 148.65)	Tantangara construction compound
Rainfall record	Eucumbene_RF_Data	SILO patched point rainfall record for the upper reaches of the Eucumbene, from 1978–2019 (lat/long: -35.80, 148.50)	Upper Eucumbene River
Stream gauge record	Yarrangobilly_SG_Data	Stream gauge record from Bureau of Meteorology (BoM) station 410574 on Yarrangobilly River from 1972– 2019.	Yarrangobilly River
Stream gauge record	Eucumbene_SG_Data	Stream gauge record from BoM station 222522 on Eucumbene River from January 1978–July 2019.	Upper Eucumbene River
Stream gauge record	Murrumbidgee_SG_Data	Stream gauge record from BoM station 410535 on Murrumbidgee River from 1978–July 2019.	Tantangara construction compound
Pan evaporation record	Pan_Evap	Class A Pan evaporation from SILO (lat/long: -35.80, 148.50)	All catchments

Table E.1 Model input data

Data type	Data name	Data source/comments	Modelled catchment
Runoff coefficients	Runoff_Coefficients	Runoff coefficients (C_v) for volumetric runoff from 'Blue Book' *Managing Urban Stormwater: Soils and Construction Volume 1* Table F2 (Landcom 2004). See Table E.3 for values.	All catchments
Disturbed areas	PIR-RTS_Disturbed_Areas	Disturbed areas associated with stormwater management categories for assessment, as developed in Attachment B of the WMR. See Table B.7 for values.	All catchments
Water quality inputs	WQ_Inputs	Water quality inputs as developed in the WMR. See Table E.5 for values.	All catchments

i Stream gauge scaling factors

Historic streamflows were scaled by catchment area to account for the difference between the catchment area upstream of the gauge location and the catchment area upstream of the modelled location. Scaling factors are given in Table E.2. The Yarrangobilly River catchment area discharges at the gauge location and does not need a scaling factor.

Table E.2 Stream gauge scaling factors

Catchment	Gauged catchment area (ha)	Modelled catchment area (ha)	Scaling factor
Eucumbene River	16,337	564	0.03
Tantangara construction compound (Kellys Plain Creek)	21,343	814	0.04

ii Runoff coefficients

The runoff coefficients used to estimate runoff from pervious areas were taken from *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom 2004) Table F2, presented in Table E.3.

Table E.3 Runoff coefficients

Soil Hydrologic Group	Design Rainfall depth (mm)							Runoff potential
	<20	21-25	26-30	31-40	41-50	51-60	61-80	
A	0.01	0.05	0.08	0.15	0.22	0.28	0.37	very low
B	0.10	0.19	0.25	0.34	0.42	0.48	0.57	low to moderate
C	0.25	0.35	0.42	0.51	0.58	0.63	0.70	moderate to high
D	0.39	0.50	0.56	0.64	0.69	0.74	0.79	high

Source: *Managing Urban Stormwater: Soils and Construction – Volume 1* Table F2 (Landcom 2004)

Impervious surfaces were modelled with an initial loss – continuing loss (ILCL) runoff model with a daily initial loss of 5 mm and a continuing loss of 0 mm/hr.

iii Disturbed areas

Disturbed areas were calculated as per the method outlined in Attachment B of the water management report. These values are presented in Table B.7.

Table E.4 Disturbance areas applied to discharge modelling

Stormwater management category	Disturbed area (ha)		
	Yarrangobilly River	Upper Eucumbene River	Tantangara Compound
WM 1.2 – Minor works	83	10	75
WM 1.3 – Major works	89	14	38
WM 2.2 – Accommodation camps	10	-	7
WM 2.3 – Construction pads	23	-	11
WM 2.4 – Access roads	16	1	12
WM 2.5 – Large temporary stockpiles	12	12	5
WM 3.2 – Permanent surface infrastructure	12	-	7
WM 3.3 – Permanent access roads	-	-	-
Unsealed	10	1	8
Sealed	5	-	-
WM 3.3 Total	15	1	8

Notes: Values are presented to the nearest integer.

iv Water quality inputs

The water quality of water within undisturbed streams and rivers in the project area was found through project water quality sampling to be fresh with low concentrations of dissolved metals, nutrients and suspended sediments.

For the purposes of undertaking dilution calculations, receiving waters were assumed to have a water quality profile equivalent to the values listed in the water quality objectives (WQO) in the Australian and New Zealand guidelines for fresh and marine water quality for the protection of 99% of freshwater aquatic species (ANZECC and ARMCANZ 2000).

Project level discharge characteristics were estimated for each stormwater management category for the following parameters:

- pH (note pH has been excluded from modelling as dilution calculations require complex chemical modelling);
- turbidity;
- suspended sediment;
- total nitrogen (TN);
- total phosphorus (TP);
- Aluminium (Al); and

- Copper (Cu).

The estimated discharge characteristics applied in the model are summarised in Table E.5. The approach used and assumptions made in the estimation of the discharge characteristics for each stormwater management category are presented in Chapter 3 of the WMR.

Table E.5 Model water quality factors

Stormwater management category	Turbidity	Suspended sediment	Total nitrogen	Total phosphorus	Aluminium	Copper
Units	**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Water quality objective value (WQO)	2–25	(10)[1]	0.25	0.02	0.027	0.001
Receiving waters (assumed)	25	10	0.25	0.02	0.027	0.001
WM 1.2 – Minor works	250	50	0.8	0.15	10 x WQO value	7 x WQO value
WM 1.3 – Major works	250	50	0.8	0.15	10 x WQO value	7 x WQO value
WM 2.2 – Accommodation camps	25	25	0.4	0.05	1 x WQO value	1 x WQO value
WM 2.3 – Construction pads	50	50	1	0.1	1 x WQO value	1 x WQO value
WM 2.4 – Access roads	250	50	1	0.1	10 x WQO value	1 x WQO value
WM 2.5 – Large temporary stockpiles	250	50	0.8	0.15	10 x WQO value	7 x WQO value
WM 3.2 – Permanent surface infrastructure	15	5	0.25	0.02	1 x WQO value	1 x WQO value
WM 3.3 – Permanent access roads	250	50	1	0.1	10 x WQO value	1 x WQO value

Notes: 1. As there is no available WQO value for suspended sediment, 10 mg/L was assumed.

E.4.3 Sedimentation basin sizes

Sedimentation basin sizes will be designed at a later stage of the project.

The 85th percentile, 5-day design rainfall depth was used to estimate possible sedimentation basin sizes.

The storage volume of basins was determined by a simplified *Managing Urban Stormwater: Soils and Construction – Volume 1* basin sizing calculation using the following formula:

$$V = \times A \times C \times R_d$$

Where:

- V is the basin design volume;
- A is the disturbed area associated with the relevant stormwater management category;

- C is the Blue Book (Table F2 – see Table E.3) runoff coefficient for the relevant soil class and design rainfall; and
- R_d is the design rainfall 85th percentile, 5-day rainfall event (Table E.6).

Table E.6 Design rainfall depths

Catchment	85th percentile, 5-day rainfall (mm)
Yarrangobilly River	28.1
Upper Eucumbene River	35.2
Tantangara construction compound	30.5

E.4.4 Runoff models

i Water management assumptions

Runoff models were developed for each type of disturbance. The management concept for each disturbance type is described in Table E.7.

Table E.7 Runoff model design assumptions

Stormwater management category	Soil Hydrologic Group[1] (% of disturbed area)	Discharge mechanisms and management measures
WM 1.2 – Minor works	Type C: 100%	All runoff will be discharged without capture or treatment mechanisms.
WM 1.3 – Major works	Type C: 100%	Runoff will be captured in basins. Basins are sized for 85th percentile, 5-day runoff. Captured water is dewatered at a rate of 20% of basin volume per day, for days where no material rainfall occurs (material rainfall includes events greater than 5 mm). Basins are not dewatered during material rainfall. Basin overflows are discharged to receiving waters.
WM 2.2 – Accommodation camps	Impervious: 70% Type B: 30%	Runoff will be captured in basins. Basins are sized to capture the 85th percentile, 5-day runoff. Captured water is dewatered at a rate of 20% of basin volume per day, for days where no material rainfall occurs (material rainfall includes events greater than 5 mm). Basins are not dewatered during material rainfall. Basin overflows are discharged to receiving waters.
WM 2.3 – Construction pads	Type D: 100%	Runoff will be captured in basins. Basins are sized to capture the 85th percentile, 5-day runoff. Captured water is dewatered at a rate of 20% of basin volume per day, for days where no material rainfall occurs (material rainfall includes events greater than 5 mm). Basins are not dewatered during material rainfall. Basin overflows are discharged to receiving waters.
WM 2.4 – Access roads	Type D: 100%	All runoff will be discharged without capture or treatment mechanisms.
WM 2.5 – Large temporary stockpiles	Type B: 100%	Runoff will be captured in basins. Basins are sized to capture the 85th percentile, 5-day runoff.

Table E.7 Runoff model design assumptions

Stormwater management category	Soil Hydrologic Group[1] (% of disturbed area)	Discharge mechanisms and management measures
		Captured water is dewatered at a rate of 20% of basin volume per day, for days where no material rainfall occurs (material rainfall includes events greater than 5 mm). Basins are not dewatered during material rainfall. Basin overflows are discharged to receiving waters.
WM 3.2 – Permanent surface infrastructure	Impervious: 50% Type D: 50%	All runoff will be discharged without capture or treatment mechanisms.
WM 3.3 – Permanent access roads	Impervious: 100%	All runoff will be discharged without capture or treatment mechanisms.

Notes: 1. Soil Hydrological Groups are assigned with reference to *Managing Urban Stormwater: Soils and Construction Volume 1* Table F2 (Landcom 2004)

ii Runoff model description

a Discharge without capture of treatment

Runoff from disturbance areas that was not captured and did not receive treatment was modelled using the following formula:

$$Q = C.I.A$$

Where:

- *Q* is the volumetric runoff rate [volume/day];
- *C* is the runoff coefficient for the relevant soil class and rainfall rate from Table F2 *Managing Urban Stormwater: Soils and Construction – Volume 1* (Landcom 2004);
- *I* is the rainfall rate;
- *A* is the disturbed area; and

Note that *C* as per *Managing Urban Stormwater: Soils and Construction – Volume 1* Table F2 (Landcom 2004) is generally applied to a design rainfall event (duration greater than one day) rather than a daily rainfall rate. In the model, *C* was calculated for the five-day rainfall.

This allowed the model to account for soil moisture due to previous rainfall events which will affect the volumetric runoff.

b Runoff captured in basins and harvested for dust suppression

Runoff captured and treated in basins was modelled using the GoldSim pool stock element. This element allows the modelling of multiple direct inflow inputs, and outflows with specified priority. If there is not enough water to meet both demands, the highest priority demand will first be met, followed by the second. In this model the outflow priority was:

1. Evaporation from the water surface; and

2. Dewatering at a controlled rate.

Evaporation losses were calculated as follows:

$$V_{evap} = A_{basin} \, . \, E$$

Where:

- V_{evap} is the volumetric rate of evaporation loss;
- A_{basin} is the assumed total surface area of the basins, assumed equal to the volume divided by 1.5 m depth; and
- E is the evaporation rate.

Dewatering demand was modelled at a maximum controlled rate of 20% of total basin storage volume per day, for days with no material rainfall. No dewatering was modelled to occur during material rainfall (daily rainfall in excess of 5 mm). This was modelled in GOLDSIM using a selector element, which set the dewatering rate at zero if rainfall was greater than 5 mm, and otherwise at 20% of total basin storage.

Water extracted from basins for dewatering was modelled as a loss to the water system and did not reach receiving waters.

When basins were filled, excess water was discharged via an overflow process. Overflowing water was used in subsequent water quality dilution calculations.

E.4.5 Water quality model

i Impacts to watercourses

The total site runoff was calculated each model day, and assigned a water quality profile as per Table E.5. The water quality in the receiving water post-stormwater discharge was then calculated, following the formula:

$$WQ_{average} = \frac{\sum WQ_j . V_j + WQ_{RW} . V_{RW}}{\sum V_j + V_{RW}}$$

Where:

- $WQ_{average}$ is the weighted average water quality characteristics of the receiving waters post-stormwater dischage;
- j is the number of disturbance types;
- WQ_j is the water quality characteristics for water discharged from disturbance area j;
- WQ_{RW} is the water quality characteristics for the receiving waters;
- V_j is the volume of stormwater discharged from disturbance area j; and
- V_{RW} is the daily flow of water in the receiving creek or river.

ii Discharge to reservoirs

Model outputs have also been used to assess the predicted water quality characteristics of treated wastewater, treated process water and stormwater discharges to Talbingo and Tantangara reservoirs as a result of Snowy 2.0.

Modelled cumulative stormwater discharge from disturbed areas for each project phase were used to calculate pollutant loads in stormwater runoff for total nitrogen and total phosphorus using the formula:

$$L_{i,j} = V_j \times C_{i,j}$$

Where:

- $L_{i,j}$ is the pollutant load for pollutant i entering the reservoir from disturbed areas associated with stormwater management category j [kg/day];
- V_j is the cumulative discharge volume from disturbed areas associated with stormwater management category j [ML/day]; and
- C_{ij} is the assumed concentration of pollutant i for stormwater management category j [mg/L].

E.5 Calibration and validation

The model has not been calibrated or validated because no disturbance has yet occurred in these areas. Results are therefore indicative only, and further assessment of stormwater discharge will be required during detailed design. Monitoring and management of discharges will be required.

E.6 Model uncertainty

The stormwater discharge model has been applied to estimate the potential frequency and magnitude of changes to receiving water quality. Results are presented on a seasonal and wet and dry conditions basis. Table 8.3 of the WMR describes the key aspects of the model, applied approach and assumptions and the sensitivity of model results to changes in the approach and assumptions.

E.7 Assumptions and limitations

Model assumptions are documented, and the associated limitations are discussed, in Table E.8.

Table E.8 Model assumptions

Assumption	Discussion
Climate data	
Use of historical rainfall and stream gauge records to model climatic variability	Historical climate data provides actual climatic scenarios and so gives a good indication of climatic conditions at the project location. However, future climatic conditions may differ from historical conditions. This model is not able to predict future conditions and does not account for climate variability outside of the 40-year record used in the model.
Use of pan evaporation for basin evaporation and dust suppression; non-varying evaporation across modelled catchments	Historical pan evaporation records were used to calculate dust suppression demands and evaporation from basin surface. Evaporation has been assumed to be constant across the three catchments. This is adequate to reflect likely climatic conditions, where greater volumes of captured water are required for dust suppression during periods with low rainfall.
Scaling gauged data to modelled discharge point	The scale factors applied to the gauged data for the Eucumbene River and Murrumbidgee River gauges assumes consistent runoff characteristics across the catchment. Although rainfall and runoff characteristics can vary significantly over a catchment area; climate data across the project area suggests that project catchments are generally uniform in their characteristics.
Water quality inputs	
Magnitude of change assessment approach	The modelling approach assess the potential magnitude of change in water quality rather than absolute changes in water quality. This was done as there is insufficient baseline data to reliably characterise water quality during wet weather conditions when discharges are most likely to occur. Refer to Section 8.2.5 of the WMR for further details.
Discharge water quality	Discharge water quality has been establishes using the approach described in Chapter 3 of the WMR.
No change in captured water quality due to evaporation losses	This model has not simulated increases in concentrations for the modelled parameters due to evaporation losses. Evaporation losses represent a small portion of captured water.
Runoff modelling assumptions	
Runoff coefficients using Blue Book Table F2	Runoff coefficients have been approximated using Blue Book Table F2 for the five-day rainfall. This is an atypical application of these runoff coefficients which allows the approximation of increased runoff potential due to antecedent surface wetness, as saturated soils will produce more runoff than unsaturated soils.
Initial loss of 5 mm for impervious surfaces	Impervious surfaces are assumed to have an initial loss of 5 mm and then have a runoff coefficient of 1 (ie all rainfall becomes runoff apart from the first 5 mm). This accounts for losses associated with surface irregularity.
Storage assumptions	
Basin volume sizing to 85th percentile, 5-day design event.	Basins have been applied to the model as a volume which approximates Blue Book sizing methods for the full catchment area to the 85th percentile 5-day rain based on historical rainfall records. Actual basin sizing will be determined as part of detailed design.
Basin surface area	Basin surface area for direct rainfall inflows and evaporation losses has been calculated assuming a basin depth of 1.5 m. This is a standard depth for basins due to the increased design requirements associated with greater basin depths. Actual basin depths and surface areas will be determined as part of detailed design. This may affect the amount of water lost from the system as evaporation losses and therefore the discharge volumes, however, as evaporation losses are a small percentage of total model inflows, this is not anticipated to significantly change results.

Table E.8 Model assumptions

Assumption	Discussion
Direct rainfall to basin surface area	Rainfall has been applied to the full catchment area for runoff calculations, as well as directly to the basin surface as rainfall. This represents an overlap of disturbed surface area (and therefore an overestimation of total inflows). However, as basin surface areas make up approximately 1% of total catchment area this is not anticipated to significantly impact model outputs.
Basins modelled as single basin for each catchment and stormwater management category	In the absence of a detailed design plan, it was assumed that all water from each catchment area drains to a single basin. This should not materially change discharge volumes as basins will be sized during detailed design proportionally to the captured area.

E.8 Results

Model results are presented Section 8.2.5 of the WMR.

E.9 Application to assess reservoir impacts

The results from the stormwater discharge model were applied to assess changes to ambient water quality in Talbingo and Tantangara Revivors. This assessment also considered discharges of treated process and wastewater to the reservoirs. Table E.9 to Table E.14 provides a break-down of the discharge assumptions applied to the reservoir impact assessment that is presented in Section 8.3 of the WMR.

Table E.9 Talbingo Reservoir stormwater discharge loads – construction phase 1

	Units	Drought flows[1]			Summer/autumn			Winter/spring		
Combined reservoir inflows		Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus
Mean flow	ML/season[2]		4,600			22,700			90,950	
Median concentration		160 µS/cm	0.1 mg/L	0.01 mg/L	160 µS/cm	0.1 mg/L	0.01 mg/L	70 µS/cm	0.1 mg/L	0.01 mg/L
Median load	kg/season[2]	404,800	460	46	1,997,600	2,270	227	3,501,575	9,095	910
Combined stormwater discharges										
Mean discharge	ML/season[2]		122			184			278	
Median concentration		30 µS/cm	0.80 mg/L	0.15 mg/L	30 µS/cm	0.80 mg/L	0.15 mg/L	30 µS/cm	0.80 mg/L	0.15 mg/L
Mean load	kg/season[2]	2,006	97	18	3,033	147	28	4,589	222	42
Treated wastewater										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Treated process water										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Combined discharge	ML/season[2]		4,722			22,884			91,228	
Combined load	kg/season[2]	406,806	557	64	2,000,633	2,417	255	3,506,164	9,317	951

Notes: 1. Drought flows derived from 2006–2007 summer/autumn (December–May) period.
2. Seasons defined as summer/autumn (December–May) and winter/spring (June–November).
3. Factor of 0.55 used to convert salinity (as measured by electrical conductivity) from µS/cm to mg/L (SA Government 2015).

Table E.10 Talbingo Reservoir stormwater discharge loads – construction phase 2

	Units	Drought flows[1]			Summer/autumn			Winter/spring		
Combined reservoir inflows		Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus
Mean flow	ML/season[2]		4,600			22,700			90,950	
Median concentration		160 µS/cm	0.1 mg/L	0.01 mg/L	160 µS/cm	0.1 mg/L	0.01 mg/L	70 µS/cm	0.1 mg/L	0.01 mg/L
Median load	kg/season[2]	404,800	460	46	1,997,600	2,270	227	3,501,575	9,095	910
Combined stormwater discharges										
Mean discharge	ML/season[2]		37			59			90	
Median concentration		30 µS/cm	0.95 mg/L	0.10 mg/L	30 µS/cm	0.95 mg/L	0.11 mg/L	30 µS/cm	0.95 mg/L	0.11 mg/L
Mean load	kg/season[2]	615	36	4	977	56	6	1,479	85	10
Treated wastewater										
Max discharge	ML/season[2]		74			74			74	
Median concentration		700 µS/cm	0.35 mg/L	0.06 mg/L	700 µS/cm	0.35 mg/L	0.06 mg/L	700 µS/cm	0.35 mg/L	0.06 mg/L
Mean load	kg/season[2]	28,448	26	4	28,448	26	4	28,448	26	4
Treated process water										
Max discharge	ML/season[2]		228			228			228	
Median concentration		700 µS/cm	0.25 mg/L	0.02 mg/L	700 µS/cm	0.25 mg/L	0.02 mg/L	700 µS/cm	0.25 mg/L	0.02 mg/L
Median load	kg/season[2]	87,881	57	5	87,881	57	5	87,881	57	5
Combined discharge	ML/season[2]		4,939			23,061			91,342	
Combined load	kg/season[2]	521,745	579	59	2,114,907	2,409	242	3,619,384	9,263	928

Notes: 1. Drought flows derived from 2006–2007 summer/autumn (December–May) period.
2. Seasons defined as summer/autumn (December–May) and winter/spring (June–November).
3. Factor of 0.55 used to convert salinity (as measured by electrical conductivity) from µS/cm to mg/L (SA Government 2015).

Table E.11 Talbingo Reservoir stormwater discharge loads – operational phase (phase 3)

	Units		Drought flows[1]			Summer/autumn			Winter/spring	
Combined reservoir inflows		Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus
Mean flow	ML/season[2]		4,600			22,700			90,950	
Median concentration		160 µS/cm	0.1 mg/L	0.01 mg/L	160 µS/cm	0.1 mg/L	0.01 mg/L	70 µS/cm	0.1 mg/L	0.01 mg/L
Median load	kg/season[2]	404,800	460	46	1,997,600	2,270	227	3,501,575	9,095	910
Combined stormwater discharges										
Mean discharge	ML/season[2]		43			53			73	
Median concentration		30 µS/cm	0.57 mg/L	0.05 mg/L	30 µS/cm	0.57 mg/L	0.05 mg/L	30 µS/cm	0.57 mg/L	0.05 mg/L
Mean load	kg/season[2]	708	25	2	875	30	3	1,204	41	4
Treated wastewater										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Treated process water										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Combined discharge	ML/season[2]		4,643			22,753			91,023	
Combined load	kg/season[2]	405,508	485	48	1,998,475	2,300	230	3,502,779	9,136	913

Notes: 1. Drought flows derived from 2006–2007 summer/autumn (December–May) period.
2. Seasons defined as summer/autumn (December–May) and winter/spring (June–November).
3. Factor of 0.55 used to convert salinity (as measured by electrical conductivity) from µS/cm to mg/L (SA Government 2015).

Table E.12 Tantangara Reservoir stormwater discharge loads – construction phase 1

	Units	Drought flows[1]			Summer/autumn			Winter/spring		
Combined reservoir inflows		Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus
Mean flow[4]	ML/season[2]		12,750			45,300			201,650	
Median concentration		32 µS/cm	0.10 mg/L	0.01 mg/L	32 µS/cm	0.10 mg/L	0.01 mg/L	26 µS/cm	0.10 mg/L	0.01 mg/L
Median load	kg/season[2]	224,400	1,275	128	797,280	4,530	453	2,883,595	20,165	2,017
Combined stormwater discharges										
Mean discharge	ML/season[2]		121			156			245	
Median concentration		30 µS/cm	0.80 mg/L	0.15 mg/L	30 µS/cm	0.80 mg/L	0.15 mg/L	30 µS/cm	0.80 mg/L	0.15 mg/L
Mean load	kg/season[2]	1,998	97	18	2,567	124	23	4,050	196	37
Treated wastewater										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Treated process water										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Combined discharge	ML/season[2]		12,871			45,456			201,895	
Combined load	kg/season[2]	226,398	1,372	146	799,847	4,654	476	2,887,645	20,361	2,053

Notes: 1. Drought flows derived from 2006–2007 summer/autumn (December–May) period.
2. Seasons defined as summer/autumn (December–May) and winter/spring (June–November).
3. Factor of 0.55 used to convert salinity (as measured by electrical conductivity) from µS/cm to mg/L (SA Government 2015).
4. Mean flow at the Murrumbidgee River gauged (410535) have been scaled up to reflect total inflows to Tantangara Reservoir. Murrumbidgee River gauge flows account for 58% of total inflow to Tantangara Reservoir (WCR, Annexure A to the water assessment).

Table E.13 Tantangara Reservoir stormwater discharge loads – construction phase 2

	Units	Drought flows[1]			Summer/autumn			Winter/spring		
Combined reservoir inflows		Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus
Mean flow[4]	ML/season[2]		12,750			45,300			201,650	
Median concentration		32 µS/cm	0.10 mg/L	0.01 mg/L	32 µS/cm	0.10 mg/L	0.01 mg/L	26 µS/cm	0.10 mg/L	0.01 mg/L
Median load	kg/season[2]	224,400	1,275	128	797,280	4,530	453	2,883,595	20,165	2,017
Combined stormwater discharges										
Mean discharge	ML/season[2]		29			41			65	
Median concentration		30 µS/cm	0.90 mg/L	0.10 mg/L	30 µS/cm	0.90 mg/L	0.10 mg/L	30 µS/cm	0.90 mg/L	0.10 mg/L
Mean load	kg/season[2]	482	27	3	675	36	4	1,068	57	7
Treated wastewater										
Max discharge	ML/season[2]		23			23			23	
Median concentration		700 µS/cm	0.35 mg/L	0.06 mg/L	700 µS/cm	0.35 mg/L	0.06 mg/L	700 µS/cm	0.35 mg/L	0.06 mg/L
Mean load	kg/season[2]	8,759	8	1	8,759	8	1	8,759	8	1
Treated process water										
Max discharge	ML/season[2]		670			670			670	
Median concentration		150 µS/cm	0.25 mg/L	0.02 mg/L	150 µS/cm	0.25 mg/L	0.02 mg/L	150 µS/cm	0.25 mg/L	0.02 mg/L
Mean load	kg/season[2]	55,255	167	13	55,255	167	13	55,255	167	13
Combined discharge	ML/season[2]		13,472			46,033			202,407	
Combined load	kg/season[2]	288,896	1,477	145	861,969	4,742	472	2,948,677	20,398	2,038

Notes:
1. Drought flows derived from 2006–2007 summer/autumn (December–May) period.
2. Seasons defined as summer/autumn (December–May) and winter/spring (June–November).
3. Factor of 0.55 used to convert salinity (as measured by electrical conductivity) from µS/cm to mg/L (SA Government 2015).
4. Mean flow at the Murrumbidgee River gauged (410535) have been scaled up to reflect total inflows to Tantangara Reservoir. Murrumbidgee River gauge flows account for 58% of total inflow to Tantangara Reservoir (WCR, Annexure A to the water assessment).

Table E.14 Tantangara Reservoir stormwater discharge loads – operational phase (phase 3)

	Units	Drought flows[1]			Summer/autumn			Winter/spring		
Combined reservoir inflows		Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus	Salinity[3]	Total nitrogen	Total phosphorus
Mean flow[4]	ML/season[2]		12,750			45,300			201,650	
Median concentration		32 µS/cm	0.10 mg/L	0.01 mg/L	32 µS/cm	0.10 mg/L	0.01 mg/L	26 µS/cm	0.10 mg/L	0.01 mg/L
Median load	kg/season[2]	224,400	1,275	128	797,280	4,530	453	2,883,595	20,165	2,017
Combined stormwater discharges										
Mean discharge	ML/season[2]		27			32			46	
Median concentration		30 µS/cm	0.70 mg/L	0.07 mg/L	30 µS/cm	0.70 mg/L	0.07 mg/L	30 µS/cm	0.70 mg/L	0.07 mg/L
Mean load	kg/season[2]	446	19	2	527	23	2	760	33	3
Treated wastewater										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Treated process water										
Max discharge	ML/season[2]		-			-			-	
Median concentration		-	-	-	-	-	-	-	-	-
Mean load	kg/season[2]	-	-	-	-	-	-	-	-	-
Combined discharge	ML/season[2]		12,777			45,332			201,696	
Combined load	kg/season[2]	224,846	1,294	129	797,807	4,553	455	2,884,355	20,198	2,020

Notes: 1. Drought flows derived from 2006–2007 summer/autumn (December–May) period.
2. Seasons defined as summer/autumn (December–May) and winter/spring (June–November).
3. Factor of 0.55 used to convert salinity (as measured by electrical conductivity) from µS/cm to mg/L (SA Government 2015).
4. Mean flow at the Murrumbidgee River gauged (410535) have been scaled up to reflect total inflows to Tantangara Reservoir. Murrumbidgee River gauge flows account for 58% of total inflow to Tantangara Reservoir (WCR, Annexure A to the water assessment).

Attachment F

Mixing zone assessment

REPORT

Snowy 2.0

Waste and Process Water Mixing Zone Assessment

Client: EMM Consulting Pty Ltd

Reference: PA2297

Status: Final/P01.01

Date: 07 February 2020

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Project name:	
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Date / initials:	07.02.2020 M.B

Classification
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MANAGEMENT SYSTEM CERTIFICATION
DNV·GL
ISO 9001 = ISO 14001
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1 Introduction

1.1 Purpose of report

During the construction of Snowy 2.0, wastewater will be generated at accommodation camps from amenities (i.e. toilets, showers, laundry and cooking) and from surplus process water that cannot be used for dust suppression or other construction site water demands. This wastewater will be treated at local wastewater treatment plants and then discharged into the Tantangara and Talbingo Reservoirs.

This attachment to the water management report (WMR) (Appendix J of the RTS) calculates the near-field dilution associated with the proposed controlled discharge of treated wastewater and process water to estimate the size of the mixing zone for key constituents of interest.

1.2 Factors influencing near-field dilution

The design of an effluent outfall typically depends on the dilution required to meet the relevant guideline values. A mixing zone is the region in which the initial (rapid) dilution of a discharge occurs as a result of momentum, buoyancy, turbulence and outfall geometry (Cormix, 2018). In the mixing zone, the level of pollutants may be higher than the ambient concentration for the receiving water body.

Occasionally, guidelines may be met after an appropriate level of treatment. However, some water quality constituents will rely on the dilution within receiving waters to meet these guidelines. Dilution of a constituent group depends on:

- Wastewater/discharge flowrate
- Wastewater/discharge density (i.e. temperature and salinity)
- Outlet diameter (and whether a single or multiple outlets will be used)
- Depth of water into which the wastewater is discharged
- Distance of the diffuser from the shoreline
- Configuration of the diffuser, and
- Ambient conditions (e.g. currents, temperature, density and thermal stratification processes).

After discharge, if the effluent (wastewater and/or process water) is less dense than the receiving water, the effluent rises due to buoyancy (refer **Figure 1-1**). If the effluent is denser than the receiving water it descends. The effluent then mixes with the ambient currents and is diluted.

Two types of models are used to quantify this process, namely near-field and far-field models. This separation is made because the time and space scales of the mixing processes in each model are substantially different. In the near-field, the motion of the wastewater is dominated by its initial momentum and buoyancy; the velocities and rates of dilution are high. Up to 90% of wastewater dilution takes place within the near-field. An outfall is generally designed to maximise dilution in the near-field, whereas far-field processes are typically influenced by more ‘natural’ processes which are more difficult to change or control.

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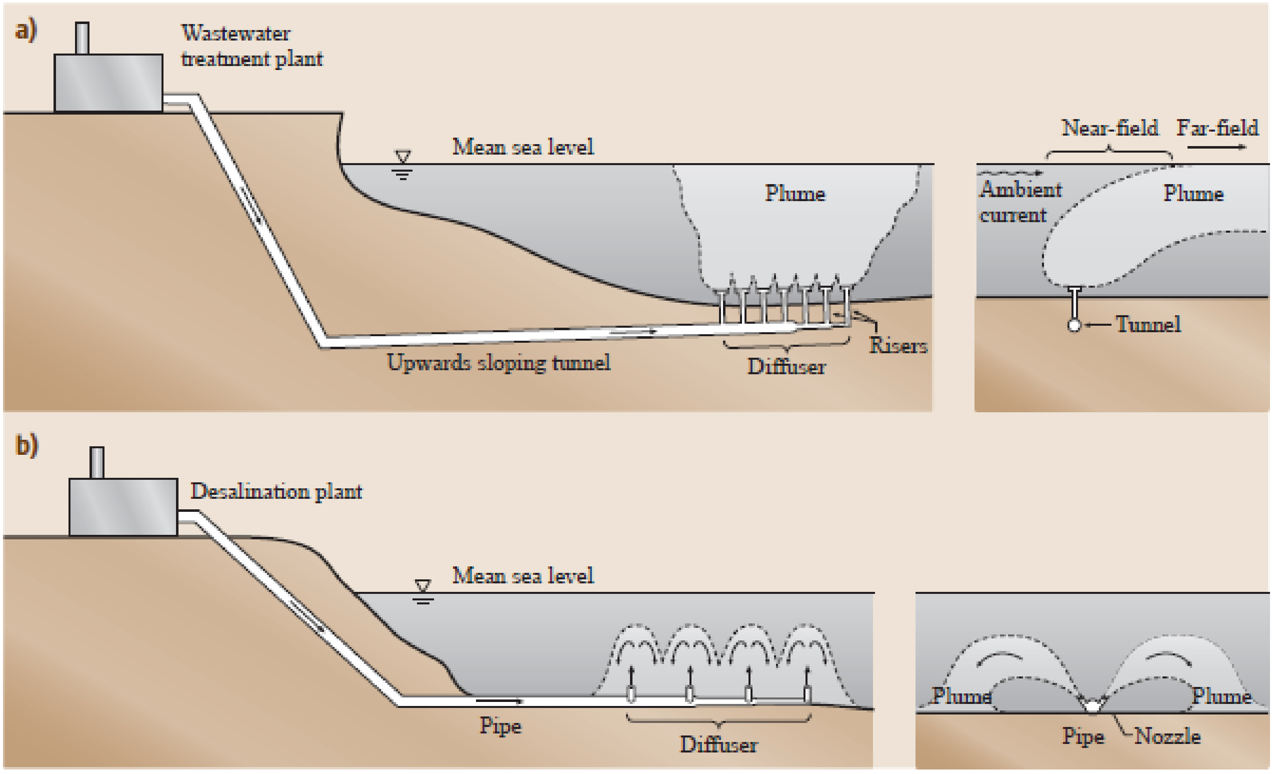


Fig. 32.1a,b Schematics of (a) a wastewater treatment plant outfall, and (b) a desalination plant outfall, showing side views and end views

Source: Peter M. Tate, Salvatore Scaturro, Bruce Cathers (2016)

Figure 1-1: Buoyant (a) vs Non-Buoyant Plumes (b)

1.3 Prediction of mixing and dilution

Near-field mixing and dilution predictions were carried out using the VISJET_v3_2017 software (Lee and Cheung, 2017), which uses the extensively validated Lagrangian jet mixing model, JETLAG. This software is similar to CORMIX or Visual Plumes but does not include estimates of far-field dilution.

For the stratified (summer) ambient conditions, the plume is non-buoyant and dilution is primarily due to turbulent mixing due to the jet velocity. This means that:

- Smaller port sizes (and hence high jet velocity) produce larger dilutions, and
- For the higher discharge scenarios dilutions tend to be greater.

After considering the pre-dilution of the wastewater stream by the process water stream, significantly greater rates of wastewater dilution are achieved.

1.4 Dilution and target concentration

Near-field modelling results are presented in terms of dilution. The number of dilutions required to achieve a target concentration can be calculated as follows:

Number of dilutions required = effluent concentration / (target concentration – ambient concentration)

For example, assuming an effluent concentration of 1 mg/L, ambient concentration of 0.05 mg/L, and target concentration of 0.055 mg/L, the number of dilutions required is 200. The extent of the mixing zone can be estimated from near-field model results which includes calculation of dilution with distance from the outfall.

1.5 Proposed discharges and effluent quality

The volume and quality of discharges to Talbingo Reservoir and Tantangara Reservoir is summarised in **Table 1-1** and **Table 1-2** respectively.

The concentration of total nitrogen (TN) and total phosphorous (TP) in wastewater is low and indicative of a high level of wastewater treatment prior to discharge. When combined with process water, TN and TP in the combined discharge is further diluted to concentrations slightly above ambient conditions (see WMR Section 8.3 for further details). The number of dilutions therefore required to satisfy target concentrations is small (less than 20 for TN and TP). In the case of salinity, the number of dilutions needed to achieve ambient salinity is 30 or less.

Target concentrations are assumed for TN, TP and salinity for the purposes of calculating the dilutions required for the end of the near-field mixing zone. In the case of TN, a target concentration of 0.22 mg/L was adopted which is marginally higher than the ambient concentration (0.2 mg/L) and substantially less than the ANZECC water quality guideline value of 0.35 mg-N/L for freshwater lakes and reservoirs. For TP, the assumed target concentration of 0.035 mg-P/L is slightly higher than the ambient TP concentration (0.030 mg/L) but higher than the ANZECC water quality guideline value of 0.01 mg-P/L. The target for salinity adopted is approximately twice the ambient salinity concentration observed at the reservoirs, i.e. 50 µS/cm which is very low salinity water.

Table 1-1: Discharge characteristics to Talbingo Reservoir

	Units	Scenario		
		Summer / Autumn (drought)	*Summer / Autumn (typical)*	*Winter / Spring (typical)*
Peak discharges				
Process water discharge[2]	*ML/day*	1.254	1.254	1.254
Wastewater discharge[2]	*ML/day*	0.406	0.406	0.406
Combined discharge[3]	*ML/day*	1.66	1.66	1.66
Salinity (as indicated by electrical conductivity (EC))				
Salt in process water[2]	µS/cm	700	700	700
Salt in wastewater[2]	µS/cm	**700**	**700**	**700**
Salt in combined discharge	µS/cm	700	700	700
Ambient value[1]	µS/cm	27	27	22
Target value[3]	µS/cm	50	50	50
Number of dilutions[4]	-	**30**	**30**	**25**
Total nitrogen (TN)				
TN in process water[2]	mg/L	0.25	0.25	0.25
TN in wastewater[2]	mg/L	**0.35**	**0.35**	**0.35**
TN in combined discharge	mg/L	0.27	0.27	0.27
Ambient value[1]	mg/L	0.20	0.20	0.12
Target value[3]	mg/L	0.22	0.22	0.22
Number of dilutions[4]	-	**18**	**18**	**3.5**
Total phosphorus (TP)				
TP in process water[2]	mg/L	0.02	0.02	0.02
TP in wastewater[2]	mg/L	**0.06**	**0.06**	**0.06**
TP in combined discharge	mg/L	0.03	0.03	0.03
Ambient value[1]	mg/L	0.03	0.03	0.01
Target value[3]	mg/L	0.035	0.035	0.035
Number of dilutions[4]	-	**12**	**12**	**2.4**

Notes:
1. Ambient value refers to seasonal median established in the WMR (Appendix J of the RTS).
2. Refer to the WMR (Appendix J of the RTS) for further information on discharge characteristics.
3. Target concentration assumed for the near-field mixing zone.
4. Number of dilutions required for wastewater only discharge to satisfy target concentration at the end of the mixing zone. Dilution required for combined discharge is less.

Table 1-2: Discharge characteristics to Tantangara Reservoir

	Units	Scenario		
		Summer / Autumn (drought)	*Summer / Autumn (typical)*	*Winter / Spring (typical)*
Peak discharges				
Process water discharge[2]	*ML/day*	3.680	3.680	3.680
Wastewater discharge[2]	*ML/day*	0.125	0.125	0.125
Combined discharge[3]	*ML/day*	3.81	3.81	3.81
Salinity (as indicated by electrical conductivity (EC))				
Salt in process water[2]	µS/cm	150	150	150
Salt in wastewater[2]	µS/cm	**700**	**700**	**700**
Salt in combined discharge	µS/cm	168	168	168
Ambient value[1]	µS/cm	22	22	14
Target value[3]	µS/cm	50	50	50
Number of dilutions[4]	-	**25**	**25**	**19**
Total nitrogen (TN)				
TN in process water[2]	mg/L	0.25	0.25	0.25
TN in wastewater[2]	mg/L	**0.35**	**0.35**	**0.35**
TN in combined discharge	mg/L	0.25	0.25	0.25
Ambient value[1]	mg/L	0.20	0.20	0.11
Target value[3]	mg/L	0.22	0.22	0.22
Number of dilutions[4]	-	**18**	**18**	**3.2**
Total phosphorus (TP)				
TP in process water[2]	mg/L	0.02	0.02	0.02
TP in wastewater[2]	mg/L	**0.06**	**0.06**	**0.06**
TP in combined discharge	mg/L	0.02	0.02	0.02
Ambient value[1]	mg/L	0.03	0.03	0.01
Target value[3]	mg/L	0.035	0.035	0.035
Number of dilutions[4]	-	**12**	**12**	**2.4**

Notes:
1. Ambient value refers to seasonal median established in the WMR (Appendix J of the RTS).
2. Refer to the WMR (Appendix J of the RTS) for further information on discharge characteristics.
3. Target concentration assumed for the near-field mixing zone.
4. Number of dilutions required for wastewater only discharge to satisfy target concentration at the end of the mixing zone. Dilution required for combined discharge is less.

2 Details of outfalls, proposed discharges and diffuser design

Outfall locations at Talbingo Reservoir and Tantangara Reservoir are presented on **Figure 2-1**.

2.1 Outfall locations and ambient conditions

Outflow locations for treated water return at Talbingo and Tantangara Reservoirs are summarised in **Table 2-1** and discussed further below.

Table 2-1: Location of Outfalls

Outfall Location	Easting (m)	Northing (m)	Longitude (°E)	Latitude (°S)
Talbingo Reservoir	624 224	6 040 584	148.374	-35.771
Tantangara Reservoir	649 687	6 037 520	148.657	-35.795

Ambient reservoir conditions at the outfall locations are summarised below based on the descriptions of physical limnology (Cardno, 2019) and examination of results provided by the 3D Hydrodynamic Model developed for the reservoirs as part of the Snowy 2.0 Project.

2.1.1 Talbingo Reservoir

At the Talbingo outfall location, the reservoir bed is approximately 530 m Australian Height Datum (AHD) (refer **Figure 2-2**). Given that typical reservoir water levels operate between 538 to 543 m AHD (refer to **Appendix C**), the depth of water above the diffuser is likely to vary between 7 and 12 metres. However, while the reservoir is typically operated at higher levels to increase the available head at the T3 offtake, the minimum operating level (MOL) of the reservoir is 534.3 m AHD, which is only 3 metres above the reservoir bed at the outfall location.

The reservoir becomes stratified (i.e. reduced vertically mixing) in summer due to surface heating, while in winter the surface cools and the reservoir becomes vertically fully mixed (i.e. becomes unstratified). Current speeds near the outfall are typically very low and in the order of 1 mm/s to 10 mm/s, but occasionally can be as high as 50 mm/s or more. Surface water temperatures of approximately 20ºC (in summer) and 8ºC (in winter) have been observed at Lobs Hole (Cardno, 2019). The near bed water temperature at the outfall location is typically 10ºC in summer and 8ºC in winter. The EC of reservoir surface water is very low and typically between 20 to 30 µS/cm which is approximately 0.01 ppt (or kg/m^3 or psu).

2.1.2 Tantangara Reservoir

At the Tantangara outfall location, the reservoir bed is approximately 1 205 m AHD (refer **Figure 2-3)**. The depth of water above the diffuser would be between 1 and 24 metres based on a MOL and Full Supply Level (FSL) of approximately 1 205.8 and 1 228.8 m AHD respectively. Historically, storage levels have varied between 1 210 m AHD and 1 225 m AHD (refer to **Appendix C**), but reservoir levels will be kept below normal operating levels during the construction phase of Snowy 2.0.

There is less potential for Tantangara Reservoir to thermally stratify than Talbingo Reservoir, with a maximum depth of about 35 metres near the dam wall at the FSL, and between 5 m and 20 m near the outfall location. Based on historical storage level since 2011, a water depth of around 9 m is representative at the outfall location.

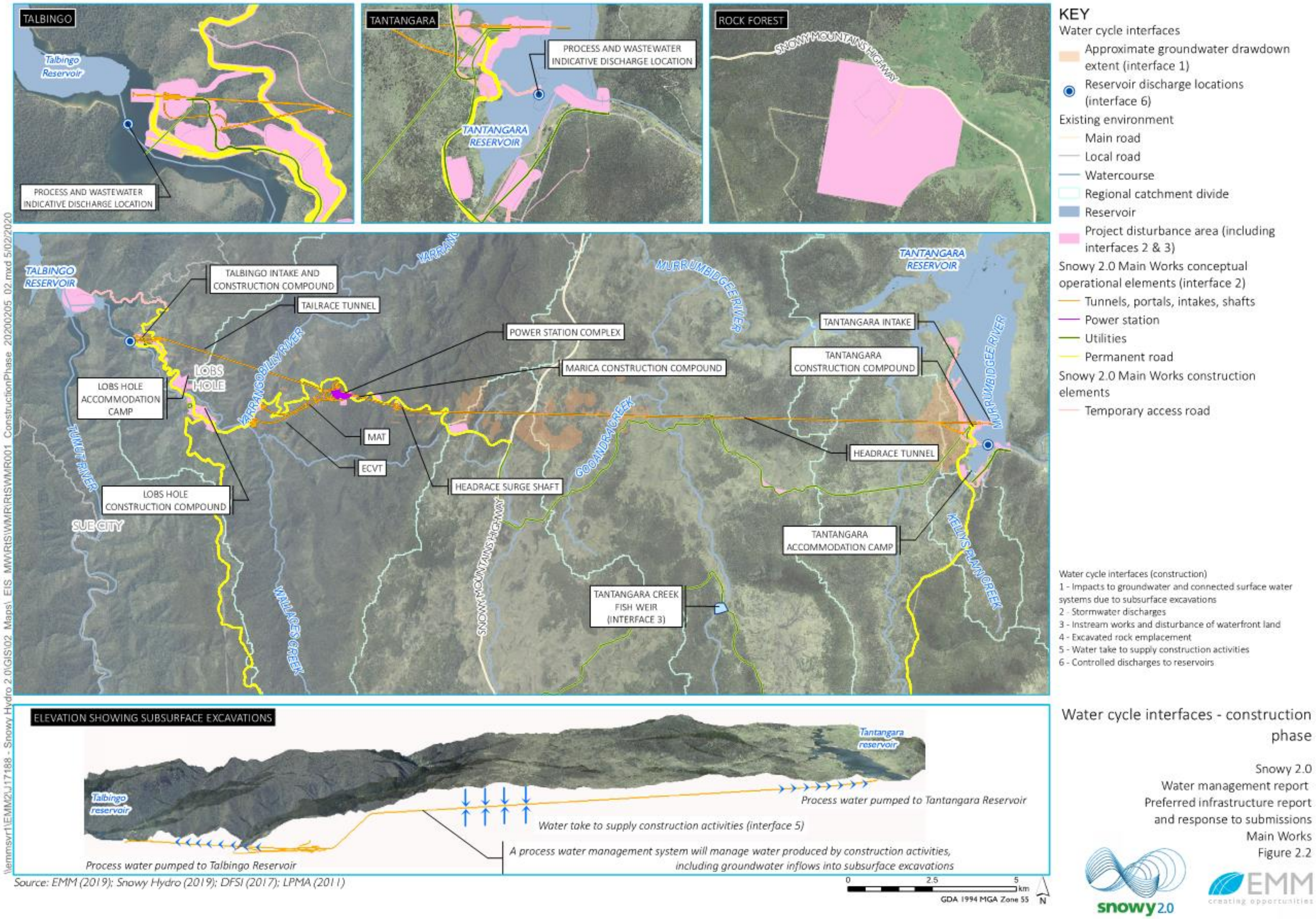
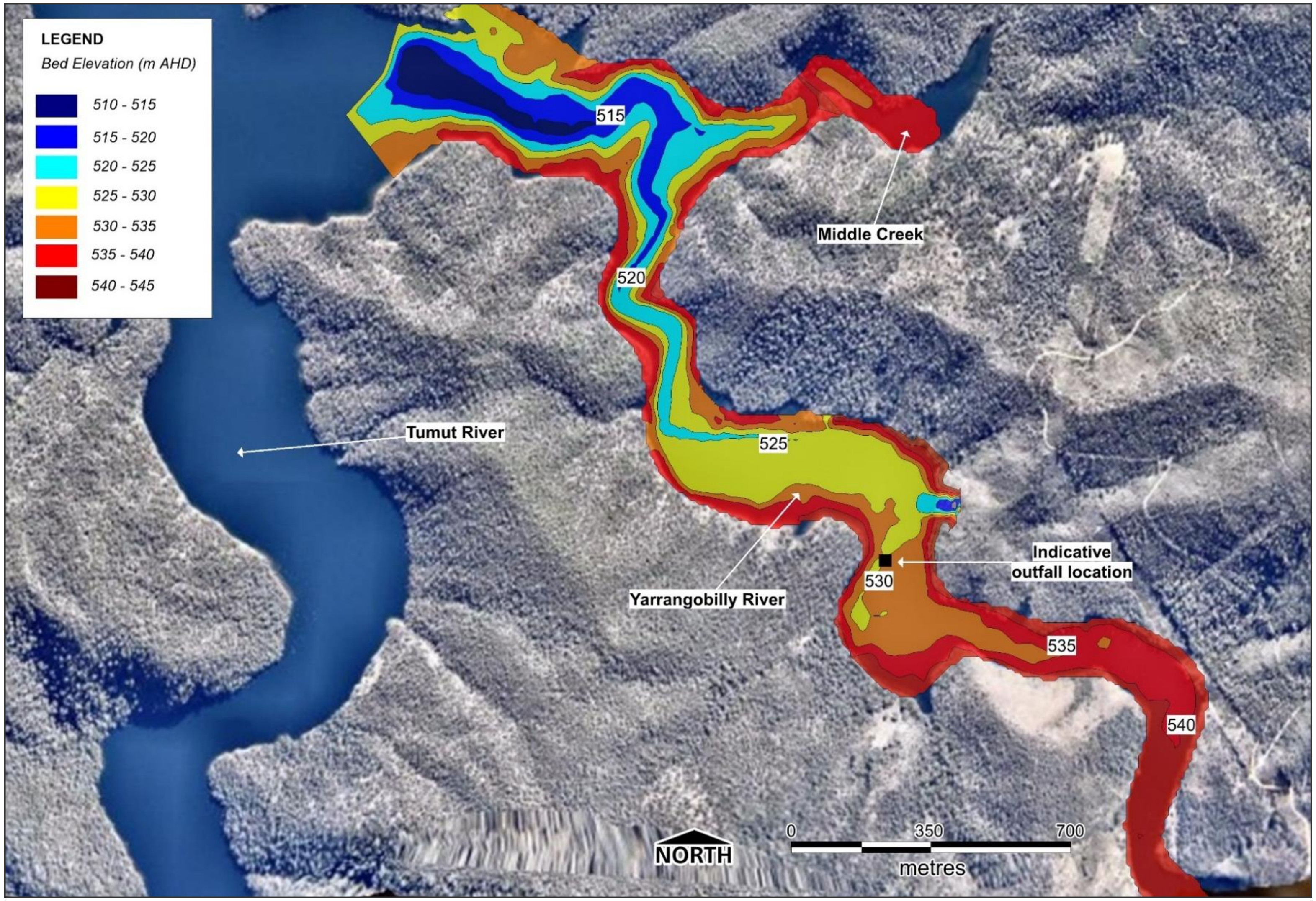
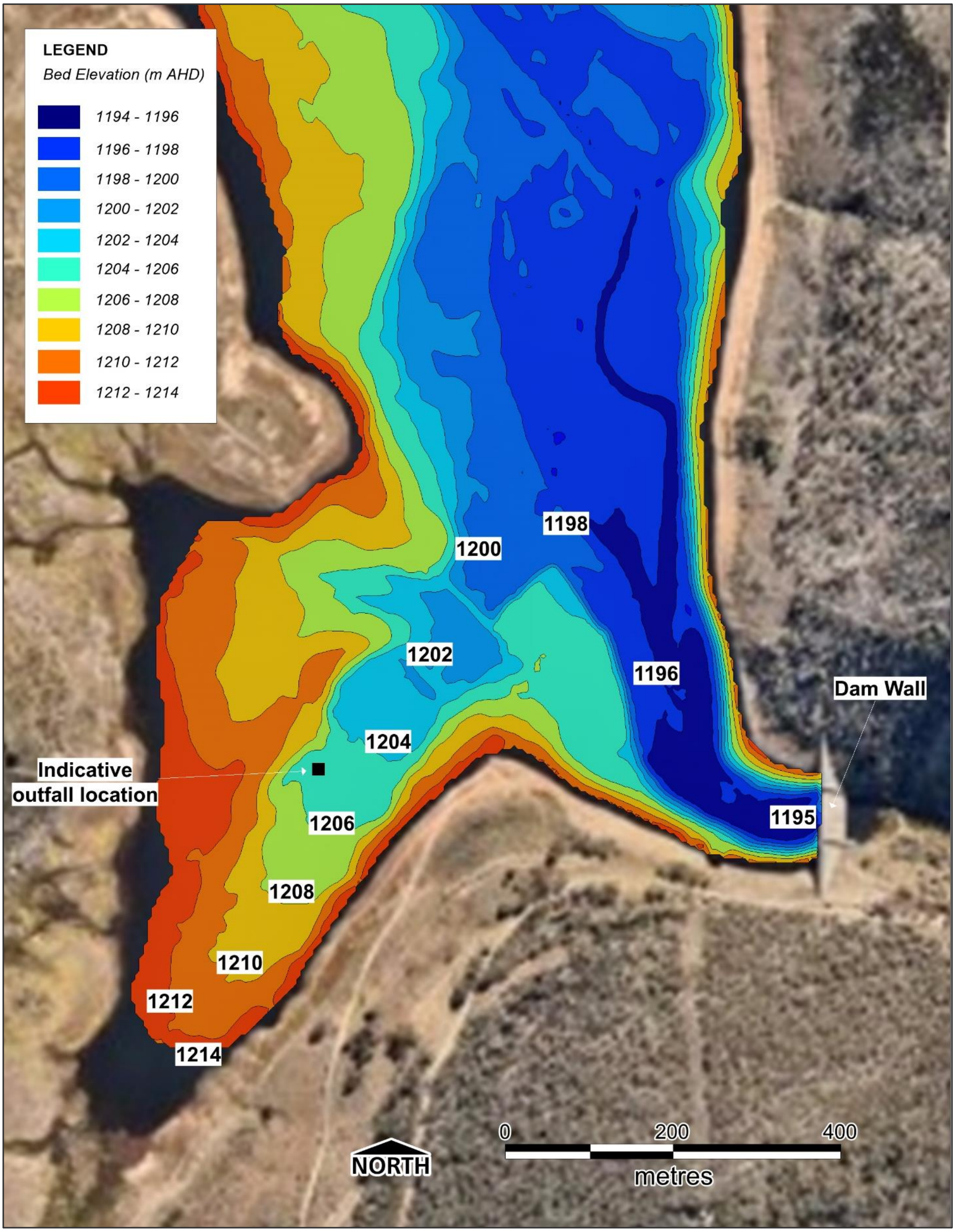


Figure 2-1: Reservoir Discharge Locations at Talbingo Reservoir and Tantangara Reservoir



Bathymetry data source: Snowy Hydro Limited, 2018

Figure 2-2: Talbingo Reservoir, Outfall Location and Local Bathymetry



Bathymetry data source: Snowy Hydro Limited, 2018

Figure 2-3: Tantangara Reservoir, Outfall Location and Local Bathymetry

The reservoir can become stratified in summer due to surface heating, but not to the degree observed at Talbingo Reservoir. In winter, the surface cools and the reservoir de-stratifies (i.e. becomes fully mixed over the water column and becomes unstratified). Current speeds near the outfall are very low and in the order of 1 mm/s to 10 mm/s. Surface water temperatures of between 20ºC and 25ºC (in summer) and around 5ºC (in winter) have been measured (Cardno, 2019). The near bed water temperature at the outfall location is typically 5ºC in winter and 15 ºC in summer. The EC of reservoir surface water is comparable to Talbingo Reservoir, i.e. also very low (approximately 0.01 ppt).

2.2 Effluent discharge streams

Details of the wastewater and process water discharge quality relevant to the assessment are summarised in the sections below.

2.2.1 Wastewater

Wastewater produced at construction camps and facilities will be treated at wastewater treatment plants and discharged into Tantangara and Talbingo reservoirs. Workers will be accommodated within accommodation camps at the two main construction areas. Wastewater will be produced from amenities (showers, toilets, laundry, cooking) within the accommodation camp and construction pad.

Peak wastewater discharge rates were provided by the construction contractor. A peak discharge of 0.125 ML/day and 0.406 ML/day is expected for the Tantangara and Talbingo systems respectively. Wastewater discharges will vary over the construction phase of the project in line with the size of the construction workforce. However, the peak discharge estimates have been applied to assess the mixing zone of waste and process water.

2.2.2 Process water

Construction activities that may produce contaminated water streams will be isolated from the stormwater system to avoid the contamination of stormwater runoff (see WMR for further details). Excess process water is expected to discharge to the reservoirs year round. All process water discharged to the reservoirs will go to the treatment plant first and then combined with treated wastewater (i.e. both outfalls will be a combined process and wastewater trunk main).

2.2.3 Discharge and quality

Assumed discharge rate, salinity and temperature of the wastewater and process water streams at Talbingo Reservoir and Tantangara Reservoir are provided in **Table 2-2** and **Table 2-3** respectively. These values are used in the near-field model to define the physical properties of the discharge water.

Table 2-2: Effluent Discharge, Salinity, Temperature and Flow Characteristics (Talbingo Reservoir)

Parameter	Wastewater Discharge	Process Water Discharge	Combined Discharge
EC (µS/cm)	700	700	700
Salinity (ppt)	0.35	0.35	0.35
Temperature (°C)	15	15	15
Flow (kL/D)	406	1 254	1 660
Flow (m^3/s)	0.00470	0.01451	0.01921
Flow (L/s)	4.7	14.5	19.2
Wastewater Pre-Dilution Factor[1]	1	n/a	3.1

Table 2-3: Effluent Discharge, Salinity, Temperature and Flow Characteristics (Tantangara Reservoir)

Parameter	Wastewater Discharge	Process Water Discharge	Combined Discharge
EC (µS/cm)	700	150	170
Salinity (ppt)	0.35	0.08	0.08
Temperature (°C)	15	15	15
Flow (kL/D)	125	3 680	3 805
Flow (m^3/s)	0.00145	0.04259	0.04404
Flow (L/s)	1.45	42.6	44.0
Wastewater Pre-Dilution Factor	1	n/a	29.4

2.3 Diffuser design

2.3.1 Port size and spacing

Dilution increases with plume initial velocity (V). For a constant discharge, the only way to increase jet velocity is to reduce the port diameter. However, as port head loss (and hence the required pumping head) is proportional to $V^2/2g$ (where g is gravitational acceleration), a compromise between initial dilution and pumping costs is required. Also, there tends to be a minimum preferred port size below which fouling / blockage could be an issue.

For the outfalls at Talbingo Reservoir and Tantangara Reservoir, the diffuser was assumed to comprise a 160 mm dia. pipe affixed to concrete sleepers with a span of approximately 4 metres and a total length of approximately 10 metres. The outfall diffuser would be positioned approximately 1 metre above the bed of

[1] Applies for constituents that are not present in the process water stream.

the reservoir. Port (or diffuser holes) would be 2.5 cm diameter and spaced 750 mm apart on alternate sides of the diffuser pipe to increase the distance between jet plumes (i.e. ports are spaced 1.5 m apart on each side of the diffuser pipe).

2.3.2 Port discharge angle

To maximise dilution for a neutral or slightly negatively buoyant plume, diffuser holes are offset 45 degrees from the vertical.

2.3.3 Adopted diffuser

For the Talbingo Reservoir outfall, the diffuser was assumed to be located in approximately 9 metres depth of water with the port located at 532 m AHD (approximately 1 metre above the reservoir bed). Raising the diffuser outlet above the bed increases dilution by preventing the reservoir bed from inhibiting mixing.

Similarly, for the Tantangara Reservoir outfall, the diffuser was assumed to be 1 metre above the bottom of the reservoir. During construction, Tantangara Reservoir is likely to be operated close to MOL and as such the outfall location would be located in approximately 5 to 10 metres depth of water.

In both cases, the orientation of the diffuser was assumed to be perpendicular to the dominant (primary) direction of flow experienced at the outfall location.

3 Near-field plume and dilution assessment

The following outfall discharge (Q) scenarios were assessed by this investigation for Talbingo and Tantangara reservoirs:

- Q1 – Wastewater discharge only, and
- Q2 – Process water (typical) combined with wastewater.

The assessment assumes that a single pipeline will be used so the wastewater and process water streams will be combined prior to being discharged to the reservoirs.

3.1 Stratified conditions

Near-field dilution results for outfalls at Talbingo Reservoir and Tantangara Reservoir for stratified receiving water conditions are presented below. Near-field mixing plots showing the predicted plumes for varying outfall discharge and ambient reservoir conditions are provided in **Appendix A**.

3.1.1 Outfall at Talbingo Reservoir

Results of near-field dilution are presented in **Table 3-1** for an outfall at Talbingo Reservoir and a range of stratified conditions with ambient current speeds (V) of 1 mm/s, 10 mm/s and 50 mm/s. While current speeds are typically between 1 and 10mm/s, higher current speeds of up to 50 mm/s were measured in Talbingo Reservoir. Near-field mixing is strongly influenced by the ambient current speed, and as such a range of typical currents speeds were tested.

Table 3-1: Predicted Dilution for Different Outfall Discharge and Ambient Velocity Field Conditions at Talbingo Reservoir (Stratified)

Discharge ID	Discharge (m^3/s)[b]	Dilution with plume interaction at (distance m) from multi-port diffuser	Maximum single port dilution[d] (distance m)
		Stratified, 1 mm/s Ambient Velocity	
Q1	0.00470	n/a[c]	28 (2 m)
Q2[a]	0.01921	n/a[c]	56 (4 m)
		Stratified, 10 mm/s Ambient Velocity	
Q1	0.00470	n/a[c]	51 (2 m)
Q2[a]	0.01921	n/a[c]	62 (4 m)
		Stratified,50 mm/s Ambient Velocity	
Q1	0.00470	n/a[c]	107 (5 m)
Q2[a]	0.01921	46 (5 m); 153 (10 m); 215 (25 m); 274 (50 m); 358 (100 m)	160 (7 m)

[a] need to consider additional process water dilution of wastewater stream of 3.1 times (see **Table 2-2**).
[b] total discharge distributed equally along length of diffuser (i.e. each port discharges 1/27 of the discharge).
[c] merging of jet plumes does not occur – single port dilution applies.
[d] best case scenario, no plume interaction reducing total dilution. Increasing port spacing could lead to dilutions of a single port. This tends to occur within 10 to 50 m of the port.

For the stratified (i.e. non-buoyant plume) conditions, the mixing zone occurred within 10 metres of the diffuser/outfall location based on dilution factors ranging between 28 and 153. The results show that for the wastewater discharge only scenario (i.e. Q1, discharge = 4.7 L/s) using a 2.5 cm diameter port, an initial dilution of 28 is achieved in a stratified near still (V = 1 mm/s) ambient condition. For a higher ambient velocity (V = 50 mm/s) which can occur from time to time, the predicted initial dilution increases to 107. Further assessment of a single port diffuser for the Q1 discharge is presented in **Section 3.3.1**.

For the Q2 scenarios (i.e. combined wastewater and process water (discharge = 19.2 L/s)), dilution in a stratified near still (V = 1mm/s) ambient condition of 56 is predicted. **Table 2-2** shows that a pre-dilution of 3.1 times is applicable to Q2 which increases the total dilution to about 174 for constituents that are not present in the process water stream. Greater dilution (e.g. 56 within 10 m) is achieved with higher ambient velocities (i.e. 10 mm/s and 50 mm/s) for the Q2 scenario, as expected.

3.1.2 Outfall at Tantangara Reservoir

Results of near-field dilution are presented in **Table 3-2** for an outfall at Tantangara Reservoir and a range of stratified conditions with ambient current speeds (V) of 1 mm/s, 10 mm/s and 50 mm/s.

Table 3-2: Predicted Dilution for Different Outfall Discharge and Ambient Velocity Field Conditions at Tantangara Reservoir (Stratified)

Discharge Scenario	Discharge (m^3/s)[b]	Dilution with plume interaction at (distance m) from multi-port diffuser	Maximum single port dilution[d] (distance m)
		Stratified, 1 mm/s Ambient Velocity	
Q1	0.00145	n/a[c]	17 (1 m)
Q2[a]	0.04404	0.7 (5 m); 1.6 (10 m); 2 (25 m); 3 (50 m); 11 (75 m)	113 (7 m)
		Stratified, 10 mm/s Ambient Velocity	
Q1	0.00145	164 (5 m); 230 (10 m); 336 (25 m); 388 (50 m); 650 (100 m)	4 925 (175 m)
Q2[a]	0.04404	4 (3 m); 10 (7 m)	120 (8 m)
		Stratified, 50 mm/s Ambient Velocity	
Q1	0.00145	100 (5 m); 157 (10 m) 281 (25 m); 432 (50 m); 686 (100 m)	5 620 (750 m)
Q2[a]	0.04404	31 (5 m); 43 (8 m)	222 (9 m)

[a] need to consider additional process water dilution of wastewater stream of 29.4 times (see **Table 2-2**).
[b] total discharge distributed equally along length of the diffuser (i.e. each port discharges 1/27 of the discharge).
[c] merging of jet plumes does not occur – single port dilution applies.
[d] best case scenario, no plume interaction reducing total dilution. Increasing port spacing could lead to dilutions of a single port. This tends to occur within 10 to 50 m of the port.

The results show that for the wastewater discharge only scenario (i.e. Q1, discharge = 1.45 L/s) using a 2.5 cm diameter port, an initial dilution of 17 is achieved in a stratified near still (V = 1 mm/s) ambient condition. For a higher ambient velocity (V = 50 mm/s), the predicted dilution at 5 m from the diffuser increases to 100. Taking into account the pre-dilution of wastewater which is applicable for Scenario Q2, the minimum dilution predicted at 10 m from the outfall is approximately 50 for constituents that are not present in the process water stream.

3.2 Unstratified conditions

The following presents near-field dilution results for outfalls at Talbingo Reservoir and Tantangara Reservoir with unstratified receiving water conditions. Near-field mixing plots showing the predicted plumes for varying outfall discharge and ambient reservoir conditions are provided in **Appendix B**.

3.2.1 Outfall at Talbingo Reservoir

Results of near-field dilution for an outfall at Talbingo Reservoir and a range of unstratified conditions with ambient current speeds of 1 mm/s, 10 mm/s and 50 mm/s are presented in **Table 3-3**.

Table 3-3: Predicted Dilution for Different Outfall Discharge and Ambient Velocity Field Conditions at Talbingo Reservoir (Unstratified)

Discharge ID	Discharge (m^3/s)[b]	Dilution with plume interaction at (distance m) from multi-port diffuser	Maximum single port dilution[d] (distance m)
		Unstratified, 1 mm/s Ambient Velocity	
Q1	0.00470	33 (10m)	219 (4m)
Q2[a]	0.01921	1.5 (3m); 3(5m)	145 (8m)
		Unstratified, 10 mm/s Ambient Velocity	
Q1	0.00470	195 (5m); 297 (10m); 519 (25m)	2 035 (20m)
Q2[a]	0.01921	51 (5m); 56 (10m)	395 (9m)
		Unstratified,50 mm/s Ambient Velocity	
Q1	0.00470	163 (5m); 285 (10m); 511 (25m); 793 (50m); 1 263 (100m)	10 965 (200m)
Q2[a]	0.01921	144 (5m); 193 (10m); 289 (25m); 409 (50m); 612 (100m)	2 663 (80m)

[a] need to consider additional process water dilution of wastewater stream of 3.1 times (see **Table 2-2**).
[b] total discharge distributed equally along length of the diffuser (i.e. each port discharges 1/27 of the discharge).
[c] merging of jet plumes does not occur – single port dilution applies.
[d] best case scenario, no plume interaction reducing total dilution. Increasing port spacing could lead to dilutions of a single port. This tends to occur within 10 to 50 m of the port.

The results also show that the buoyant plume that occurs in unstratified ambient conditions tends to produce higher dilutions than those that occur under stratified conditions. For the unstratified case (buoyant plume), dilution due to buoyant rise dominates over the turbulent mixing afforded by the jet velocity. This means that higher outfall discharges and smaller port sizes do not necessarily result in higher dilutions being achieved.

It should be noted that for the unstratified conditions, the merging of jet plumes resulted in composite dilutions of 50 or more for most discharge conditions at a distance of 5 metres from the diffuser. The results show that for the Q1 discharge and low ambient velocity condition, initial dilutions are small (33) due to the large number of diffuser ports and reduced port exit velocity. However, with higher ambient velocities, dilutions of between 200 and 300 are estimated within 10 m of the diffuser.

Overall, for unstratified conditions, the dilution of the buoyant plume 10 m from the diffuser is approximately 200 and in most cases above 300 at a distance of 25 m or more from the diffuser.

3.2.2 Outfall at Tantangara Reservoir

Results of near-field dilution for an outfall at Tantangara Reservoir and a range of unstratified conditions with ambient current speeds of 1 mm/s, 10 mm/s and 50 mm/s are presented in **Table 3-4**. The results show high dilutions are typically achieved within 10 m of the diffuser.

Table 3-4: Predicted Dilution for Different Outfall Discharge and Ambient Velocity Field Conditions at Tantangara Reservoir (Unstratified)

Discharge ID	Discharge (m^3/s)[d]	Dilution with plume interaction at (distance m) from multi-port diffuser	Maximum single port dilution[d] (distance m)
		Unstratified, 1 mm/s Ambient Velocity	
Q1	0.00145	n/a[c]	153 (4m)
Q2[a]	0.04404	2 (6m)[e]	147 (8m)
		Unstratified, 10 mm/s Ambient Velocity	
Q1	0.00145	188 (5m); 390 (10m)	1 119 (15m)
Q2[a]	0.04404	7 (4m); 15 (8m)[e]	205 (10m)
		Unstratified, 50 mm/s Ambient Velocity	
Q1	0.00145	73 (5m); 98 (10m); 378 (25m); 1 048 (50m)	2 866 (95m)
Q2[a]	0.04404	117 (5m); 153 (10m); 220 (25m); 229 (50m)	2 372 (95m)

[a] need to consider additional process water dilution of wastewater stream of 29.4 times (see **Table 2-2**).
[b] total discharge distributed equally along length of diffuser (i.e. each port discharges 1/27 of the discharge).
[c] merging of jet plumes does not occur – single port dilution applies.
[d] best case scenario, no plume interaction reducing total dilution. Increasing port spacing could lead to dilutions of a single port. This tends to occur within 10 to 50 m of the port.
[e] limited near-field mixing due to buoyant plumes reaching surface. Mixing zone is small (<10m from outfall). Beyond the mixing zone, further dilution will occur due to far-field mixing processes.

3.3 Sensitivity tests

3.3.1 Single port diffuser for wastewater only (Q1) discharge

As noted above, high dilutions are possible where wastewater and process water are combined (Q2) (i.e. the discharge rate is proportionate to the size and configuration of the diffuser assessed). However, the results for Q1 discharge condition suggest that a diffuser configuration of 27 ports each with a diameter of 2.5 cm may not be optimal for low discharge and low ambient velocity conditions.

To demonstrate the increase to initial dilution that could be obtained with a reduced number of diffuser ports, an alternate outfall was simulated for the Q1 discharge condition with the following properties:

- Number of ports/nozzles = 1 or 2
- Port diameter = 2.5 cm
- Wastewater discharge = 4.7 L/s, and
- Location of riser above bed = 2 m.

The same effluent quality and ambient water temperature and velocity conditions were adopted. The estimated dilutions for stratified and unstratified conditions at Talbingo Reservoir is summarised below in **Table 3-5** and **Table 3-6**.

Table 3-5: Predicted Dilution for Hypothetical Outfall at Talbingo Reservoir (Stratified)

Ambient Velocity (mm/s)	Outfall with 1 port		Outfall with 2 ports	
	Dilution	*Distance from Diffuser (m)*	*Dilution*	*Distance from Diffuser (m)*
1	155	10	102	6
10	160	10	108	7
50	236	11	190	8

Table 3-6: Predicted Dilution for Hypothetical Outfall at Talbingo Reservoir (Unstratified)

Ambient Velocity (mm/s)	Outfall with 1 port		Outfall with 2 ports	
	Dilution	*Distance from Diffuser (m)*	*Dilution*	*Distance from Diffuser (m)*
1	129	7	129	7
10	129	7	159	8
50	722	12	1 153	40

The results show that a two port diffuser produces higher dilution than those predicted for a multi-port diffuser assessed in **Section 3.1** for very low ambient velocity conditions. As expected, the buoyant plume that occurs in unstratified ambient conditions produces higher dilutions than those that occur under stratified conditions which is especially apparent for an ambient velocity of 50 mm/s (i.e. single dilution of 236 and 722 for stratified and unstratified conditions respectively).

The results above indicate that a reduced number of ports could be used for low discharge (wastewater only) scenario to achieve greater dilution.

3.3.2 Ambient water temperature for stratified conditions

The sensitivity of predicted dilution to the adopted stratified ambient water temperature (i.e. 20°C at the surface and 10 °C near the bed) was tested for a ±2°C change at the bed (i.e. 8°C and 12°C). The sensitivity of the adopted water temperature gradient between the surface and near bed was found to have negligible effect on predicted dilution for a range of discharges and ambient velocity conditions that were assessed. For most combinations of discharges and ambient velocities, the change was within ±1 dilution and up to ±6 dilution for the Q1 discharge with the 50 mm/s ambient velocity. The adopted water temperature gradient for stratified conditions is, therefore, reasonable and does not over predict or under predict dilution of discharges from the outfalls at Talbingo and Tantangara Reservoirs.

4 Conclusion

Based on the results of the near-field modelling, the following key points are highlighted in the context of the proposed waste and process water discharges:

- The concentration of TN and TP in wastewater is low and indicative of a high level of wastewater treatment prior to discharge. When combined with process water, TN and TP in the combined discharge is further diluted to concentrations slightly above ambient conditions.
- Summer (stratified) conditions are expected to result in less near-field dilution than the winter (unstratified) conditions but in both cases the mixing zone is small (typically less than 10 m, but for some ambient conditions the mixing zone could be between 50 and 100 m).
- The buoyant plume that occurs during unstratified ambient conditions tends to produce higher dilutions (e.g. dilution around 200 at 10 m from the outfall) than those that occur under stratified conditions for the same conditions (i.e. dilution around 150).
- For the summer stratified (i.e. non-buoyant plume) near still ambient conditions, the mixing zone is typically within 10 m of the diffuser/outfall location. Under these conditions, the near-field dilution factor ranges between 20 and 150.
- For the winter unstratified case (buoyant plume), dilution due to buoyant rise dominates over the turbulent mixing afforded by the jet velocity, resulting in higher total dilutions.

Overall, the assessment estimates the mixing zone to be small (i.e. in the order of 10's of metres), due to the high level of wastewater treatment and the small amount of dilution required (i.e. less than 20 for TN and TP, and less than 30 for salinity) to satisfy the target concentrations at the end of the mixing zone. In the case of unstratified near still conditions (V=1mm/s) at both reservoirs, target concentrations may not be met before the plume reaches the water surface, however, such conditions are unlikely to be persistent for more than a week at a time (based on typical wind conditions experienced at the reservoirs) and further mixing (predominantly by advection) would continue to occur as a result of reservoir scale (far-field) mixing processes.

5 References

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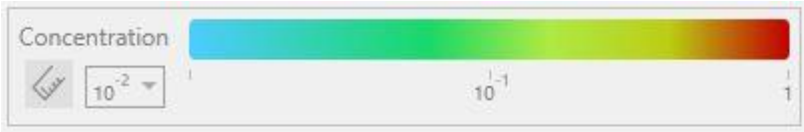
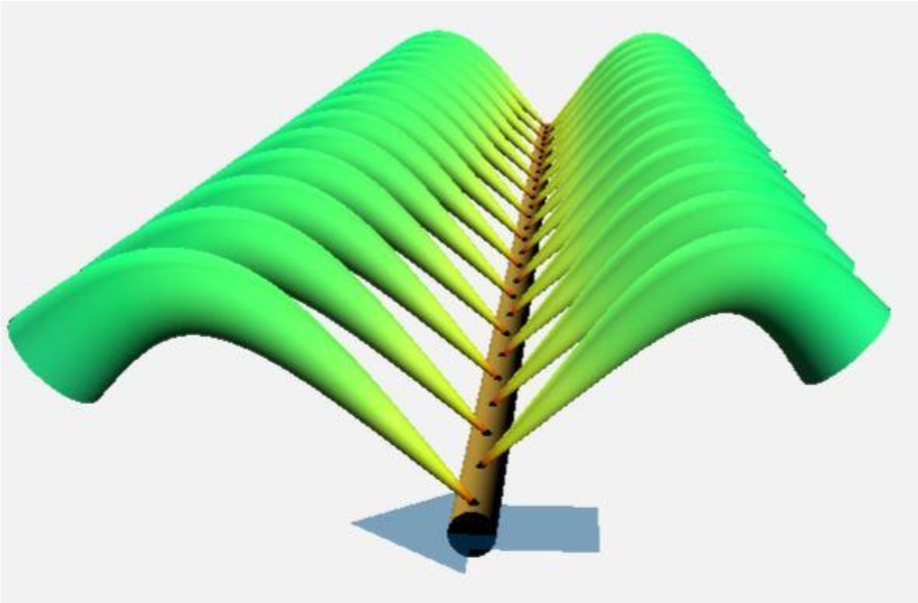
Lee J.H.W. and Cheung V. (2017) Lagrangian modeling and visualization of rosette outfall plumes, available: http://www.aoe-water.hku.hk/visjet/vjetiowa.pdf [accessed: 10 December 2019].

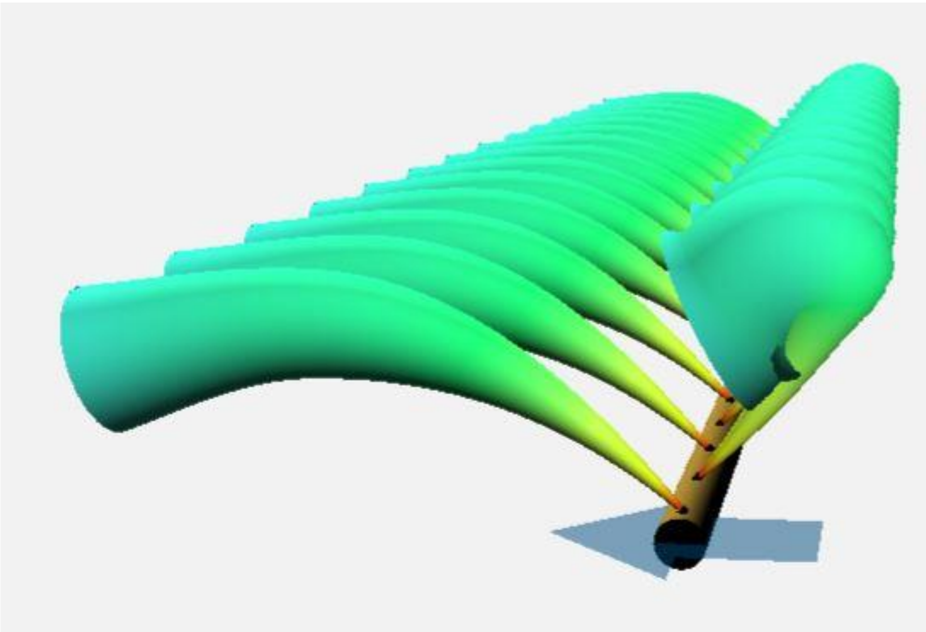
Appendix A: Example Near-Field Plume Model Results (Stratified Conditions)



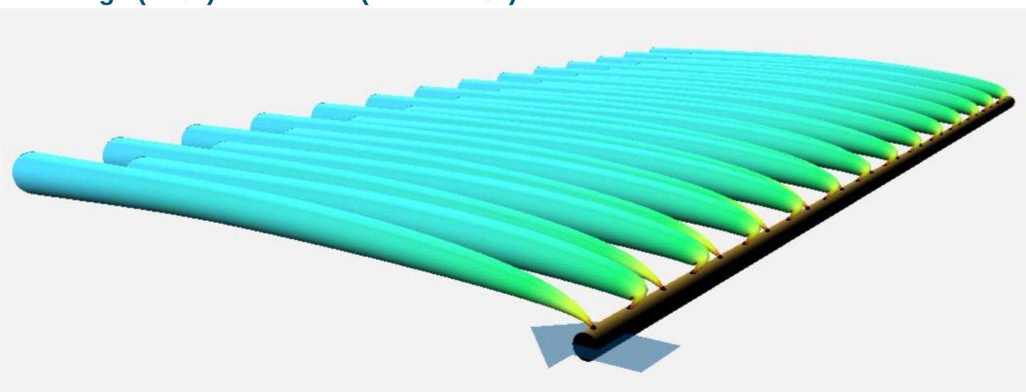
Discharge (3 L/s) – Ambient (V=1 mm/s)

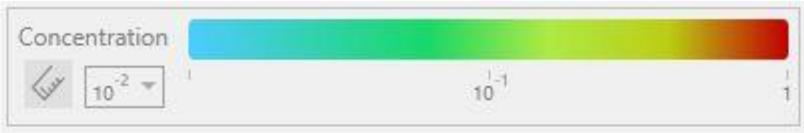


Discharge (3 L/s) – Ambient (V=10 mm/s)

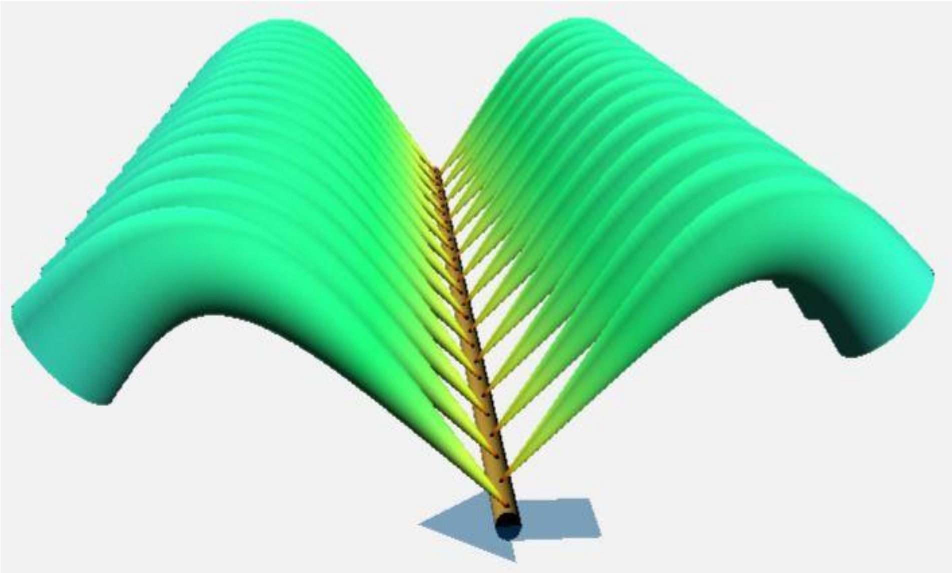


Discharge (3 L/s) – Ambient (V=50 mm/s)

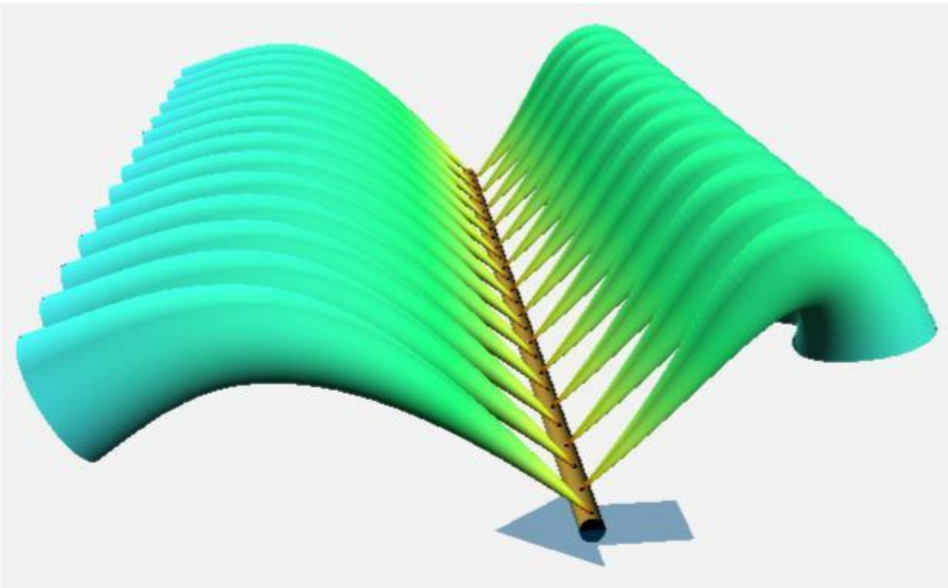




Discharge (10 L/s) – Ambient (V=1 mm/s)



Discharge (10 L/s) – Ambient (V=10 mm/s)



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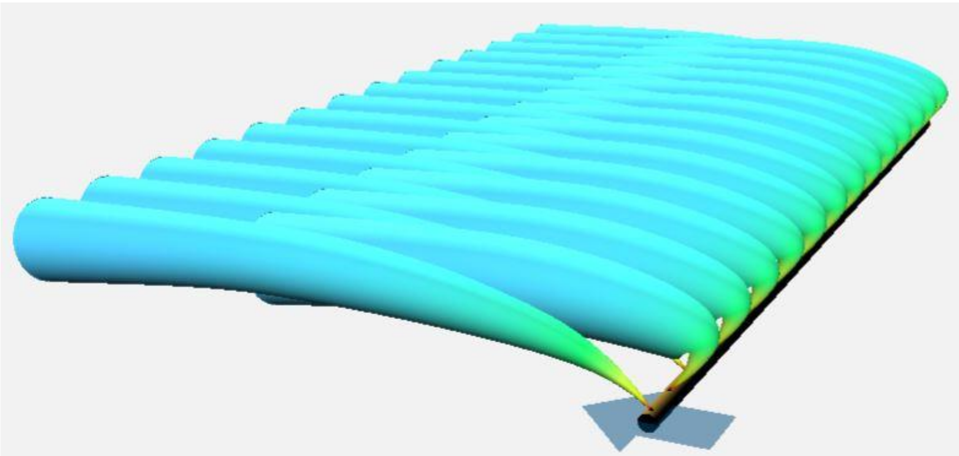
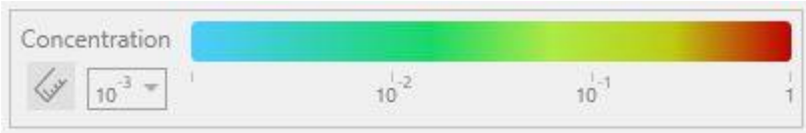
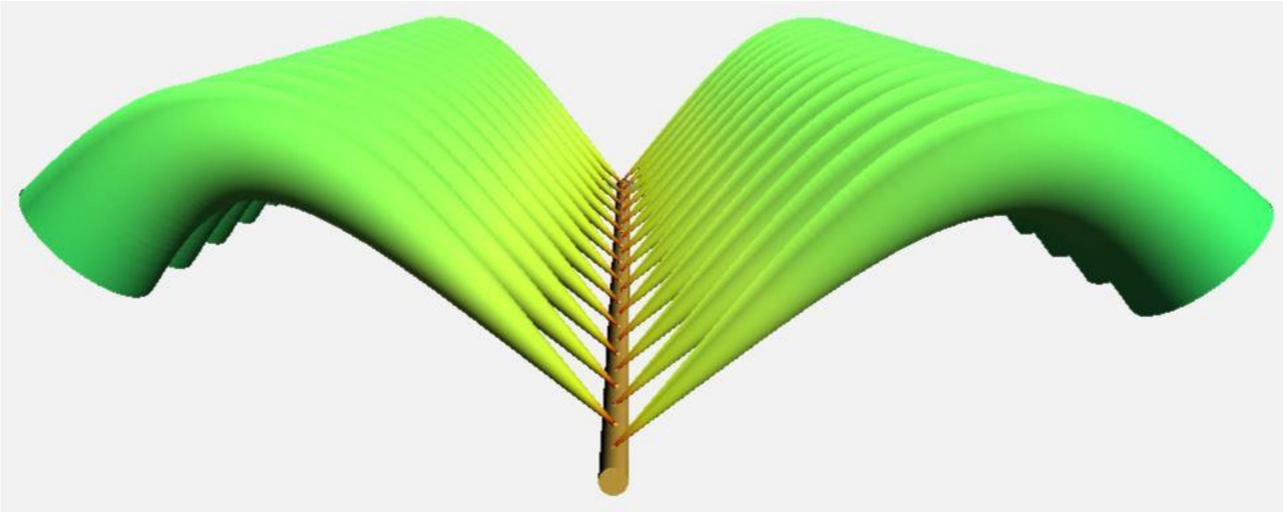
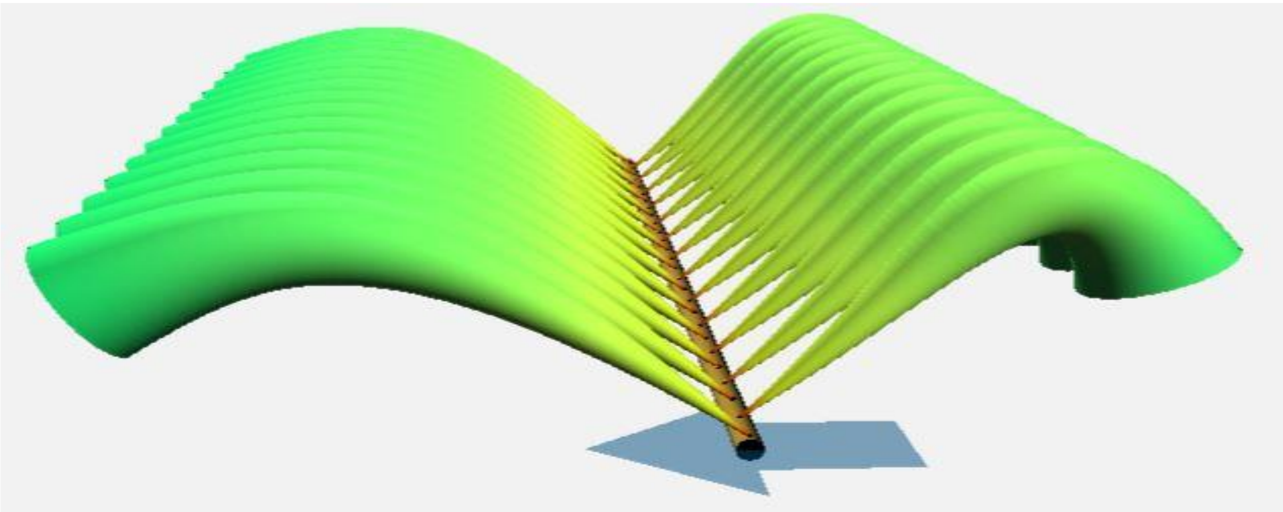




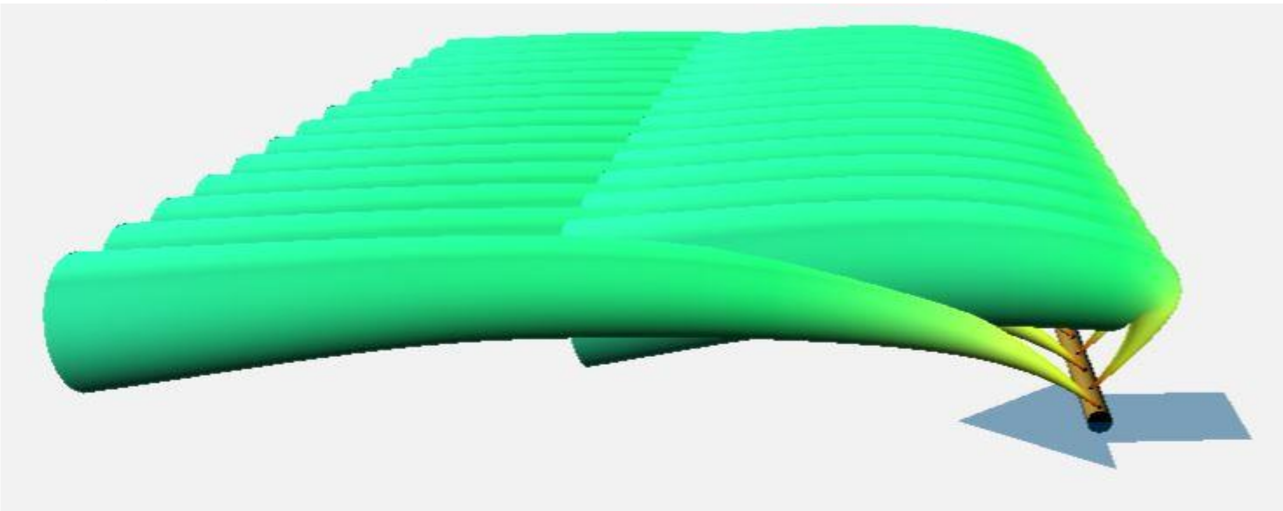
Discharge (15 L/s) – Ambient (V=1 mm/s)



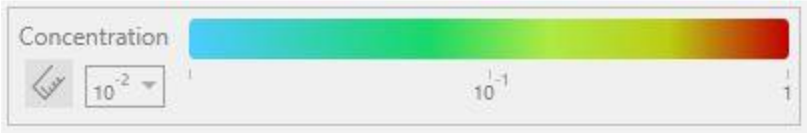
Discharge (15 L/s) – Ambient (V=10 mm/s)



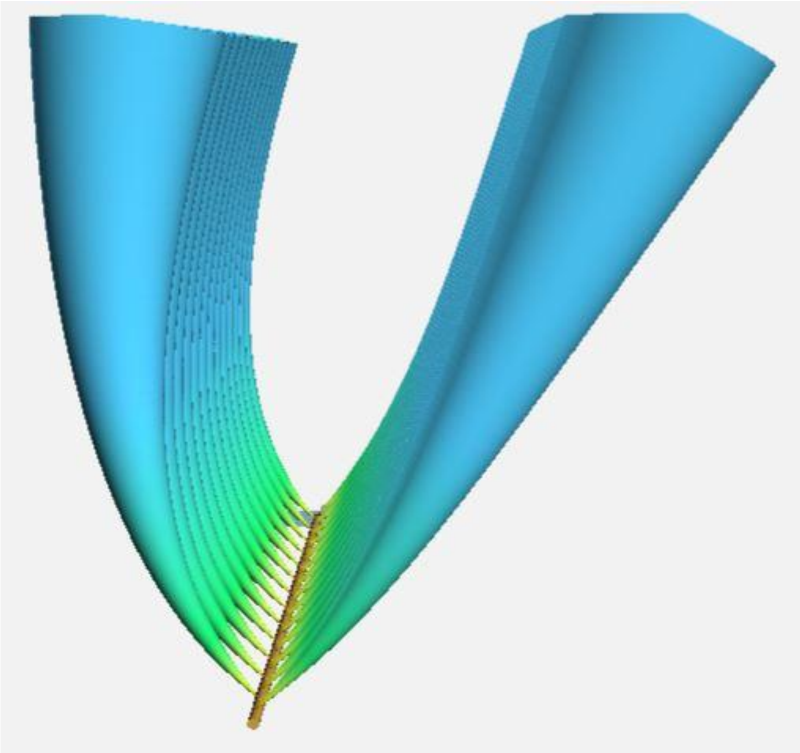
Discharge (15 L/s) – Ambient (V=50 mm/s)



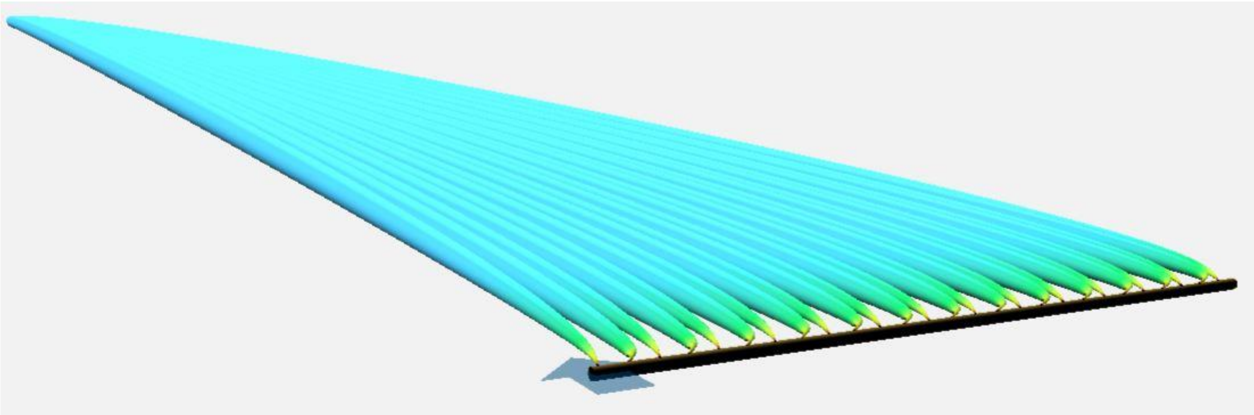
Appendix B: Example Near-Field Plume Model Results (Unstratified Conditions)



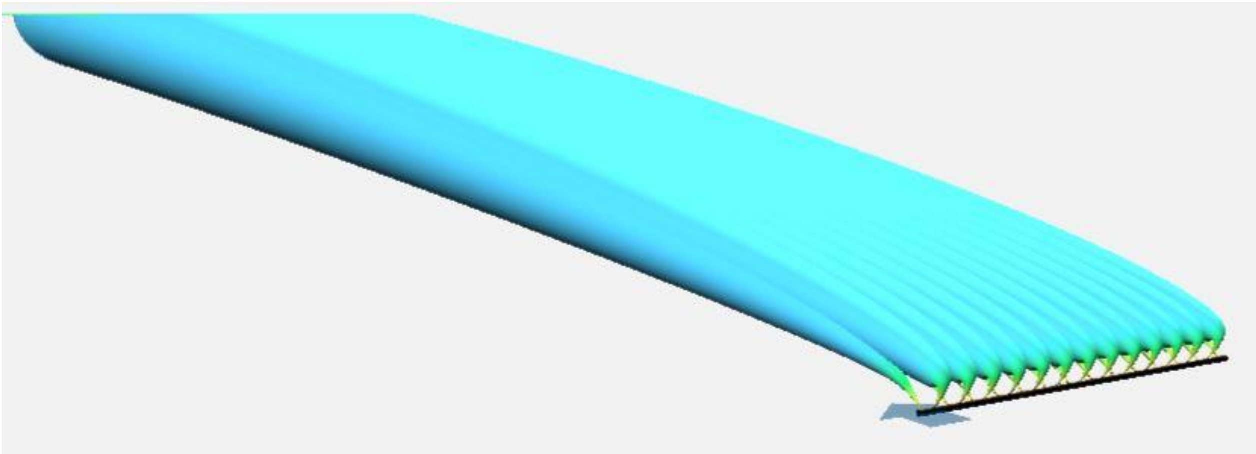
Discharge (3 L/s) – Ambient (V=1 mm/s)

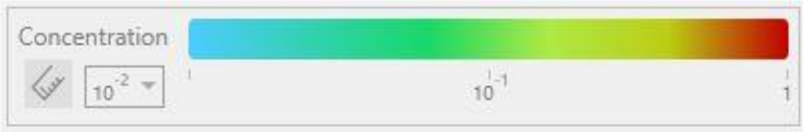


Discharge (3 L/s) – Ambient (V=10 mm/s)

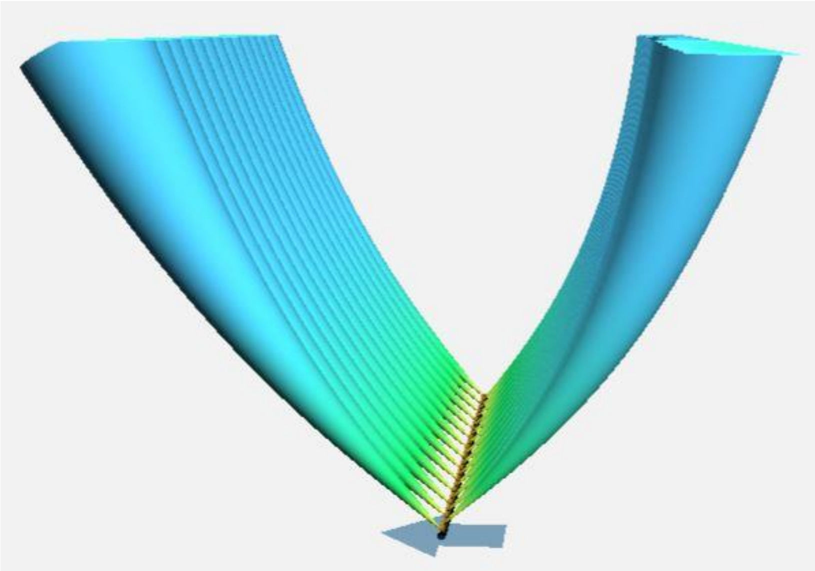


Discharge (3 L/s) – Ambient (V=50 mm/s)

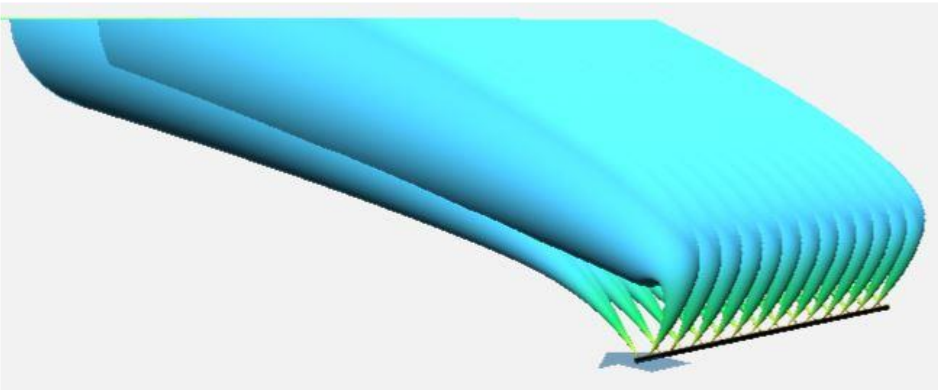




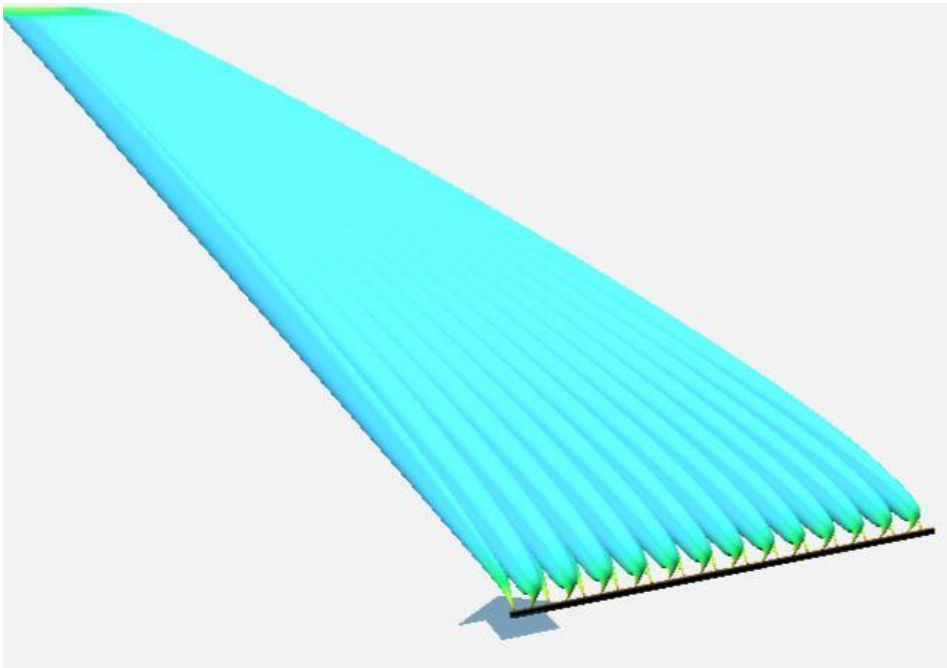
Discharge (10 L/s) – Ambient (V=1 mm/s)

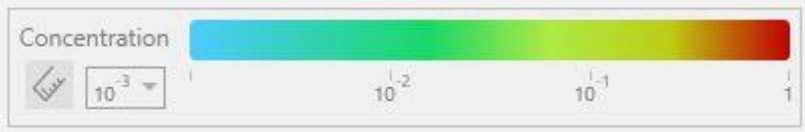


Discharge (10 L/s) – Ambient (V=10 mm/s)

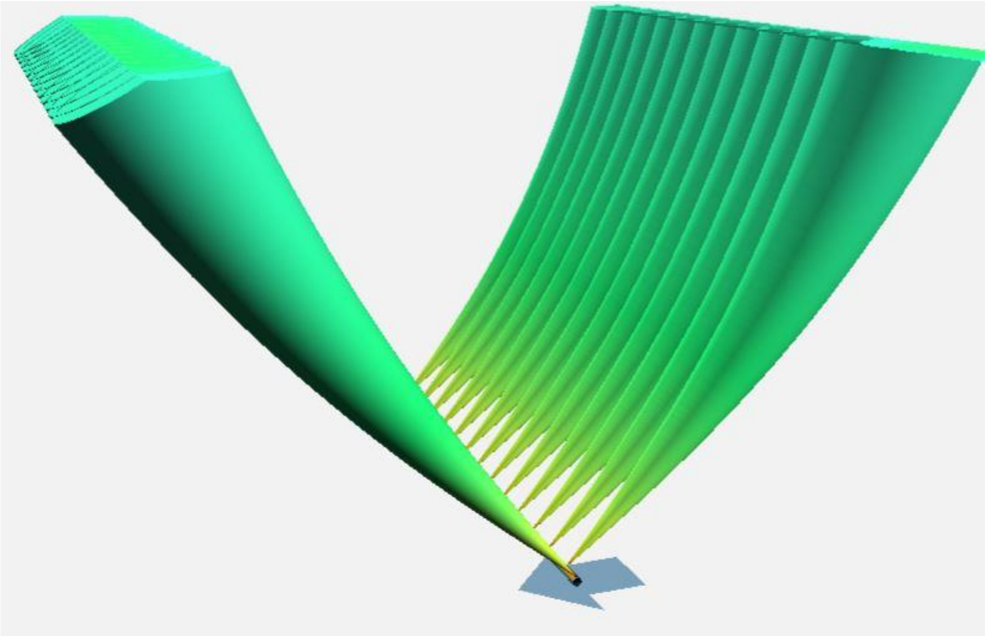


Discharge (10 L/s) – Ambient (V=50 mm/s)

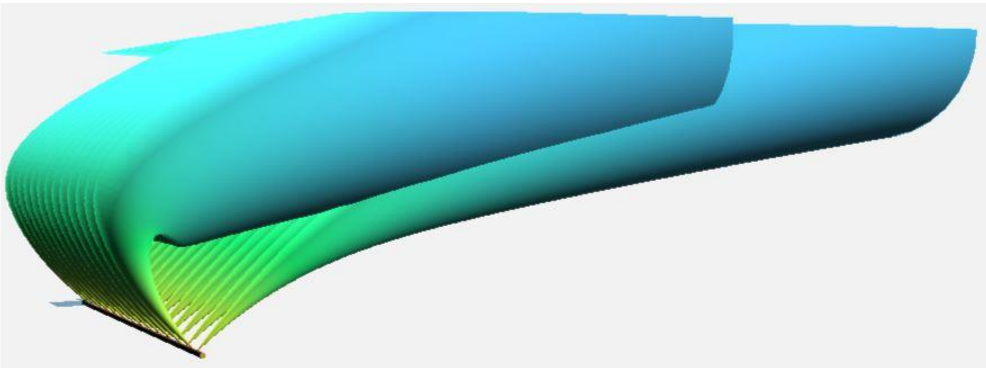




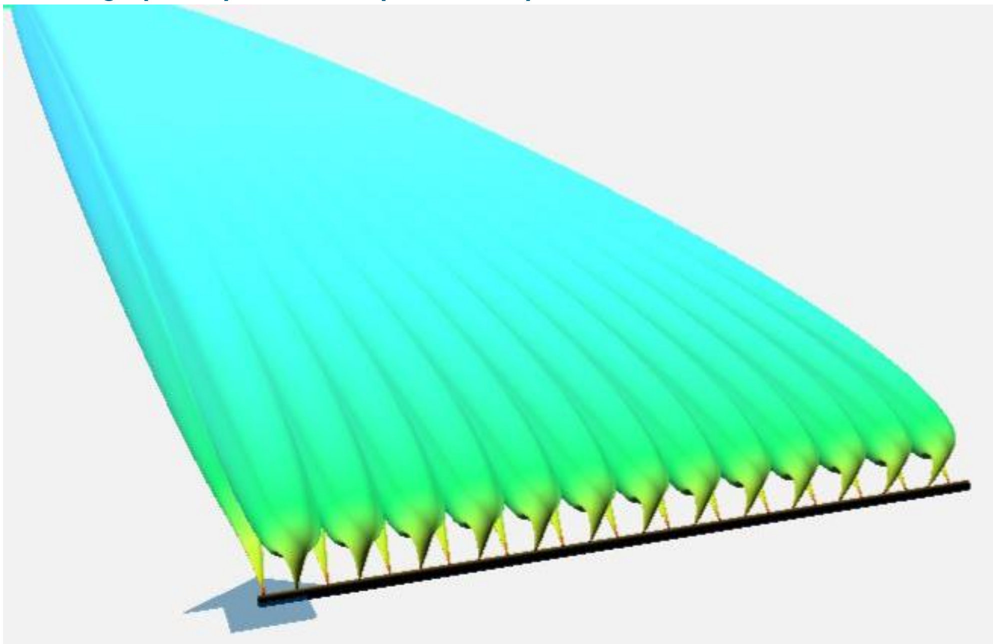
Discharge (15 L/s) – Ambient (V=1 mm/s)



Discharge (15 L/s) – Ambient (V=10 mm/s)

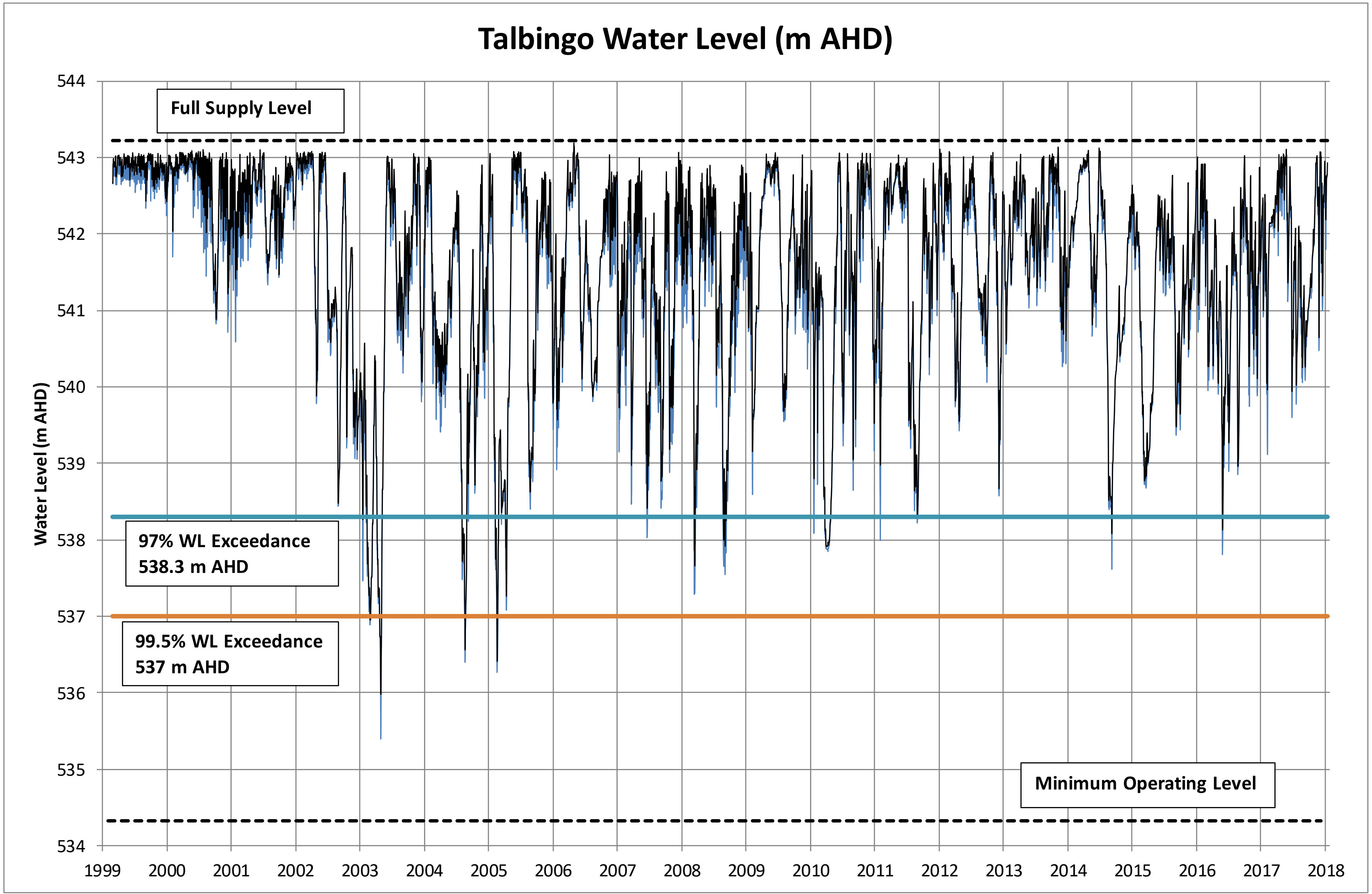


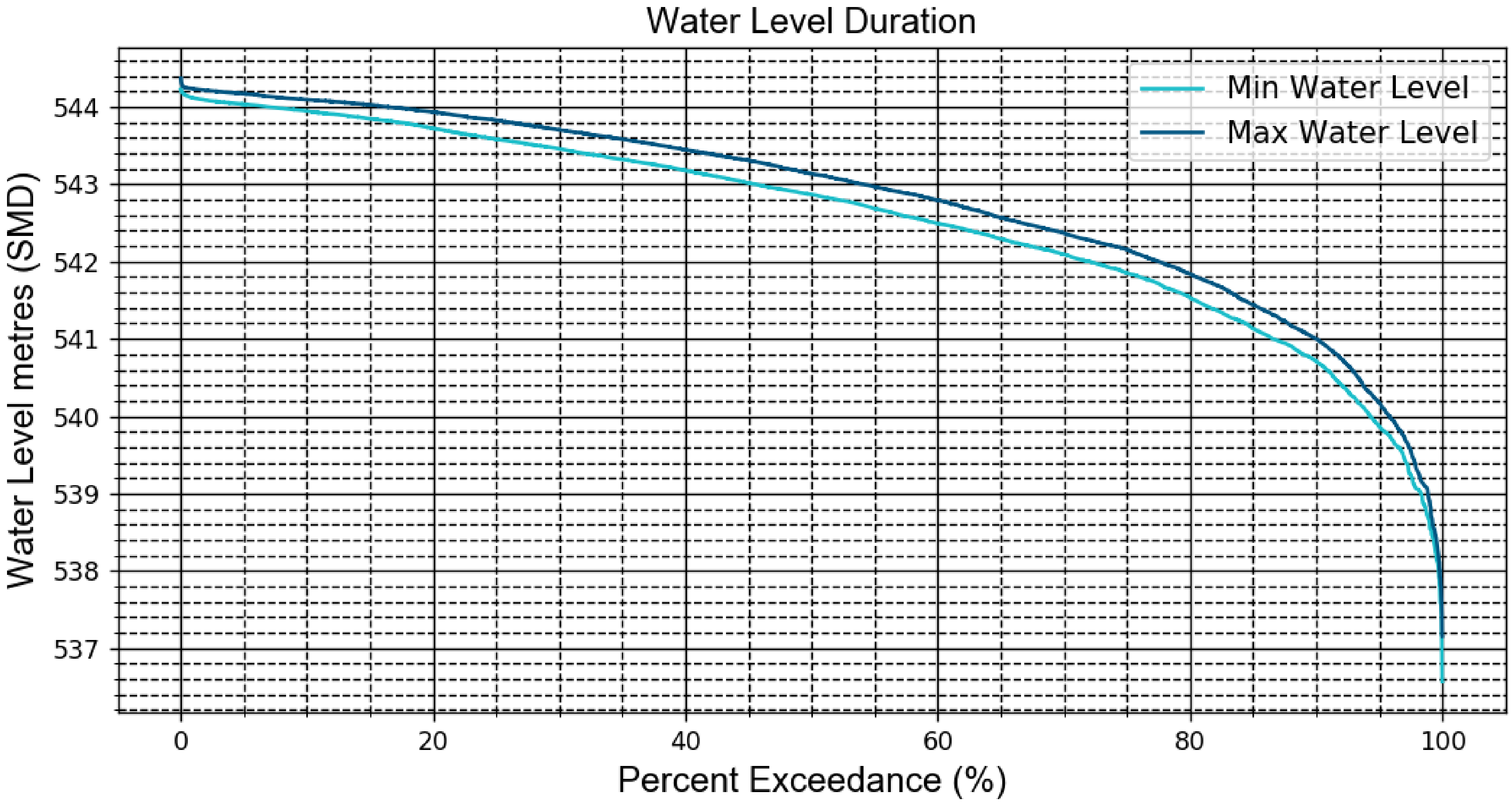
Discharge (15 L/s) – Ambient (V=50 mm/s)



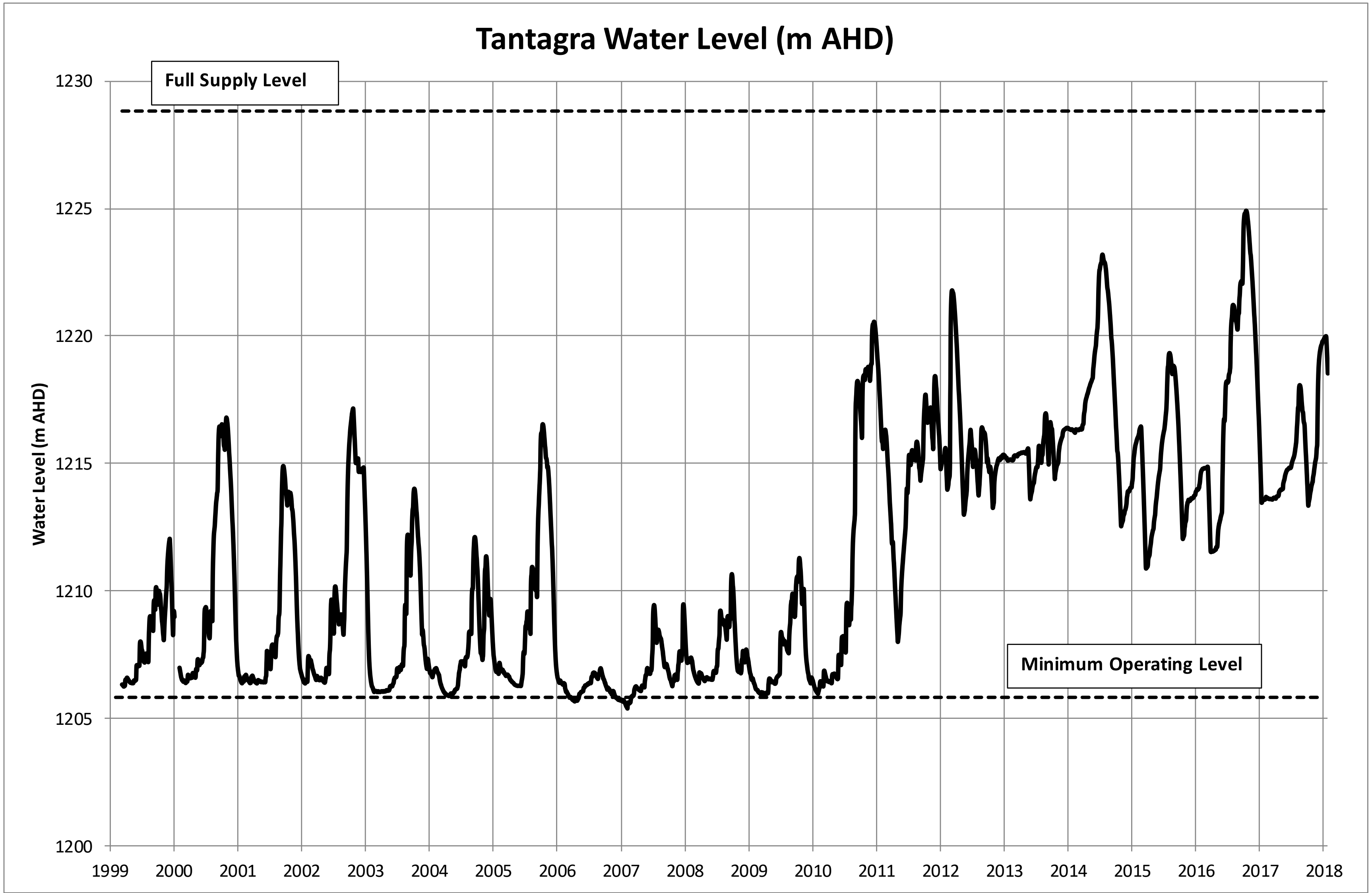
Appendix C: Reservoir Storage Levels

Royal HaskoningDHV

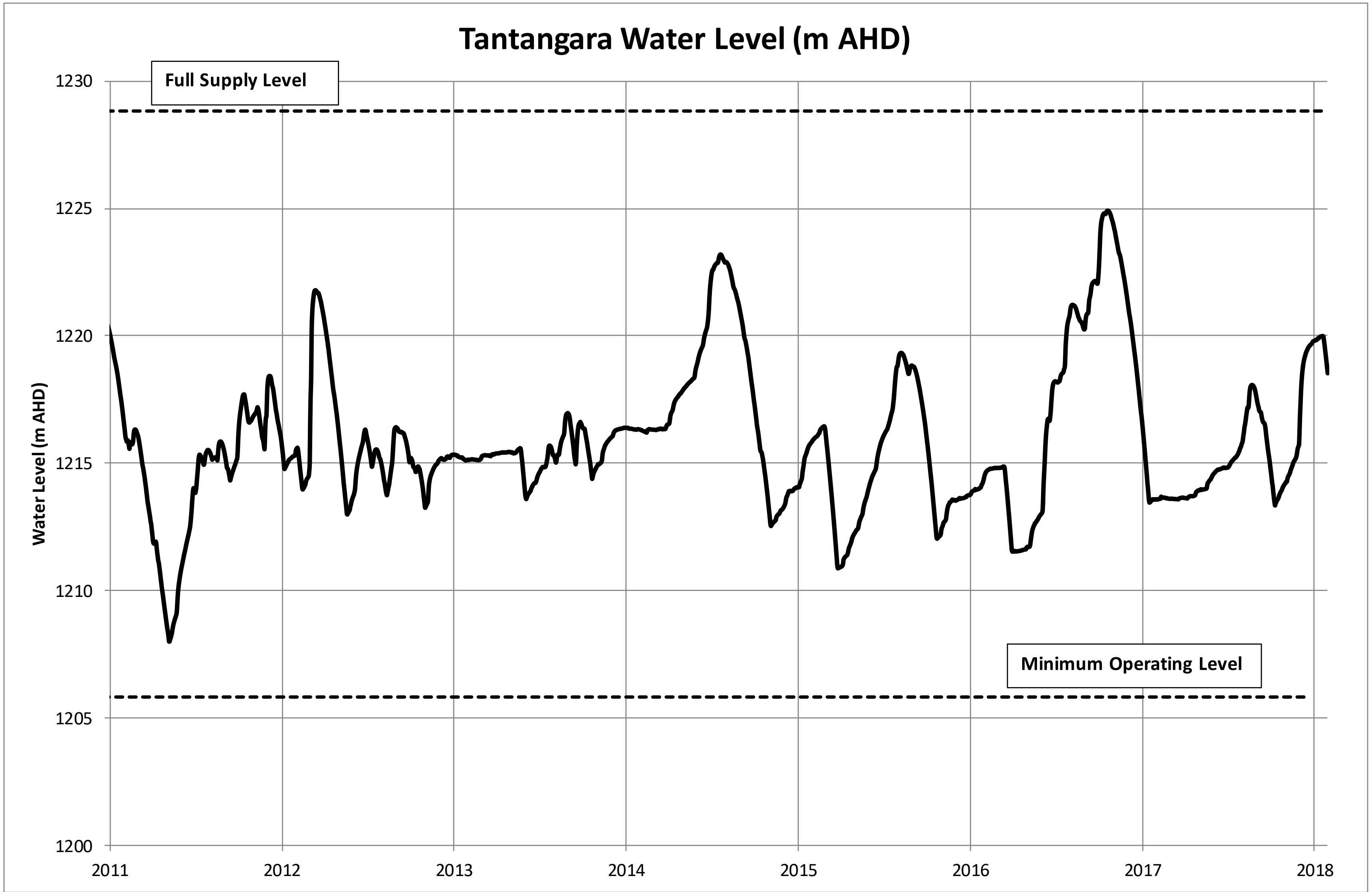


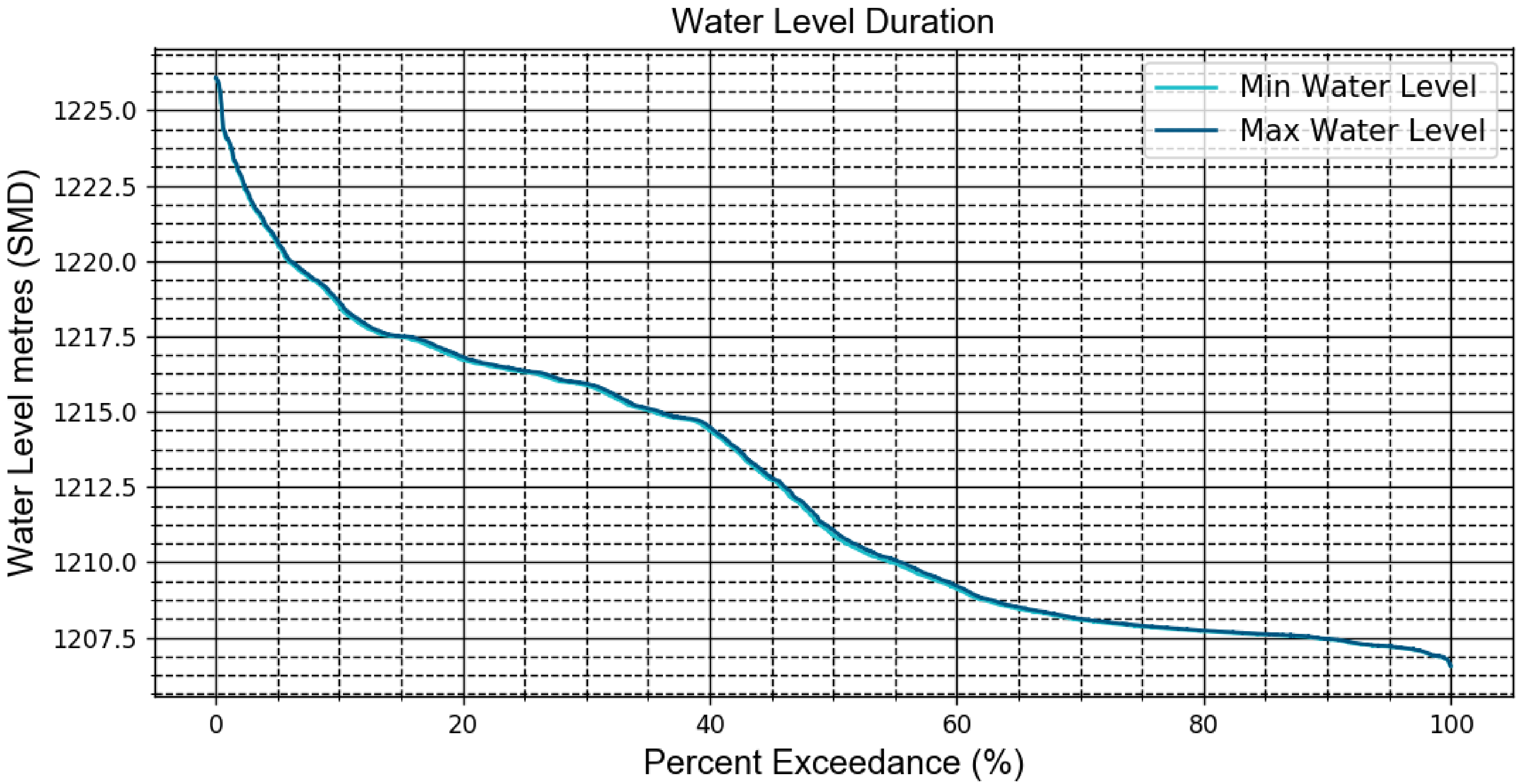

Water Level Duration
Min Water Level
Max Water Level
Water Level metres (SMD)
544
543
542
541
540
539
538
537
0
20
40
60
80
100
Percent Exceedance (%)

Royal HaskoningDHV



Royal HaskoningDHV




Water Level Duration
Min Water Level
Max Water Level
1225.0
1222.5
1220.0
1217.5
1215.0
1212.5
1210.0
1207.5
Water Level metres (SMD)
0
20
40
60
80
100
Percent Exceedance (%)