

8. Inland Waters

8.1 EPA environmental factor and objective

To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.

For the purposes of EIA, the EPA (2018a) defines inland waters as the occurrence, distribution, connectivity, movement, and quantity (hydrological regimes) of inland water including its chemical, physical, biological and aesthetic characteristics (quality).

8.2 Policy and guidance

8.2.1 EPA policy and guidance

- *Environmental Factor Guideline – Inland Waters* (EPA 2018a)
- *Instructions on how to prepare an Environmental Review Document* (EPA 2021b)
- *Instructions on how to prepare Environmental Protection Act 1986 Part IV Environmental Management Plans* (EPA 2024)

8.2.2 Other policy and guidance

- *Australian Drinking Water Guidelines* (National Health and Medical Research Council 2024)
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Department of Agriculture and Water Resources 2018).
- *Ecological Character Description of the Peel-Yalgorup Ramsar Site* (Hale and Butcher 2007 Report to the Department of Environment and Conservation and the Peel-Harvey Catchment Council 2007)
- *Manual for the application of Health-based Targets for Drinking Water Safety* (Water Services Association of Australia 2015)
- *Peel-Yalgorup System Information Sheet on Ramsar Wetland (RIS)* (Western Australian Department of Conservation and Land Management (DCLM) 2003)
- *Policy: Land use compatibility in public drinking water source areas* (DWER 2021a)
- *Preventing acid and metalliferous drainage – Leading practice sustainable development program for the mining industry* (Department of Industry, Innovation and Science, September 2016)
- *Serpentine Dam Catchment Area and Serpentine Pipehead Dam Catchment Area Drinking Water Source Protection Plan – WRP 78* (Department of Water 2007)
- *Significant Impact Guidelines 1.1 - Matters of National Environmental Significance* (DoE 2013).
- *South Dandalup Dam & South Dandalup Pipehead Dam Catchment Areas Drinking Water Source Protection Plan – WRP 55* (Department of Environment 2005)
- *Statutory Guidelines for Mine Closure Plans* (Department of Mines, Industry Regulation and Safety 2020)
- *Strategic policy: Protecting public drinking water source areas in Western Australia* (Department of Water 2016)

- *Water Quality Protection Note 15 - Extractive Industries near sensitive water resources* (Department of Water 2013b)
- *Water Quality Protection Note 18 - Information the Department of Water requires to assess a proposed development or activity* (Department of Water 2016)
- *Water Quality Protection Note 25 - Land use compatibility tables for public drinking water source areas* (DWER 2021b)
- *Water Quality Protection Note 3 - Using water quality protection notes* (DWER 2024)
- *Water Quality Protection Note 44 - Roads near sensitive water resources* (Department of Water 2006)
- *Water Quality Protection Note 52 - Stormwater management at industrial sites* (Department of Water 2010)
- *Water Quality Protection Note 77 - Risk assessment process for public drinking water source areas* (DWER 2022)
- *Water Quality Protection Note 81 - Tracks and trails near sensitive water resources* (Department of Water 2015)
- *Water Quality Protection Note 83 - Infrastructure corridors near sensitive water resources* (Department of Water 2007)
- *Western Australian water in mining guidelines* (Department of Water 2013a)

8.3 Receiving environment

8.3.1 Baseline studies and peer review

A summary of the key inland waters studies that have been undertaken for this Proposal are presented in Table 8.1 and presented in Appendix B.

Table 8.1 Inland Waters baseline studies and peer review

Year	Author	Study name	Relevant Proposal Components
2021	HydroEnviro	Hydrology and Water Quality Assessment – Huntly Mine Extension – Peer Review	Mine DE
2021	CSIRO	Drinking Water Risk Assessment – Peer Review	Mine DE
2023c	GHD	Drinking Water Risk Assessment – Serpentine, Serpentine Pipehead, South Dandalup, and Wungong Brook Catchments	Mine DE
2023a, 2024	GHD	Hydrology and Water Quality Assessment Component studies: <ul style="list-style-type: none"> • Baseline Surface and Ground Water Monitoring Report – Myara North and Holyoake (GHD 2021b)¹ • Hydrological Setting and Understanding – Myara North and Holyoake (GHD 2021c) • Groundwater Modelling Report for Huntly Mine – Myara North (GHD 2021d)² • Groundwater Modelling Report for Huntly Mine – Holyoake (GHD 2021e)² • Review of catchment clearing with respect to groundwater modelling report (GHD 2023) 	Mine DE

Year	Author	Study name	Relevant Proposal Components
		<ul style="list-style-type: none"> O’Neil Inland Waters Baseline Report Year 1 (2023 – 2024) and Bore Completion Report (GHD 2024) 	
<p>Notes:</p> <p>1 – Report has been updated to provide groundwater and surface water monitoring completed between 2020 and 2023 in the proposed Myara North DE and Holyoake DE, and one (1) year of monitoring within the proposed O’Neil DE and address the editorial comments outlined in the 2021 Peer Review.</p> <p>2 – Reports have been updated to address the editorial comments outlined in the 2021 Peer Review.</p>			

8.3.2 Surface water systems

8.3.2.1 Regional hydrology

The Mine DE is primarily located within the Murray River basin, with a small portion of the Myara North mine region located in the Swan Coastal basin. Approximately 21,364 ha (89.4 per cent) of the Mine DE lies within the catchments of six water supply dams, of which four dams impound all flows with no downstream release and two dams (North Dandalup Dam and Conjurunup Pipehead Dam) release limited flows (<10 per cent of inflow) to maintain downstream beneficial uses (Table 8.2). The six dams are used for drinking water and their catchments comprise Priority Drinking Water Source Protection Areas (PDWSAs) (Figure 8-1, Figure 8-2, and Figure 8-3). The majority of the Mine DE (83.0 per cent of total) lies within the regulated subcatchments of Serpentine and South Dandalup dams. An additional 6.4 per cent of the Mine DE is located within regulated catchments, flows from which are impounded at Conjurunup Pipehead Dam, North Dandalup Dam, Canning Dam and Wungong Dam (Table 8.2).

An approximate 2,536 ha (10.6 per cent) of the Mine DE lies within the un-regulated catchments of the Serpentine and Murray Rivers, which discharge into the Peel Inlet near Mandurah (Table 8.2). The Peel Inlet forms part of the Peel-Harvey Estuary and Peel-Yalgorup System Ramsar site (Figure 8-1).

The Serpentine, Murray and Canning River Catchments have their headwaters in the Darling Plateau, an undulating lateritic regolith over Archaean granite with dolerite intrusions (see Section 7.3.1.1) that retains extensive forested land of the Northern Jarrah Forest (NJF) (see Section 5.3.4.1). The Darling Plateau generally lies at elevations of approximately 250 to 350 metres Australian Height Datum (mAHD), interspersed by isolated granite hills or ‘monadnocks’ that can exceed 400 mAHD. Rainfall is greatest in the western edge of the plateau near the Darling Scarp, decreasing to the north and east. The Serpentine, Murray and Canning rivers run in a characteristic north-west direction influenced by underlying granite and dolerite structures (Hickman et al 1992).

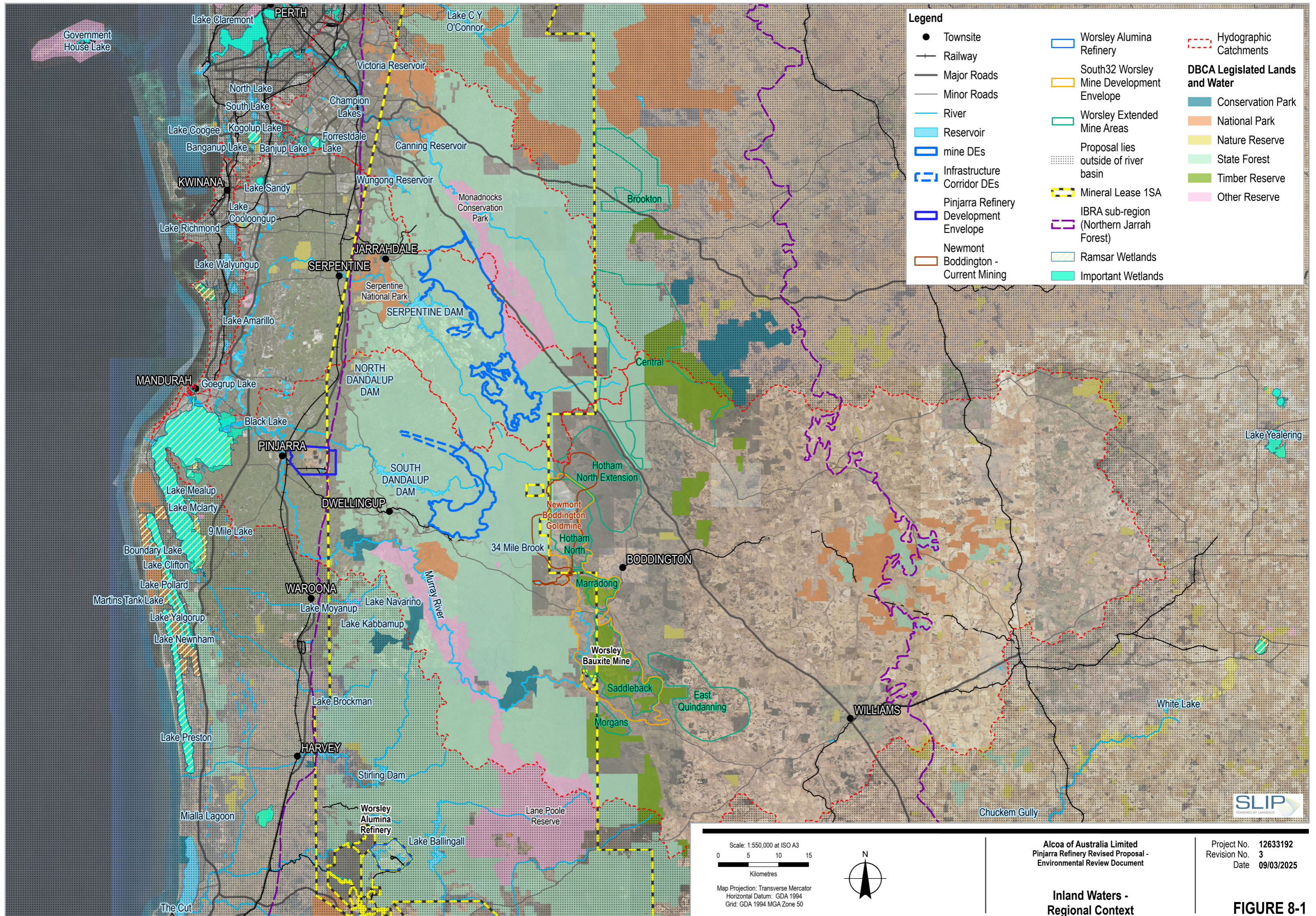
Public water supply dams have been developed along the Darling Scarp (Figure 8-1) to harness the water resources created by the relatively high rainfall over the forested regolith, and the relative elevation that enables gravity supply to urban and agricultural water demand on the Swan Coastal Plain (SCP). The water supply dams have substantially reduced riverine flows within the SCP downstream and have been subject to declining rainfall and inflows since the 1970s (see Section 5.3.4.8). The lower Canning River is hydrologically isolated from the upper catchment with no downstream releases from the Wungong and Canning dams. The Murray River’s upper catchment lies east of the NJF and covers extensive agricultural land uses of the Avon-Wheatbelt, which results in elevated salinity in the river (Figure 8-1). Accordingly, the main channel of the Murray River is not dammed for water supply, though major tributaries of the river comprising the North and South Dandalup rivers lie over forested catchments and are dammed.

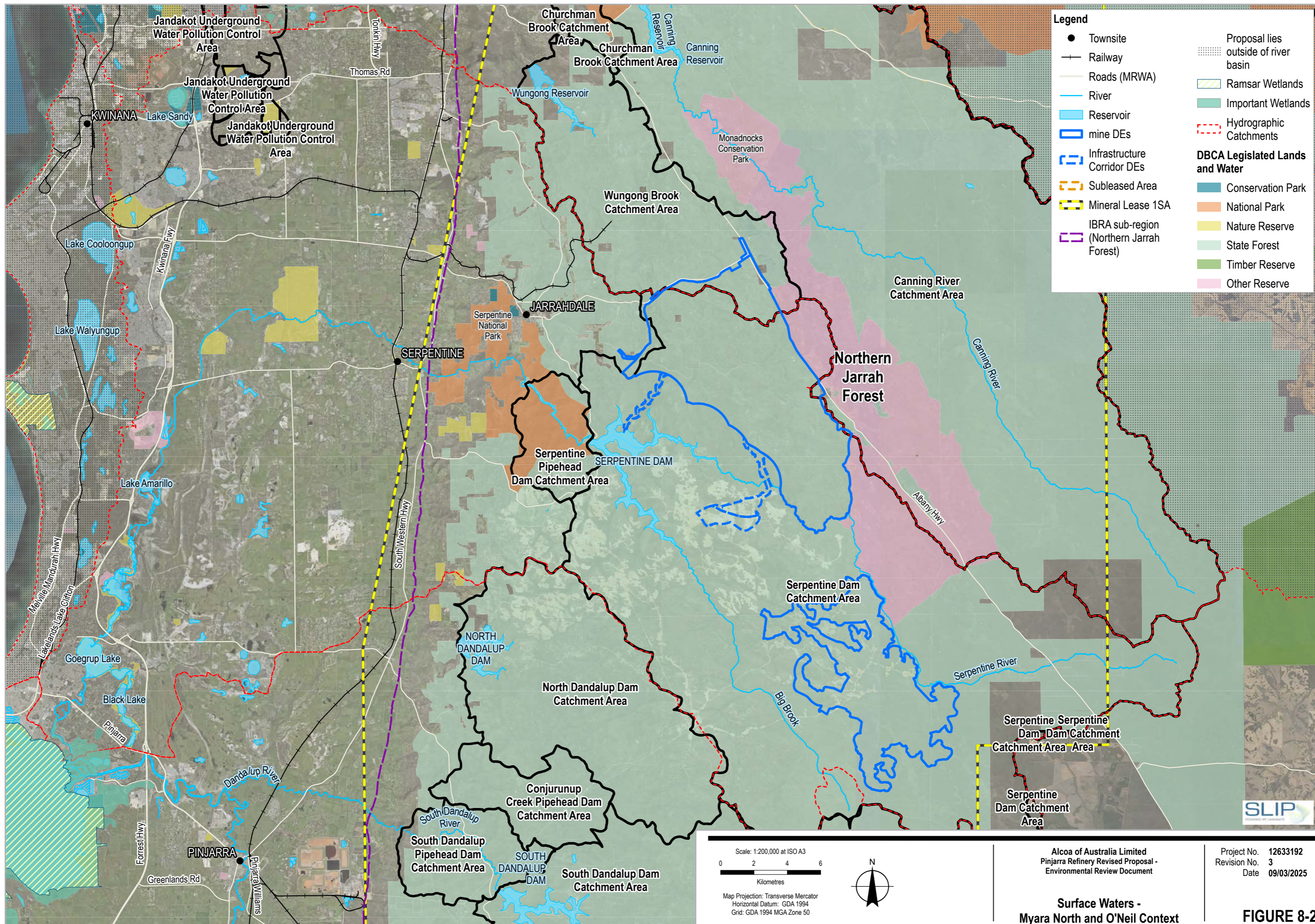
The Serpentine and Murray rivers flow west off the Darling Plateau, via incised valleys through the Darling Scarp, and onto the SCP. The SCP comprises deep sediments deposited from the ocean or washed down from the Darling Scarp, with a series of sandy dunes to the west and the relatively flat Pinjarra Plain to the east. The SCP lies at elevations from sea level on the coast up to 50 mAHD near the Darling Scarp with higher elevations in larger dune landforms. The SCP has been extensively developed for urban land uses over the sandy dunes, and for agricultural land use on the heavier soils of the Pinjarra Plain.

The Serpentine and Murray rivers meander through the SCP towards the coast. The Serpentine River adopts a southerly direction due to the influence of north-south coastal dunes, before discharging into the Peel Inlet. The extensive agricultural development of the Pinjarra Plain has resulted in high nutrient loads and eutrophication of the Peel-Harvey Estuary (Hale and Butcher 2007). Along with river diversions, agricultural land use poses a key threat to the environmental values of the Peel-Yalgorup Ramsar site (Hale and Butcher 2007).

Table 8.2 Regional hydrology – Mine DE

Basin	Catchment	Myara North DE (ha)	Holyoake DE (ha)	O'Neil DE (ha)	Mine DE total (ha)	Proportion of Mine DE within catchment (%)	Downstream release to rivers
Regulated catchments							
Peel-Inlet – Serpentine River Catchment							
Murra River	Serpentine Dam	9,397	20	5571	14,988	62.7	Yes – managed release to Serpentine River
Peel Inlet – Murray River Catchment							
Murray River	South Dandalup Dam	-	4,795	-	4,795	20.1	No
Murray River	North Dandalup Pipehead Dam	-	309	-	309	1.3	Yes – managed release to North Dandalup River, Murray River
Murray River	Conjurunup Creek Pipehead Dam	0	128	-	128	0.5	Yes – overflow to South Dandalup River, Murray River
Swan-Avon – Canning River Catchment							
Canning River	Wungong Brook	1,046	-	-	1,046	4.4	No
Canning River	Canning Dam	61	-	-	61	0.3	No
DE area subtotal within regulated catchments		10,505	5,252	5,571	21,328	89.2	
Un-regulated catchments							
Murray River	Davis Brook	-	1,739	-	1,739	7.3	Yes
Murray River	Swamp Oak Brook	-	592	-	592	2.5	Yes
Murray River	Gooralong Brook	204	-	-	204	0.9	Yes
DE area subtotal un-regulated catchments		204	2,332	-	2,572	10.8	
Total DE area		10,708	7,584	5,571	23,900		





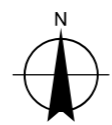
Legend

- Townsite
- Railway
- Roads (MRWA)
- River
- Reservoir
- mine DEs
- Infrastructure Corridor DEs
- Subleased Area
- Mineral Lease 1SA
- IBRA sub-region (Northern Jarrah Forest)
- Proposal lies outside of river basin
- Ramsar Wetlands
- Important Wetlands
- Hydrographic Catchments

DBCAs Legislated Lands and Water

- Conservation Park
- National Park
- Nature Reserve
- State Forest
- Timber Reserve
- Other Reserve

Scale: 1:200,000 at ISO A3
 0 2 4 6
 Kilometres
 Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



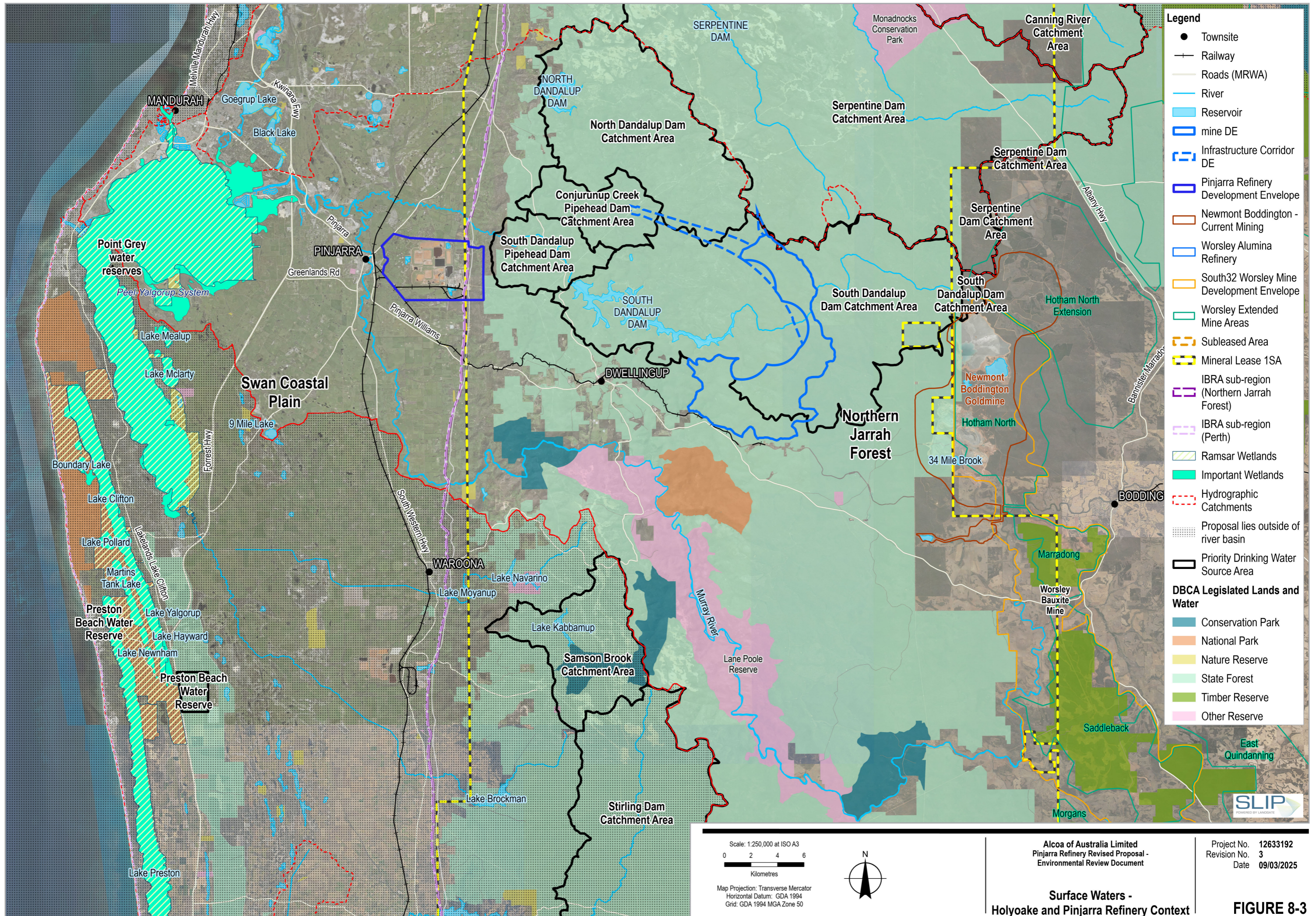
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 Pinjarra Refinery Revised Proposal -
 Environmental Review Document

Project No. 12633192
 Revision No. 3
 Date 09/03/2025

**Surface Waters -
 Myara North and O'Neil Context**

FIGURE 8-2

Data source: WANow; Landgate / SLIP.



8.3.2.2 Local hydrology

Myara North

The Myara North DE is predominantly (9,393 ha or 87.7 per cent of total) located within the catchment of Serpentine Dam. Minor portions of the Myara North DE lie within the catchments of Gooralong Brook (204 ha or 1.9 per cent of total) and Wungong Dam (1,046 ha or 9.8 per cent of total) (Figure 8-2, Table 8-2). Very minor portions lie within the catchment of Canning Dam (61 ha or 0.5 per cent of total). The topography of the Myara North is presented in Figure 8-4.1 and the slope within the catchment is presented in Figure 8-5.1.

O'Neil

The O'Neil DE (5,571 ha) is entirely located within the catchment of Serpentine Dam (Table 8.2, Figure 8-2). The topography of the O'Neil is presented in Figure 8-4.3 and the slope within the catchment is presented in Figure 8-5.3.

Serpentine River

The majority of the Serpentine River within and upstream of the Myara North DE and O'Neil DE is regulated by the Serpentine Dam. The Serpentine Dam was constructed in 1961 and supplies the Serpentine Pipehead Dam (Figure 8-2), which was constructed in 1957. Sections 8.3.2.4 and 8.3.2.5 present the hydrodynamics and water quality, and beneficial uses of the Serpentine and Pipehead dams.

Serpentine Dam is used for public drinking water supply and diverts the majority of flow from its catchment for this beneficial use. Releases to the Serpentine River downstream of the Pipehead Dam are managed according to the Serpentine allocation statement (DWER 2017a), which allows for the release of 0.8 GL/year for 'low-inflow' years (inflow to dam less than 30 GL) and 0.86 GL/year for 'standard' years (inflow to dam greater than 30 GL). Accordingly, for average inflows of approximately 14 GL/year, as was recorded over 2008-2015 (DWER 2017a), Serpentine Dam would divert more than 94 per cent of inflow from the Serpentine River catchment upstream, with less than 6 per cent released downstream. For average inflows of approximately 33 GL/year, as was recorded over 1975-2008 (DWER 2017a), the dam would divert more than 97 per cent, with less than 3 per cent released downstream.

Chart 8-1 presents the recorded and projected inflows into the Serpentine Dam, reproduced from the Serpentine River allocation statement (DWER 2017a). As presented, inflows have decreased from an average of approximately 87 GL/yr over 1960-1974 to approximately 33 GL/yr over 1975-2008, to approximately 14 GL/yr over 2008-2015 (DWER 2017a).

Within the Myara North DE, the Serpentine Dam is supplied by seasonal streams, with major tributaries being the Serpentine River, 39 Mile Brook, Banksia Gully and Goldmine Gully (Figure 8-2). The Myara North infrastructure corridor lies within the catchment of the Serpentine River, within which the Serpentine River and Big Brook discharge to Serpentine Dam. DWER gauging stations are located on the Serpentine River at River Road (no. 614035), on 39 Mile Brook at Jack Rocks (no. 614031) and Big Brook at O'Neill road (no. 614037) (Figure 8-2). The Serpentine River and tributaries typically flow from June to November. Chart 8-2 presents the recorded flows on the Serpentine River at the DWER gauging station at River Road, which is located on the southern end of the Myara North DE.

The seasonal streams are interspersed by headwater swamps that occupy colluvial and alluvial sediments in valley floors. The swamps comprise seasonally waterlogged wetlands with distinct vegetation types (see Section 5.3.4.6).

Gooralong Brook is an un-regulated tributary of Serpentine River, which flows west through Jarrahdale townsite then south-west through Serpentine National Park and discharges into the Serpentine River approximately 5.5 km downstream of the Serpentine Pipehead Dam (Figure

8-2). Gooralong Brook has a subcatchment area of approximately 2,151 ha. A gauging station is located at Mundlimup (no. 614073) approximately 2.3 km upstream of the confluence with Serpentine River.

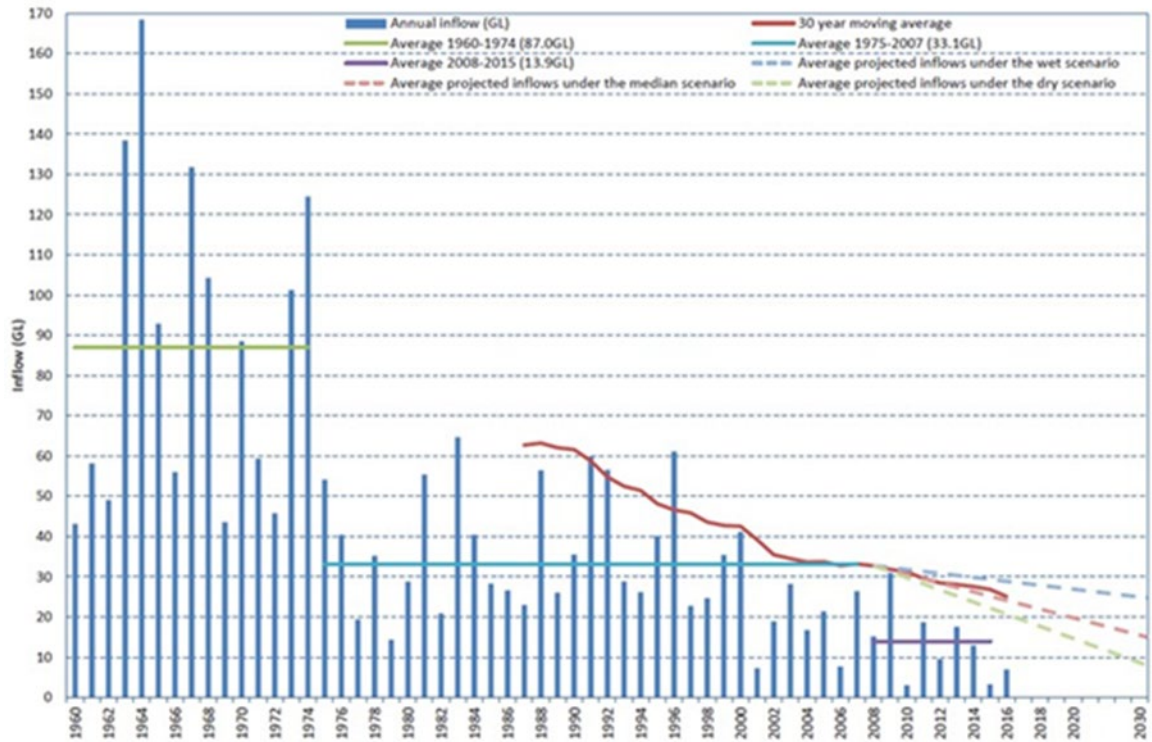


Chart 8-1 Inflows into Serpentine Dam as presented in Serpentine River allocation statement (DWER 2017a)

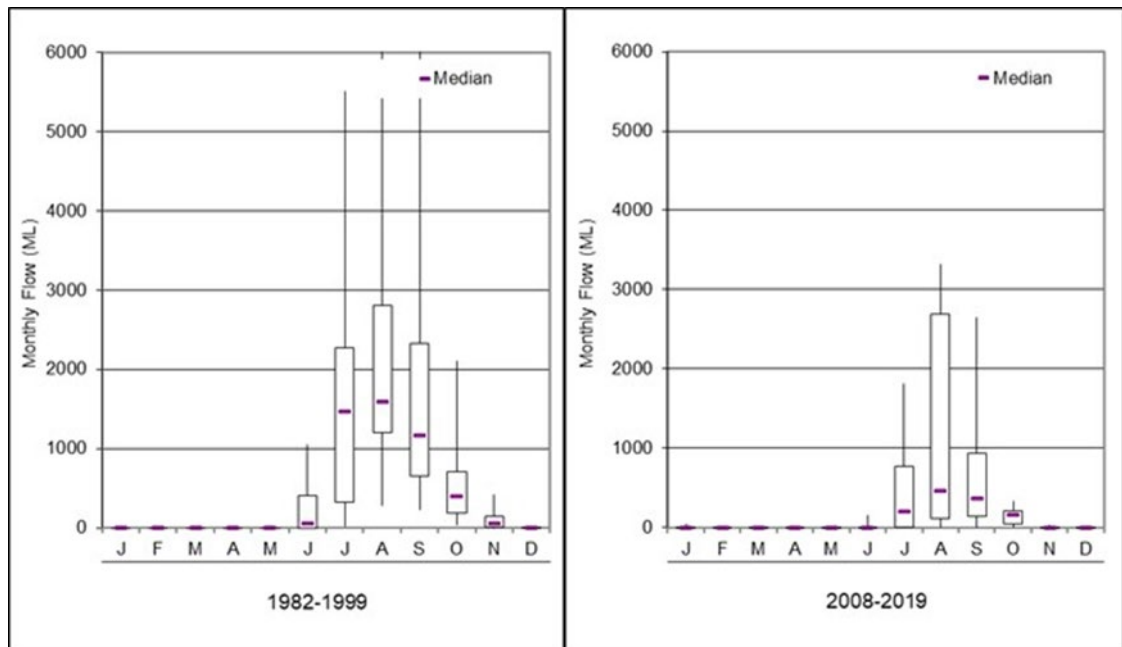


Chart 8-2 Flow seasonality – Serpentine River at River Road (station 614035)

Upper Wungong Brook

Upper Wungong Brook flows from the Myara North DE north-west through State Forest, including Alcoa's former Jarrahdale Mine (operated 1963 to 1998), and discharges into Wungong Dam (Figure 8-2). Wungong Dam was constructed in 1979 and has a catchment area of approximately 8,086 ha. The dam impounds all flow from upper Wungong Brook and does not release flow into lower Wungong Brook downstream of the dam. Chart 8-3 presents the annual flows recorded at DWER gauging stations on upper Wungong Brook. The Vardi Road station is located approximately 1 km upstream of the reservoir, approximately 7.5 km north of the Myara North DE. As presented, flows in upper Wungong Brook have declined from historic levels, similar to that observed in the Serpentine River. Wungong Brook is seasonal, with flows predominantly during June to November (Chart 8-4).

Upper Wungong Brook predominantly flows through incised valley Murray landforms with the exception of headwater swamps at Mundlimup Swamp located approximately 1 km north of the Myara North DE.

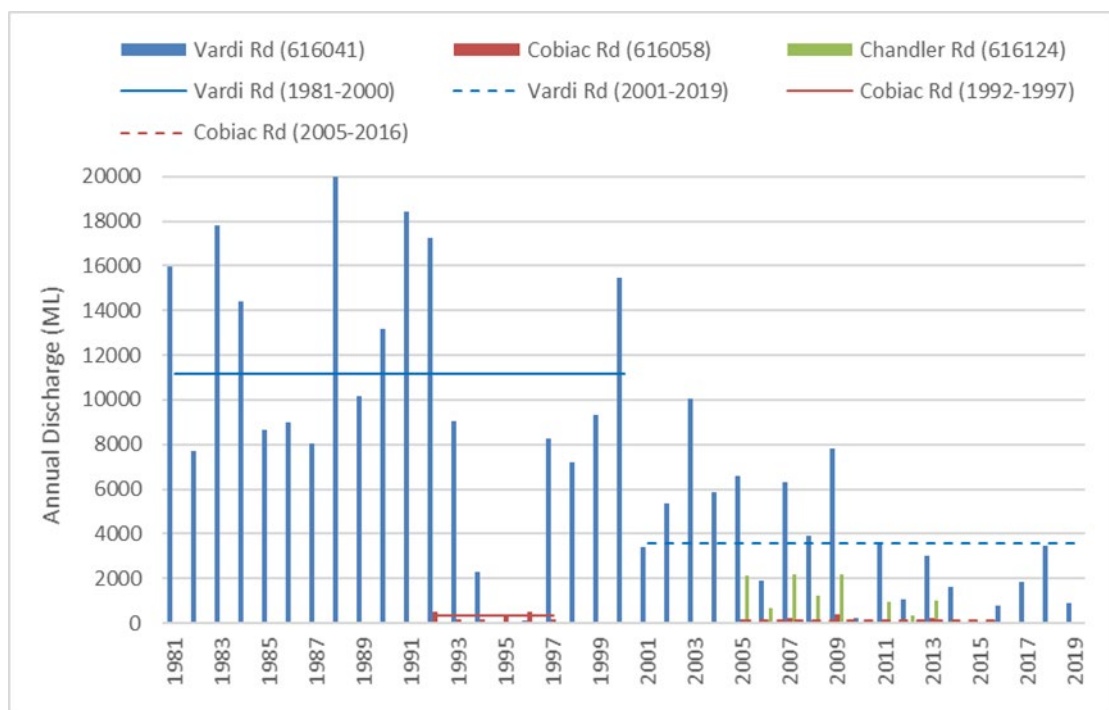


Chart 8-3 Annual flow on upper Wungong Brook

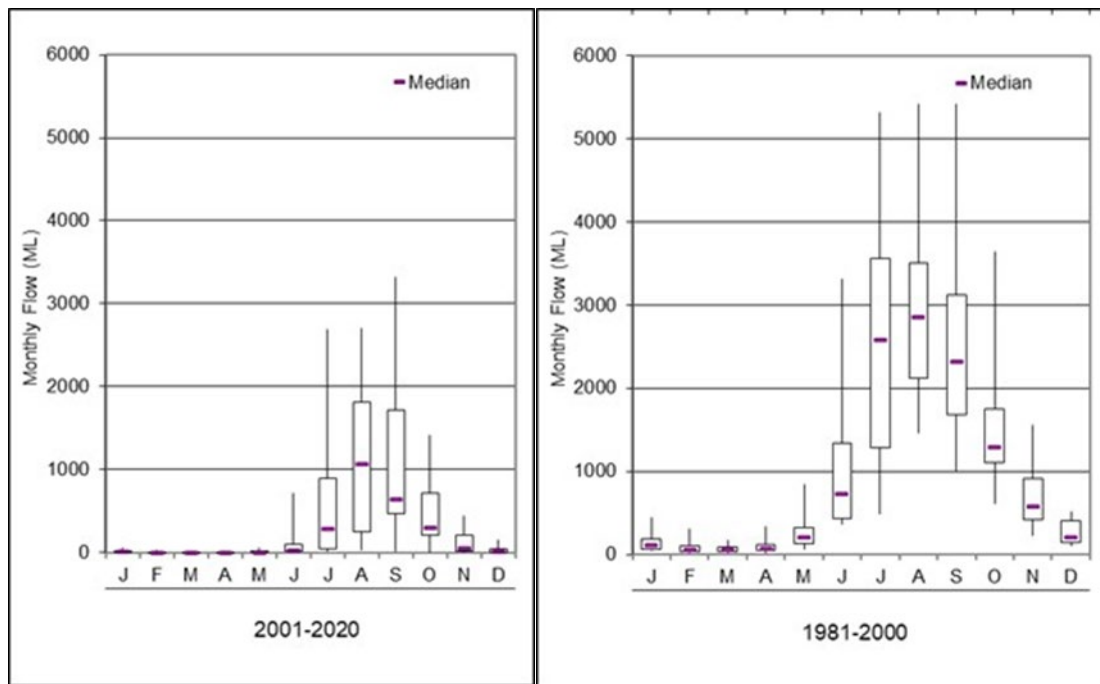


Chart 8-4 Flow seasonality – Wungong Brook at Vardi Road (station 616041) Holyoake

The Holyoake DE is predominantly (4,843 ha or 63.5 per cent of total) located within the catchment of South Dandalup Dam (Table 8.2, Figure 8-3). A portion of the Holyoake infrastructure corridor is within the catchment of North Dandalup Dam, comprising 297 ha or 3.9 per cent of the Holyoake DE. The southern 2,332 ha portion of the DE (30.6 per cent of total) lies within the catchments of Davis Brook and Swamp Oak Brook, which are un-regulated tributaries to the Murray River. The infrastructure corridor also comprises 133 ha (1.7 per cent of total) within the catchment of the Conjurunup Pipehead Dam which flows into the Serpentine Dam. The topography of the Holyoake is presented in Figure 8-4.2 and the slope within the catchment is presented in Figure 8-5.2.

South Dandalup River

The South Dandalup River within the Holyoake DE is regulated by South Dandalup Dam, which was constructed in 1974 and has created Lake Banksiadale (Figure 8-3). The South Dandalup Dam supplies the South Dandalup Pipehead, which was constructed in 1971. Section 8.3.2.4 and Section 8.3.2.5 present the beneficial use, hydrodynamics and water quality of the South Dandalup Dam.

South Dandalup Dam and the South Dandalup Pipehead are used for public drinking water supply and divert all flow from its catchment for this beneficial use. The South Dandalup Dam and Pipehead supply the Integrated Water Supply Scheme (IWSS). There are no releases from the dams to the South Dandalup River downstream. Annual inflow to the South Dandalup Dam averaged 36.5 GL from 1948-1974, decreasing to an average of 18.8 GL/year from 1974-2003.

Within the Holyoake DE the South Dandalup Dam is supplied by seasonal streams including the South Dandalup River and un-named tributaries. There is limited flow gauging in the South Dandalup Dam catchment with gauging stations on the South Dandalup River at Gordon (614060) approximately 4.5 km upstream of the Holyoake DE as well as on un-named tributaries at Skeleton Road (no. 614059) and Pindalup (no. 614043). The gauging station at Gordon records limited flow as presented in Chart 8-5 and Chart 8-6. South Dandalup River is seasonal with flow predominantly in June to November as presented in Chart 8-6 and Chart 8-7.

The seasonal streams are interspersed by headwater swamps that occupy colluvial and alluvial sediments in valley floors. The swamps comprise seasonally waterlogged wetlands with distinct vegetation types (see Section 5.3.4.6).

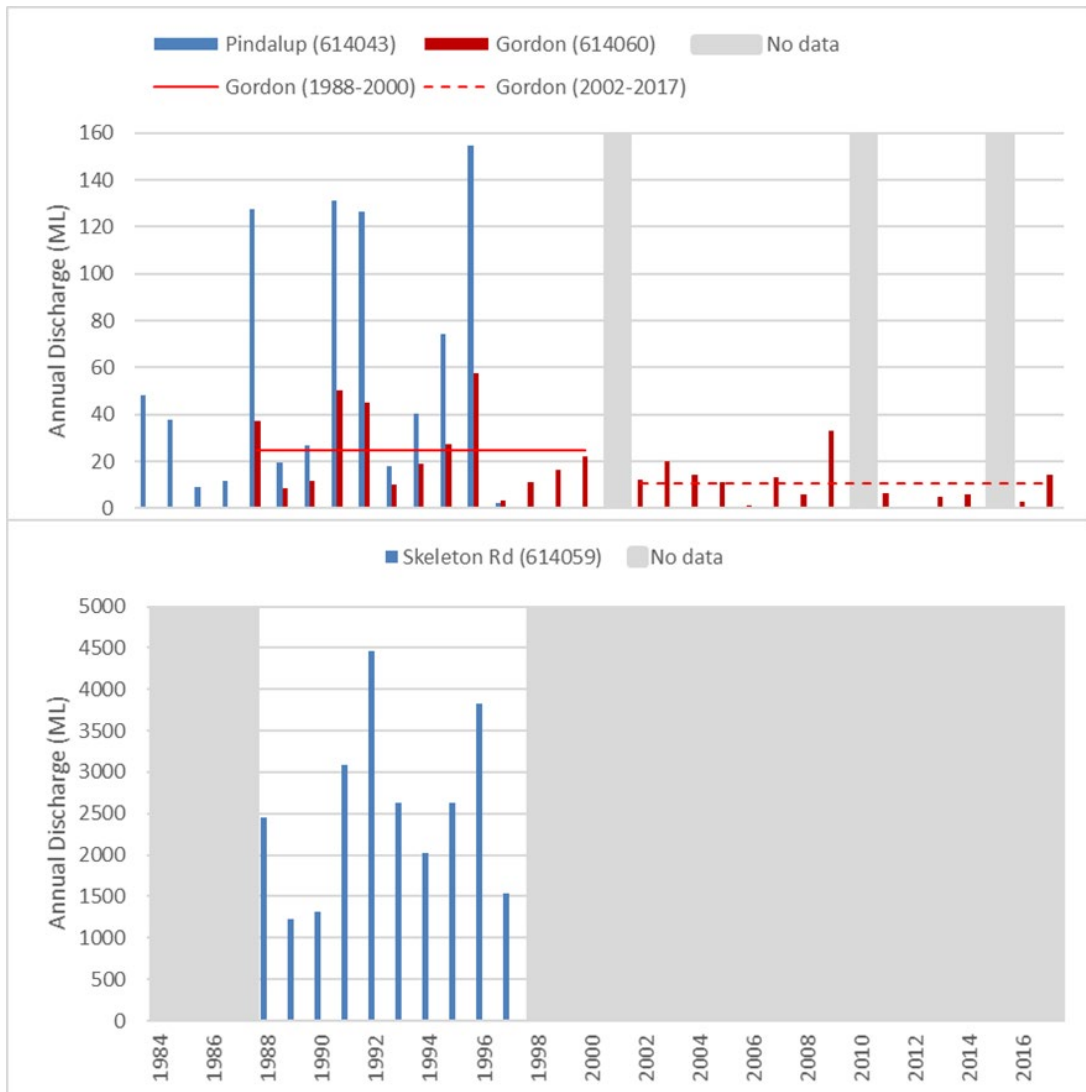


Chart 8-5 Annual flow on South Dandalup River gauging stations

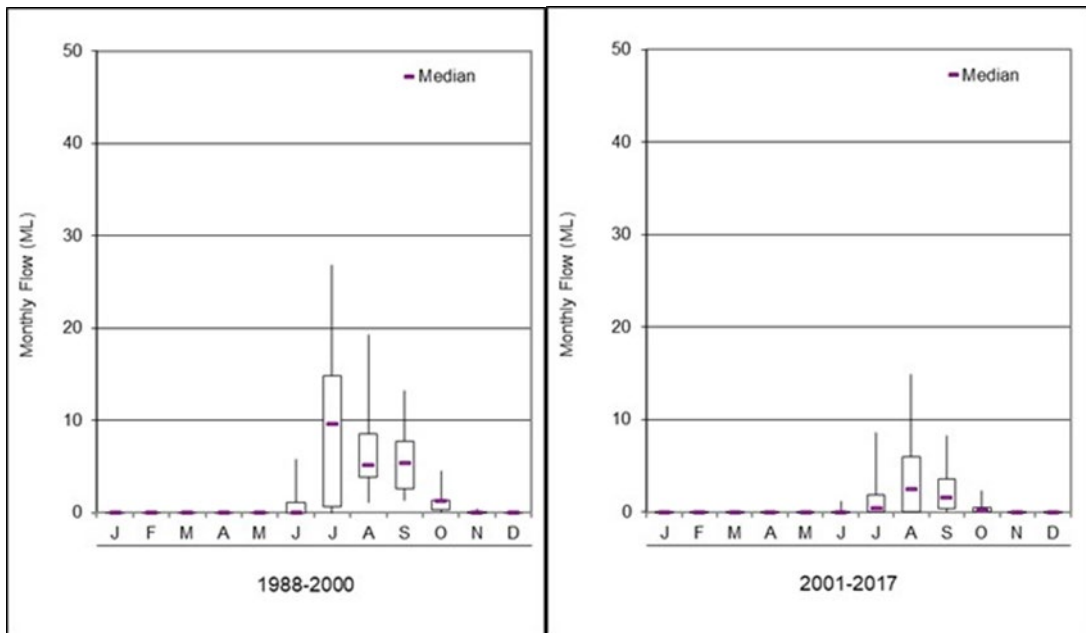


Chart 8-6 Flow seasonality – South Dandalup River at Gordon (no. 614060)

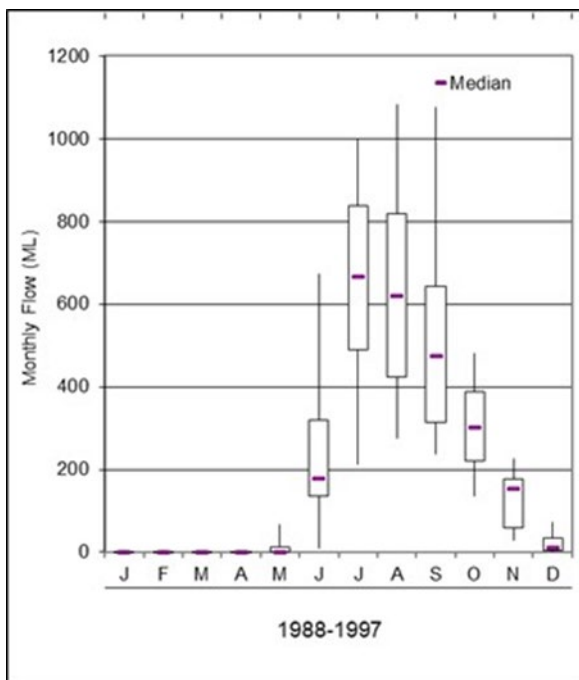


Chart 8-7 Flow seasonality – South Dandalup River tributary at Skeleton Road (no. 614958)

Murray River

The southern portion of the Holyoake DE lies in the catchments of Davis Brook (1,739 ha) and Swamp Oak Brook (592 ha), which are un-regulated tributaries of the Murray River.

Davis Brook drains the south-west portion of the Holyoake DE and flows approximately 5.3 km to the south-west through State Forest and properties at Etmilyn, then discharges to the Murray River at the boundary of Lane Poole Reserve (Figure 8-3). Davis Brook has a catchment of approximately 6,565 ha and has a gauging station the Murray Valley Plantation (no. 614047) approximately 1.5 km upstream of the confluence with Murray River. Chart 8-8 presents flow seasonality for Davis Brook at the Murray Valley Plantation, which shows that Davis Brook is perennial, with low flows during summer months.

Swamp Oak Brook drains the south-east portion of the Holyoake DE and flows approximately 15 km west through rural properties at Inglehope, State Forest and Lane Poole Reserve then discharges to the Murray River (Figure 8-3). Swamp Oak Brook has a catchment of 7,097 ha and has a gauging station on its upper reach at Chadoora (no. 614045), approximately 2.6 km east of the Holyoake DE. The gauging station records limited flow.

The Murray River is gauged at the Baden Powell station (no. 614006) which has a catchment of approximately 811,000 ha. The station lies immediately downstream of Lane Poole Reserve approximately 1.7 km downstream of the confluence with Davis Brook and approximately 5.6 km downstream of the confluence with Swamp Oak Brook (Figure 8-3). Chart 8-9 presents annual streamflow at Baden Powell station, which averaged 128 GL/year over 2010 to 2020. The Murray River is perennial, however very low flows (< 10 ML/month) were recorded in autumn in 2011 and 2020 following record low rainfalls in 2010 and 2019.

Davis Brook and Swamp Oak Brook flow through shallow valleys of Yarragil landform transitioning to moderately incised valleys of Murray landform as they approach the Murray River. The Murray River flows through deeply incised valleys of the Murray landform and transitions to the steep, rocky Helena landform as it dissects the Darling Scarp.

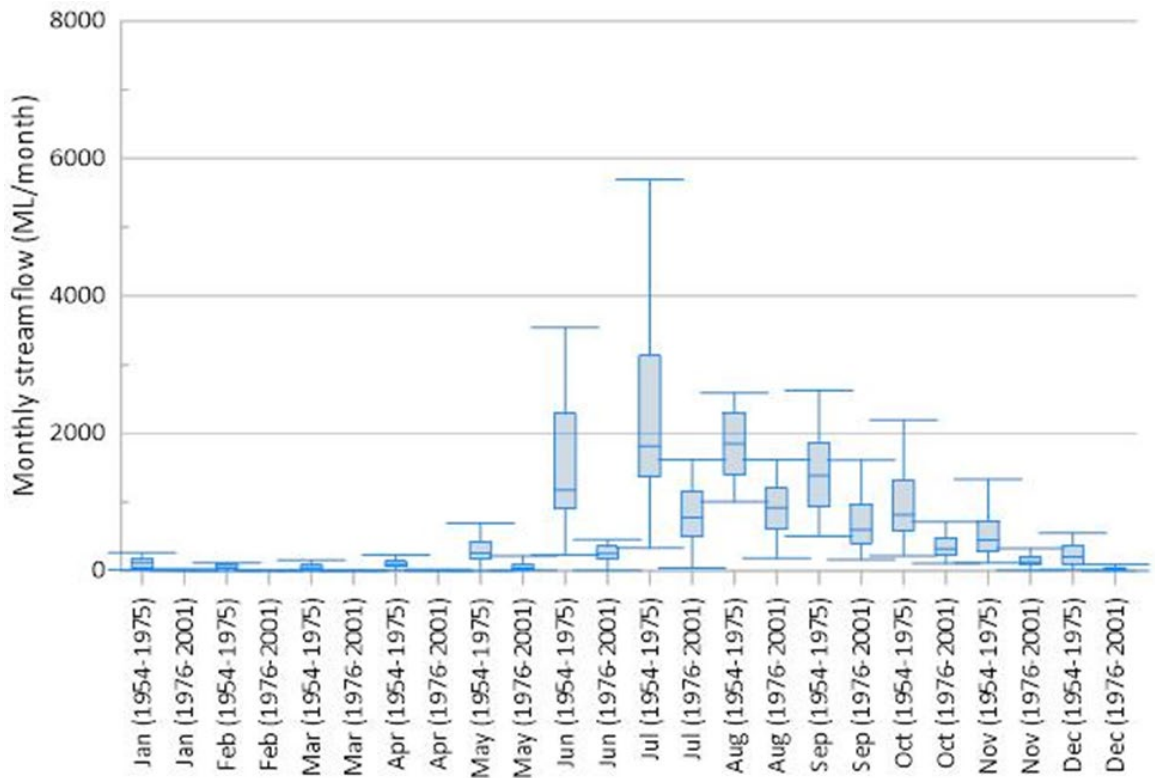


Chart 8-8 Flow seasonality – Davis Brook at Murray Valley Plantation (station 614047)

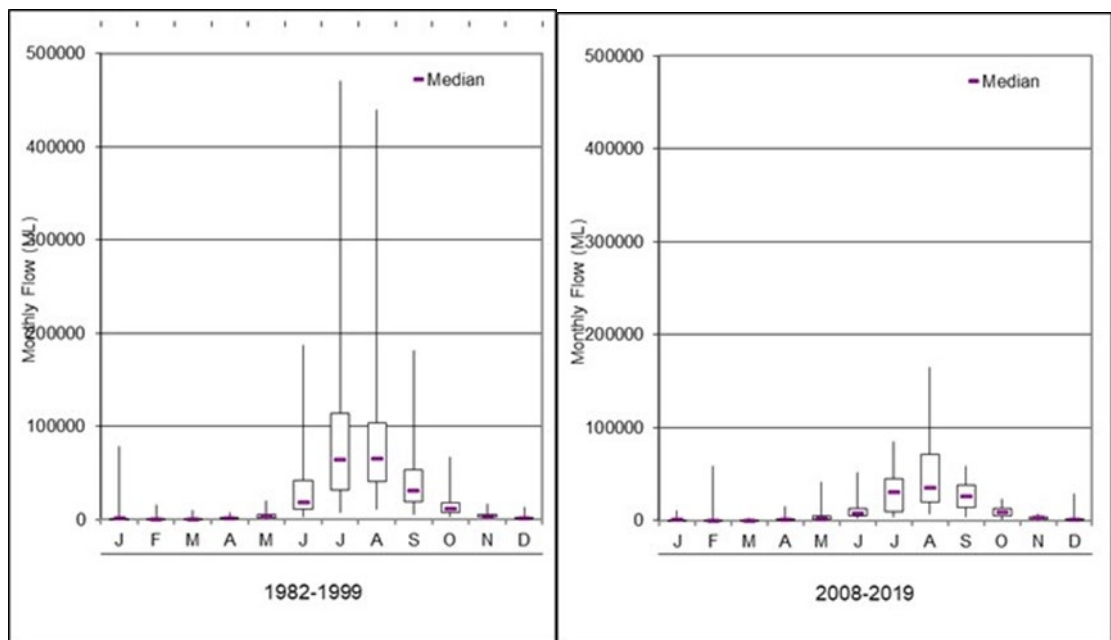


Chart 8-9 Flow seasonality – Murray River at Baden Powell (station 614006)

North Dandalup River

The Holyoake infrastructure corridor lies partially in the catchment of the North Dandalup River, which is regulated by North Dandalup Dam (Figure 8-3). North Dandalup Dam was constructed in 1994 and supplies the IWSS.

North Dandalup Dam is used for public drinking water supply and diverts the majority of flow from its catchment for this beneficial use. Releases from the dam to North Dandalup River downstream are managed according to the North Dandalup allocation statement (DWER 2017b), which allows for the release of 0.46 GL/year for 'low-inflow' years (inflow to dam less than 30 GL) and 0.51 GL/year for 'standard' years (inflow to dam greater than 30 GL). Accordingly, for average inflows of approximately 8 GL/year, as was recorded over 2008-2015 (DWER 2017b), North Dandalup Dam would divert more than 95 per cent, with less than 5 per cent released downstream. For inflows exceeding 30 GL/year, the dam would divert more than 98 per cent, with less than 2 per cent released downstream.

Within the Holyoake DE the North Dandalup Dam is supplied by the North Dandalup River. There is a stream gauging station at North Road (no. 614036), approximately 1 km upstream of the reservoir. Annual flows in the North Dandalup River and North Dandalup Dam have declined from an average of 37.6 GL/year over 1960-1974, to an average of 17.1 GL/year over 1975-2007, to an average of 8.4 GL/year over 2008-2015 (DWER 2017b).

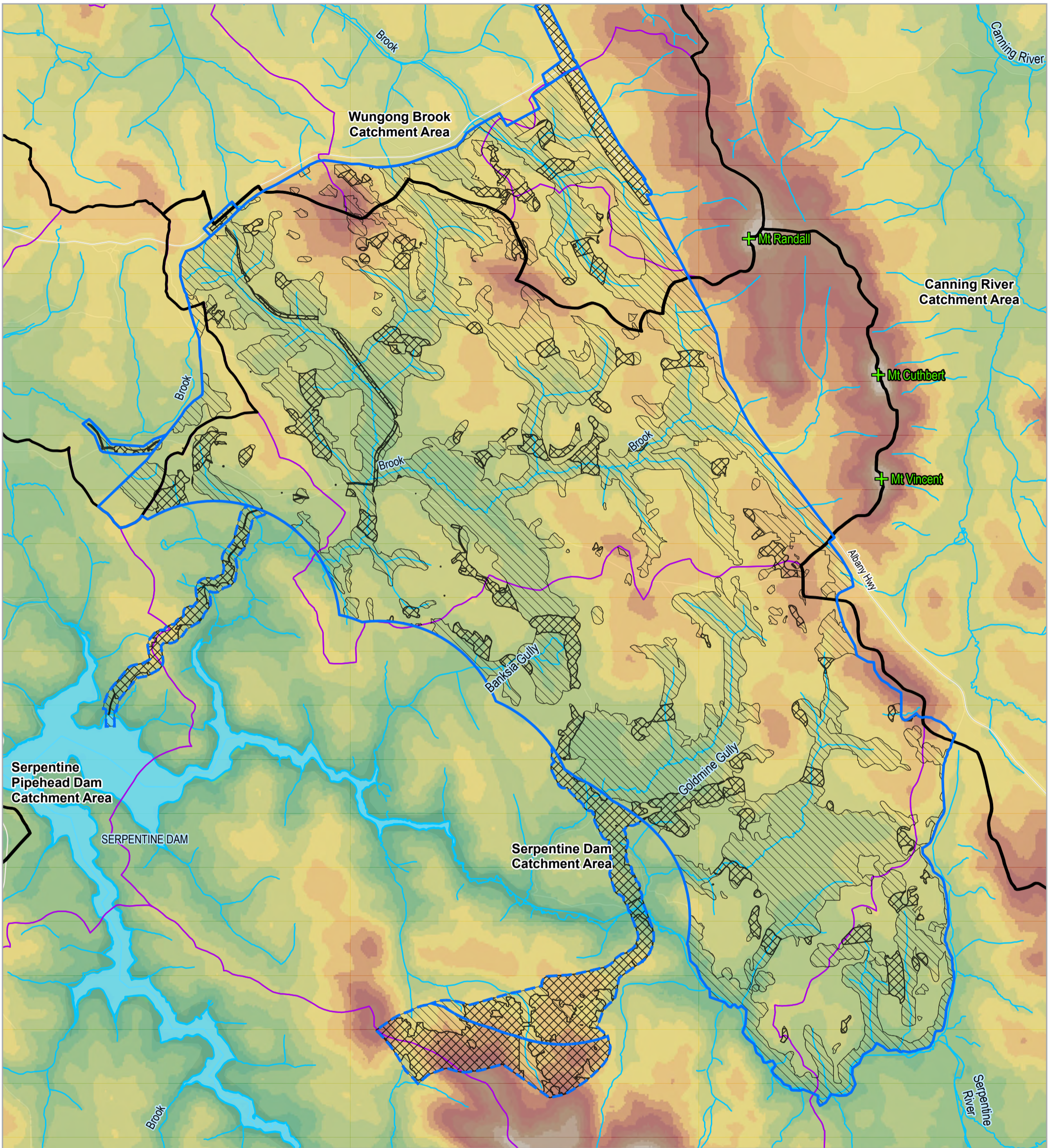
The North Dandalup River is interspersed by a series of headwater swamps that occupy colluvial and alluvial sediments in valley floors (Figure 8-4.1).

The North Dandalup River downstream of the dam meanders to the west then south-west for approximately 24 km through predominantly cleared agricultural land, joining with the South Dandalup River and discharging into the Murray River (Figure 8-3). The Dandalup River confluences with the Murray River approximately 8 km downstream of Pinjarra town and approximately 17 km upstream of the Peel Inlet.

Conjurunup Creek

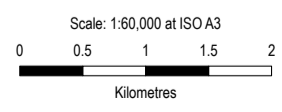
The Holyoake infrastructure corridor lies partially in the catchment of Conjurunup Creek, also known as Little Dandalup Creek, which is regulated by the Conjurunup Pipehead Dam. Conjurunup Pipehead Dam was constructed in 1992 and is used to pump back to North Dandalup Pipehead Dam, which supplies the IWSS. Annual streamflow in Conjurunup Creek was 9.5 GL from 1948 to 2000, decreasing to 7.4 GL over 1975 to 2004, and decreasing to an average of 1.5 GL/year over 2008 to 2018. The Conjurunup Pipehead Dam was generally subject to annual overflows from 2000 to 2010 and also during 2013, however, overflows have generally not occurred during the lower rainfall period from 2011 to 2020.

Conjurunup Creek downstream of the Pipehead meanders west for approximately 6.7 km through State Forest, the Darling Scarp and agricultural land on the SCP before discharging to the South Dandalup River (Figure 8-3). The South Dandalup River meanders west from the confluence with Conjurunup Creek, flowing for approximately 12 km through agricultural land on the SCP and joining with the North Dandalup River.

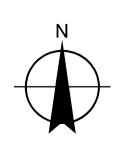


Legend			
Reservoir	Public Drinking Water Source Areas	261 - 280	421 - 440
River	Hydrographic Subcatchments	281 - 300	441 - 460
mine DE	Elevation (mAHD)	301 - 320	461 - 480
Infrastructure Corridor DE	181 - 200	321 - 340	481 - 500
Development Zone	201 - 220	341 - 360	501 - 520
LDA/LDA - fixed	221 - 240	361 - 380	521 - 540
AZ	241 - 260	381 - 400	541 - 560
		401 - 420	561 - 580

North Dandalup Dam Catchment Area
 SLIP
PROCESSED BY SARGENT & Lundy



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



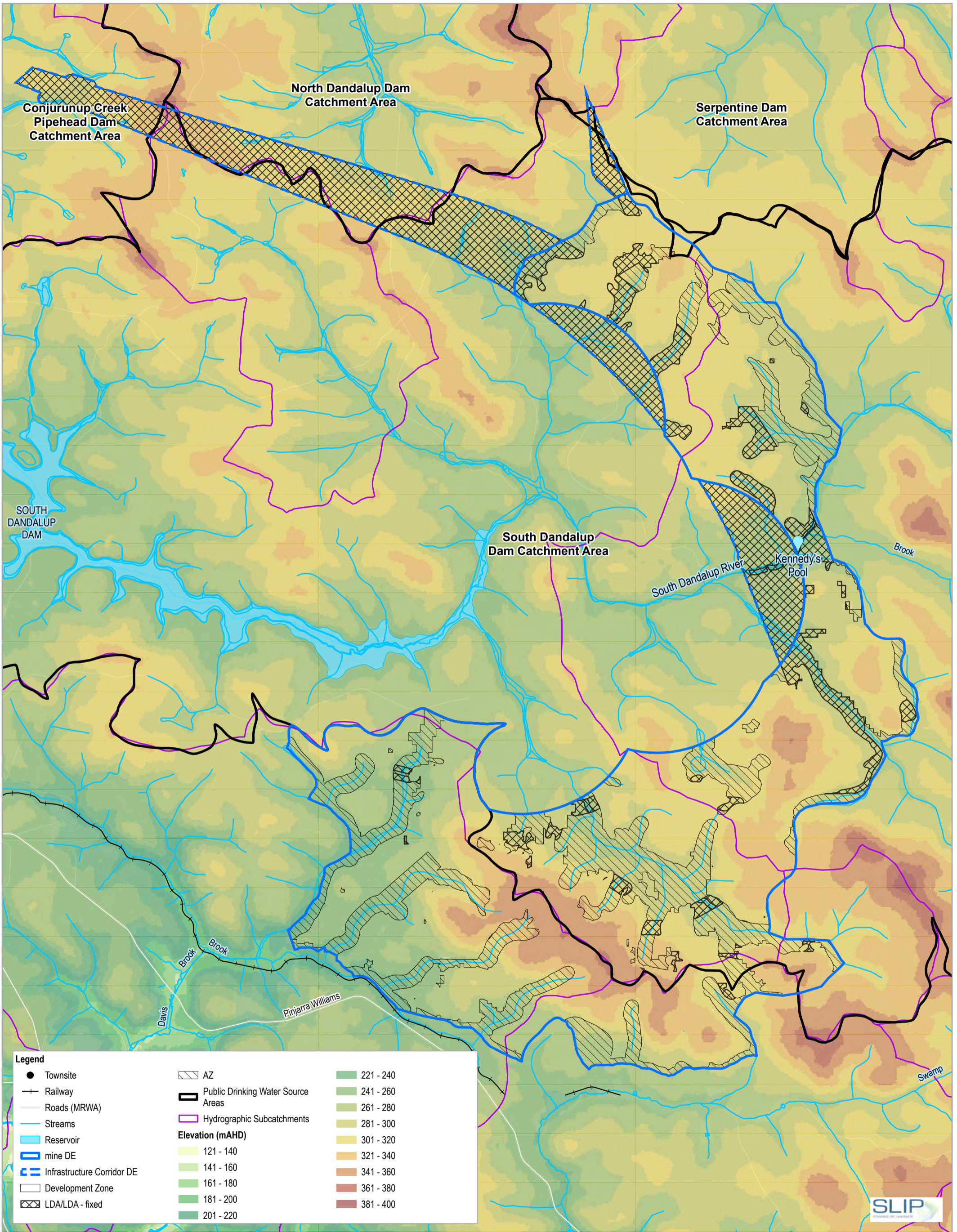
Alcoa of Australia Limited
 Pinjarra Refinery Revised Proposal -
 Environmental Review Document

Project No. 12633192
 Revision No. 3
 Date 09/03/2025

**Topographic Elevation -
 Myara North**

FIGURE 8-4.1

Data source: Light Gray Base: Esri, TomTom, Garmin, Foursquare, METI/NASA, USGS.

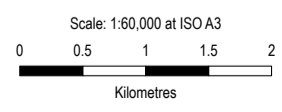


Legend

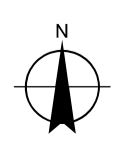
- Townsite
- Railway
- Roads (MRWA)
- Streams
- Reservoir
- mine DE
- Infrastructure Corridor DE
- Development Zone
- LDA/LDA - fixed
- AZ
- Public Drinking Water Source Areas
- Hydrographic Subcatchments

Elevation (mAHD)

121 - 140	221 - 240
141 - 160	241 - 260
161 - 180	261 - 280
181 - 200	281 - 300
201 - 220	301 - 320
	321 - 340
	341 - 360
	361 - 380
	381 - 400



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



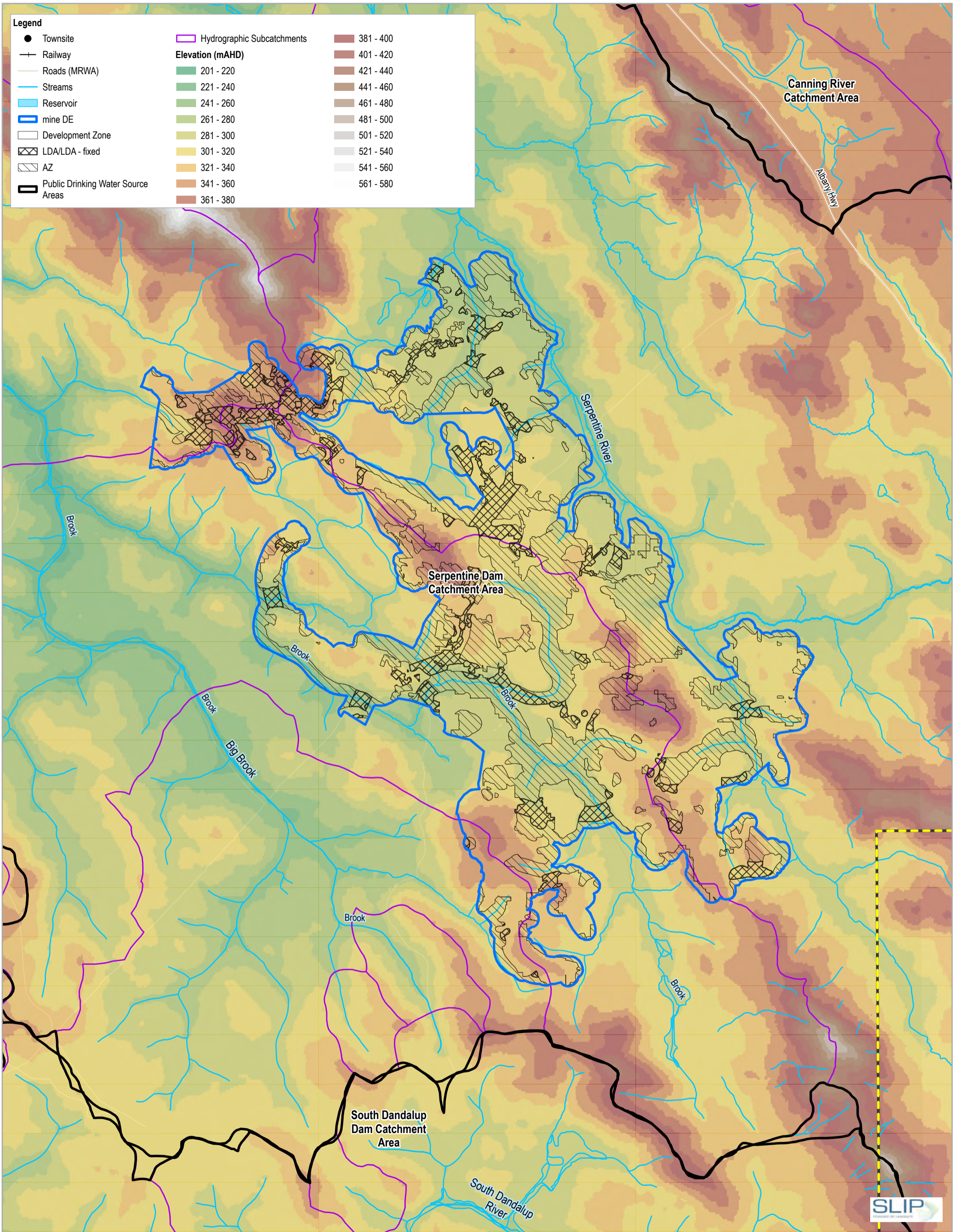
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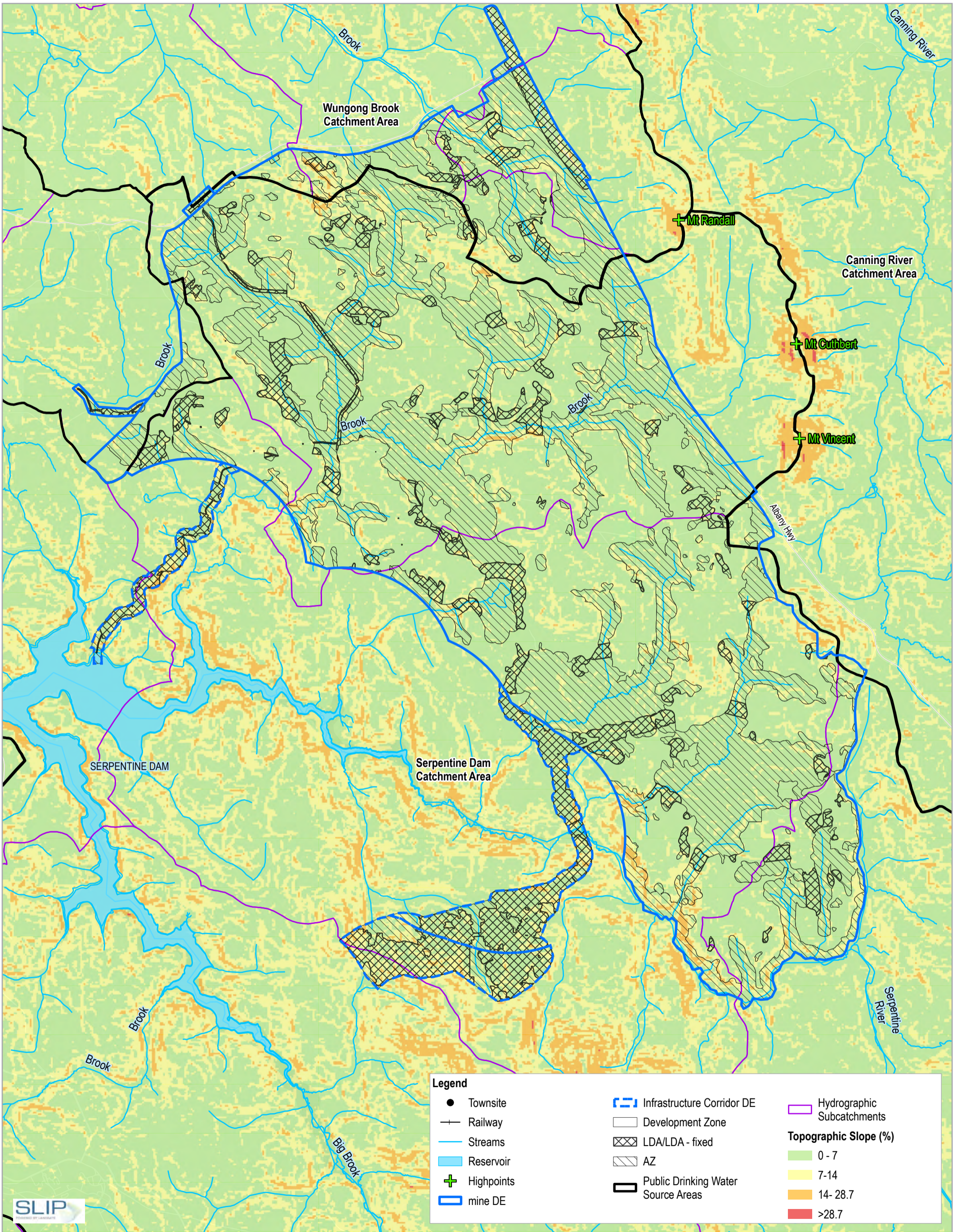
Project No. 12633192
 Revision No. 3
 Date 09/03/2025

**Topographic Elevation -
 Holyoake**

FIGURE 8-4.2

Data source: Light Gray Base: Esri, TomTom, Garmin, Foursquare, METINASA, USGS.



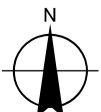


Legend

● Townsite	Infrastructure Corridor DE	Hydrographic Subcatchments
—+— Railway	Development Zone	Topographic Slope (%)
Streams	LDA/LDA - fixed	0 - 7
Reservoir	AZ	7-14
Highpoints	Public Drinking Water Source Areas	14- 28.7
mine DE		>28.7



Scale: 1:60,000 at ISO A3
 0 0.5 1 1.5 2
 Kilometres



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50

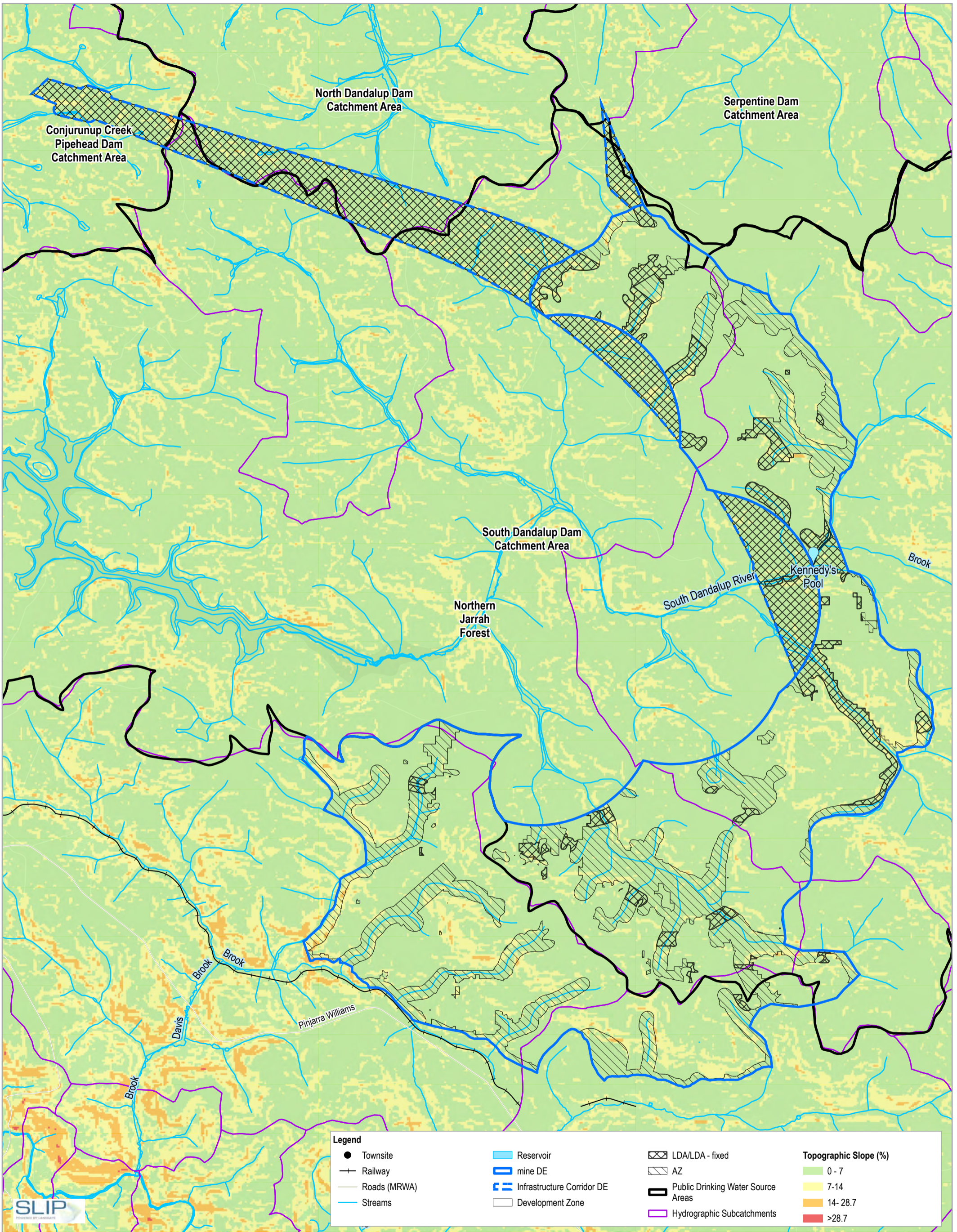
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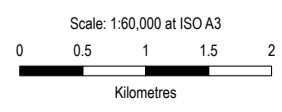
**Topographic Slope -
 Myara North**

FIGURE 8-5.1

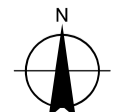
Data source: Light Gray Base: Esri, TomTom, Garmin, Foursquare, METI/NASA, USGS.



Legend			
● Townsite	Reservoir	▨ LDA/LDA - fixed	Topographic Slope (%)
— Railway	mine DE	▨ AZ	0 - 7
— Roads (MRWA)	Infrastructure Corridor DE	▨ Public Drinking Water Source Areas	7-14
— Streams	Development Zone	▨ Hydrographic Subcatchments	14- 28.7
			>28.7



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



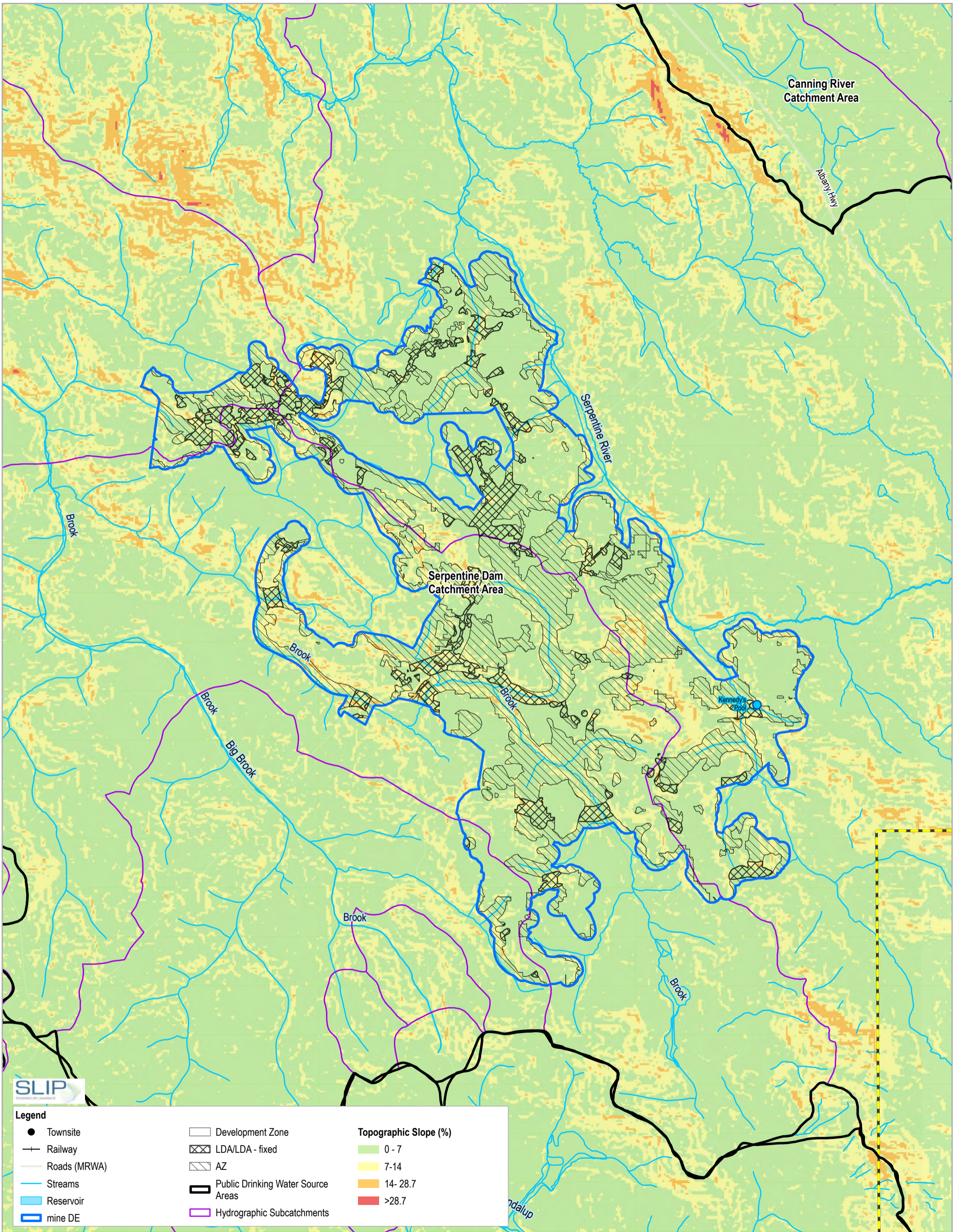
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Project No. 12633192
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**Topographic Slope -
 Holyoake**

FIGURE 8-5.2

Data source: Light Gray Base: Esri, TomTom, Garmin, Foursquare, METINASA, USGS

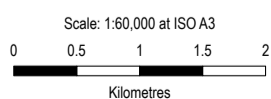


Legend

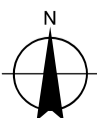
- Townsite
- +— Railway
- Roads (MRWA)
- Streams
- Reservoir
- mine DE
- Development Zone
- ▣ LDA/LDA - fixed
- ▤ AZ
- ▭ Public Drinking Water Source Areas
- ▮ Hydrographic Subcatchments

Topographic Slope (%)

- 0 - 7
- 7 - 14
- 14 - 28.7
- >28.7



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



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**Topographic Slope -
 O'Neil**

FIGURE 8-5.3

Data source: Light Gray Base: Esri, TomTom, Garmin, Foursquare, METINASA, USGS

8.3.2.3 Surface water quality

The Hydrology and Water Quality Assessment (GHD 2023a, Appendix B8) details historic and baseline surface water quality in the Mine DE. A summary is provided below.

Myara North

Historic water quality monitoring over the Myara North DE is available from the 1970s to 1990s, though discontinuous and limited to salinity, pH and some turbidity data (GHD 2023a). Historic monitoring indicates that surface water salinity is fresh (less than 500 mg/L total dissolved salts [TDS]) in streams west of the 1100 mm/year rainfall isohyet. Peak salinity levels increase in streams east of the 1100 mm/year isohyet, with median salinity remaining fresh. pH is typically neutral with some streams recording minimum pH in the acidic range. Turbidity monitoring in the Myara North DE indicates median turbidity below 1.5 nephelometric turbidity units (NTU) with occasional values exceeding 25 NTU at some locations on Gooralong Brook, 39 Mile Brook and Banksia Gully. DWER monitoring indicates turbidity ranging from 1.6 to 2.6 NTU (GHD 2023a).

GHD (2023a) undertook baseline surface water monitoring at 20 sites within the Myara North DE between August 2020 and November 2022. Baseline surface water monitoring (i.e. sampling) included all major tributaries of Serpentine Dam, Gooralong Brook and Wungong Brook. The results indicate that surface water is similar across the Myara North DE, being fresh and relatively un-impacted by anthropogenic use, with key parameters as follows:

- non-saline
- moderately acidic
- marginally elevated salinity was observed in some samples during late season monitoring or when sampling occurred from pools
- salinity was observed to increase with decreasing streamflow (example presented in Chart 8-10)
- typically low turbidity and low total suspended solids
- low nutrient levels
- metal concentrations representative of the geological setting
- microbiological parameters detected at all sampling sites, consistent with the presence of fauna species
- low concentrations of Per- and polyfluoroalkyl substances (PFAS) was detected at four sites, however, all detections were significantly below drinking water assessment criteria.
- polycyclic aromatic hydrocarbons (PAHs) were detected above the drinking water guideline at one site in October 2020, with PAH concentration dominated by naphthalene and attributed to the natural introduction from a prescribed burn in the catchment in late September 2020.
- Dieldrin was detected in a single sample at a concentration significantly lower than the drinking water assessment criteria.

Other contaminants of potential concern recorded at less than laboratory limits of reporting, including methylene blue active substances (MBAS) surfactants; benzene, toluene, ethylbenzene and xylene (BTEX) compounds, total recoverable hydrocarbons (TRH), organochlorine (OC) pesticides and explosives. A short continuous Electrical Conductivity (EC) logger record at two tributaries east of the 1,100 mm isohyet (Banksia Gully and Goldmine Gully) showed EC levels at the lower end of historically observed ranges. In September 2020, Banksia Gully had a stable EC of 167.1 $\mu\text{S}/\text{cm}$ over four days, while Goldmine Gully saw a steady rise from 236.2 to 377.6 $\mu\text{S}/\text{cm}$ over four weeks. In July 2021, Banksia Gully recorded

EC between 50.2 and 201.3 $\mu\text{S}/\text{cm}$, and Goldmine Gully ranged from 49.5 to 338.66 $\mu\text{S}/\text{cm}$, increasing to 663.4 $\mu\text{S}/\text{cm}$ in mid-October before returning to normal levels. A trend was observed linking decreasing streamflow with increasing salinity (Chart 8-10).

Between September 2020 and February 2023, turbidity data were collected from several sites near Serpentine Dam using turbidity loggers. In September 2020, loggers were installed at 39 Mile Brook (SW03), an unnamed tributary (SW04), Goolagong Brook (GG03), and the Serpentine River (SW08). Turbidity ranged from 0.4 NTU (GG03) to 1.9 NTU (SW03), with pulses up to 138.7 NTU, typically after rainfall. From August 2022 to February 2023, loggers were added at TN14, upstream of 39 Mile Brook, and at 614035, a DWER stream gauging site. At TN14, turbidity ranged from -0.9 to 98.9 NTU (average 2.44 NTU), and at 614035, from -0.9 to 60.2 NTU (average 3.92 NTU). Elevated turbidity pulses, linked to rainfall or water disturbances, were recorded at both sites.

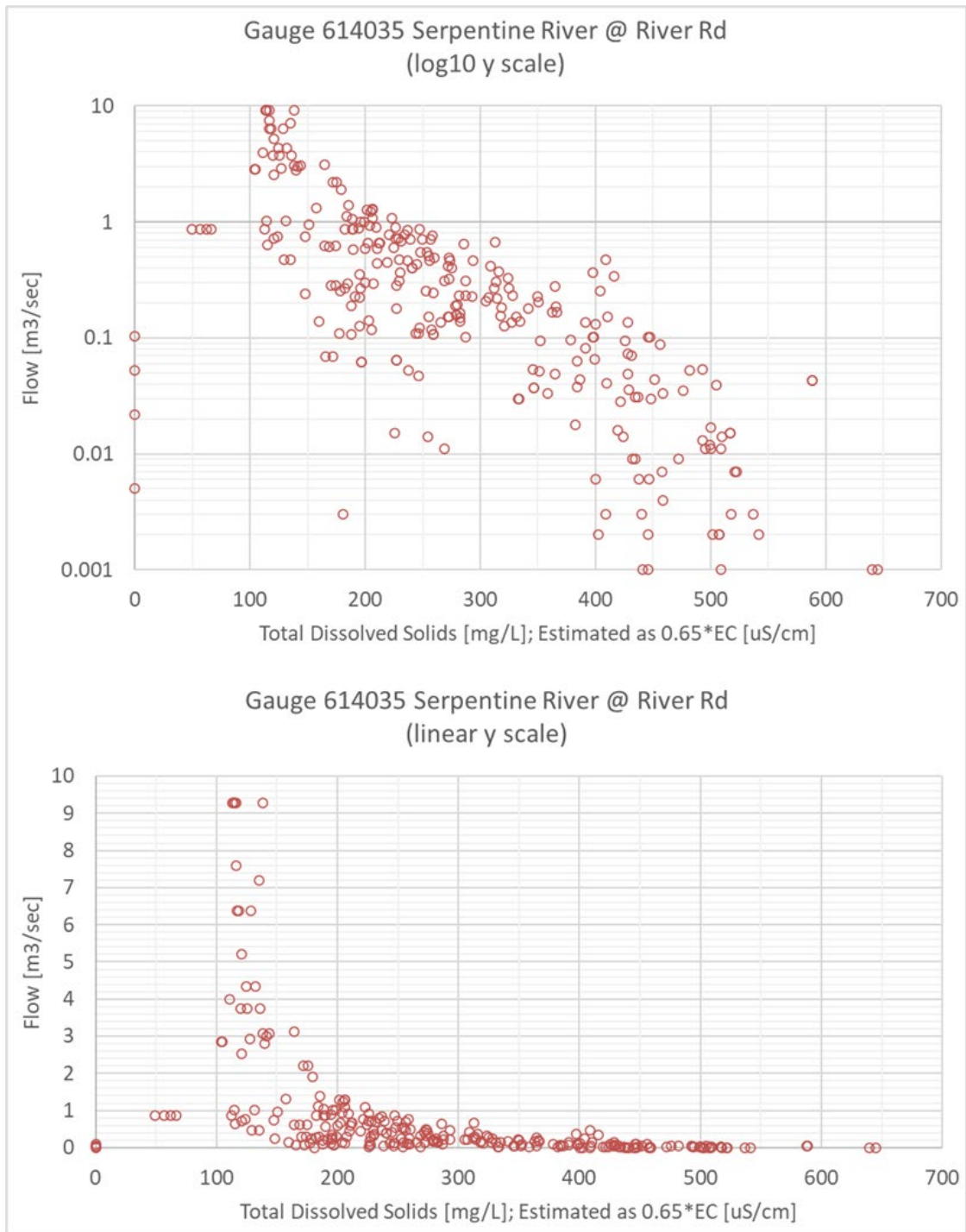


Chart 8-10 Example of relationship between streamflow rate and salinity

Holyoake

Historic water quality monitoring of the Holyoake DE has been limited to a site on Davis Brook, with discontinuous records from the 1970s to 1990s and data limited to salinity, pH and some turbidity data (GHD 2023a). Historic monitoring indicates that surface water is typically fresh, with a median EC below 350 $\mu\text{S}/\text{cm}$. Limited pH data is available for gauging locations which indicates that the median pH of tributaries is neutral. Baseline turbidity for monitoring locations in the South Dandalup catchment are marginally higher than Myara North, with median values ranging between 0.9 and 7.3 NTU.

GHD (2023a) undertook baseline surface water monitoring at 15 sites within the Holyoake DE between August 2020 and November 2022. Baseline surface water monitoring included South Dandalup River, Davis Brook and Swamp Oak Brook. The results indicate that surface water is similar across the Holyoake DE, being fresh and relatively un-impacted by anthropogenic use, with key parameters as follows:

- non-saline
- neutral pH
- moderate to low turbidity and low total suspended solids
- nutrient concentrations are generally low and align with the typical land-use for the region (conservation and historic timber harvesting), where no nutrients are applied. However, some samples showed slight increases in total nitrogen and total Kjeldahl nitrogen, with two samples exceeding guidelines. Additionally, three samples had total phosphorus concentrations above the recommended limits, including two notably high readings in September 2020.
- Metals concentrations were representative of the similar geological setting, with ANZECC guideline exceedances reported for zinc and copper in limited samples in August 2021.
- microbiological parameters detected at all sampling sites, with relatively higher maximum levels than reported in Myara North
- low concentrations of PFAS were detected at five sites across different monitoring months, however, all detections were significantly below drinking water assessment criteria.

Other contaminants of potential concern were recorded at less than laboratory limits of reporting, including PAHs, MBAS surfactants, BTEX compounds, TRH, OC pesticides, and explosives. EC loggers were installed at three sites: South Dandalup River (6141005), an unnamed northern tributary (HSW05), and the Holyoake mine region outflow to the Swamp Oak Tributary (HSW03). No data was collected from HSW03 due to dry conditions. At the end of the flow season, median EC values were similar at sites 6141005 (197.7 $\mu\text{S}/\text{cm}$) and HSW05 (186.7 $\mu\text{S}/\text{cm}$), with 6141005 showing a higher maximum EC (244.6 $\mu\text{S}/\text{cm}$). In July 2021, EC ranged from 33.9 to 193.9 $\mu\text{S}/\text{cm}$ (average 149.9 $\mu\text{S}/\text{cm}$) at HSW05, and 74.0 to 225.9 $\mu\text{S}/\text{cm}$ (average 156.3 $\mu\text{S}/\text{cm}$) at 6141005. Gradual EC increases indicated rising groundwater contributions, while sudden decreases were linked to surface runoff events.

Turbidity loggers were installed at the same sites, with no data from HSW03 due to dry conditions. In September 2020, turbidity was recorded for one week, with median values of 4 NTU at 6141005 and 6 NTU at HSW05. The average turbidity at 6141005 was 25.9 NTU, peaking at 130 NTU, with longer turbidity pulses linked to storm events, particularly earlier in the season. The source of turbidity remains unclear but may be related to prescribed burns in late 2018. From August 2022 to February 2023, turbidity at HSW05 ranged from 0.3 to 73.3 NTU (average 6.17 NTU), and at 6141005, it ranged from 0.6 to 223.4 NTU (average 12.69 NTU). In November 2022, turbidity spiked, ranging from 86.9 to 313.4 NTU (average 199.07 NTU), with pulses often linked to rainfall and some attributed to sampling disturbances. HSW05 had shorter-duration turbidity spikes, peaking at 129.2 NTU.

O'Neil

Historic water quality monitoring is not available for the O'Neil DE (GHD 2023a). Despite the lack of historic observational data within the O'Neil mine region, the nature of and the processes involved in surface water and groundwater connectivity are assumed identical to those described for Myara North and Holyoake mine regions.

GHD (2024) undertook baseline water monitoring at six monitoring sites within the O'Neil mine region between July and November 2023. Key observations of surface water flow conditions include that all sites recorded flows during the wet season, which gradually declined and ceased by October and November 2023. By the November monitoring round, all locations were dry. Results of the baseline surface water program identified the following characteristics:

- non-saline
- near neutral pH with minor exceedance of the ANZECC 2000 Upland River assessment criteria of 6.5 – 8 pH units (recorded value of 6.25).
- low to moderate turbidity and low total suspended solids.
- the nutrient concentrations in the samples are generally low and align with the typical land-use for the region (conservation and historic timber harvesting), where no nutrients are applied.
- metal concentrations representative of the geological setting, with exceedance of the ANZG (2018) for zinc and copper in a small number of samples
- microbiological parameters were detected at all sampling sites on at least one of the sampling rounds
- low concentrations of PFAS were detected across five sites however, all detections were significantly below drinking water assessment criteria.
- other contaminants of potential concern, including surfactants, BTEX compounds, TRH, PAH, OC pesticides and explosives, all samples analysed returned results less than the laboratory limit of reporting with the exception of TRH recorded at one site in October.

8.3.2.4 Reservoir hydrodynamics and water quality

Reservoir hydrodynamics

GHD (2023a) undertook hydrodynamic modelling of the Serpentine, Serpentine Pipehead and South Dandalup reservoirs, based on synthetic bathymetries and input data on catchment inflows, withdrawals and meteorology. Chart 8-11 presents the monthly water balance developed by GHD (2023a) for the three reservoirs, which indicates the following key patterns:

- Catchment inflows and withdrawals from both Serpentine and South Dandalup dams have decreased over the past 20 years. In particular, Serpentine Dam withdrawals have decreased substantially over the past decade with very low extractions to supply Serpentine Pipehead Dam from July 2017-October 2019.
- The primary water source of Serpentine Pipehead Dam has transitioned from Serpentine Dam withdrawals before 2006 to external transfers from other sources.

GHD (2023a) selected a modelling period from 1 July 2017 to 1 October 2019, corresponding to low reservoir water levels in Serpentine and South Dandalup dams and two relatively wet winters in 2017 and 2018 and then a dry 2019 winter. In contrast, during this period the Serpentine Pipehead Dam maintained a relatively constant level due to the highly managed balance between external transfers and withdrawals to the IWSS.

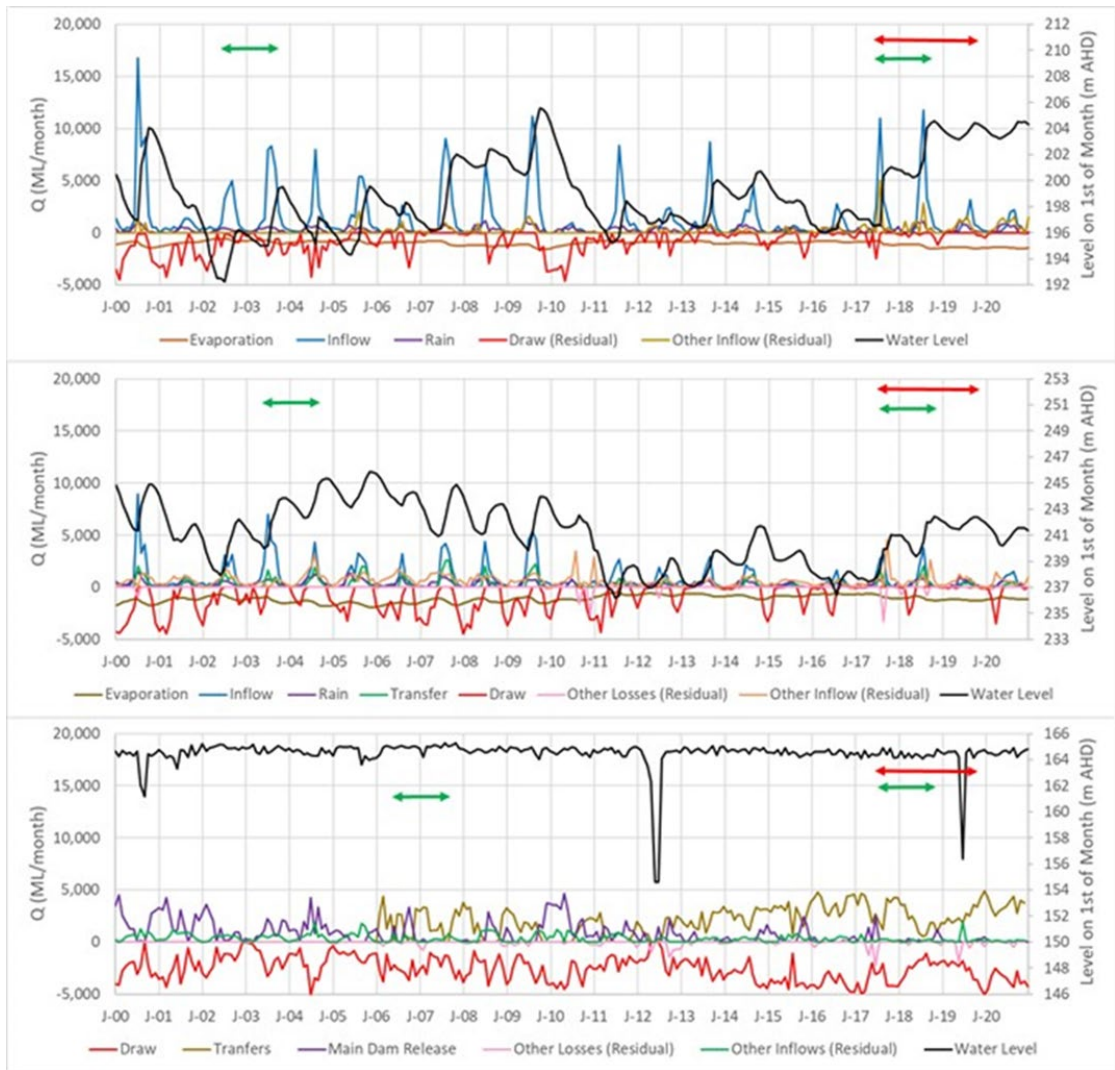


Chart 8-11 Water balance (2000-2020) for Serpentine Dam (top), South Dandalup Dam (middle) and Serpentine Pipehead Dam (bottom)

Chart 8-12, Chart 8-13 and Chart 8-14 present the simulated seasonal patterns of thermal stratification for the three reservoirs for the 2017-2019 period. The charts present water levels, patterns of thermal stratification (as isotherms through the water column with time at each assessment site), and withdrawal temperatures at three representative assessment sites per reservoir, being the dam wall near the intake towers and two up-reservoir sites. The Serpentine and South Dandalup dams demonstrated thermal stratification patterns as follows:

- Seasonal thermal stratification is maintained at the up-reservoir sites, but more so with the substantially cooler hypolimnetic temperatures at the dam site.
- The several meter increase in water levels during the 2018 winter resulted in seasonal thermal stratification that was more pronounced in the up-reservoir sites than the previous season at lower water levels.
- Short-term (~1 day) fluctuations in hypolimnetic temperatures are simulated at the dam sites over the thermally stratified period. These fluctuations are caused by sustained high wind events that induce internal waves via tilting of the thermocline at the dam wall. During such events, higher rates of vertical mixing occur.

In Serpentine Pipehead Dam, seasonal thermal stratification was not maintained, but brief periods (days to weeks) of intermittent thermal stratification were simulated.

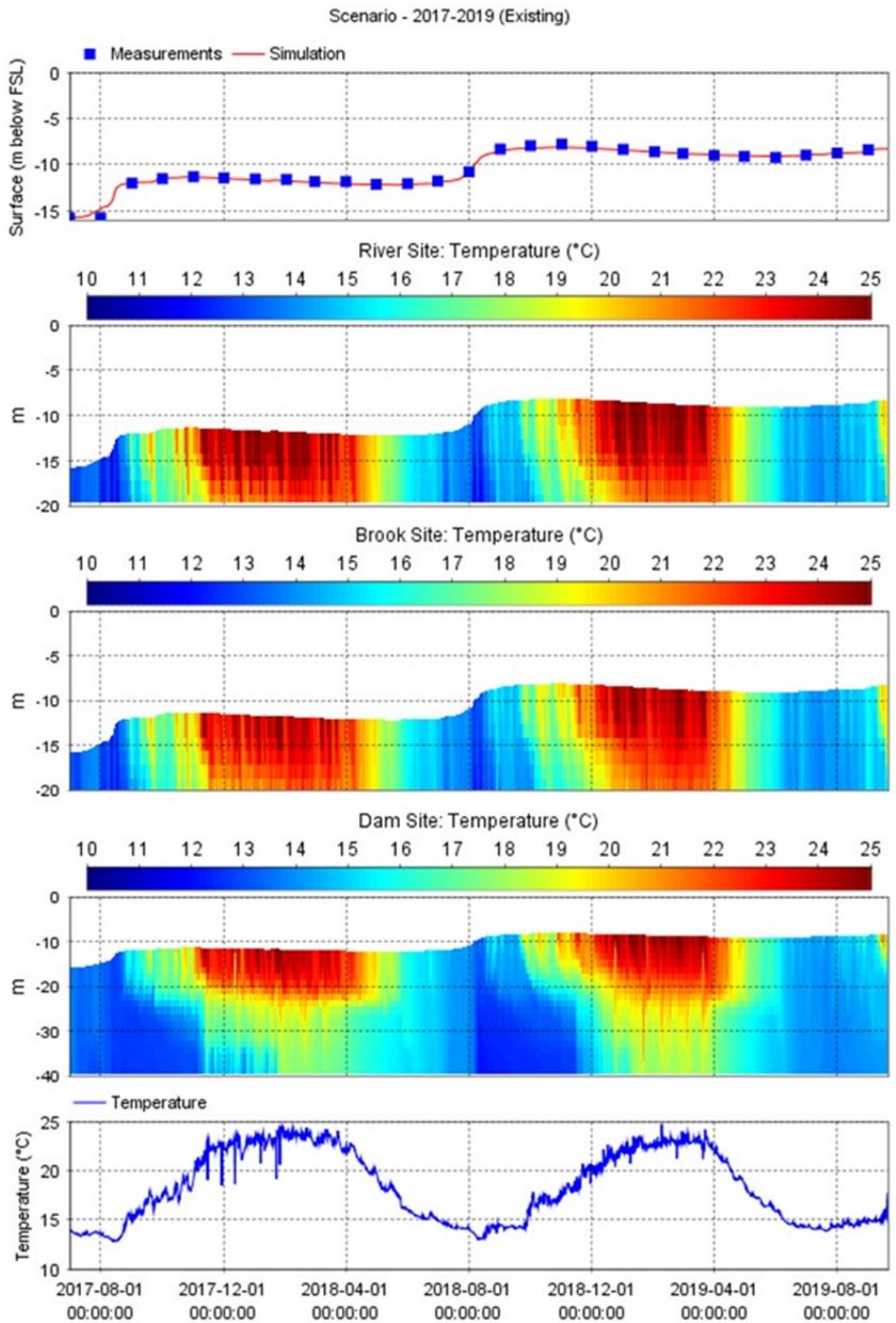


Chart 8-12 Simulated and measured Serpentine Dam water levels (top), simulated isotherms at dam (upper middle), river (middle) and brook (lower middle), and simulated withdrawal temperatures (bottom).

Scenario - 2017-2019 (Existing)

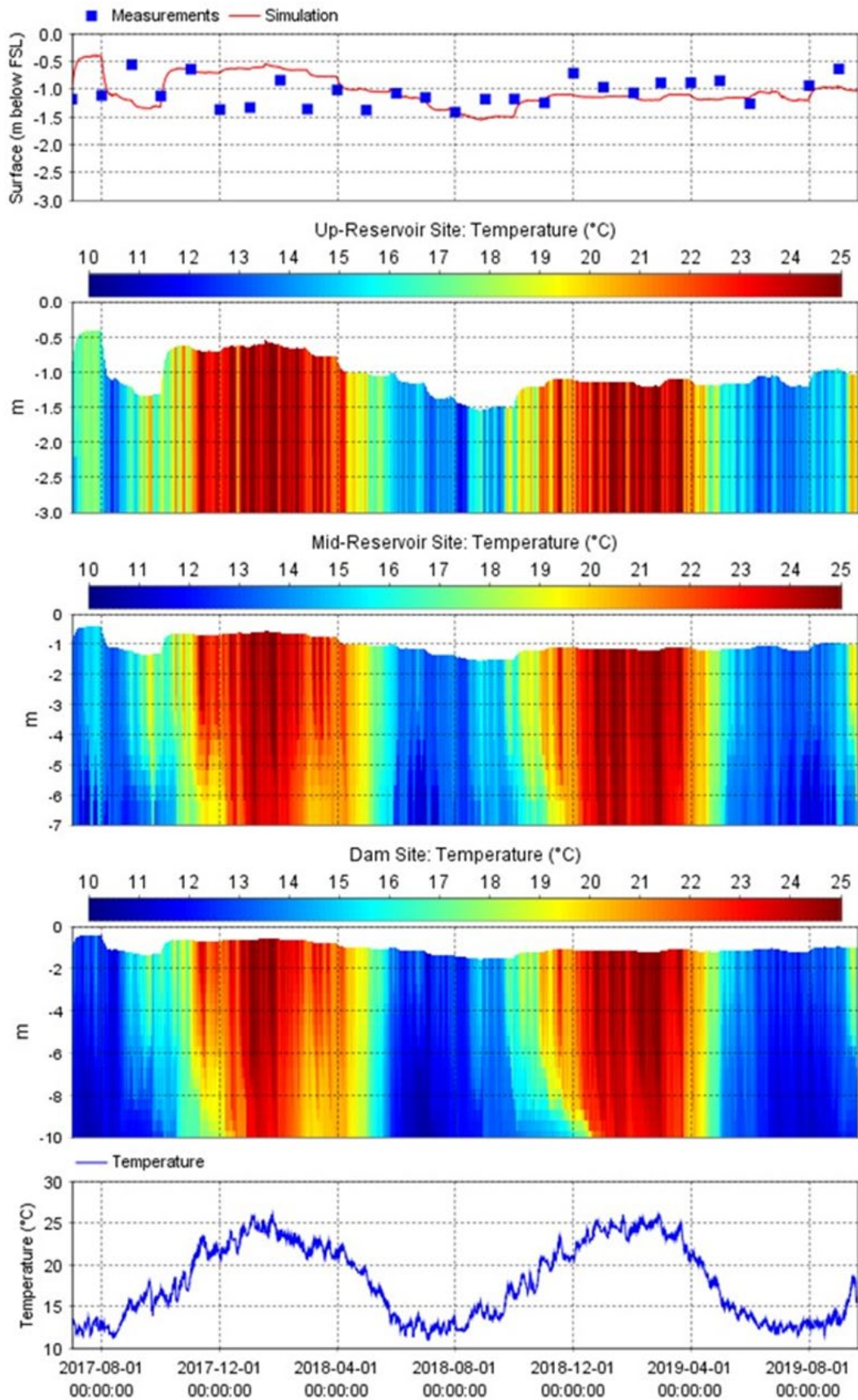


Chart 8-13 Simulated and measured Serpentine Pipehead Dam water levels (top), simulated isotherms at dam (upper middle), river (middle) and brook (lower middle), and simulated withdrawal temperatures (bottom)

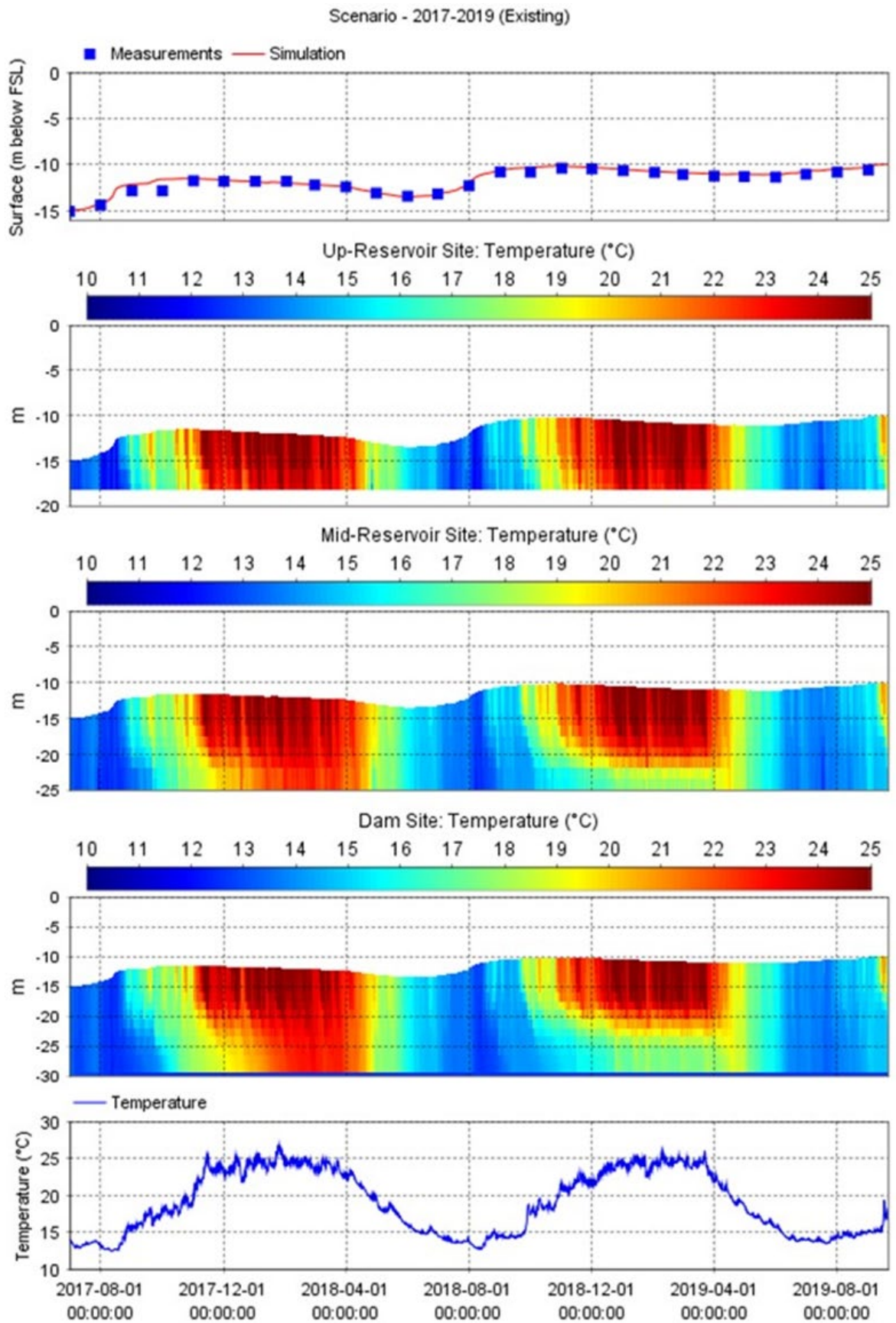


Chart 8-14 Simulated and measured South Dandalup Dam water levels (top), simulated isotherms at dam (upper middle), river (middle) and brook (lower middle), and simulated withdrawal temperatures (bottom).

Reservoir water quality

Chart 8-15 to Chart 8-20 present historic turbidity and colour monitoring data at the offtake of the Serpentine, Serpentine Pipehead and South Dandalup reservoirs, based on water quality data collected by Water Corporation over 2000-2020. For context, the charts present estimated inflows and water storage volumes.

As presented, turbidity levels at the reservoir offtakes were generally recorded below 1 NTU. Turbidity peaks were recorded at the Serpentine Dam offtake during 2002, 2004, 2005 and 2008, and at South Dandalup Dam offtake during 2002, 2011 and 2016. Monitoring frequency at Serpentine Dam was reduced from about 2010 onwards and may have missed turbidity peaks over that period.

Colour levels at the reservoir offtakes were generally recorded at between 1-6 true colour units (TCU) at all three reservoir offtakes over the 2000-2020 monitoring period.

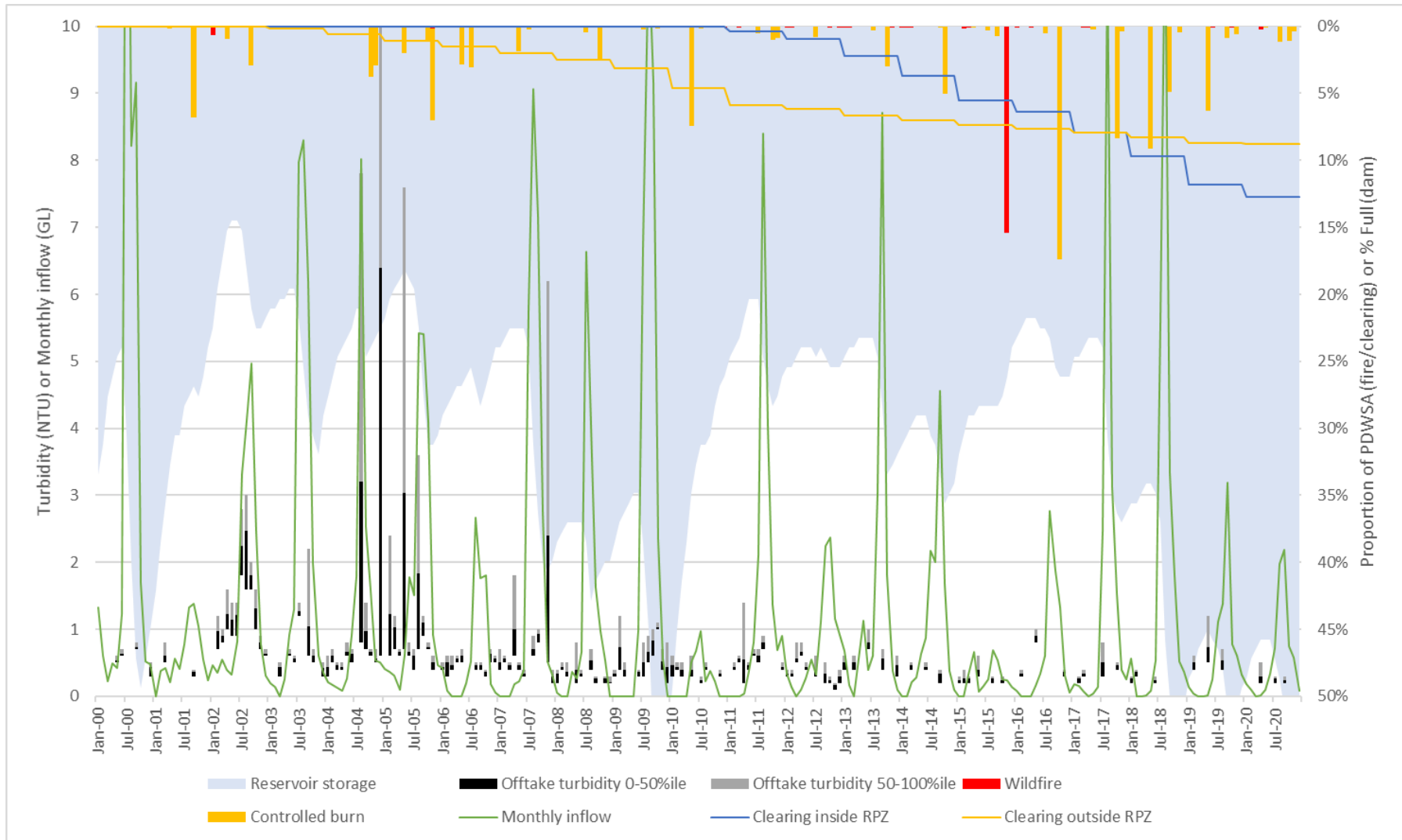


Chart 8-15 Serpentine Dam – inflows, storage and offtake turbidity

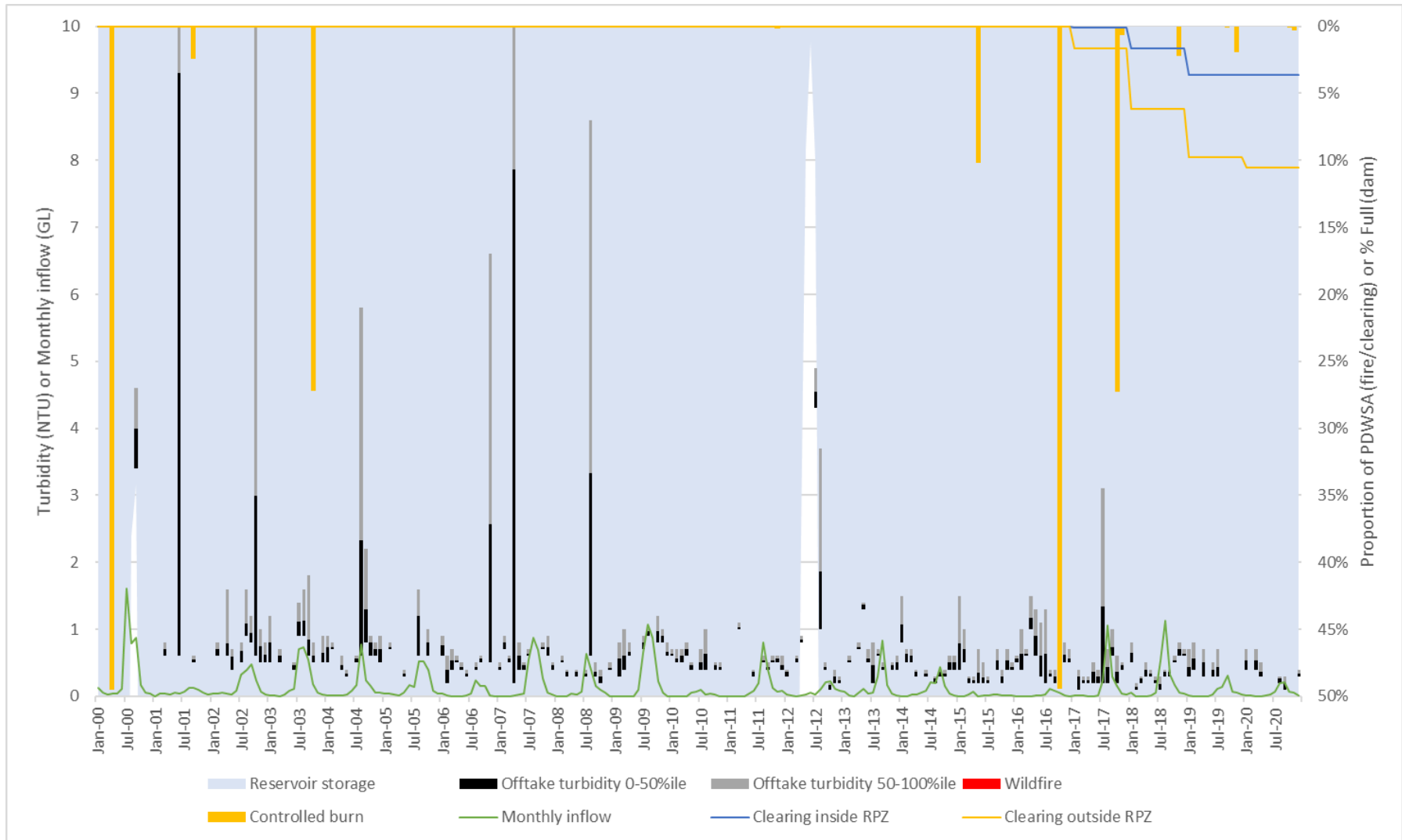


Chart 8-16 Serpentine Pipehead Dam – inflows, storage and offtake turbidity

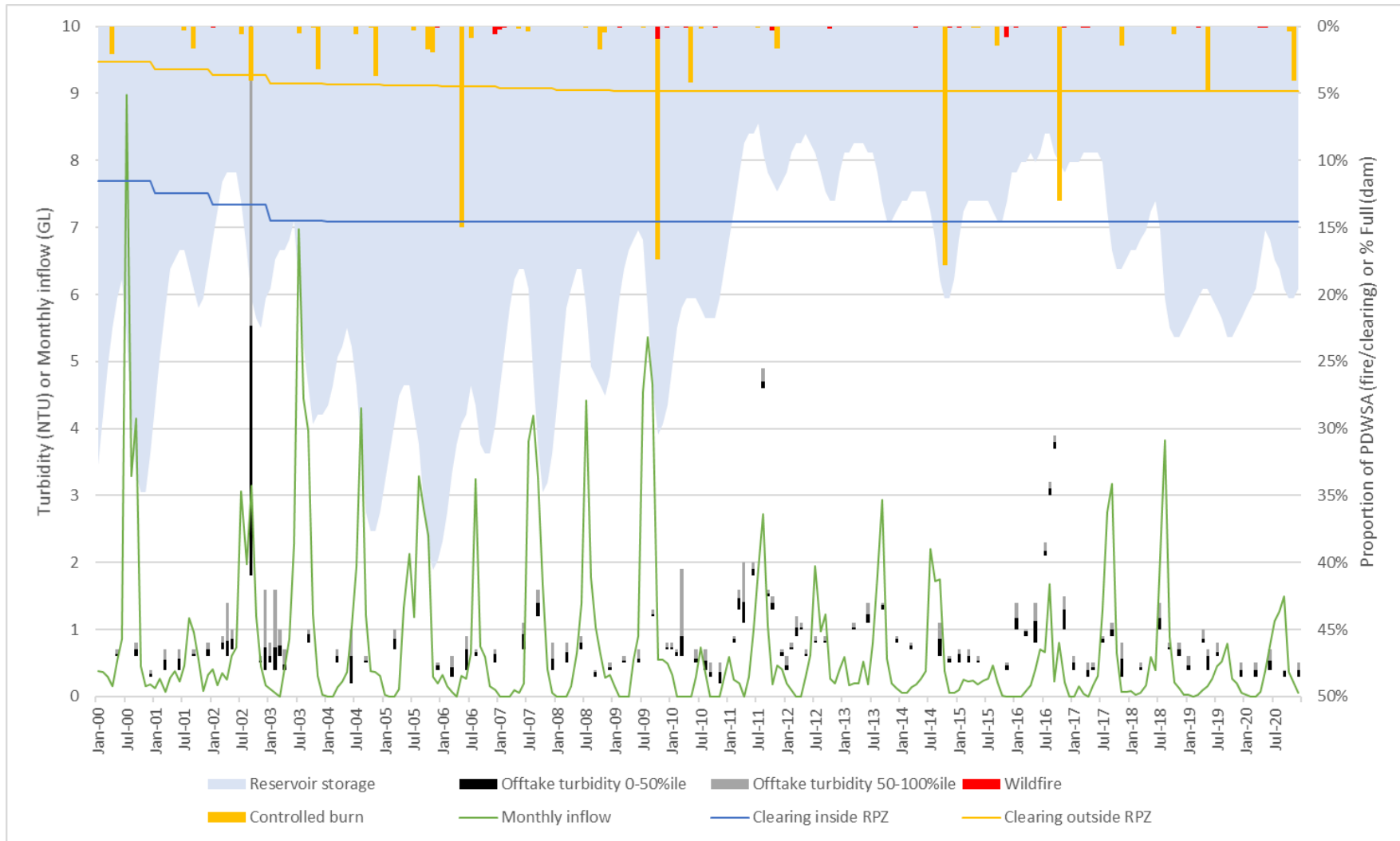


Chart 8-17 South Dandalup Dam – inflows, storage and offtake turbidity

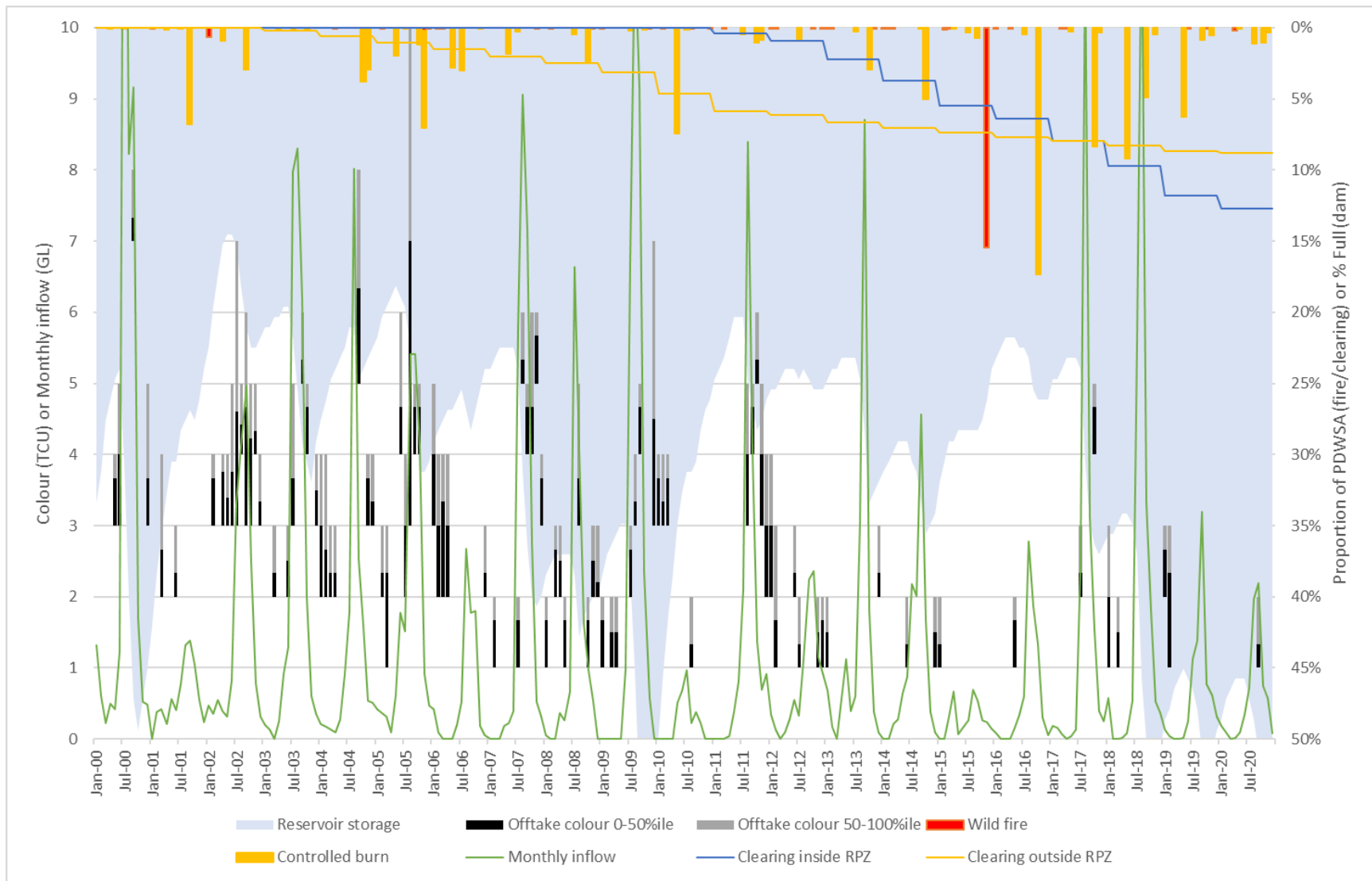


Chart 8-18 Serpentine Dam – inflows, storage and offtake colour

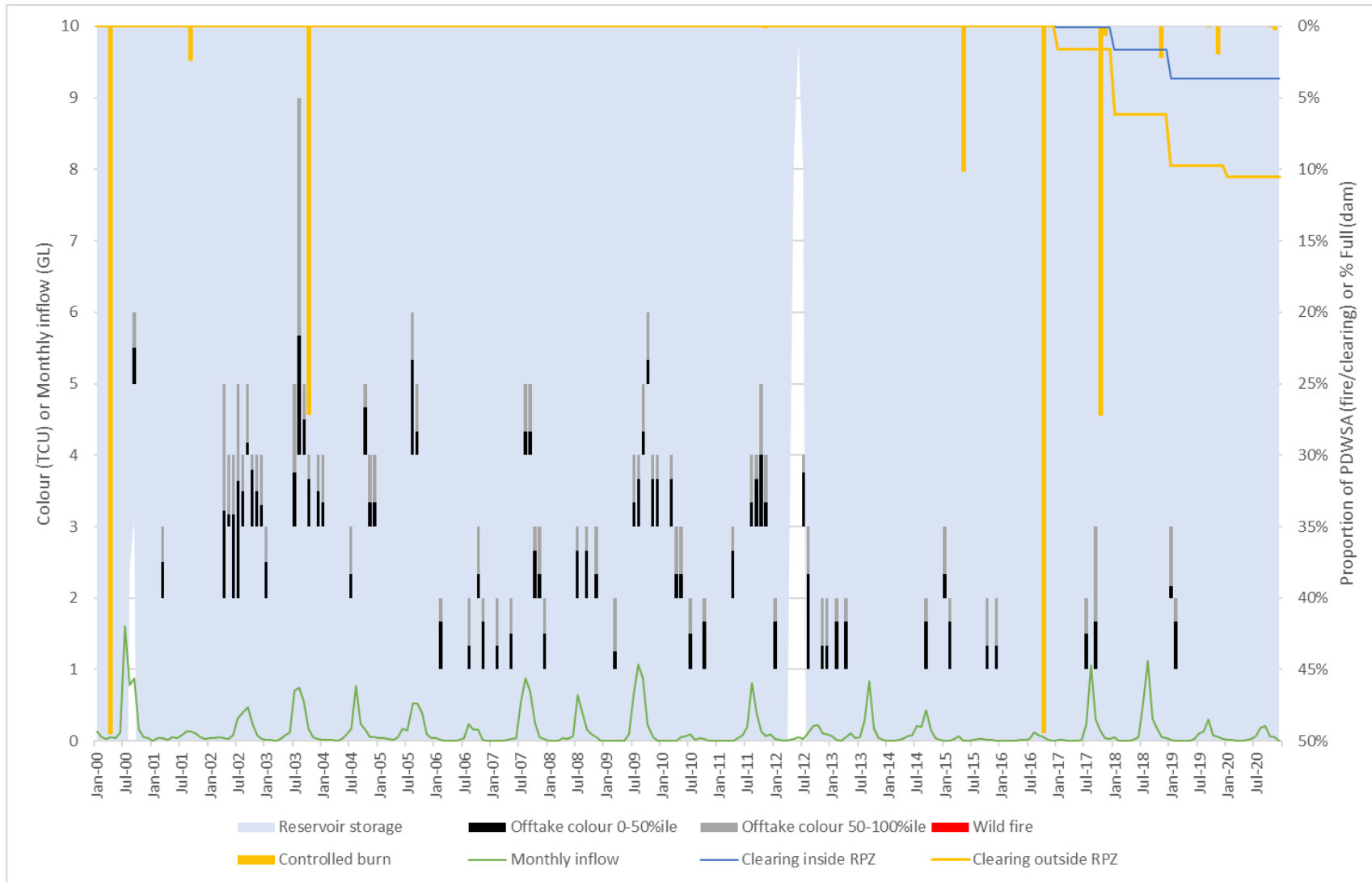


Chart 8-19 Serpentine Pipehead Dam – inflows, storage and offtake colour

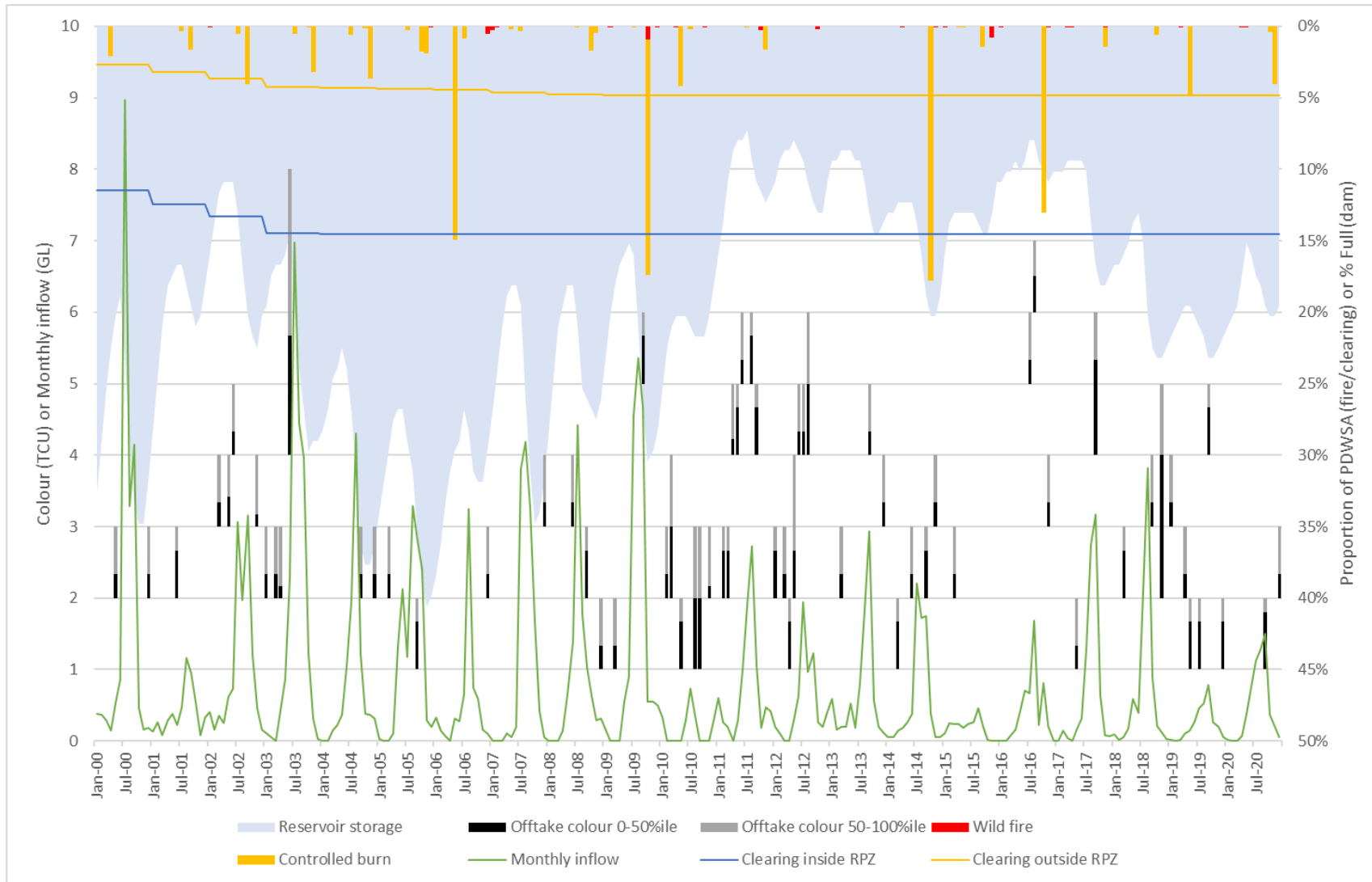


Chart 8-20 South Dandalup Dam – inflows, storage and offtake colour

8.3.2.5 Surface water beneficial uses

Integrated Water Supply Scheme (IWSS)

Approximately 21,328 ha (89.2 per cent) of the Mine DE lies within Priority Drinking Water Source Areas (PDWSAs) (see Table 8.3). The majority (19,783 ha or 82.8 per cent) of the Mine DE lies within the Serpentine Dam and South Dandalup Dam PDSWAs and a small portion (1,046 ha of 4.4 per cent) in Wungong Dam PDWSA. A total of 498 ha (2.1 per cent) of the Proposal DE lies within the North Dandalup, Conjurunup Creek and Canning Dam PDWSAs.

The PDWSAs within the Northern Jarrah Forest are connected to the Integrated Water Supply Scheme (IWSS), the largest water supply scheme within Western Australia. The IWSS is managed by Water Corporation and delivers 332 GL/year to over two million people¹. The distribution network includes Perth, the Goldfields and Agricultural Region and parts of the South West.

The IWSS is made up of the following water sources:

- desalinated seawater (35 per cent supply)
- groundwater (36 per cent supply)
- dams (26 per cent supply)
- groundwater replenishment (three per cent supply)

Catchment inflows to IWSS dams have declined substantially since the 1970s (see Chart 8-21²). In future, more water will come from seawater desalination, secure groundwater sources and groundwater replenishment, with less reliance on dams³.

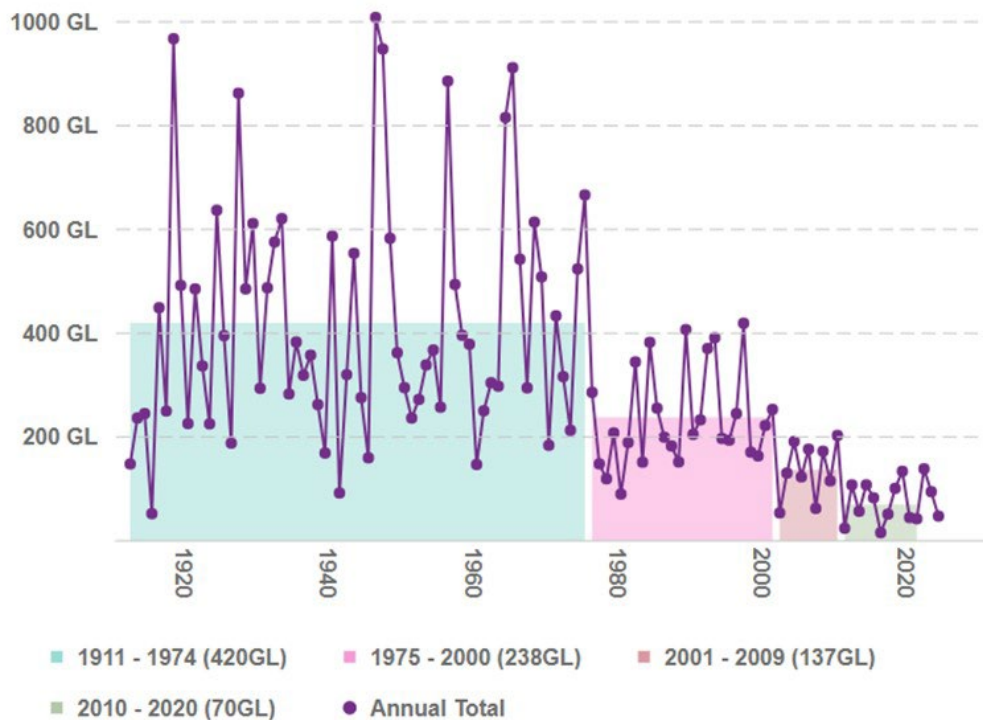


Chart 8-21 Catchment inflows to IWSS dams

¹ <https://www.watercorporation.com.au/Our-water/Perths-water-supply/Integrated-water-supply-scheme>

² <https://www.watercorporation.com.au/Our-water/Rainfall-and-dams/Streamflow>

³ <https://www.watercorporation.com.au/Our-water/Perths-water-supply/How-our-water-sources-have-changed>

The Water Corporation ten-year plan '*Water Forever, Whatever the weather, Drought-proofing Perth*' (2011) states:

"The way we use our dams will change into the future due to expected low inflow from catchments in most years. Dams will assume a bigger role as storage reservoirs for climate-independent, year-round water production from our new sources before it is distributed to our customers in periods of greater demand.

Dams also help us to move water around, including supplying towns in the Goldfields and Agricultural areas through CY O'Connor's famous pipeline.

Over the past 10 years we have invested to connect to more southern dams. This provides greater flexibility and security of water supply to Perth as well as for towns in the south west of Western Australia."

The Water Corporation (pers. comm. 2024) advise the dams continue to play an ongoing and crucial role in the IWSS through the following:

- storage and transfer for runoff and for desalinated water and groundwater
- balancing groundwater and desalination production against IWSS demand
- supply contingency
- enabling orderly capital investment in new sources.

The IWSS dams provide direct supply to approximately half a million people in the Perth metropolitan and Perth hills areas and act as reservoirs with a combined capacity of 630 GL (Water Corporation, pers. comm. 2024).

Table 8.3 Mine DE within Priority Drinking Water Source Areas

Priority Drinking Water Source Area	Myara North DE (ha)	Holyoake DE (ha)	O'Neil DE (ha)	Mine DE total (ha)	Proportion of Mine DE within PDWSA (%)
Serpentine Dam	9,397	20	5571	14,988	62.7
South Dandalup Dam	-0	4,795	-	4,795	20.1
Wungong Brook	1,046	-	-	1,046	4.4
North Dandalup Pipehead Dam	-	309	-	309	1.3
Canning Dam	61	-	-	61	0.3
Conjurunup Creek Pipehead Dam	0	128	-	128	0.5
Total DE area within PDWSAs	10,505	5,252	5,571	21,328	89.2
DE area outside of PDWSAs	200	2,372	0	2,572	10.8
Total DE area	10,705	7,624	5,571	23,900	

The IWSS desalination and groundwater sources are operated year-round. During winter and shoulder seasons, water produced by the IWSS sources but not consumed by IWSS customers is transferred and stored in the IWSS dams, amounting to approximately 85 GL of internal transfers per year. This storage method is efficient for supplying the IWSS during peak times, as the elevation of the dams eliminates the need for pumping (Water Corporation, pers. comm. 2024).

The Water Corporation aims to maintain around five years of dam reliance in storage to provide contingency and enable orderly capital investment in new sources (Water Corporation, pers. comm. 2024).

During the summer of 2023/24, extremely hot conditions caused IWSS demand to exceed the forecast by 20 GL, increasing dam reliance by 30% from 60 GL to 80 GL. With groundwater and desalination operating at full capacity, the additional demand had to be met from dam storage. The Perth Seawater Desalination Plant, with a capacity of 45 GL, will have its marine works impacted by the Westport project, necessitating contingency measures while new marine works are constructed. Inflow variability also needs to be managed with dam storage, as inflows have occasionally been well below dam reliance, leading to a net reduction in dam storage (Water Corporation, pers. comm. 2024).

Maintaining five years of dam reliance in storage enables orderly capital investment in new sources. This buffer allows for dam reliance to be met over a drought sequence while simultaneously expanding a desalination plant.

Myara North

The surface waters within and downstream of the Myara North DE are used for the following social and economic uses:

- Cultural heritage: Serpentine River registered Aboriginal heritage site
- Recreation and tourism: Serpentine Dam, Gooralong Brook, Serpentine River downstream
- Public water supply: Serpentine Dam, Serpentine Pipehead Dam, Wungong Dam

The cultural heritage values of the Serpentine River Aboriginal heritage site are presented under the Social Surroundings factor in Section 11.

Serpentine Dam provides recreational and tourism amenities including the Serpentine Dam Café and picnic grounds adjacent and below the dam wall. Picnic facilities are maintained by the Water Corporation. Gooralong Brook flows through Jarrahdale townsite and Serpentine National Park and is incorporated into trails including Mundlimup Timber Trail, Heritage Town Walk, Stacey's Track and Kitty's Gorge. The Serpentine Falls recreational area is located downstream of the confluence of Gooralong Brook and Serpentine River and includes trails, viewing and picnic areas within Serpentine National Park. Recreational facilities within the National Park and State Forest are maintained by DBCA. The recreational and tourism values of Jarrahdale, Serpentine National Park and Serpentine Dam are presented under the Social Surroundings factor in Section 12.

O'Neil

The surface waters within and downstream of the O'Neil DE are used for the following social and economic uses:

- Cultural heritage: Serpentine River registered Aboriginal heritage site
- Recreation and tourism: Serpentine Dam and Serpentine River downstream
- Public water supply: Serpentine Dam

The cultural heritage values of the Serpentine River Aboriginal heritage site are presented under the Social Surroundings (Heritage) factor in Section 11. The recreational, tourism and water supply values within the O'Neil DE are as described above for Myara North.

Serpentine Dam and Pipehead Dam

The Serpentine Dam has a full supply capacity of 137.7 GL and collects water from a 664 km² catchment. The catchment is proclaimed under the *Metropolitan Water Supply Sewerage and Drainage Act 1909* (MWSSD Act), and primarily classified as a Priority 1 PDWSA, with some private lands within the catchment classified as Priority 2. The reservoir is surrounded by a 2 km wide 'Reservoir Protection Zone' (RPZ) around its top water level, which includes the reservoir itself and does not extend outside the catchment area.

Approximately 9,397 ha (88 per cent) of the Myara North DE and 5,571 ha (100 per cent) of the O'Neil DE lies within the Serpentine Dam PDWSA, comprising approximately 22 per cent of the PDWSA, of which a portion will be disturbed by construction and mining. The existing Myara mine region of the Huntly Mine occupies a portion of the PDWSA.

Water Corporation's current allocation licence for Serpentine Dam and Serpentine Pipehead Dam (licence 56737) totals 53.89 GL/annum and is issued to provide water for public potable water supply and irrigation.

Source water arising from the Serpentine and Pipehead Dam PDWSAs is drawn from the Pipehead Dam and treated with chlorine. Finished water is transferred to the IWSS for distribution to downstream customers.

As presented in Section 1.9.2.4, the Proposal was amended to exclude the Myara North DE from the Serpentine Pipehead Dam PDWSA and accordingly the Pipehead Dam is not a direct receptor for the Mine DE. The Serpentine Pipehead Dam is a potential episodic receptor for the Myara North DE as the Pipehead may indirectly receive water from Serpentine Dam in the atypical (contingency) event that inputs from the IWSS (e.g. desalinated water) are not available to supply the Pipehead.

Wungong Dam

The Upper Wungong Brook catchment comprises 128 km² and discharges into Wungong Dam, a drinking water supply reservoir with a capacity of approximately 60 GL. The catchment is proclaimed under the MWSSD Act, and is primarily classified as a Priority 1 PDWSA, with a small area classified as Priority 2. The reservoir is surrounded by a 2 km wide RPZ around its top water level.

Approximately 1,046 ha (10 per cent) of the Myara North DE lies within the Upper Wungong Brook PDWSA, comprising approximately 8 per cent PDWSA, of which a portion may be disturbed by construction and mining. The Myara North region lies in the upper reaches of the PDWSA and lies approximately 9 km upstream of the dam's RPZ. The historic Jarrahdale Mine has formerly occupied a portion of the PDWSA.

The Water Corporation's current allocation licence for Wungong Dam (licence 58767) is 20.6 GL/annum. This licence is issued to provide potable water for public water supply. Source water arising from the Upper Wungong Brook PDWSA is drawn from the Wungong Dam and treated with chlorine before supply to the IWSS.

Holyoake

The surface waters downstream of the Holyoake DE are used for the following social and economic uses:

- Cultural heritage: South Dandalup River registered Aboriginal heritage site
- Recreation and tourism: South Dandalup Dam, North Dandalup Dam, Murray River
- Public water supply: South Dandalup Dam, North Dandalup Dam, Conjurunup Pipehead Dam

The Water Corporation maintains recreational facilities at the South and North Dandalup dams. There is a lookout and picnic facilities at the South Dandalup Dam, above the dam wall near the spillway⁴. There is a lookout at the North Dandalup Dam⁵, with picnic facilities below the dam wall.

The Murray River downstream of the Holyoake DE runs through Lane Poole Reserve and is incorporated into several recreational facilities as a foreshore and for swimming and paddling. The majority of Lane Poole Reserve campsites and trails lie upstream of the confluence with Davis Brook and Swamp Oak Brook. The Charlies Flat and Bobs Crossing day-use areas are downstream of the confluence of Swamp Oak Brook, and the Dwaarlindjirrap day-use area, Baden Powell campsite, and Nanga Bush Camp are downstream of the confluence with Davis Brook. The recreational facilities at Lane Poole Reserve are managed by DBCA and details are presented under the Social Surroundings factor (Section 12).

South Dandalup Dam

The 208.2 GL capacity South Dandalup Dam is the largest reservoir supplying the IWSS. The catchment covers 311 km² and is proclaimed under the MWSSD Act 1909. Similar to Serpentine Dam, the catchment is predominantly classified as a priority 1 PDWSA, with a small area of private land managed as a priority 2 PDWSA. The South Dandalup Dam is also connected to the South Dandalup Pipehead Dam, which acts as a pump back for South Dandalup Dam, adding to the available water for supply. Water from the South Dandalup Pipehead Dam is chlorinated before pump back to the South Dandalup Dam.

Approximately 4,795 ha (63 per cent) of the Holyoake DE lies within the South Dandalup Dam PDWSA, comprising approximately 15 per cent of the PDWSA, of which a portion will be disturbed by construction and mining. The historic McCoy mine region of the Huntly Mine has formerly occupied a portion of the PDWSA.

Water Corporation's current allocation licence for South Dandalup Dam (licence 56734) is 26.9 GL/annum. This licence is issued to provide potable water for public water supply to the IWSS. Alcoa currently has three licences to abstract a total of 0.6 GL/yr from South Dandalup Dam, which is used to supply water (primarily for dust suppression) to the Huntly Mine.

Source water arising from the South Dandalup Dam PDWSAs is drawn from the Serpentine Pipehead Dam and treated with chlorine. Finished water is transferred to the IWSS for distribution to downstream customers.

8.3.2.6 Aquatic ecosystems

WRM (2021, Appendix B6) reviewed the aquatic ecology of seasonal waterbodies, which include:

- hyporheic zones known to support stygal species that are potentially SRE

⁴ <https://www.watercorporation.com.au/About-us/Visiting-our-dams/South-Dandalup-Dam>

⁵ <https://www.watercorporation.com.au/About-us/Visiting-our-dams/North-Dandalup-Dam>

- aquatic invertebrate species richness often similar between seasonal and perennial reaches of streams in the Jarrah forest
- aquatic fauna communities typically comprise assemblages of species including those only found in seasonal waters and those that periodically disperse/recolonise from nearby refuges in perennial waters
- many aquatic invertebrates in south-west WA are found only in temporary waters, are adapted to drying and refilling cycles, and require a period of desiccation for further development.

Perennial aquatic habitat within the Mine DE is limited to isolated stream pools and farm dams as well as perennial waters downstream (see Section 6.3.4.2). Kennedy's Pool which is within the Holyoake DE, and Mundalup Pool located upstream of the Holyoake DE, may be perennial water bodies. Small stream pools within the Myara North DE, including at Jack Rocks on 39 Mile Brook, dry up in summer and are considered seasonal. Farm dams associated with rural properties are located along Gooralong Brook in the Myara North DE.

The Mine DE lies upstream of perennial surface waters, including Serpentine Dam, South Dandalup Dam, Wungong Dam and the Murray River, which are known or highly likely to support populations of aquatic fauna. The presence of dams is expected to have disrupted aquatic fauna migrations from downstream rivers. Murray River remains un-dammed and has the potential to support migrations of aquatic fauna, however, the river has elevated salinity from its cleared agricultural upper catchment.

Table 8.4 presents the length of streams within each Mine DE, broken down into stream order. Higher-order streams are associated with the major tributaries within the Mine DE and typically support a greater depth and width of aquatic habitat and a longer duration of stream flow. As presented, there is a total of 203.9 km of streams mapped within the Mine DE, of which 159.5 km (78 per cent) comprise minor (1st order) streams.

The seasonal streamflow and seasonal river pools within the Mine DE have the potential to support transitory populations of aquatic species dispersing upstream from perennial waterways and reservoirs during winter and spring stream flows, as well as habitat for aquatic invertebrates. Kennedy's Pool and Mundalup Pool are potential perennial water bodies that provide refuges for aquatic fauna on the South Dandalup River during the summer and autumn. Farm dams in the Myara North DE may also provide refuges for aquatic fauna on Gooralong Brook during summer and autumn.

Table 8.4 Mapped streams within the Mine DE

Stream order	Total stream length within Myara North DE (km)	Total stream length within Holyoake DE (km)	Total stream length within O'Neil DE (km)	Total stream length within Mine DE (km)
1	54.4	40.9	16.3	111.6
2	30.9	12.1	4.9	47.9
3	13.3	10.2	9.6	33.1
4	3.2	2.6	1.9	7.7
5	3.9	0	0	3.9
Total	105.5	65.7	32.7	203.9

The alluvial/colluvial sediments that lie within streams and swamps are subject to seasonal saturation through surface and groundwater inflows, creating a hyporheic zone that may provide

habitat for macroinvertebrates. The hyporheic zone can provide refuge for aquatic fauna that can burrow to avoid desiccation during dry periods and/or high flow events (WRM 2021), including crustaceans, earthworms and insect larvae. Stygal amphipods have been recovered from the hyporheic zone of streams within the Huntly Mine, which may be potential SRE fauna (WRM 2021). Potential stygofauna habitats within hyporheos are described in Chapter 13 Other Factors.

8.3.3 Groundwater systems

8.3.3.1 Regional hydrogeology

The Hydrology and Water Quality Assessment (GHD 2023a) presents a review of regional hydrology. A summary is provided below.

The Mine DE lies within the Darling Plateau, an undulating lateritic regolith over Archaean granite with dolerite intrusions. This geology is detailed in Section 7.3.1 and supports the regional hydrogeology, comprising of aquifers predominantly within weathered and fresh Archaean basement rocks, as well as superficial aquifers within more recent sediments incised in the basement, coincident with existing and paleo drainage lines. Table 8.5 presents the main aquifer units that characterise the regional hydrogeology across the Darling Plateau, from surface level down to the basement.

Table 8.5 Main aquifer units within Darling Plateau geology

Aquifer unit	Description
Shallow weathered zone	Shallow gravely and sandy sediments, lateritic caprock and friable upper saprolite. The lateritic caprock and friable saprolite can contain economic bauxite and be subject to mining. Seasonal aquifer with significant storage, infiltration and flow capability.
Deep weathered zone	Lower saprolite layer. Aquifer of some storage potential, but limited bulk permeability, comprising clays. Clayey nature of this zone can be interspersed by macropore features developed along deep root systems which were subsequently filled with more clastic material.
Transition zone	Transition zone between fresh basement and saprolite, referred to as saprock, which typically has enhanced permeability
Fractured bedrock	Permeability and yields are dependent on fracture development and connectivity of fractures

Groundwater has been an active part of lateritisation across the Darling Plateau, particularly in the development of the duricrust or caprock which lies above the weathered saprolite clays. The formation of caprock has been driven by groundwater flow and capillary action which lead to the precipitation of iron minerals leached from the weathered bedrock. Caprock can also form in valley floors due to the accumulation of iron brought by groundwater flow and its precipitation due to evapotranspiration or exposure to the surface.

The caprock layer is discontinuous and of varying thickness, being found on slopes but generally being absent in valley floors, as well as where the basement rock outcrops. Of hydrological significance, root channels penetrate vertically via fissures and discontinuities in the caprock and deep into the saprolite clays are a consistent feature in the lateritic profiles. These channels create preferential flow paths which are understood to enable significant vertical fluxes from the shallow weathered zone into the deeper aquifers of weathered saprolite and saprock.

In addition to the aquifers presented in Table 8.5, aquifers are present in alluvial and colluvial sediments accumulated in drainage lines, where these are sufficiently developed and have eroded the basement. The permeability of the alluvial / colluvial sediments is variably distributed and related to lithology, depth and degree of weathering.

Broadly, groundwater levels within all aquifers appear to follow topography, such that groundwater level is highest in areas of highest topography and lowest in areas of lowest topography. Where groundwater levels intersect the base of streams, groundwater discharges provide baseflow following winter rains (topped up aquifer storage and groundwater levels).

8.3.3.2 Local hydrogeology

Myara North

GHD (2023a) detail the local hydrogeology of the Myara North DE. A summary of aquifer units identified in the Myara North DE is presented in Table 8.6.

Table 8.6 Aquifer units identified within the Myara North DE

Aquifer unit	Description
Lateritic / caprock	1 to 4.5 m thick, comprising minor soils with pea-gravel and cemented duricrust or laterites. Caprock is hard to very hard and often strongly cemented with pisolitic nodules. In valley floors, this can be overlain or replaced by relatively thin alluvial sediments.
Saprolite clay	Highly variable depths from 1 to 29 m thick, comprising clays derived from weathered basement. Clays are mottled or pallid towards the top becoming less pallid with depth reflecting weathered bedrock lithology.
Weathered basement	Weathered basement zone characterised by decreasing clay content, an increasing rock texture/relict features which grades sharply into basement rocks, with a thickness of less than 2 to 4 m. Most active groundwater flow occurs in this zone and is often pressurised.
Fractured bedrock	Depth to fractured basement varies from 6 to 28.5 metres below ground level (mbgl) and extended to end of bore hole. Basement rocks are predominantly granite interspersed with a few occurrences of dolerite.

Slug tests conducted over 14 boreholes indicate an average hydraulic conductivity of approximately 0.6 m/day for the transition zone between weathered basement and bedrock, and a range of <0.05 to 1.2 m/day. The saprolite clays which overlie the transition zone are inferred to be less permeable at less than 0.001 m/day.

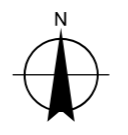
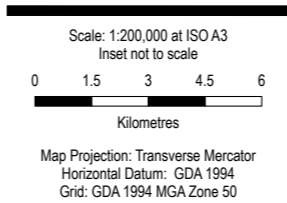
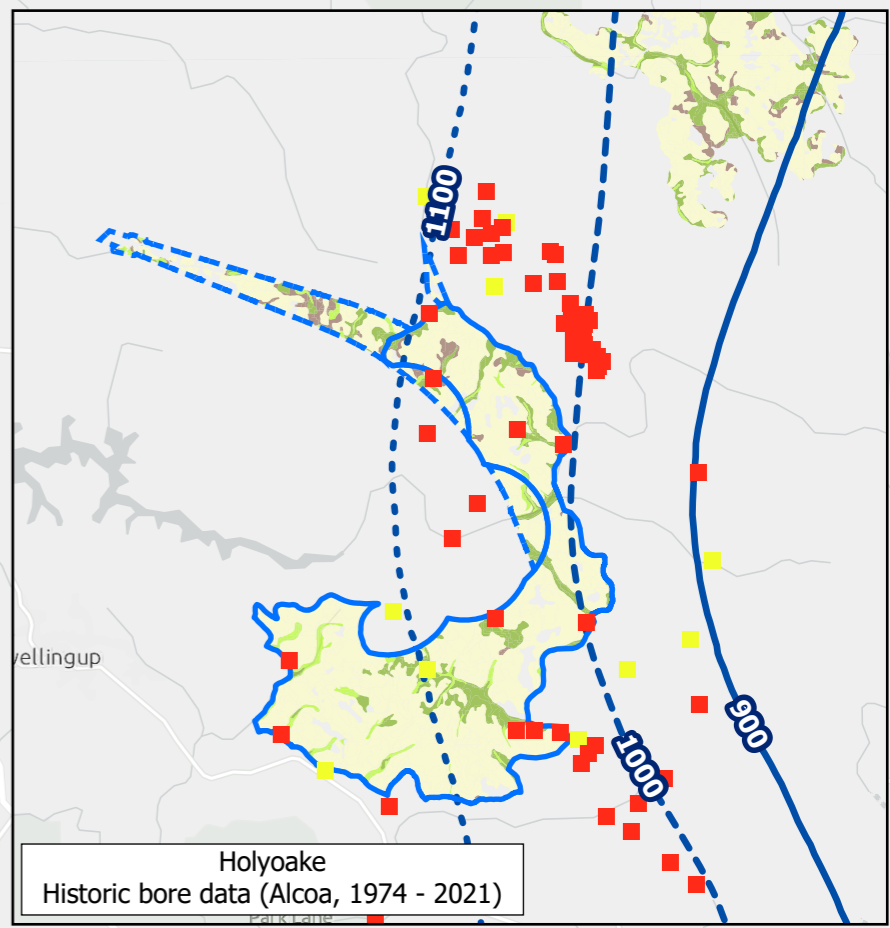
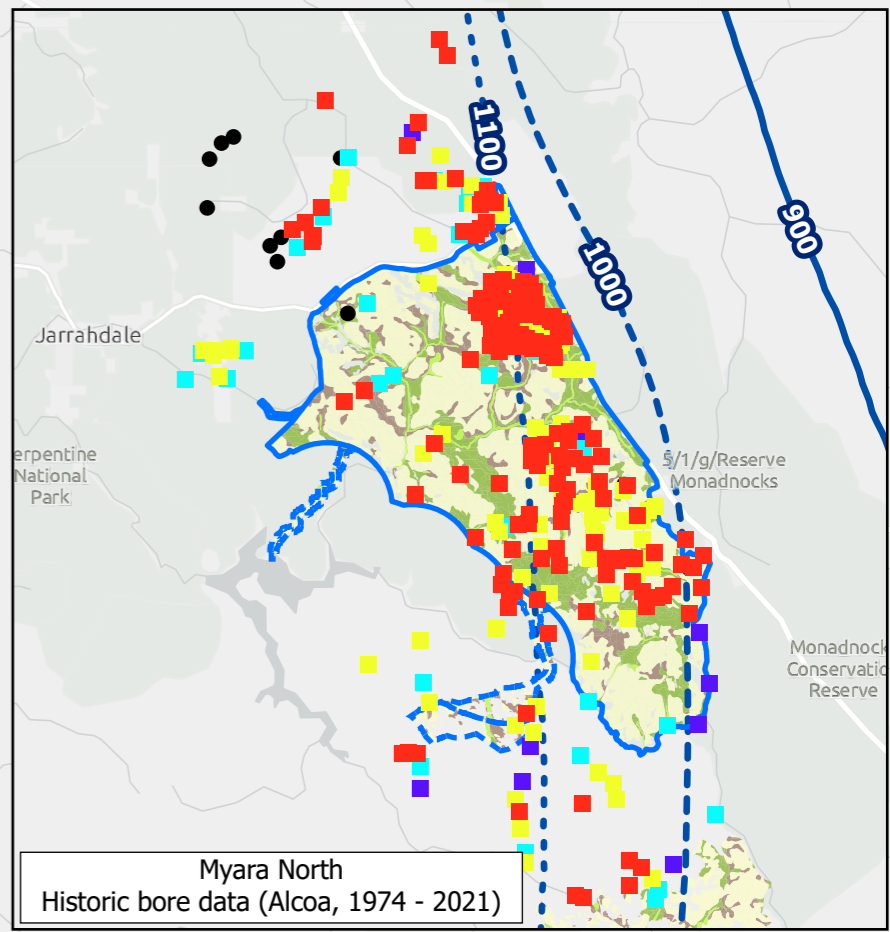
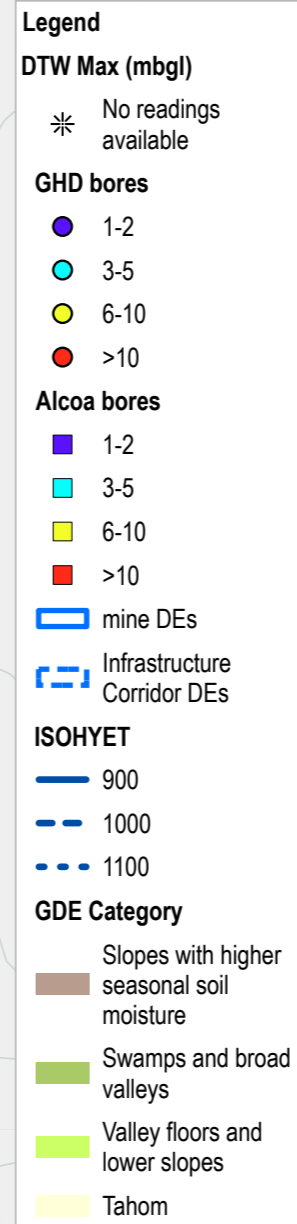
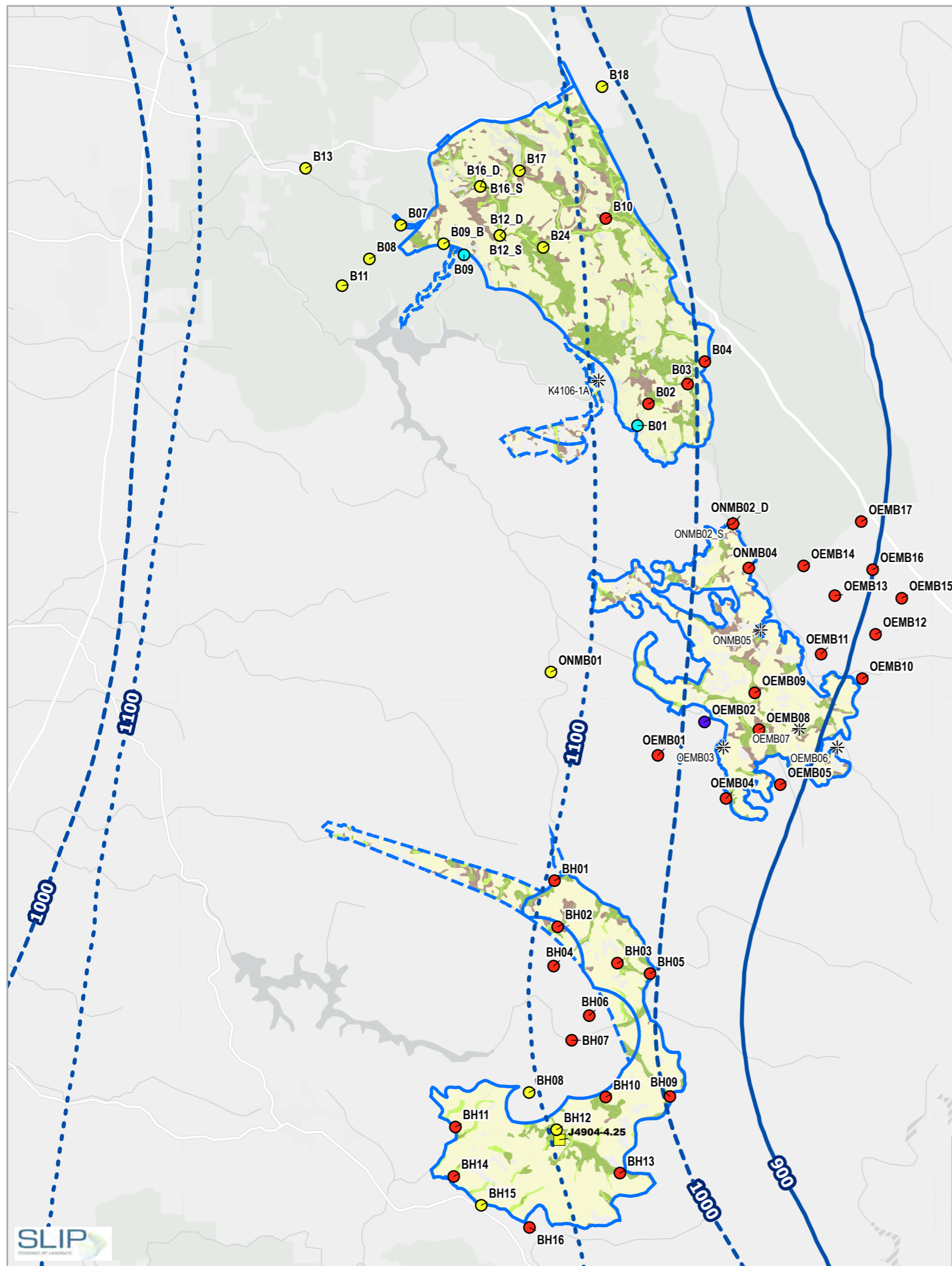
GHD (2023a) identified the following key features and long-term trends based on a review of historic groundwater monitoring data over the Myara North DE:

- strong seasonal variation in groundwater levels, typically varying over an annual cycle by between 1 to 5 m, in response to natural recharge events, confirming that recharge occurs during every winter season.
- monitoring bores that have a relatively greater depth to groundwater (i.e. more than 10 m BGL) have a tendency to have a less significant seasonal variation.
- most monitoring bores show declining groundwater levels since 1990, which is considered to reflect the reducing rainfall pattern.
- all but two monitoring bores within the DE show declining groundwater levels of between 1 to 10 m since 1990 (0.05 to 0.33 m/year), with an average decline of close to 4.5 m over 30 years (0.15 m/year).

Groundwater monitoring data across the Myara North DE indicates a strong correlation between topographic and groundwater levels, suggesting that the groundwater level surface is a subtle replica of topography (GHD 2023a).

Figure 8-6 presents the measured depth to groundwater within the Mine DE, including the Myara North DE. As presented, the majority of bores recorded groundwater at depths of ten or more

metres, however there are areas with groundwater at depth less than ten metres. Groundwater depths are expected to be shallower in valleys.



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Revision No. 3
Date 09/03/2025

Measured depth to groundwater

FIGURE 8-6

Data source: Light Gray Base: Esri, TomTom, Garmin, Foursquare, METINASA, USGS
World Topographic Map: Esri, TomTom, Garmin, Foursquare, METINASA, USGS
Light Gray Reference: Esri, TomTom, Garmin, Foursquare, METINASA, USGS

Figure 8-7 presents modelled groundwater levels over 2010-2021, matched to groundwater monitoring data, for a typical climatic period (i.e. median rainfall) (GHD 2023a). Based on the observed and modelled groundwater levels, groundwater is expected to flow from topographical highs towards groundwater discharge boundaries along major tributaries of the Serpentine Dam, Wungong Brook and Gooralong Brook.

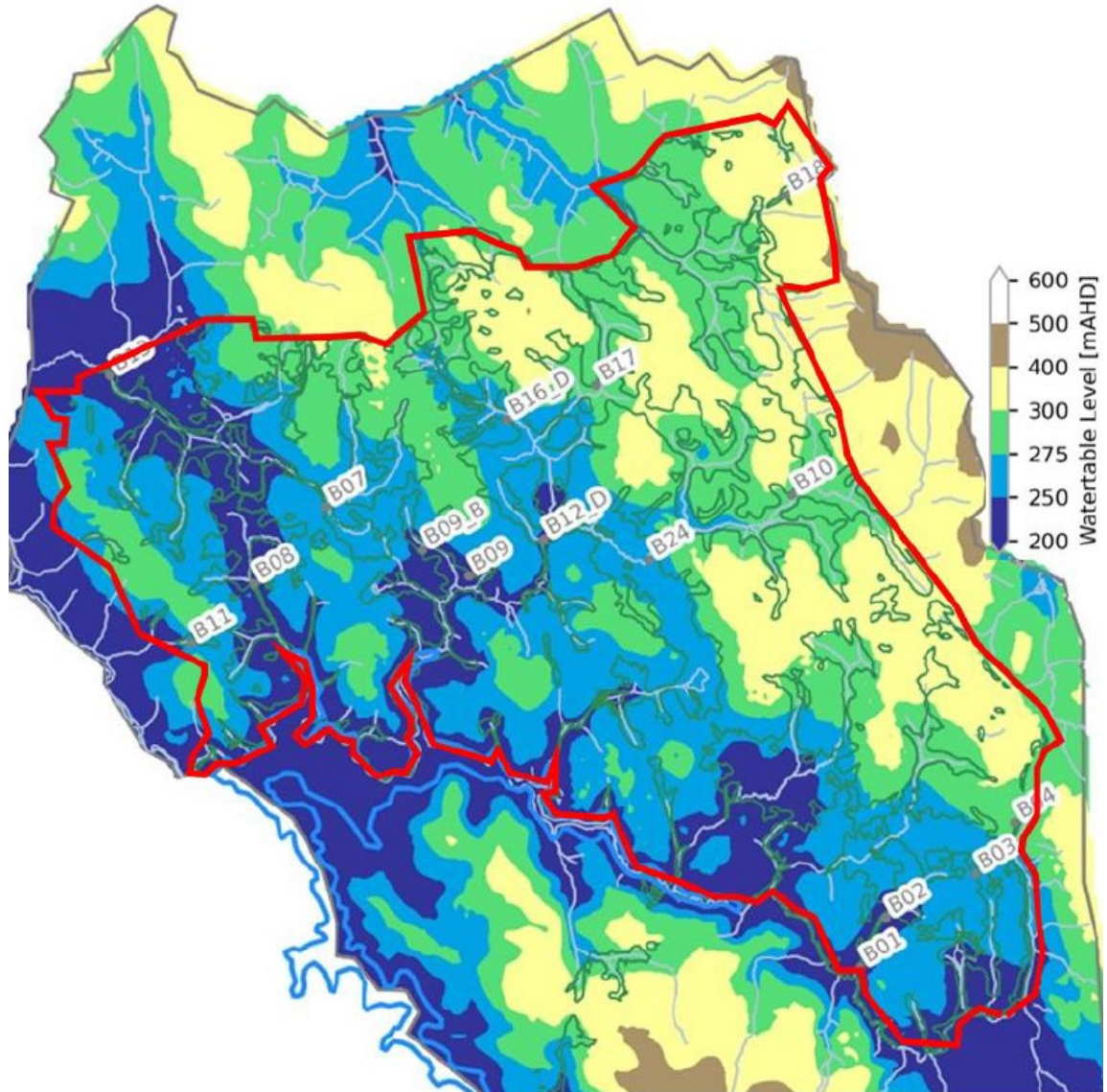


Figure 8-7 Modelled groundwater table levels for 2010-2021 (typical climatic periods) – Myara North mine region (region boundary is representative of the region boundary at the time of commissioning the study)

Groundwater depths are expected to vary substantially across the Myara North DE in response to annual rainfall. Modelled groundwater depths over 2010-2021 are presented in typical (median rainfall), wet (95th percentile rainfall) and dry (5th percentile rainfall) climatic periods in Figure 8-8, Figure 8-9 and Figure 8-10, respectively (GHD 2023a). As presented, groundwater depths over 2010-2021 were typically greater than 5 metres below ground level (mbgl) over most of the DE and less than 5 mbgl in some valley floors and depressions in the vicinity of streams and swamps (Figure 8-8). Groundwater depths were substantially shallower for wet climatic periods, at less than 5 mbgl over most of the DE (Figure 8-9). The wet climatic periods are indicative of groundwater conditions that are likely to have prevailed in higher rainfall years before 2010. Conversely, groundwater depths were relatively deeper for dry climatic periods, being greater than 10 mbgl over large areas of the DE (Figure 8-10).

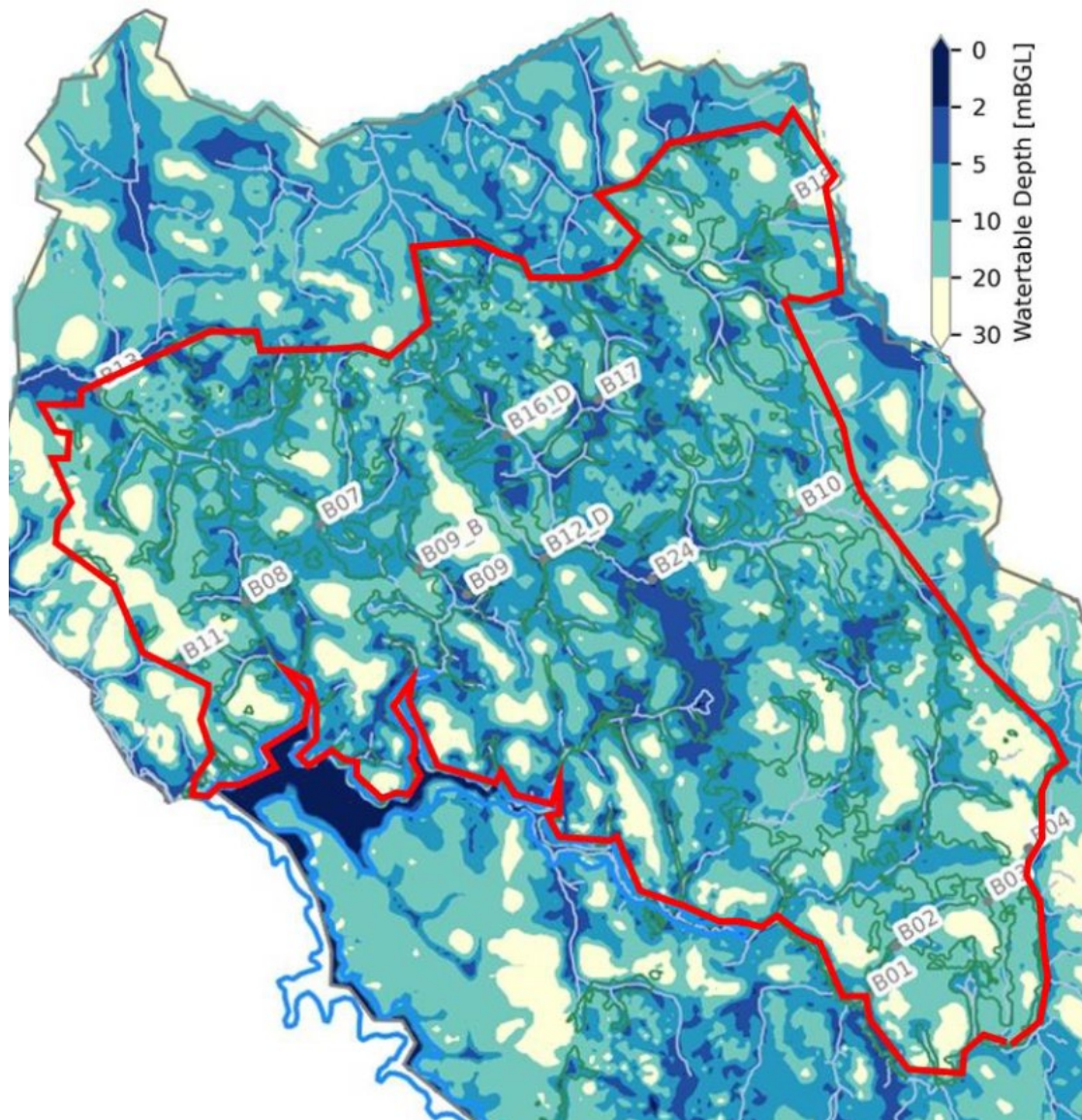


Figure 8-8 Modelled groundwater table depth for 2010-2021 (typical climatic periods) – Myara North mine region (region boundary is representative of the region boundary at the time of commissioning the study)

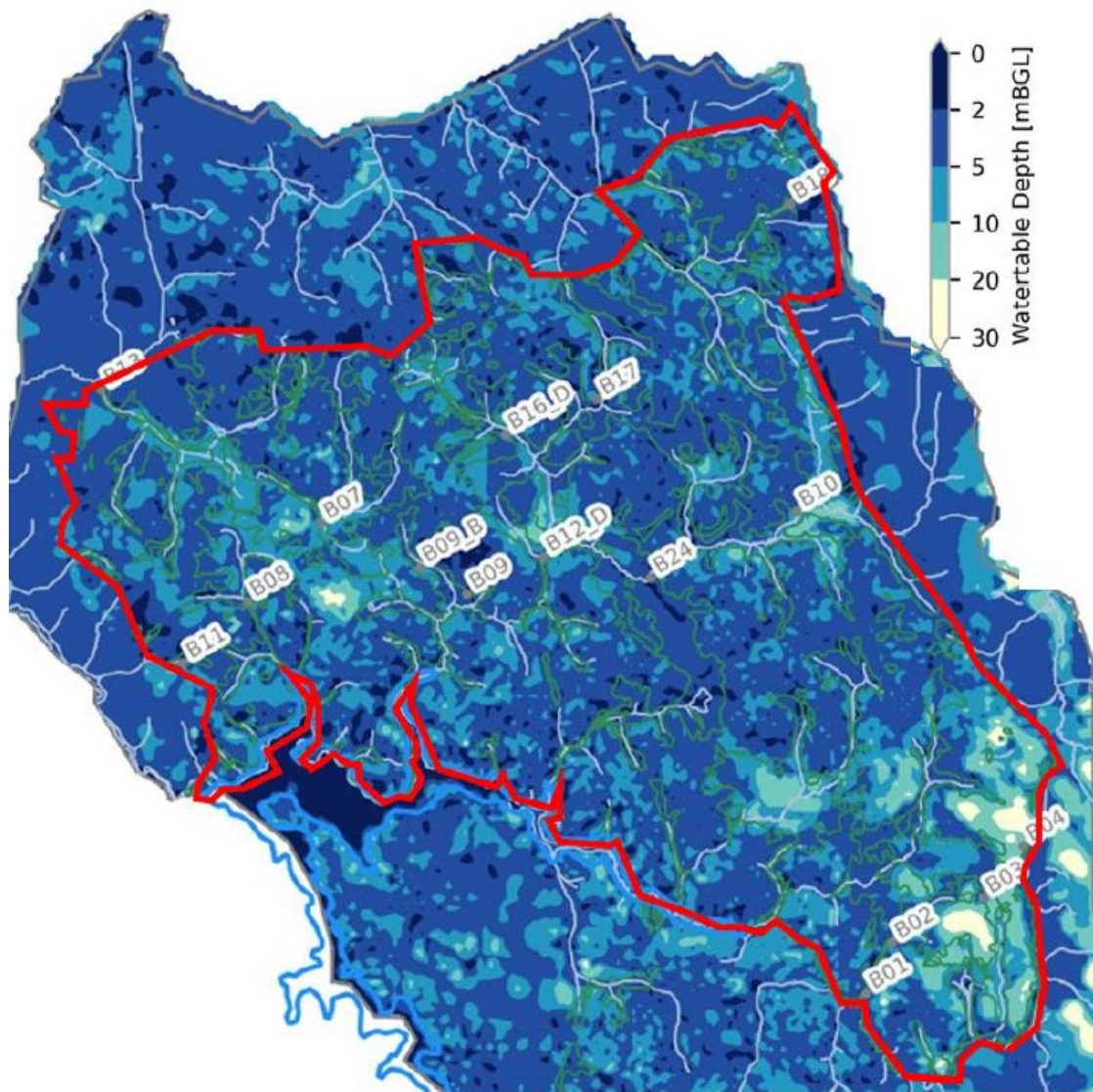


Figure 8-9 Modelled groundwater table depth for 2010-2021 (wet climatic periods) – Myara North region (region boundary is representative of the region boundary at the time of commissioning the study)

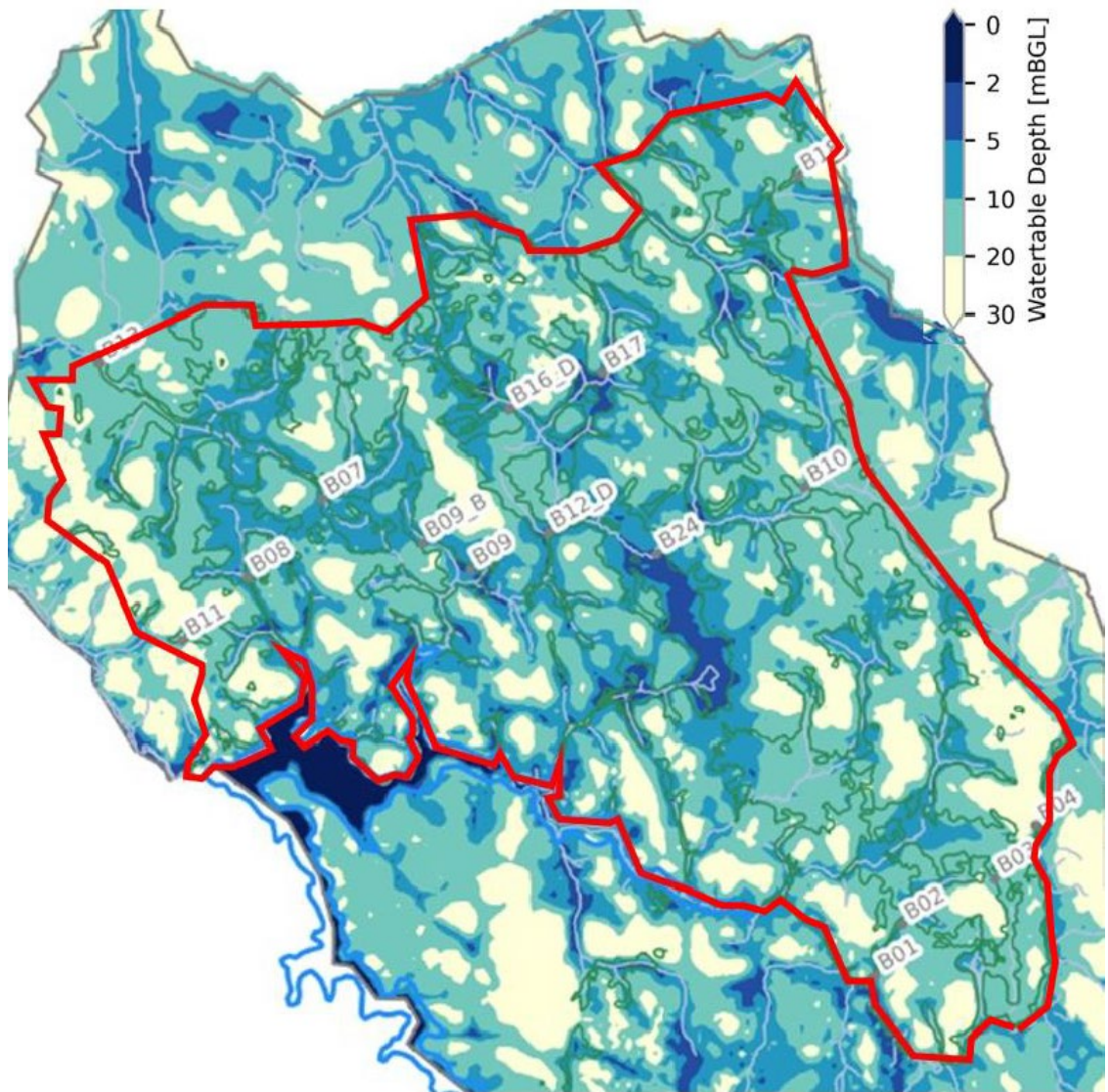


Figure 8-10 Modelled groundwater table depth for 2010-2021 (dry climatic periods) – Myara North region (region boundary is representative of the region boundary at the time of commissioning the study)

Holyoake

GHD (2023a) detail the local hydrogeology of the Holyoake DE. A summary of aquifer units identified at Holyoake is presented in Table 8.7.

Table 8.7 Aquifer units identified within the Holyoake DE

Aquifer unit	Description
Lateritic / caprock	1 to 7.5 m thick with an average of 1 to 2 m, comprising minor soils with pea-gravel and cemented duricrust or laterites.
Saprolite clay	Highly variable depths from 1 to 32 m thick, comprising completely weathered clay. Generally, clay is mottled or pallid towards the top becoming greener with depth indicating transition to weathered bedrock. Several bores also returned a uniform silty clay lens up to 20 m thick within this succession
Weathered basement	Weathered basement zone (which includes saprock) characterised by gravelly texture and decreasing clay content but with a higher clay content than in Myara North. Groundwater flow was minor with measured flows during drilling of only 4 L/minute, significantly less than in Myara North.
Fractured bedrock	Depth to fractured granite varies from 6 to 36 mbgl. Two notably shallower bores intercepted a quartzite and dolerite intrusions whereas one deep bore recorded a schist at 33.5 m.

Slug tests undertaken over 12 boreholes indicate an average hydraulic conductivity of 0.3 m/day with a range of <0.1 to 1.0 m/day. The average hydraulic conductivity at Holyoake is lower compared to Myara North, consistent with the higher clay content in the weathered basement. The highest hydraulic conductivity values were returned from bores screened in the basement saprock to highly weathered granite and likely related to discrete high permeable zones within this unit.

There is limited historic monitoring data within the Holyoake DE to assess long-term groundwater level changes. Six bores were identified that have longer-term monitoring data which, combined with more recent data (2020/21) and knowledge from neighbouring regions, provide a basis for estimation of long-term groundwater trends. Historic monitoring data indicates declining groundwater levels since the 1990s of an average of 9 m (0.3 m/yr), which is considered to reflect the reducing rainfall (GHD 2023a).

Data from 17 groundwater bores installed during 2020 across the Holyoake DE, which are predominately located close to, or within the valley floors/ creek lines, highlighted that groundwater levels are more variable and generally deeper than in the Myara North. The average depth to groundwater was 14.5 mbgl, with one of the 17 bores recording depth to groundwater shallower than 5 mbgl (see Figure 8-12). The average seasonal groundwater level decline was 0.7 m, significantly less than Myara North at 1.9 m, which may be due to the greater depth to groundwater at Holyoake.

Figure 8-11 presents modelled groundwater levels over 2010-2021, matched to groundwater monitoring data, for a typical climatic period (i.e. median rainfall) (GHD 2023a). Based on the modelled groundwater levels, groundwater is expected to flow from topographical highs towards groundwater discharge boundaries along major tributaries of the Serpentine River, Davis Brook and Swamp Oak Brook.

Groundwater depths are expected to be substantially deeper within the Holyoake DE compared to the Myara North DE. Modelled groundwater depths over 2010-2021 are presented in typical (median rainfall), wet (95th rainfall) and dry (5th percentile) climatic periods in Figure 8-12, Figure 8-13 and Figure 8-14, respectively (GHD 2023a). As presented, groundwater depths over 2010-2021 were typically greater than 20 mbgl over most of the DE, less than 20 mbgl in

lower slopes, and less than 10 mbgl in valley floors in the vicinity of streams and swamps (Figure 8-12). As with Myara North, groundwater depths were modelled to substantially change with annual rainfall. Groundwater depths were substantially shallower for wet climatic periods, at less than 20 mbgl over most of the DE and less than 10 mbgl in lower slopes (Figure 8-13). The wet climatic periods are indicative of groundwater conditions that are likely to have prevailed in higher rainfall years before 2010. Conversely, groundwater depths were relatively deeper for dry climatic periods and at least 5-10 m below valley floors (Figure 8-14).

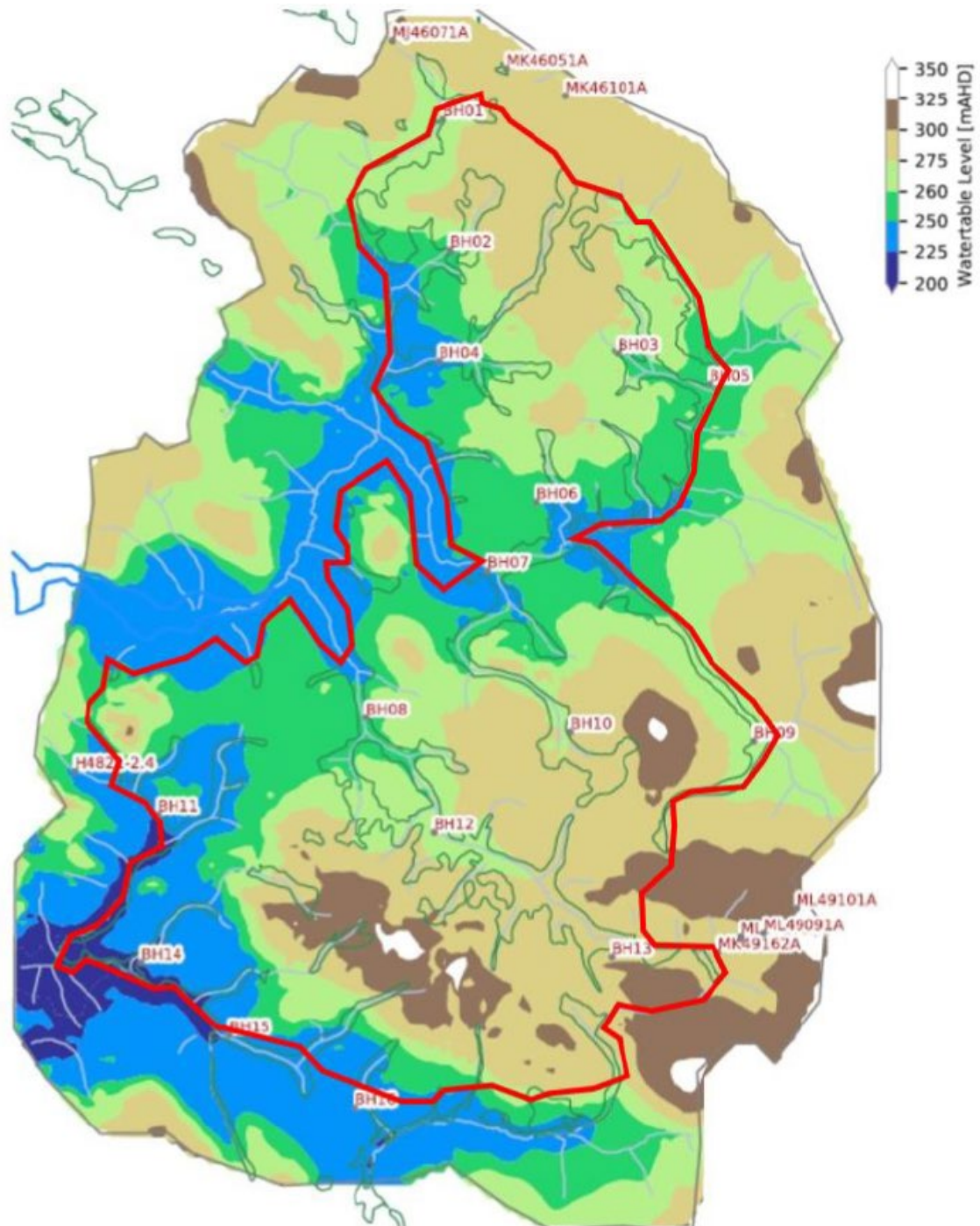


Figure 8-11 Modelled groundwater table levels for 2010-2021 (typical climatic periods) – Holyoake region (region boundary is representative of the region boundary at the time of commissioning the study)

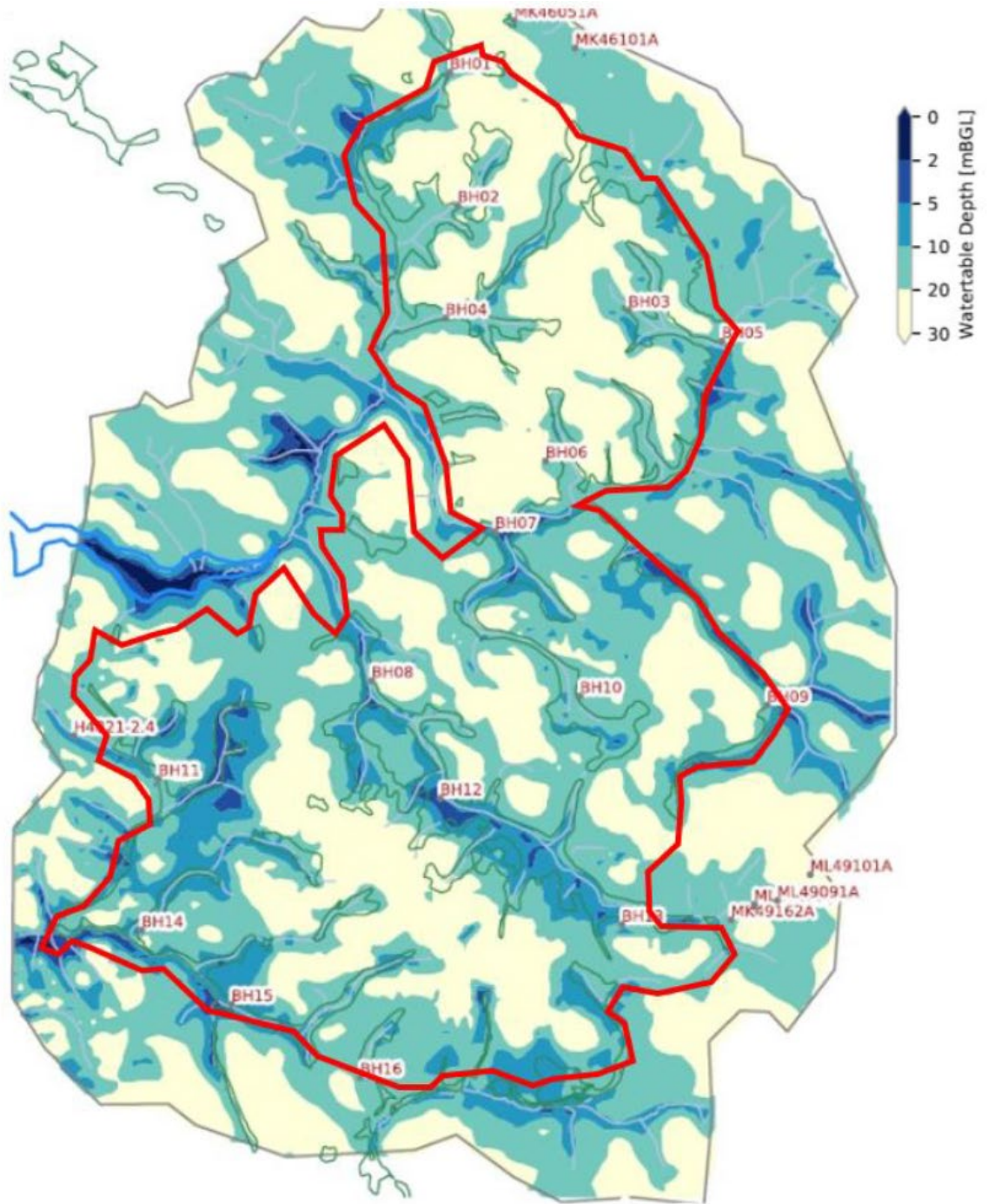


Figure 8-12 Modelled groundwater table depth for 2010-2021 (typical climatic periods) – Holyoake region (region boundary is representative of the region boundary at the time of commissioning the study)

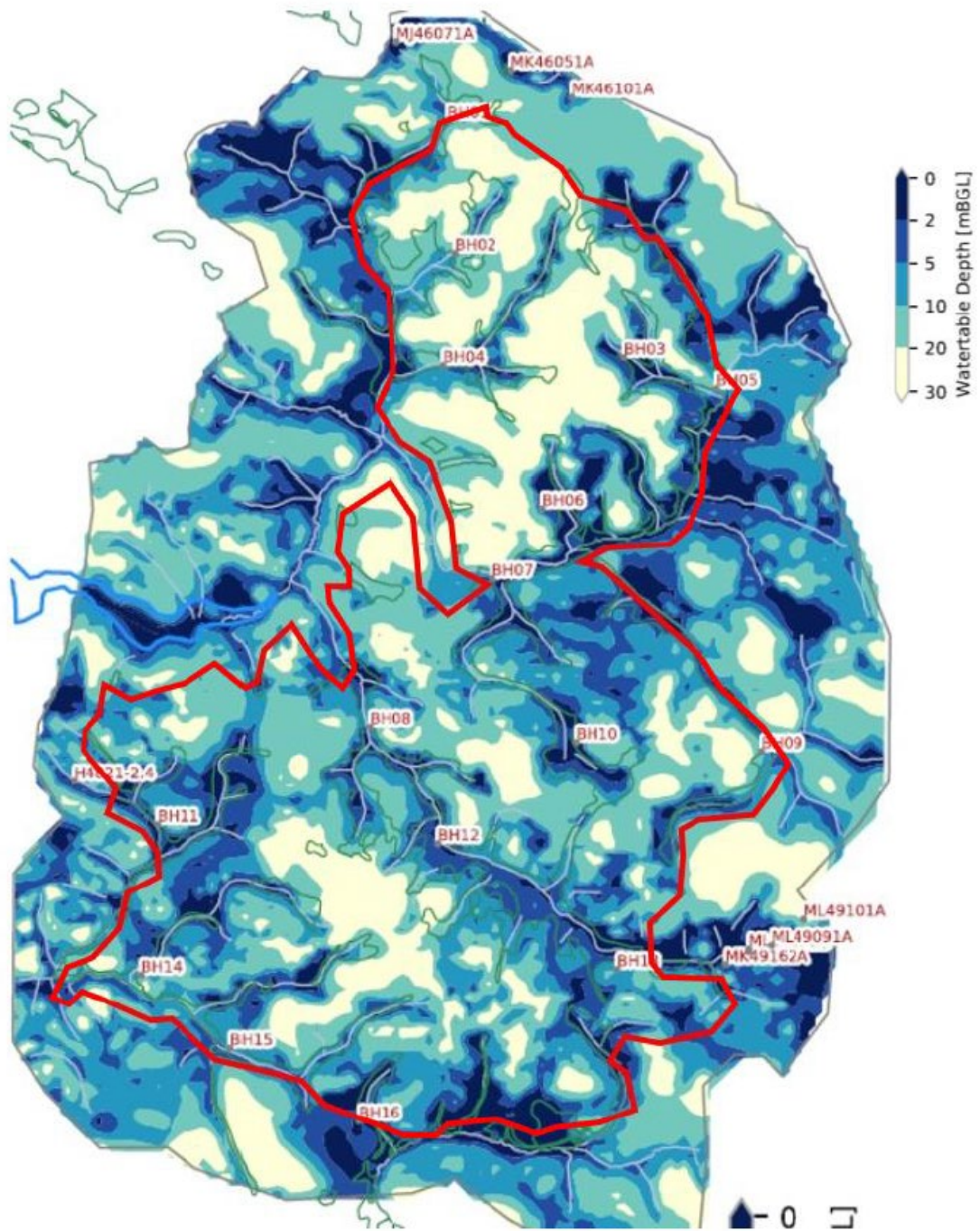


Figure 8-13 Modelled groundwater table depth for 2010-2021 (wet climatic periods) – Holyoake region (region boundary is representative of the region boundary at the time of commissioning the study)

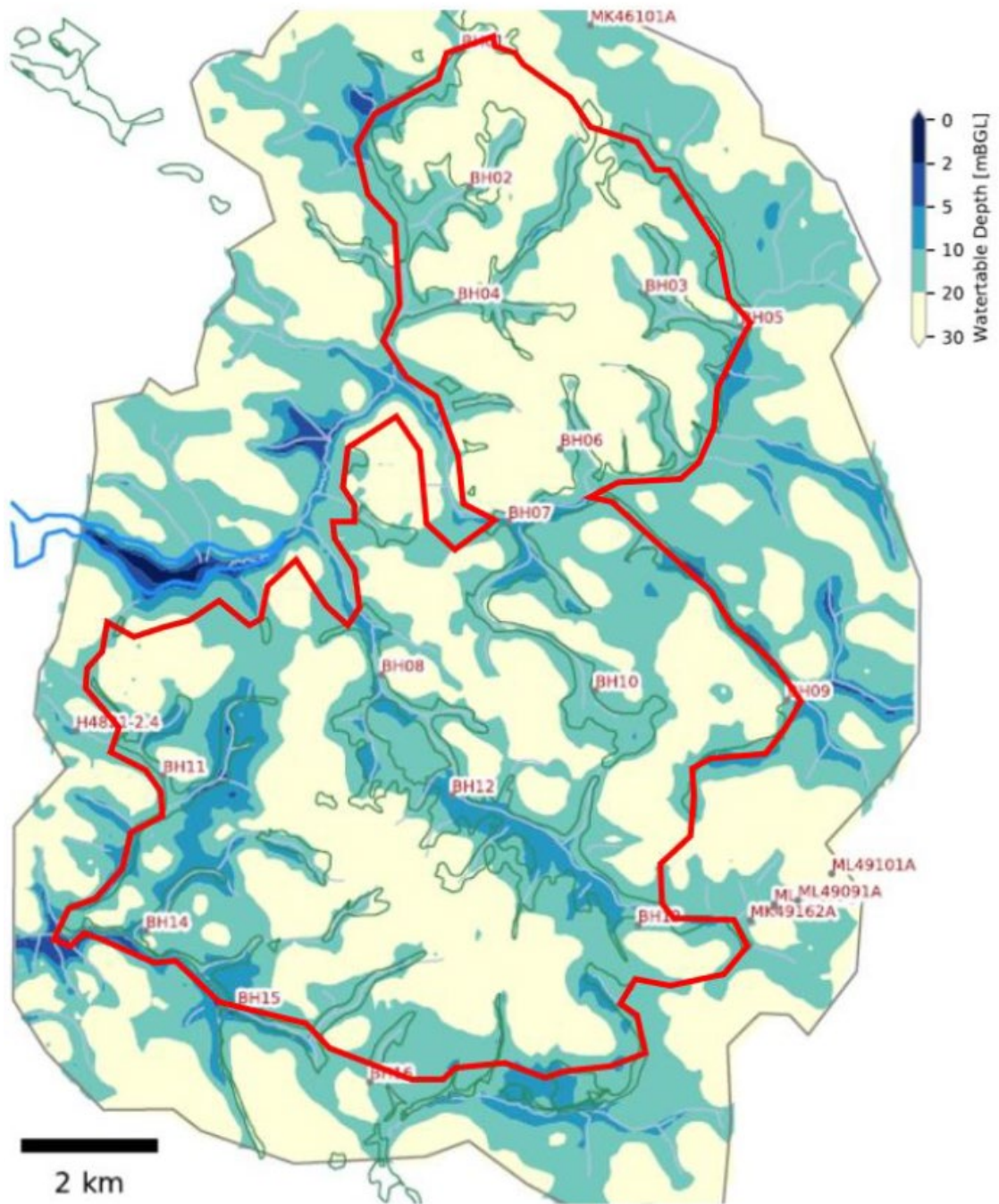


Figure 8-14 Modelled groundwater table depth for 2010-2021 (dry climatic periods) – Holyoake region (region boundary is representative of the region boundary at the time of commissioning the study)

O'Neil

GHD (2023a) details the local hydrogeology of the O'Neil DE. Hydrogeological information on the aquifer system units was confirmed from installation and hydraulic testing of groundwater monitoring bores by GHD at O'Neil. The drilling and testing program indicates the following generalised profile:

- Lateritic/ duricrust caprock: 0.5 to 4 m deep. The caprock comprises loose pisolitic soils underlain by superficial cemented duricrust or laterites (0.5 – 2 m thick). Some bores contained a transported sandy stiff clay (0.5 – 2 m thick) below the laterite.
- Saprolite: Highly variable depths from 4 to 30 m, comprising highly weathered clay. Generally, clay is mottled or pallid towards the top becoming greener with depth indicating transition to weathered bedrock noting saprolite transitions to saprock through development of chips of weathered basement (0.1 - 12m thick).
- Weathered zone: Weathered basement zone (which includes granitic saprock ranging 0.5-4m thick) noting saprock grading to weathered bedrock was not observed in eight bores.
- Fractured basement: Depth to fractured granite varies from 16 to 35 m BGL.
- Quartz veins, ranging in thickness between 0.5 – 2.5m, were intercepted in seven bores.

Slug tests (GHD 2024a) were conducted on nine of the GHD monitoring bores. The estimated hydraulic conductivity at the monitoring bores is within an expected range of the geology and ranged from between 0.0041 m/day to 0.42 m/day, with an average hydraulic conductivity of 0.12 m/day. The average hydraulic conductivity for the O'Neil bores is lower compared to those in the Myara North (0.6 m/day) and Holyoake (0.3 m/day) mine regions. The bore with the highest hydraulic conductivity is screened in the basement/highly weathered granite.

The 2023 – 2024 monitoring period (GHD 2024) indicate that groundwater is generally deep (>15 m BGL), with average depth to groundwater ranging between 1.1 m BGL and 24 m BGL. Seasonal variations in field dips from January 2024 to June 2024 were observed in all bores with a varying degree of change with the majority of water levels decreased during the monitoring period. Manual dips broadly indicate regional groundwater flows from the northeast to the southwest, which are generally consistent with topography.

8.3.3.3 Surface water-groundwater interaction

Surface water and groundwater are hydraulically connected in streams, swamps and downstream reservoirs. Surface water is seasonally or at least intermittently connected to both the regional (or in some instances perched) water table and the interflow vadose zone. This is supported by observations from streamflow monitoring, which demonstrates a correlation and concurrence of streamflow with elevated groundwater levels.

In summary, groundwater is expected to have been the major contributor to stream flows across much of the Northern Jarrah Forest, through direct inflow (baseflow) and indirectly through creating a variable source area in saturated valley floors that generates runoff from rainfall. As groundwater levels decline across the Northern Jarrah Forest, the contribution of groundwater (direct and indirect) to streamflow is expected to reduce as the areas of seasonally groundwater-connected valleys contract within the landscape. The substantially reduced streamflows in permanently disconnected streams are expected to be reliant on shallow throughflow contributions, as infiltration-excess overland flow makes very limited contributions over the permeable soils.

Streamflow contribution from groundwater

Groundwater has been demonstrated as the major contribution (direct and indirect) to streamflow generation, as detailed by Grigg & Kinal (2020), Grigg (2017), Kinal & Stoneman (2012) and Hughes *et al* (2012).

The hydrogeology of the Northern Jarrah Forest is characterised by two groundwater systems (Kinal & Stoneman 2012) (see Figure 8-15):

- an ephemeral perched aquifer that forms in winter and spring, typically within the sandy gravels that overlies the bauxite layers (duricrust and/or friable fragmental layer).
- lower aquifer in permanent groundwater which located within the middle to lower regolith overlying the bedrock.

Permanent groundwater that is sufficiently close to the soil surface may contribute to streamflow generation both directly by discharging into the stream and indirectly by contributing to the formation of variable source areas (Kinal & Stoneman 2012). Variable source areas are formed when perched or permanent groundwater tables intersect the valley floors and lower slopes (see Figure 8-15) and are considered the primary contributor to streamflow on the Darling Plateau, contributing both groundwater discharge (baseflow) and runoff of rainfall on the saturated (i.e. impervious) surface. The contribution of baseflow to streamflow is highly variable and depends on the connectivity of the stream to groundwater and potentially to regolith characteristics (e.g. preferential flow channels) (Grigg & Kinal 2020). Infiltration excess overland flow is a relatively small proportion of streamflow due to the high infiltration capacities of surface soils that are rarely exceeded by rainfall events (Kinal & Stoneman 2012).

As presented in Figure 8-15, streamflow typically occurs within Quaternary Deposits (alluvium or colluvium) that are formed in valleys eroded in the lateritic regolith, with bauxite layers (duricrust and friable / fragmental layer) typically absent in the valley floors and lower slopes. The groundwater table lies in the mid to lower regolith comprising lower permeability mottled clays transitioning to pallid clays, underlain by higher permeability saprock inferred at the base of the regolith. The mid to lower regolith contains a varying degree of macropores (e.g. deep root channels) and discontinuities that may act as preferential flow paths, thereby increasing the permeability of the regolith from that of the clayey matrix (Grigg & Kinal 2020). In areas where streams have more deeply eroded in the regolith, Quaternary Deposits may also occur over shallow bedrock and potentially connected to the saprock aquifer.

Shallow subsurface flow or 'throughflow' (also referred to as interflow) may occur where there is a perched aquifer that forms seasonally within the higher permeability sandy gravels overlying the bauxite layers in the upper regolith, and discharge where the perched aquifer meets the waterlogged valley floor and lower slopes due to the influence of the rising groundwater table in winter and spring. Where the stream is permanently disconnected from groundwater (as suggested to have occurred widely over the Northern Jarrah Forest since the 1990s, see below) then the groundwater table no longer rises to saturate the valley floors and accordingly the throughflow discharges directly into the Quaternary Deposits (Figure 8-16).

Streamflows are usually ephemeral, with perennial flow restricted to those catchments where groundwater remains connected through the summer dry period (Grigg & Kinal 2020). In areas of native forest with annual rainfall less than 1100 mm, groundwater is less extensive and is usually too deep below the valley floor to discharge directly to streams, in which streamflow consists entirely of surface runoff and shallow throughflow from the perched aquifer if present (Grigg & Kinal 2020).

LEGEND

- ← Surface runoff
- ← Overland flow (minor contribution)
- ← Throughflow
- ← Groundwater baseflow
- ↕ Infiltration/recharge
- Spring groundwater table

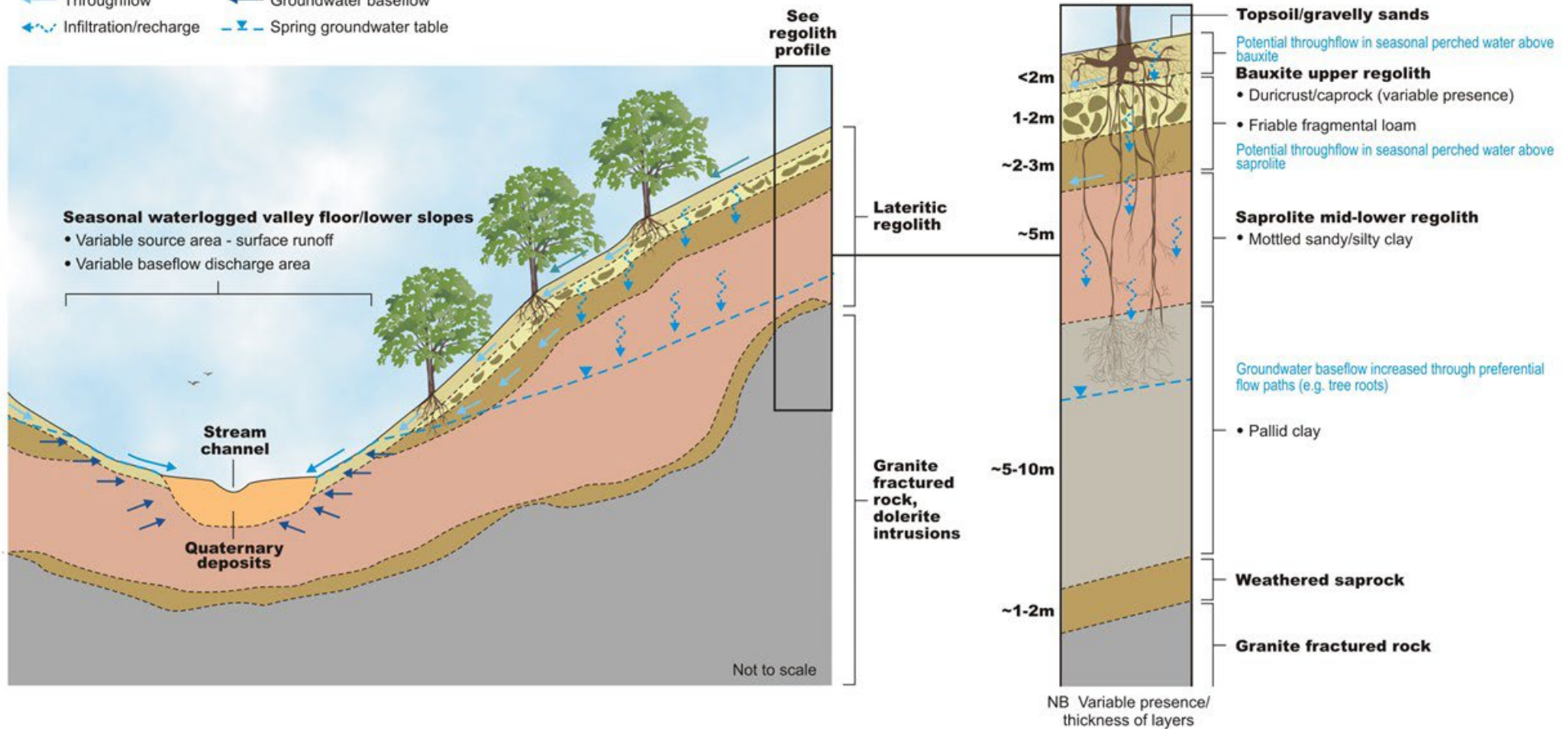


Figure 8-15 Streamflow generation processes in the Northern Jarrah Forest for a stream connected to groundwater

LEGEND

- Throughflow
- Spring groundwater table
- Infiltration/recharge
- Overland flow (minor contribution)

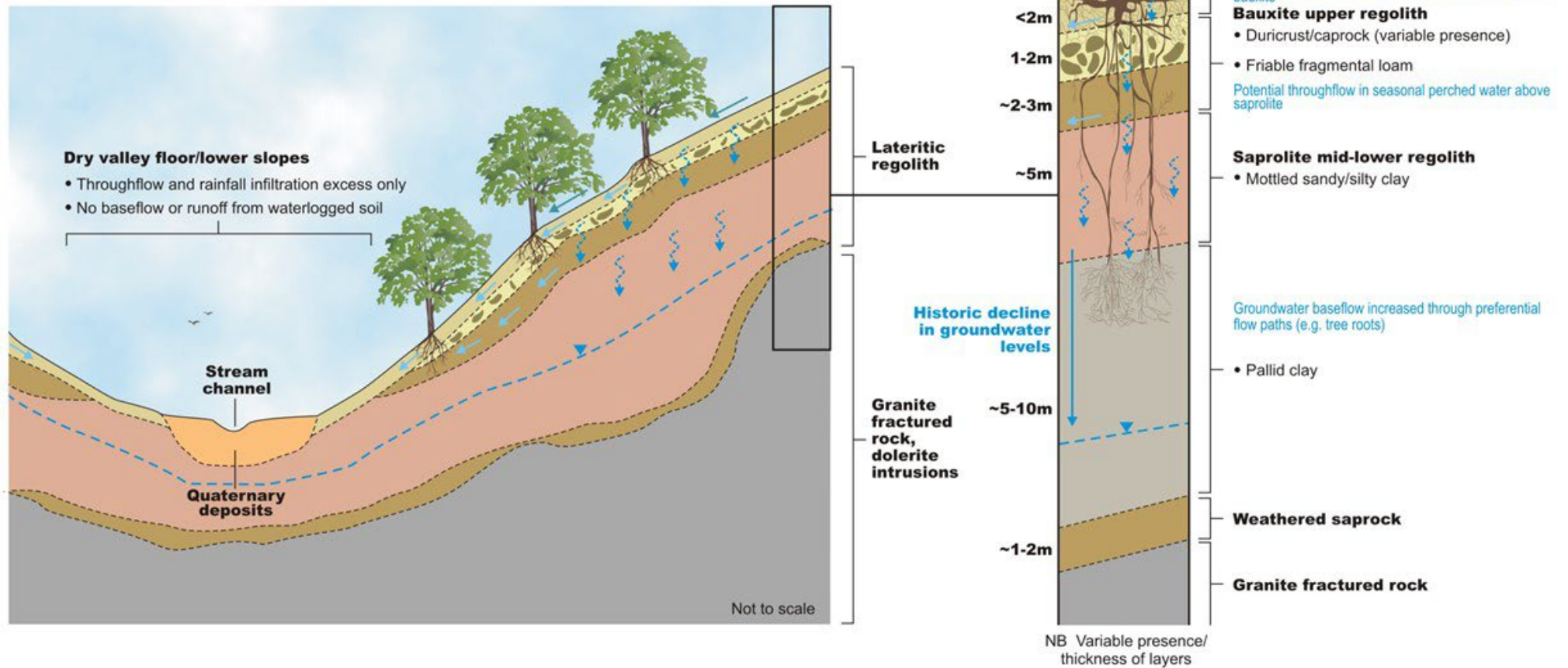


Figure 8-16 Streamflow generation processes in the Northern Jarrah Forest for a stream disconnected from groundwater

Contribution of throughflow versus variable source areas

Throughflow from the perched aquifer was previously considered to be the main source of streamflow following research in the 1970s and 1980s, with groundwater considered to be a minor source (Kinal & Stoneman 2012, Grigg & Kinal 2020). However, more recent observations of a step change reduction in stream flow with declining groundwater tables and subsequent studies have indicated that groundwater contributions (direct through baseflow and indirect through variable source area) are the predominant streamflow generating process where streams are at least seasonally connected to the groundwater table.

The step change reduction in stream flow was reported by Petrone et al (2010). From 1950–2008, trend tests showed significant declines in annual rainfall and runoff over the Northern Jarrah Forest, including inflows to public drinking water supply dams. The decline in stream flow was noted to be associated with declining rainfall in the late 1960s or mid-1970s, however in the more recent record (1989–2008) runoff declined whereas rainfall did not show a significant downward trend. Streamflow decline was observed as a step change, with a shift from perennial to ephemeral streams and a decline in the runoff coefficient (i.e. runoff divided by rainfall) suggesting a new hydrologic regime had developed (Petrone et al 2010).

Kinal & Stoneman (2012) suggested that the step change in stream hydrology in the Northern Jarrah Forest could be due to the hydraulic disconnection of streams with the groundwater table, and that the large disparity between the rates of decline in annual rainfall and inflow into drinking water reservoirs mostly reflects the aggregate loss of connectivity of streams across the reservoir catchments.

Kinal & Stoneman (2012) investigated the disproportionate decline in annual streamflow in a catchment in the Northern Jarrah Forest by examining records of annual streamflow, stream salinity and groundwater which progressively declined from 1976 to 2011. The study indicated that the streams were disconnected from the groundwater table around 2001, which precipitated a change in the annual stream salinity signature from moderately high and variable, to low and constant, and abrupt fall (by more than half) in the average runoff coefficient which remained relatively low and constant.

The results of Kinal & Stoneman (2012) indicated that the connection of the groundwater table to streams played a dominant role in streamflow generation, and confirmed earlier studies that groundwater was the major contributor to streamflow salinity. The results also suggested that throughflow in the shallow perched aquifer played a less important role in streamflow generation, as the substantial loss in runoff coefficient occurred following disconnection from the groundwater table (i.e. loss of the variable source area derived runoff and loss of baseflow), with throughflow continuing to occur through the seasonal perched aquifer in the upper regolith (see Figure 8-16) and thus contributing the residual runoff coefficient following stream disconnection. The contribution of throughflow to streamflow is dependent on the presence of a seasonal perched aquifer in the upper regolith, which in turn is dependent on the extent and rate of rainfall versus the infiltrative loss into the deeper regolith, which is relatively independent of the decline of the deeper groundwater table.

Contribution of groundwater baseflow

Grigg & Kinal (2020) conducted chemical hydrograph separation approach to estimate annual groundwater discharge for three catchments over periods of up to 39 years and found that groundwater baseflow contributions to streamflow were far more variable across catchments and through time than indicated by previous studies. The estimated proportion of annual streamflow sourced directly from groundwater ranged from zero to 93 per cent and was related linearly to the size of the groundwater saturated area in catchment valley floors. In contrast, contributions from shallow sources (throughflow and runoff in variable source areas) varied

primarily and linearly with annual rainfall, amplified by the size of the saturated area in the valley floors. The findings fell within the range of earlier, short term (e.g. single year) studies in the 1980s that analysed short term catchment responses and estimated baseflow contributions ranging from five to 40 per cent.

Grigg & Kinal (2020) noted that the presence of preferential flow pathways in the regolith may act to increase groundwater baseflow into streams to a much greater extent than would be expected in the predominantly clayey matrix.

Myara North

Stream gauges within the Myara North DE confirm that surface water flows are relatively short-lived following winter rains, ceasing to flow within two to three weeks following peak streamflow. This indicates the influence of surface runoff from variable source areas in waterlogged valleys and throughflow in the sandy gravels of the upper regolith.

Groundwater baseflow occurs at smaller rates over the winter and spring period, extending for weeks or months following winter and spring rains and when groundwater table levels are highest. Analysis of stream gauging data for Myara North indicates that baseflow comprises approximately 40 to 80 per cent of streamflow, depending on the location and the analytical method (GHD 2023a).

Given the shallow depth to groundwater in areas beneath vegetation types associated with potential GDEs and wetlands, the regional groundwater may continue to support the potential GDEs and wetlands, particularly during the summer months in absence of surface water flows. As long as groundwater within the topographical slopes surrounding the drainage lines or creeks do not considerably fall below the creek level (which would lead to hydraulic disconnection), or the flow gradient reduces such that the incoming flow is completely removed by riparian evapotranspiration, groundwater continues to exfiltrate to the creek or supporting sufficiently shallow water table in the riparian zone accessible for the support of vegetation communities.

Surface-groundwater interactions – Holyoake

Despite the lack of observational data within the Holyoake DE, the nature of and the processes involved in surface water and groundwater connectivity are expected to be comparable to Myara North DE. However, groundwater in Holyoake DE is deeper than in Myara North DE. More limited access to the groundwater table reduces the likely occurrence of GDEs and would also limit their lateral extent. This is supported by the lower proportion of vegetation types associated with GDEs mapped over the Holyoake DE, comprising 17 per cent of the DE compared to 28 per cent of the Myara North DE.

Due to the deeper groundwater levels, surface flows are also likely to be smaller and flow events shorter than in Myara North DE, since less baseflow and variable source areas would be available and streamflow reliant on throughflow and infiltration excess overland flow. This is supported by baseline surface water monitoring completed in 2020. It is however possible that during the historical period before the last two decades the groundwater levels in Holyoake DE were shallower and surface flows greater than observed in 2020.

Surface-groundwater interactions – O’Neil

Long-term observations of streamflow and groundwater level observations from the O’Neil mine DE are not available. Despite the lack of historic observational data within the O’Neil mine DE, the nature of and the processes involved in surface water and groundwater connectivity are expected to be comparable to those described for Myara North and Holyoake mine regions. This is considered a precautionary approach in the absence of comprehensive baseline information for this mine DE.

8.3.3.4 Groundwater quality

The Hydrology and Water Quality Assessment (GHD 2023a, Appendix B8) details historic and baseline groundwater quality in the Mine DE. A summary is provided below.

Myara North

Groundwater quality within the Myara North DE is typically fresh, with an average salinity of around 450 mg/L though some variability with isolated bores having salinities around 2,000 mg/L (see Figure 8-17). Unlike the widespread decline in groundwater levels, historic monitoring data does not indicate a site-wide trend for groundwater salinity, which may be partly due to the more limited salinity data available over the last decade.

Within the limited spatial extent of the historical data, there does not appear to be a relationship between bore salinity and location, with salinity ranges within each catchment being as variable as those between catchments. This may be partly explained by fewer salinity observations available for the last decade.

GHD (2023a) undertook baseline groundwater monitoring at 25 sites within the Myara North DE for up to seven sampling rounds between September 2020 and February 2023. The results indicate that groundwater is similar across the Myara North DE, being fresh and relatively un-impacted by anthropogenic use, with key parameters as follows:

- consistently fresh (< 500 mg/L TDS) for the majority of bores and sampling rounds
- average maximum salinity per bore is 474 mg/L, compared to an average minimum salinity per bore of 260 mg/L TDS
- pH is relatively consistent, averaging 5.3 with an average variation of less than 0.5
- sampling for other parameters showed no discernible seasonal change in quality
- low nutrient levels; typical for the land-use, suggesting lack of applied nutrients or sources
- dissolved metal concentrations typical of natural conditions and representative of the geological setting
- low concentrations of PFAS detected in four bores, all of which were significantly below drinking water assessment criteria
- minor detection of TRH and PAH, with concentrations reducing in the second sampling round, possibly indicating that drilling was the source or low levels associated with bush fires
- BTEX and explosives at less than laboratory limits of reporting.

Holyoake

Groundwater quality within the Holyoake DE is typically fresh, with an average salinity of around 400 mg/L (see Figure 8-17). The limited historic data available suggests a slight rise in salinity concurrent with the decline in groundwater levels, though it may also fall within seasonal variations (lack of seasonal data). There is a relatively large range in salinities measured in the 1990s with TDS data in the range of 150 mg/L to 2000 mg/L (average of 850 mg/L).

GHD (2023a) undertook baseline groundwater monitoring at 21 sites within the Holyoake DE for up to four sampling rounds over October 2020 and February 2023. The results indicate that groundwater is similar across the Holyoake DE, being fresh and relatively un-impacted by anthropogenic use, with key parameters as follows:

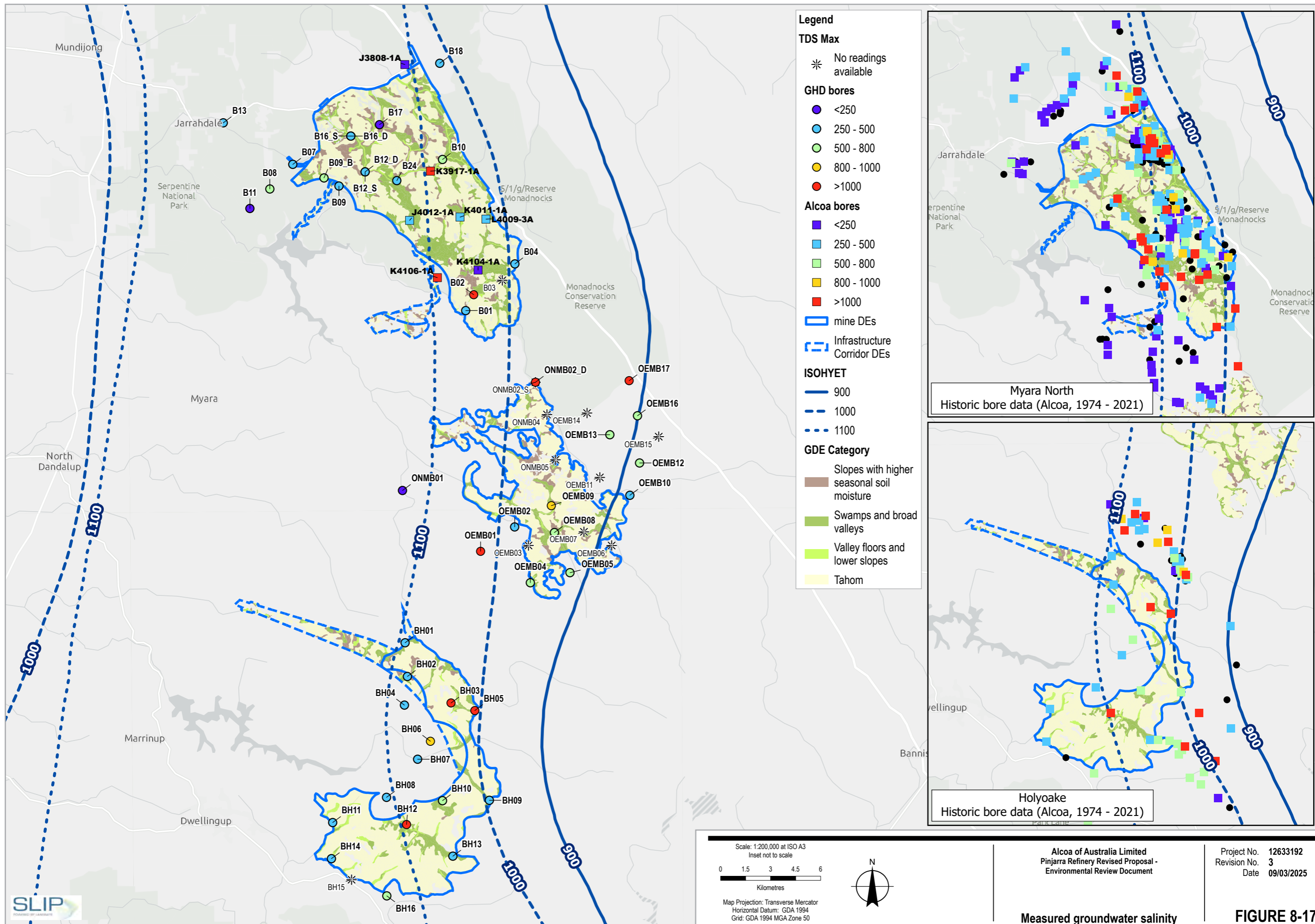
- consistently fresh (< 500 mg/L TDS) for the majority of bores and sampling rounds
- average salinity across bores of 400 mg/L TDS, except for three bores that had salinity of 1000 to 1500 mg/L
- pH is relatively consistent, averaging 6.5 with an average variation of less than 0.5

- sampling for other parameters showed no discernible seasonal change in quality
- low nutrient levels, albeit marginally higher than in Myara North
- metal concentrations marginally higher than Myara north but still typical of natural conditions and representative of the geological setting
- low concentrations of PFAS detected in five bores, all of which were below drinking water assessment criteria
- low concentrations of TRH in five bores suggest potential cross-contamination from sampling sources
- low concentrations of PAH (pyrene) were detected in most bores, with concentrations reducing in the second sampling round, possibly indicating that drilling was the source, or the low levels are associated with bush fires
- BTEX and explosives at less than laboratory limits of reporting.

O'Neil

Groundwater physical parameters were collected for the GHD monitoring wells in April 2024 and June 2024 monitoring rounds. Groundwater ranges from fresh to brackish with an average EC of 1,910 $\mu\text{S}/\text{cm}$, ranging from 248 $\mu\text{S}/\text{cm}$ (average DTW; 4.56 m BGL) to 5,450 $\mu\text{S}/\text{cm}$ in (average DTW; 24 m BGL). Both bores are located on the western boundary of the O'Neil DE approximately 6 km apart (see Figure 8-17).

Similar to Myara North and Holyoake, the results showed low nutrient levels consistent with the land-use type (i.e. lack of applied nutrients or sources). Metal concentrations were typical of 'natural' conditions and representative of the geological setting, with ANZG exceedances reported for zinc and cadmium in limited samples. No concentrations of BTEX or PFAS were detected. TRH and PAH concentrations were noted across the same four bores. No microbiological testing was undertaken as part of the monitoring program.



Measured groundwater salinity

FIGURE 8-17

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Date 09/03/2025

Data source: Light Gray Base: Esri, TomTom, Garmin, Foursquare, METINASA, USGS
World Topographic Map: Esri, TomTom, Garmin, Foursquare, METINASA, USGS
Light Gray Reference: Esri, TomTom, Garmin, Foursquare, METINASA, USGS



8.3.3.5 Groundwater users

There are no licensed groundwater users within the Mine DE. Groundwater contributes yield to surface waters including reservoirs and downstream rivers, which have beneficial uses as detailed in Section 8.3.2.5.

8.3.3.6 Groundwater dependent ecosystems

Potential groundwater-dependent ecosystems (GDEs) present within the Mine DE include:

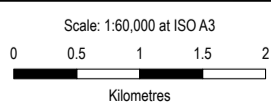
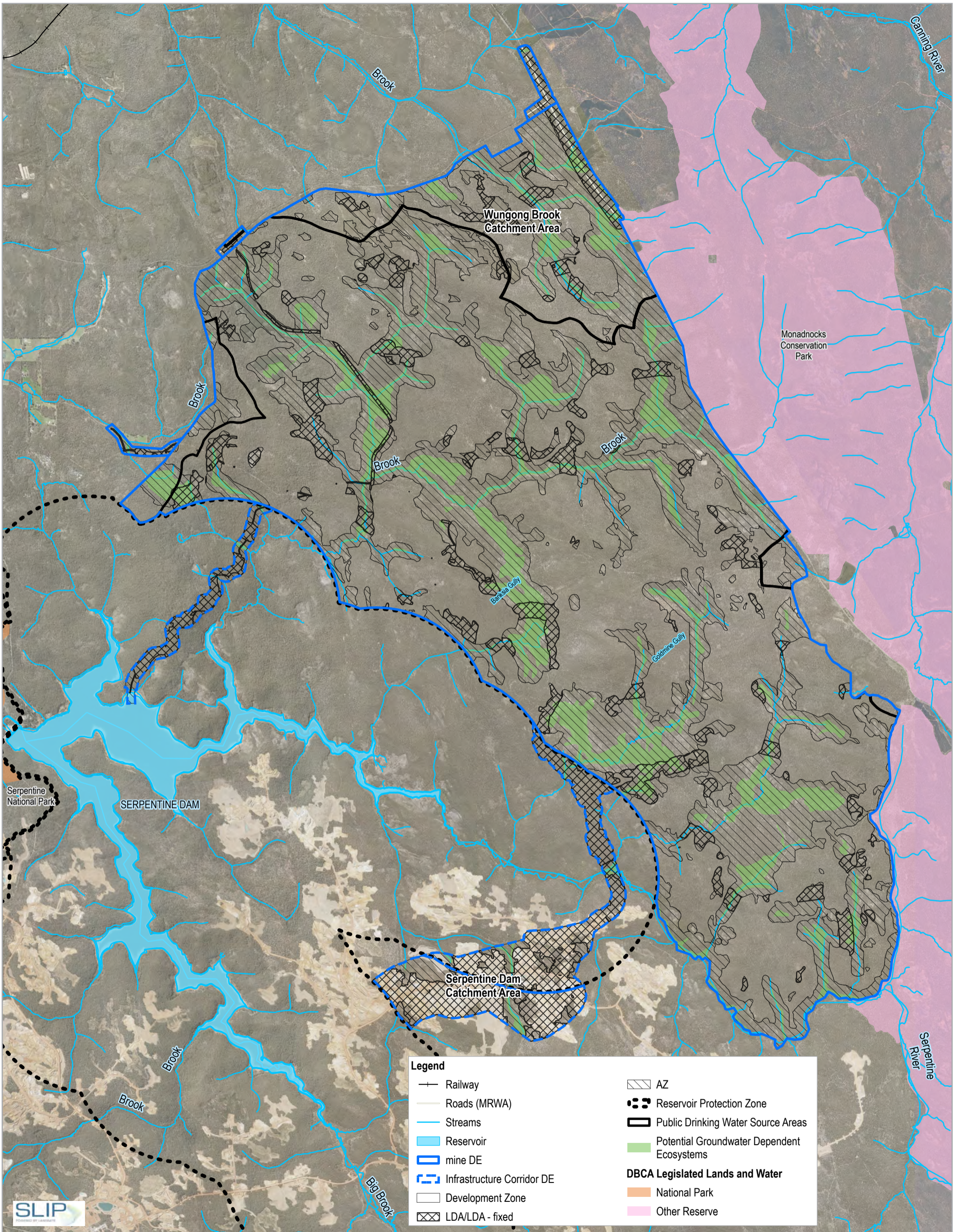
- Riparian, swamp and lower slope vegetation subject to seasonal inundation and/or waterlogging
- Seasonal aquatic ecosystems
- Seasonally saturated sediments in valley floors (hyporheic zone)

Potential GDEs are mapped in Figure 8-18, Figure 8-19, and Figure 8-20, and detailed under the Flora and Vegetation factor in Section 5.3.4.6. The potential GDEs are based on vegetation types (VTs) and key flora indicator species that prefer and occur on seasonally moister and wetter soils on the swamps, valley floors and lower slopes. The GDEs include riparian, swamp and lower slope vegetation, being those with A, C, D, W and Y dominant type types, as well as upland vegetation subject to seasonal higher moisture (PW, SW) that may be a result of localised perching over lower permeability regolith. As presented in Section 5.3.4.6, potential GDEs are mapped over a total of 6,238 ha (26.1 per cent) of the Mine DE, including 3,485 ha (32.6 per cent) of the Myara North DE, 1,480 ha (19.4 per cent) of the Holyoake DE and 1,281 ha (23.0 per cent) of the O'Neil DE. Of the 6,238 ha of mapped GDEs, the majority (4,905 ha or 78.6 per cent) lie within the proposed Avoidance Zone (AZ) and the remaining 1,340 ha (21.4 per cent) lie within the proposed Low Disturbance Areas (LDAs).

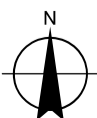
There is a lack of groundwater monitoring data for the potential GDEs mapped within the Mine DE and there is potential for local variability in hydrogeological conditions between the areas. This includes the seasonal and inter-annual depth of the groundwater table within the surrounding weathered rocks, the presence of low permeability strata (e.g. deposited silt and clay) and the duration of saturation in the alluvial/colluvial sediments as the surrounding groundwater table recedes.

Groundwater modelling indicates that potential GDEs are typically located in areas of relatively shallow groundwater depth (less than 10 mbgl) however average groundwater depths are typically greater than 5 mbgl, suggesting that the groundwater table seasonally recedes to below the level of stream and swamp sediments. This indicates that, in the absence of perched water on low permeability strata, stream and swamp sediments within the Mine DE may become unsaturated on a seasonal basis. Stream and swamp vegetation may therefore utilise soil moisture in the unsaturated sediments during the late summer or autumn, suggesting that groundwater-dependent vegetation if present comprises facultative rather than obligate phreatophytes.

Seasonal aquatic ecosystems are discussed in Section 8.3.2.6.



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



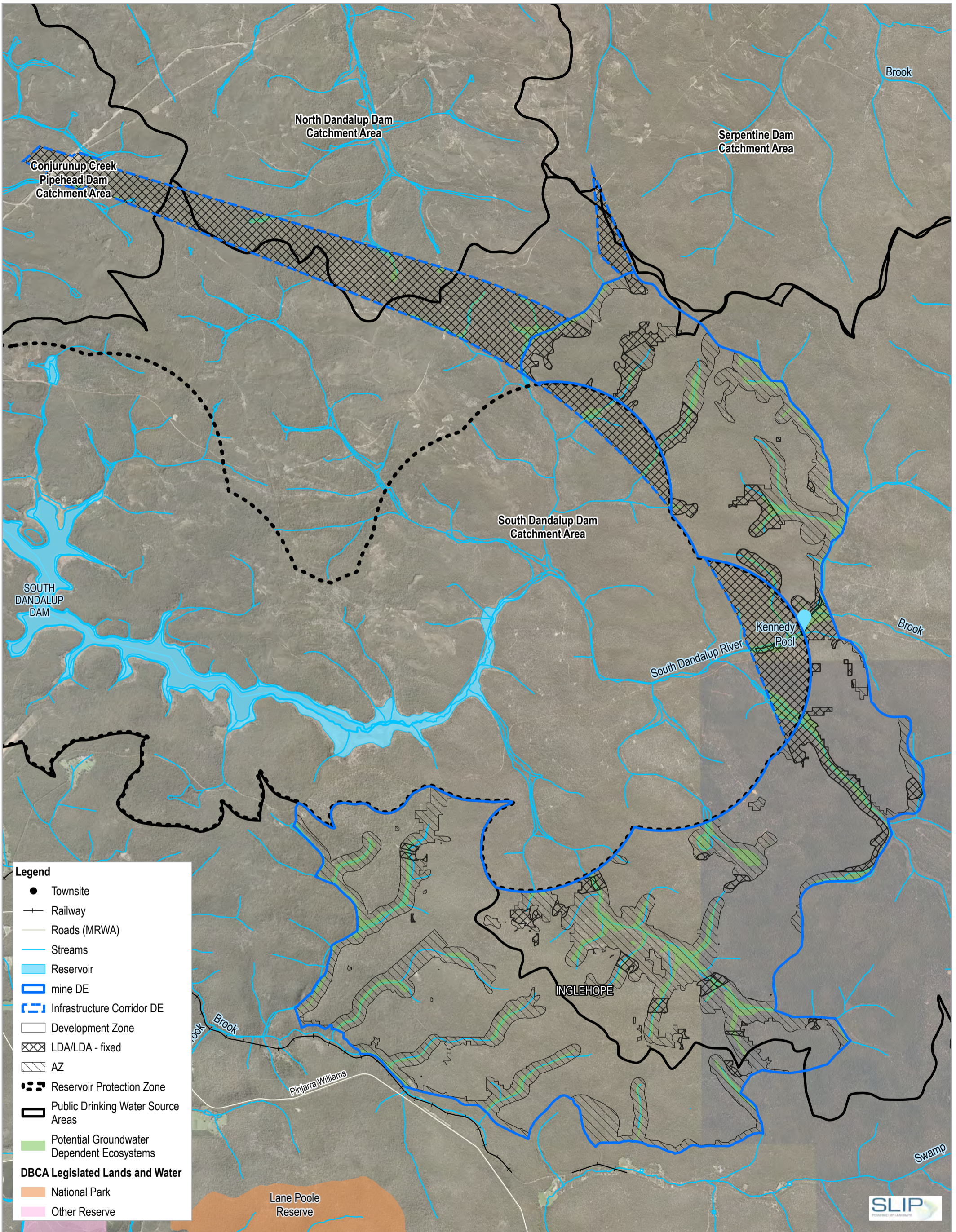
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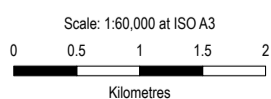
**Inland Waters Receptors-
 Myara North**

FIGURE 8-18

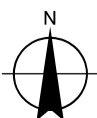
Data source: WAnow; Landgate / SLIP.



- Legend**
- Townsite
 - +— Railway
 - Roads (MRWA)
 - Streams
 - Reservoir
 - mine DE
 - Infrastructure Corridor DE
 - Development Zone
 - ▨ LDA/LDA - fixed
 - ▧ AZ
 - ⊖ Reservoir Protection Zone
 - ⊖ Public Drinking Water Source Areas
 - ▭ Potential Groundwater Dependent Ecosystems
 - DBCA Legislated Lands and Water**
 - ▭ National Park
 - ▭ Other Reserve



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



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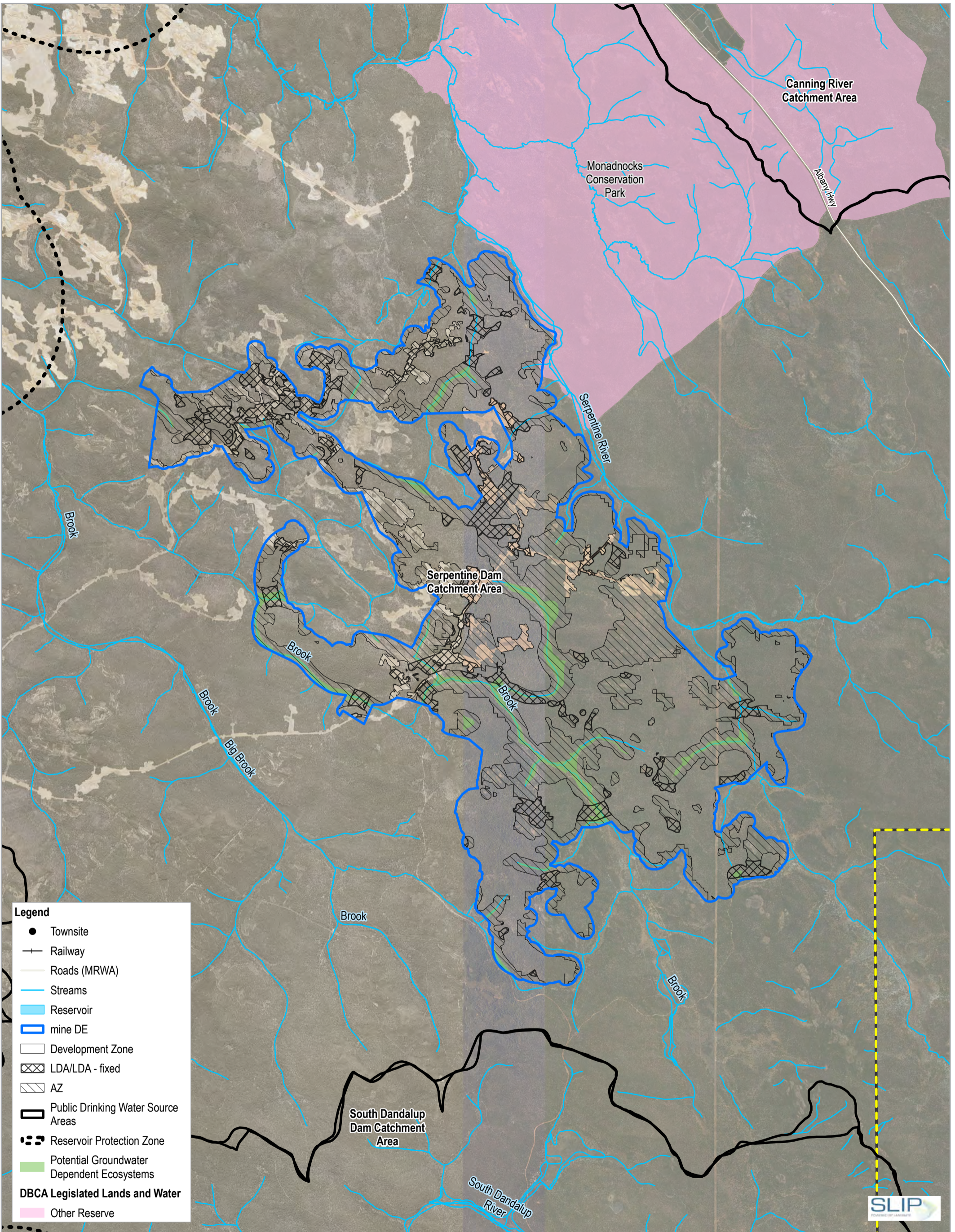
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**Inland Waters Receptors -
 Holyoake**

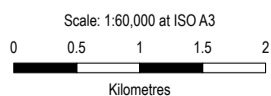
FIGURE 8-19

Data source: WAnow; Landgate / SLIP

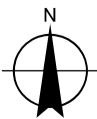




- Legend**
- Townsite
 - +— Railway
 - Roads (MRWA)
 - Streams
 - Reservoir
 - mine DE
 - Development Zone
 - ▣ LDA/LDA - fixed
 - ▣ AZ
 - Public Drinking Water Source Areas
 - ▣ Reservoir Protection Zone
 - ▣ Potential Groundwater Dependent Ecosystems
 - DBCA Legislated Lands and Water**
 - ▣ Other Reserve



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50



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**Inland Waters Receptors -
 O'Neil**

FIGURE 8-20

Data source: WAnow; Landgate / SLIP.



8.4 Assessment of potential impacts

8.4.1 Identification of potential impacts

The following Proposal activities have the potential to impact inland waters:

- Clearing of native vegetation
- Alteration of natural drainage regimes
- Water use for construction, mining and refining activities
- Waste disposal
- Storage and handling of contaminants
- Closure and decommissioning
- Mining activities within PDWSAs
- Human and mining presence within the RPZs
- Application of chemicals (fertilisers and pesticides) within PDWSAs
- Alteration of hydrological regimes.

The Proposal may result in the following potential impacts to inland waters:

- Changes in groundwater level and streamflow as a result of clearing and mining
- Increases in stream salinity as a result of mining-induced saline groundwater discharge
- Increased water supply for alumina refining
- Increased sediment from erosion of post-mining landforms
- Contamination from spills and/or leaks from storage and handling of hazardous materials and waste
- Potential impacts to public health
- Potential for service interruption of the public drinking water supply
- Water quality deterioration in streams and reservoirs (for example, turbidity, salinity, pathogens, hydrocarbons, PFAS, nutrients, pesticides), including cumulative impacts from existing mining operations / increased human activity
- Potential disturbance to the downstream Peel-Yalgorup System Ramsar site through potential changes to water quality and changes to the hydrological regime of the region upstream.

8.4.2 Overview of Huntly Mine disturbance to catchments

Table 8.8 presents indicative estimates of disturbance to surface water catchments due to the transition of the Huntly Mine into the Myara North and Holyoake mine regions and re-entry to the O'Neil mine region. Estimates are based on the following:

- GIS mapping of mine disturbance to 2023 (historic disturbance)
- Total 7,500 ha disturbance under the Proposal (Myara North, Holyoake and O'Neil DEs), distributed to catchments based on the proportion of mine regions in each catchment
- Disturbance proposed under other approvals granted to Alcoa (MMP and EPA assessments 2384/2385), outside of the scope of the Proposal.

As presented, disturbance from the Proposal is expected to predominantly occur in the Serpentine Dam and South Dandalup Dam catchments, and to a lesser extent in the Upper Wungong Brook, North Dandalup, Serpentine River (Gooralong Brook) and Murray River (Davis Brook, Swamp Oak Brook) catchments.

An analysis of clearing at a subcatchment scale is presented in Section 8.4.9.3.

Table 8.8 Indicative estimates of mining disturbance to surface water catchments due to the Huntly Mine transition to Myara North, Holyoake and O'Neil mine regions

Catchment	Catchment area (ha)	Historic disturbance at end of 2023 (ha)	Rehabilitation at end of 2023 (ha)	Area open at end of 2023 (ha)	Indicative disturbance from Proposal (2026-2044) (ha)	Indicative future disturbance under other Alcoa approvals (2024-2044) (ha)	Total disturbance at end of 2044 (ha)	Total disturbance at end of 2044 as a proportion of catchment area (%)
Regulated catchments								
Serpentine Dam	66,423	6,972	4,015	2,958	3,919	2,367	13,259	20.0
South Dandalup Dam	31,327	2,159	2,159	~ 0	2,124	17	4,300	13.7
North Dandalup Pipehead Dam	15,155	4,457	3,908	549	227	255	4,939	32.6
Conjurunup Creek Pipehead Dam	3,920	1,653	1,622	31	102	7	1,762	45.0
Wungong Brook	12,845	2,507	2,507	~ 0	297	-	2,804	21.8
Canning Dam	72,823	35	35	~ 0	30	-	65	0.1
Regulated catchment subtotal	202,493	17,783	14,246	3,538	6,699	2,646	27,129	13.4
Un-regulated catchments								
Davis Brook	6,569	-	-	-	560	-	560	8.5
Swamp Oak Brook	7,101	-	-	-	195	-	195	2.7
Gooralong Brook	5,155	849	849	~ 0	53	0	902	17.5
Un-regulated catchment subtotal	18,825	849	849	~ 0	808	0	1,657	8.8%
Total		18,632	15,095	3,538	7,500	2,646	28,786	

8.4.3 Groundwater level and streamflow change as a result of clearing and mining

8.4.3.1 Previous studies of mining effects on streamflow

Grigg (2017) studied three catchments in the Northern Jarrah Forest for streamflow, rainfall, groundwater and leaf area index (LAI) over a 36 year period. One catchment was subject to mining, the second subject to intensive forest thinning treatment and a third was an untreated control.

The study indicated that mining caused a peak streamflow response of 225 mm or 18 per cent of rainfall, before returning to pre-disturbance levels 11 years after mining commenced. Streamflow changes were closely associated with changes in a groundwater discharge area in the valley floor. Changes in groundwater level, in turn, were related to rainfall and LAI, and these effects did not differ between mine rehabilitation and unmined catchment areas (Grigg 2017).

The streamflow response to mining could not be distinguished from the intensive thinning treatment in the study, or from clearfelling or clearing for agriculture reported elsewhere in the jarrah forest. The study concluded that shallow subsurface flow processes, considered to dominate streamflow generation in jarrah forest catchments, do not extend beyond the valley floor and immediately adjacent slopes which were not disturbed by mining (Grigg 2017).

It is noted that the three catchments studied by Grigg (2017) were in the high rainfall zone on the western extent of the Darling Plateau. The results of studies for more eastern catchments in upper catchments of the Serpentine and South Dandalup rivers, within the intermediate rainfall zone (IRZ) (see Section 8.4.4.1) indicated an almost complete absence of response to mining in streamflow (Croton et al 2011). These studies concluded that the lack of response was due to the decline in groundwater levels in the regolith and that the groundwater rise from mining was insufficient to cause groundwater discharge into streams (Croton et al 2011). Similar findings were reported for other catchments in the IRZ that were subject to forest thinning experiments over a comparable period (Kinal and Stoneman 2011).

The effect of mining on streamflow is therefore expected to be highly dependent on the groundwater levels present within individual catchments and the effects of climate change in the future. Mining is expected to have a more noticeable effect on streamflow in catchments in the high rainfall zone near the Darling Scarp and less so for catchments in the eastern IRZ. As groundwater levels are expected to continue to decline across the Northern Jarrah Forest with declining rainfall, the effects of mining in the Huntly Mine and Willowdale Mine are expected to be less pronounced, as temporary rising groundwater levels from mining will have less effect on an increasing extent of permanently disconnected streams.

Dixon et al (2019) investigated the effects of mining and rehabilitation in the Serpentine Dam catchment for DWER, using the LUCICAT catchment hydrology model. Dixon et al (2019) modelled a 'no-mining' scenario and two scenarios of mining at nine and 12 per cent of the catchment, under two climate scenarios of average rainfall (914 mm/year) and low rainfall (841 mm/year). Projected inflows to Serpentine Reservoir were divided into two periods 2011–2030 and 2031–2050. The first period was characterised by mining and rehabilitation activities taking place concurrently, while in the second period there was no further clearing for mining, and rehabilitated vegetation on all previously mined areas was in various stages of regrowth. The modelled results for streamflow yield into the reservoir are summarised in Table 8.9 and indicate that streamflow yield is expected to increase during mining then decrease during rehabilitation, by up to five per cent compared to the non-mining scenario. Climate change is predicted to have a greater effect, with a low rainfall reducing inflow by 11 to 14 per cent compared to an average rainfall.

The total disturbance within the PDWSA as of 2024, including historic clearing, the Proposal and clearing under other approvals is estimated at 20.0 per cent (see Section 8.4.11). This exceeds the 12 per cent catchment clearing modelled by Dixon et al (2019) for the Serpentine Dam and therefore could potentially result in an increased variation in streamflows from that presented in Table 8.9. The variation in streamflows (increase during mining and decrease post-rehabilitation) may be up to ten per cent compared to no mining. As noted above, the effects of mining on streamflows are expected to be strongly dependent on the groundwater levels in individual catchments, declining in influence with deeper groundwater levels and with lower rainfall catchments such as in the IRZ.

Table 8.9 Modelled effect of mining on streamflow yield into Serpentine Dam (Dixon et al 2019)

Scenario	Average inflow 2011-2030 (GL)	Average inflow 2031-2050 (GL)	Difference 2011-2030 GL (%)	Difference 2031-2050 GL (%)
Unmined – average rainfall	28.9	28.0	-	-
Unmined – low rainfall	24.9	24.9	-4 (-14)	-3.1 (-11)
Mined 8 per cent – average rainfall	30.0	26.6	+1.1 (4)	-1.4 (-5)
Mined 8 per cent – low rainfall	25.8	23.7	+0.9 (4)	-1.2 (-5)
Mined 12 per cent – average rainfall	29.7	26.9	+0.8 (3)	-1.1 (-4)
Mined 12 per cent – low rainfall	25.6	23.9	+0.7 (3)	-1.0 (-4)

8.4.3.2 Studies conducted for the Proposal – Groundwater numerical modelling

GHD (2023a) conducted a Hydrology and Water Quality Assessment for the mine components of the Proposal, including groundwater modelling for the Myara North and Holyoake mine regions to estimate changes in groundwater and surface water. Modelling accounted for key factors such as groundwater flow and near-surface flow processes, as well as surface water-groundwater interactions and the anticipated changes in streamflow salinity resulting from the proposed bauxite mining in both mine regions.

The objective of modelling was to predict the potential nature, range, and magnitude of groundwater level and streamflow effects from activities related to bauxite mining, including clearing of forested land, surface stripping during mining, followed by rehabilitation and revegetation of the forest, in the proposed Myara North and Holyoake mine regions. These effects are further translated to:

- Potential effects on total dissolved solids (TDS) of inflows to streams, and ultimately the Serpentine and South Dandalup reservoirs, which are used for public water supply (see Section 8.4.4).
- Potential risks to flora and vegetation including potential GDEs from groundwater level change (see Section 5.4.3.6).

The groundwater modelling covered a simulation period of 40 years for Myara North from 2021 to 2060, with clearing and mining simulated over 2022 to 2030 and rehabilitation completed by 2033, with a post-rehabilitation period from 2034 to 2060. The groundwater modelling covered a

simulation period of 2029 to 2068 for Holyoake, with clearing and mining simulated over 2029 to 2034 and rehabilitation completed by 2037, with a post-rehabilitation period from 2038 to 2068.

The Hydrology and Water Quality Assessment is presented in Appendix B8, a summary is provided below.

8.4.3.3 Altered hydrological regime – groundwater changes

Within both mine regions, the modelling indicates that changes in recharge and surface flow dynamics due to bauxite mining have the potential to raise the groundwater levels in mined areas by several metres. Predicted change in groundwater levels is noted to follow seasonal variation.

Within the Myara North mine region, groundwater level mounding during the clearing and mining period has the potential to increase groundwater levels by several metres, with more than 10 m rises immediately below cleared and mined areas in some instances compared to unmined conditions. This aligns well with historical observations of groundwater level changes around other mined areas. For instance, a rise of 12 m was observed near a cleared area south of the Myara North mining region. If bores located farther away from the cleared areas show water level increases of this magnitude, the groundwater rise directly underneath the cleared areas is likely to be even more pronounced. Within the Holyoake mine region, groundwater level mounding during the clearing and mining period has the potential to temporarily raise groundwater levels by several metres, with more than 10 m rises below cleared and mined areas compared to unmined conditions.

Groundwater levels in and around cleared and mined areas rise over the first 15 years. The climate change model, that considers a step decrease in recharge and runoff by 30 per cent shows groundwater levels to be projected deeper but with similar mounding effects. In locations close to mining, mining essentially offsets and delays climate related groundwater level declines.

Within both mine regions the extent of mounding is predicted to be generally localised to cleared and mined areas. The magnitude of mounding decreases towards lower slopes and valley floors where potential GDEs are located. Mounding within most of the vegetation types associated with potential GDEs is predicted to be less than one metre, however in some localised areas, groundwater rise during mining may be up to five metres.

The groundwater level mounding effects in the Myara North and the Holyoake mine regions recede over the post-mining rehabilitation period with the following key observations made:

- In the Myara North mine region, residual groundwater level mounding of between one to five metres is predicted by the end of the simulation in 2060 for drier periods, and up to ten metres during wetter periods.
- In the Holyoake mine region, residual groundwater level mounding is predicted to be typically one to ten metres, but up to 20 m beneath the most densely mined areas.
- The magnitude of mounding diminishes to approximately one metre in valley floors away from mining.

The predicted change in groundwater levels in valley floors are generally predicted to be within the historical groundwater level range, however there is potential for increased saturation or waterlogging in valley floors during the mining period until rehabilitation establishes. This increased extent and/or duration of waterlogging in valley floors is expected to be the main mechanism for streamflow increases (see Section 8.4.3.4) and potential salinity discharges (see Section 8.4.4) and has potential to affect flora and vegetation depending on their tolerance for waterlogging (see Section 5.4.3.6).

The predicted change in groundwater levels is a snapshot in time relative to the baseline scenario. Due to the trend decline in groundwater levels, the rise is simulated to be less when compared to current or historic groundwater levels.

8.4.3.4 Altered hydrological regime – streamflow changes

Time series predictions of streamflow and differences arising from Myara North and Holyoake mining on the Serpentine Dam and South Dandalup Dam are presented in Chart 8-22 and Chart 8-23, respectively.

Higher annual inflows to Serpentine Dam are predicted during the first decade of mining in Myara North, typically an additional 1 GL/year, peaking at an additional 2.5 GL/year towards the end of mining. The annual inflows over this period in the unmined scenario were typically 8 to 17 GL/year, therefore the increase due to mining was in the order of ten percent but varied from year to year.

Higher annual inflows to South Dandalup Dam are predicted during the first decade of mining in Holyoake, typically an additional 0.2 to 0.4 GL/year and peaking at an additional 0.55 GL/year for Holyoake. The annual inflows over this period in the unmined scenario were typically 6 to 15 GL/year, therefore the increase due to mining was in the order of five to ten percent but varied from year to year.

After the early 2030s and 2040s, in the post-rehabilitation period, annual flows generally decrease, ranging from no decrease in dry years to an approximate 1 GL/year decrease in wetter years. In some dry years, slightly higher flows occur due to residual higher groundwater levels from mining and ongoing runoff and throughflow redirection. The lower charts highlight that the largest proportional flow changes occur in the driest years.

The increase of 1-3 GL/year over mining and reduction of 0-1 GL/year over post-rehabilitation for the Serpentine Dam is within the range of streamflow variation predicted by Dixon et al (2019) using the LUCICAT model (see Section 8.4.3.1). The annual inflows of 8-17 GL/year predicted for Serpentine Dam in the unmined scenario were less than the 24.9 and 28.9 GL/year predicted by Dixon et al (2019), which may relate to the lower rainfall in some years over the 2001 to 2020 sequence compared to the average rainfall values adopted by Dixon et al (2019).

Model predictions for the standard and drying climate cases (30 per cent reduction in overland flow, throughflow and recharge) indicate:

- The drying climate case shows lower reservoir inflows due to reduced recharge and throughflow.
- While the absolute flow impact from Myara North mining is reduced, the proportional differences between the two mining cases are larger, particularly in the years following dry spells (.).
- Proportional differences between the two mining cases for Holyoake are also generally smaller in the climate change case. Proportionally larger impact in the base climate case is most significant in dry years during the active mining period.

The groundwater numerical modelling was based on an estimated 5,473 ha of disturbance within the Serpentine Dam portion of the model domain or 8.2 per cent of the PDWSA area. The modelling was based on an estimated 1,990 ha of disturbance within the South Dandalup Dam portion of the model domain or 6.0 per cent of the PDWSA area.

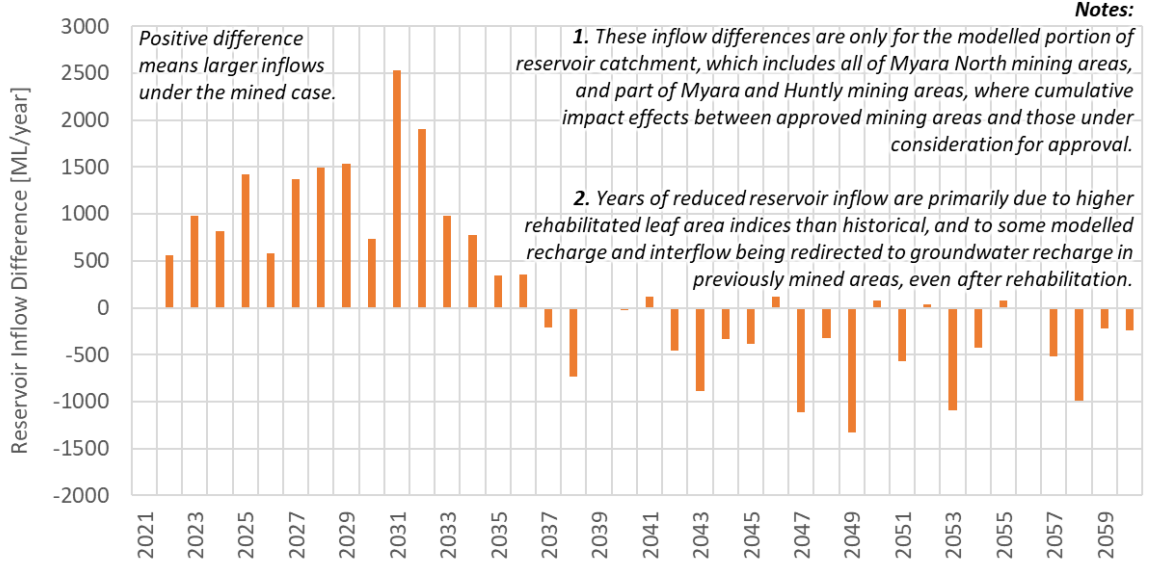
Clearing within the Serpentine Dam PDWSA is estimated to comprise 3,919 ha for the Proposal and 2,367 ha under other approvals. Combined with historic disturbance (including area open and rehabilitated), the total disturbance within the PDWSA is estimated at 13,259 ha or 20.0 percent of the PDWSA (see Section 8.4.9.3).

Clearing within the South Dandalup Dam PDWSA is estimated to comprise 2,214 ha for the Proposal and 17 ha under other approvals. Combined with historic disturbance (fully rehabilitated), the total disturbance within the PDWSA is estimated at 4,300 ha or 13.7 per cent of the PDWSA (see Section 8.4.9.3).

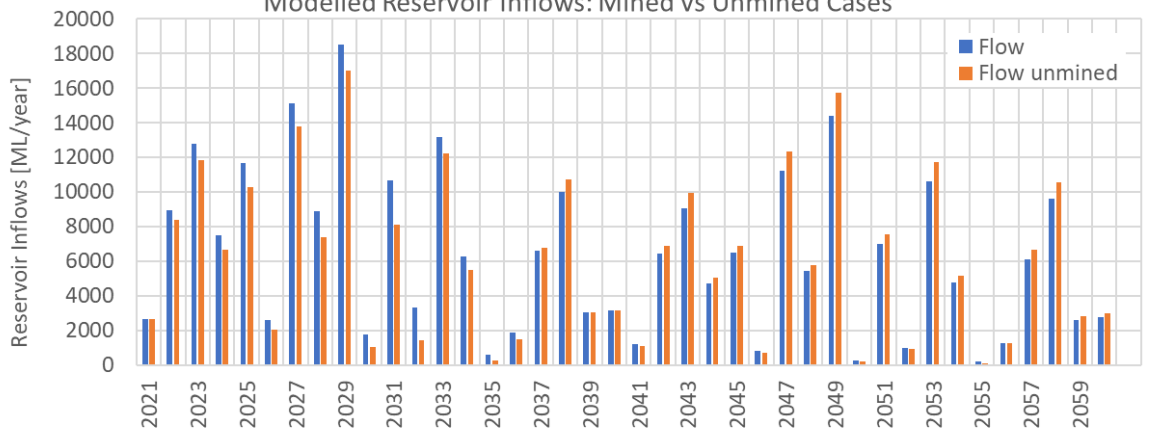
The extent of disturbance (cleared and rehabilitated) within the Serpentine and South Dandalup PDWSAs is therefore forecast to be about double that modelled for the Proposal. Accordingly, the variation in aggregate streamflows (increases and decreases) into the Serpentine and South Dandalup PDWSAs has potential to be greater than that predicted by the numerical modelling undertaken for the Proposal.

As noted above, the effects of mining on streamflows are expected to be strongly dependent on the groundwater levels in individual catchments, declining in influence with deeper groundwater levels and with lower rainfall catchments such as in the IRZ. Accordingly, there is potential for a wide variation in streamflow responses within individual subcatchments of the Mine DE depending on subcatchment antecedent groundwater conditions, as well as the future rainfall sequences occurring during mining and post-rehabilitation. Some subcatchments may be subject to increased extents and/or durations of waterlogging in valleys and increased streamflow during mining, whereas other subcatchments may be subject to no additional waterlogging or increase in streamflow.

Modelled Reservoir Inflow Difference Mined vs Unmined Cases



Modelled Reservoir Inflows: Mined vs Unmined Cases



Modelled Proportional Reservoir Inflow Difference: Mined vs Unmined Cases

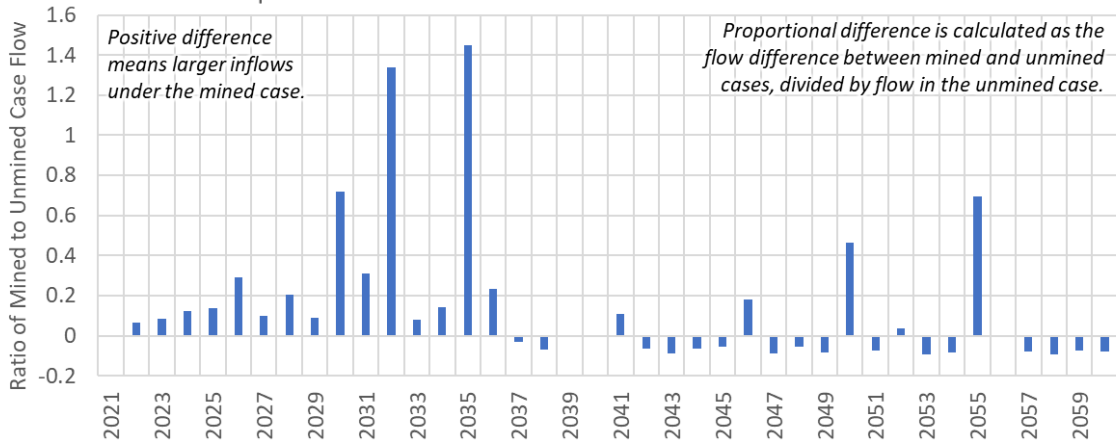


Chart 8-22 Modelled effect of mining on streamflow yield into Serpentine Dam over average climate scenario (GHD 2021b)

Modelled Reservoir Inflow Difference Mined vs Unmined Cases

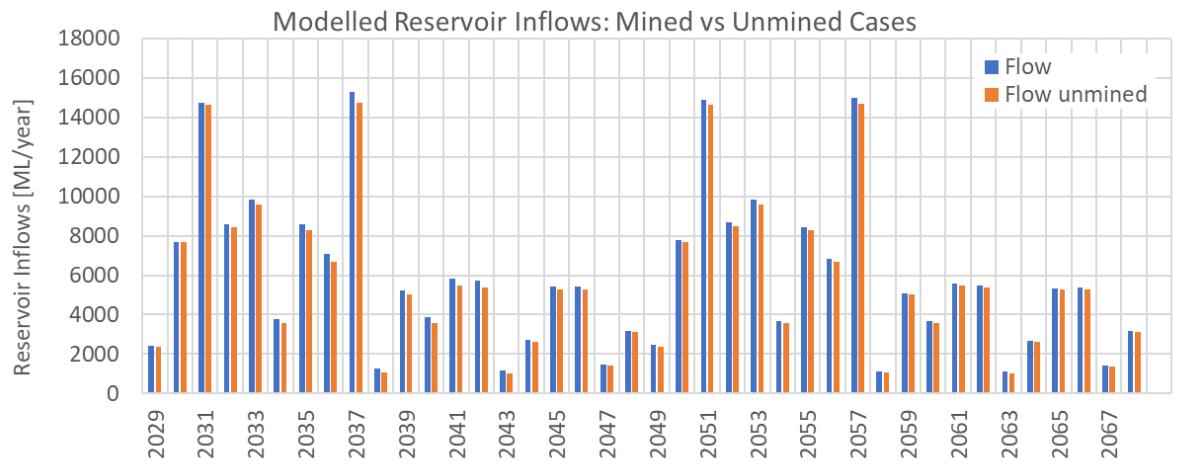
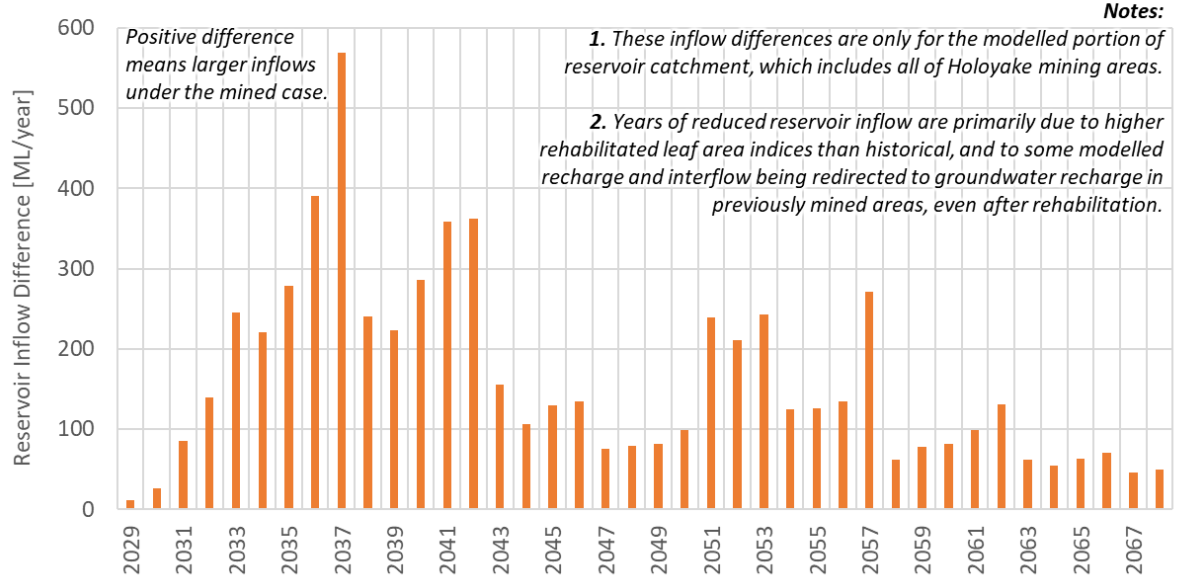


Chart 8-23 Modelled effect of mining on streamflow yield into South Dandalup Dam over average climate scenario (GHD 2021b)

8.4.4 Increases in stream salinity as a result of mining-induced saline groundwater discharge

Rainfall varies across the Huntly Mine, being highest to the west near the Darling Scarp and declining to the east (see Section 5.3.4.8). Mean annual evaporation exhibits an approximate inverse trend, increasing to the east, which results in the accumulation of salts in deep soils and increasing groundwater salinity (Schofield et al 1989). By comparison, groundwaters are fresh in the high rainfall zone near the Darling Scarp. The intermediate rainfall zone (IRZ), which has a long-term average of 900–1100 mm/year, has recorded groundwater that is sufficiently shallow such that clearing of native vegetation has the potential to result in the rise of saline groundwater and its discharge into streams (Dixon et al 2019).

8.4.4.1 Previous studies of mining effects on salinity

The potential for bauxite mining to result in stream salinity was recognised in the 1970s and led to the development of the Joint Intermediate Rainfall Zone Research Program (JIRZRP)¹. Several experiments were conducted under the JIRZRP, including the Trial Mining Project (TMP). The TMP involved the study of the effects of mining and rehabilitation during 2003-2011 in the upper catchments of the Serpentine and Dandalup rivers. The TMP findings indicated an almost complete absence of response to mining in either streamflow or stream salinity (Croton et al 2011). It was concluded that the lack of response was due to the decline in groundwater levels in the regolith and that the groundwater rise from mining was insufficient to cause saline groundwater discharge into streams (Croton et al 2011). Similar findings were reported for other catchments in the IRZ that were subject to forest thinning experiments over a comparable period (Kinal and Stoneman 2011).

Dixon et al (2019) investigated the effects of mining and rehabilitation in the Serpentine Dam catchment for DWER, using the LUCICAT catchment hydrology model (see Section 8.4.3.1). The modelled results for reservoir salinity are summarised in Table 8.10 and indicate that streamflow salinity is expected to decrease during mining then increase during rehabilitation. The modelling predicted an inverse trend in streamflow yield, an increase in streamflow during mining, and a decrease during rehabilitation (Dixon et al 2019). Dixon et al (2019) predicted that mining may increase reservoir salinity by up to three per cent compared to the no-mining case, which is within acceptable limits.

The modelling indicates that reservoir water quality would remain fresh, with salinity well within the range of good palatability (less than 600 mg/L total dissolved solids) specified in the ADWG (NHMRC & NRMCC 2024).

The predicted small effect of mining on inflow salinity is validated by the historic trend in salinity (expressed as Electrical Conductivity ($\mu\text{S}/\text{cm}$), recorded in Serpentine Dam (see Chart 8-26), which has remained in the range of 25-35 mS/m (250-350 $\mu\text{S}/\text{cm}$) over the past s despite clearing of approximately 10 per cent of the catchment, including the O’Neil and McCoy mine regions that lie within the IRZ. The historic variation in salinity recorded in Serpentine Reservoir follows the trend of reservoir inflows, rising over extended periods of low inflows and decreasing in response to higher inflows (Chart 8-26). Similarly, the historic trend in salinity recorded in South Dandalup Dam (Chart 8-27) has remained in the range of 27-33 mS/m (270-330 $\mu\text{S}/\text{cm}$) over the past 20 years despite clearing of approximately 15 per cent of the catchment. Salinity levels in the Serpentine and South Dandalup reservoirs trend lower in response to increasing reservoir levels, and higher with falling reservoir levels.

Salinity monitoring data available for Wungong Dam from 2000 to 2003 indicates salinity ranging from 27-33 mS/m (270-330 $\mu\text{S}/\text{cm}$) despite clearing of approximately 20 per cent of the catchment for the former Jarrahdale Mine.

¹ <https://www.water.wa.gov.au/water-topics/water-quality/managing-water-quality/effects-of-mining-bauxite-hydrology>

As noted in Section 8.4.2, the proposed transition of the existing mining operations in the Huntly mine's Myara region into the Myara North and Holyoake mine regions and previously mined O'Neil mine region will involve an estimated 3,919 ha of clearing within Serpentine Dam PDWSA and an estimated 2,124 ha of clearing in the South Dandalup Dam PDWSA, which represents approximately six to seven per cent of each PDWSA catchment area. Combined with historic clearing and that proposed under other approvals, the total disturbance is estimated at 20.0 per cent of the Serpentine Dam PDWSA and 14.0 per cent of the South Dandalup Dam PDWSA. These levels of disturbance exceed the 12 per cent catchment clearing modelled by Dixon et al (2019) for the Serpentine Dam, and therefore could potentially result in an increased variation in streamflow salinity from that presented in Table 8.10. The increased disturbance would occur over an extended timeframe and subject to a balancing effect of establishing rehabilitation (i.e. decreasing recharge and groundwater mounding) over that timeframe and therefore an increased variation, if occurring, is expected to be moderately greater than that modelled and less than ten per cent compared to un-mined scenarios.

Based on the available studies and reservoir monitoring data, the Proposal is unlikely to cause salinity to rise to unpalatable levels or for reservoir yield to be substantially reduced over the long term. Temporary increases in reservoir yield in the short term will occur during mining, thereby slightly increasing (rather than reducing) the reservoir storage levels and hence dilution / settling capacity.

Table 8.10 Modelled effect of mining on streamflow salinity into Serpentine Dam (Dixon et al 2019)

Scenario	Average salinity (mg/L) during mining (2011-30)	Average salinity (mg/L) post-mining (2031-50)	Difference (mg/L) during mining (2011-30)	Difference (mg/L) post-mining (2031-50)
Unmined – average rainfall	166	155	n/a	n/a
Un-mined – low rainfall	195	178	n/a	n/a
Mined 8 per cent – average rainfall	163	160	-3.9	+4.8
Mined 8 per cent – low rainfall	191	184	-4.7	+5.4
Mined 12 per cent – average rainfall	163	158	-3.1	+3.8
Mined 12 per cent – low rainfall	195	181	nil	+2.6

Note: drinking water is considered palatable within 600 mg/L total dissolved salts.

8.4.4.2 Studies conducted for the Proposal

As noted in Section 8.4.3, GHD (2023a) undertook a Hydrology and Water Quality Assessment for the Mine components of the Proposal, including groundwater modelling for the Myara North and Holyoake mine regions. The Hydrology and Water Quality Assessment is presented in Appendix B8 and a summary is provided below.

Section 5.4.3.6 details the predicted rise of groundwater levels with the clearing of vegetation and the gradual decline of groundwater levels post-mining as rehabilitation re-establishes the leaf area index (LAI). Rising groundwater has the potential to mobilise salts naturally present in deeper soils and groundwater of the catchment, particularly within the IRZ in the east, which may then enter streams with groundwater baseflow.

The potential changes to the salinity of streamflow entering the Serpentine Dam and South Dandalup Dam were estimated using modelled changes in streamflow along with observed groundwater salinity. This was achieved by comparing modelled streamflow volumes and their proportional groundwater discharge component between mined and unmined cases. Modelled streamflow were converted to salt loads using observed salinity ranges. Chart 8-24 presents modelled changes to salinity as total dissolved solids (TDS) for Serpentine Dam inflows and Chart 8-25 presents modelled changes to salinity for South Dandalup Dam inflows. Predicted salinity changes are presented for both upper and lower estimates of groundwater salinity.

Serpentine Dam

For the Myara North DE, the predicted salinity change is an average 5 mg/L decrease during mining and an average 11 mg/L increase post-mining compared to the non-mining case. When considering the impact of climate change (as reduced rainfall and groundwater recharge), the predicted average change is 4 mg/L decrease during mining and an average 13 mg/L increase post-mining compared to the non-mining case. The trend of a salinity decrease during mining followed by an increase post-mining is consistent with the findings of Dixon et al (2019).

The higher salinity increase under the climate change scenario is due to the predicted lower inflow volumes with declining groundwater levels. The predicted salinity is generally slightly higher than the estimates by Dixon et al (2019), which used a different model and assumptions for mining and climate sequences.

The higher salinity increase under the climate change scenario is due to the predicted lower inflow volumes with declining groundwater levels. The predicted salinity is generally slightly higher than the estimates by Dixon et al (2019), which used a different model and assumptions for mining and climate sequences.

Uncertainty analysis of the base climate case model indicates relatively narrow uncertainty in projected salinity loading to Serpentine Dam, except in the driest of years when groundwater discharge becomes a significant component of remaining streamflow. Uncertainty is estimated to range from an average annual decrease of 6 to 13 mg/L in annual salinity of inflows during mining, and an average annual increase from 19 to 21 mg/L post-mining.

Average annual salinity in inflows is estimated to range from 222 to 261 mg/L during mining and from 230 to 254 mg/L post-mining, with estimates largely dependent on the estimation of salinity of contributing groundwaters, which varies throughout the catchment. Accordingly, modelling indicates that the Proposal has potential to result in an average of about 2 per cent decrease in salinity of inflows during mining and an average of about 5 per cent increase in salinity of inflows post-mining compared to the non-mining case and that inflows to the Serpentine Dam are expected to fall well within the threshold of freshwater quality.

The predicted small effect of mining on inflow salinity is validated by the historic trend in salinity recorded in Serpentine Dam (see Chart 8-24), which has remained in the range of 25-35 mS/m

(250-350 $\mu\text{S}/\text{cm}$) over the past 20 years despite clearing of approximately 10 per cent of the catchment, including the O'Neil and McCoy mine regions that lie within the IRZ. The historic variation in salinity recorded in Serpentine Reservoir follows the trend of reservoir inflows, rising over extended periods of low inflows and decreasing in response to higher inflows.

Based on the model predictions and the historic trend, the Proposal is unlikely to cause a significant impact to drinking water quality in the Serpentine Dam due to changes in stream salinity.

South Dandalup Dam

For the Holyoake DE, the predicted salinity change is an average 8 mg/L increase during mining and an average increase 17 mg/L post-mining compared to the non-mining case. When considering the impact of climate change, the predicted average change is an average 5 mg/L increase during mining and an average 9 mg/L increase post-mining compared to the non-mining case. The lower salinity increase under the climate change scenario is attributed to the deeper groundwater level in response to reduced recharge, and hence reduced groundwater contribution to streamflows.

Uncertainty analysis of the base climate case indicates relatively narrow uncertainty in projected salinity loading to South Dandalup Dam, except in the driest of years when groundwater discharge becomes a significant component of remaining streamflow. Uncertainty is estimated to range from an increased 2 to 23 mg/L during mining and an increased 10 to 55 mg/L post-mining.

Average annual salinity in inflows is predicted to range from 100 to 130 mg/L during mining and from 105 to 163 mg/L post-mining, with estimates largely dependent on the estimation of salinity of contributing groundwaters. Accordingly, modelling indicates that the Proposal has the potential to result in an average of about 7 per cent increase in salinity of inflows during mining and an average of about 13 per cent increase in salinity of inflows post-mining compared to the non-mining case and that inflows to the South Dandalup Dam are expected to fall well within the threshold of freshwater quality.

Based on the model predictions and the historic trend, the Proposal is unlikely to cause a significant impact to drinking water quality in the South Dandalup Dam due to changes in stream salinity.

Upper Wungong Brook

The Myara North mine region lies predominantly (11,918 ha) within the Serpentine Dam catchment and a comparatively small area (1,562 ha) lies within the catchment of Upper Wungong Brook. The portion of the Myara North mine region that lies within Upper Wungong Brook represents about 19 per cent of the catchment area. The Myara North and Holyoake mine regions represent about 19 per cent and 22 per cent of the Serpentine Dam and South Dandalup Dam catchments and the assessments presented above indicate that mining is unlikely to cause a significant impact to those reservoirs due to changes in stream salinity.

Salinity monitoring data available for Wungong Dam from 2000 to 2003 indicates salinity ranging from 27-33 mS/m (270-330 $\mu\text{S}/\text{cm}$) despite clearing of approximately 20 per cent of the catchment for the former Jarrahdale Mine.

Given the smaller scale of mining proposed within Upper Wungong Brook (approximately 5 per cent of the catchment) and that the majority of the catchment lies in the high rainfall zone, it is expected that the effect on stream salinity will be comparable or less than that assessed for Serpentine Dam. Given the model predictions for Serpentine Dam and the historic salinity, the Proposal is unlikely to cause a significant impact to drinking water quality in the Wungong Dam due to changes in stream salinity.

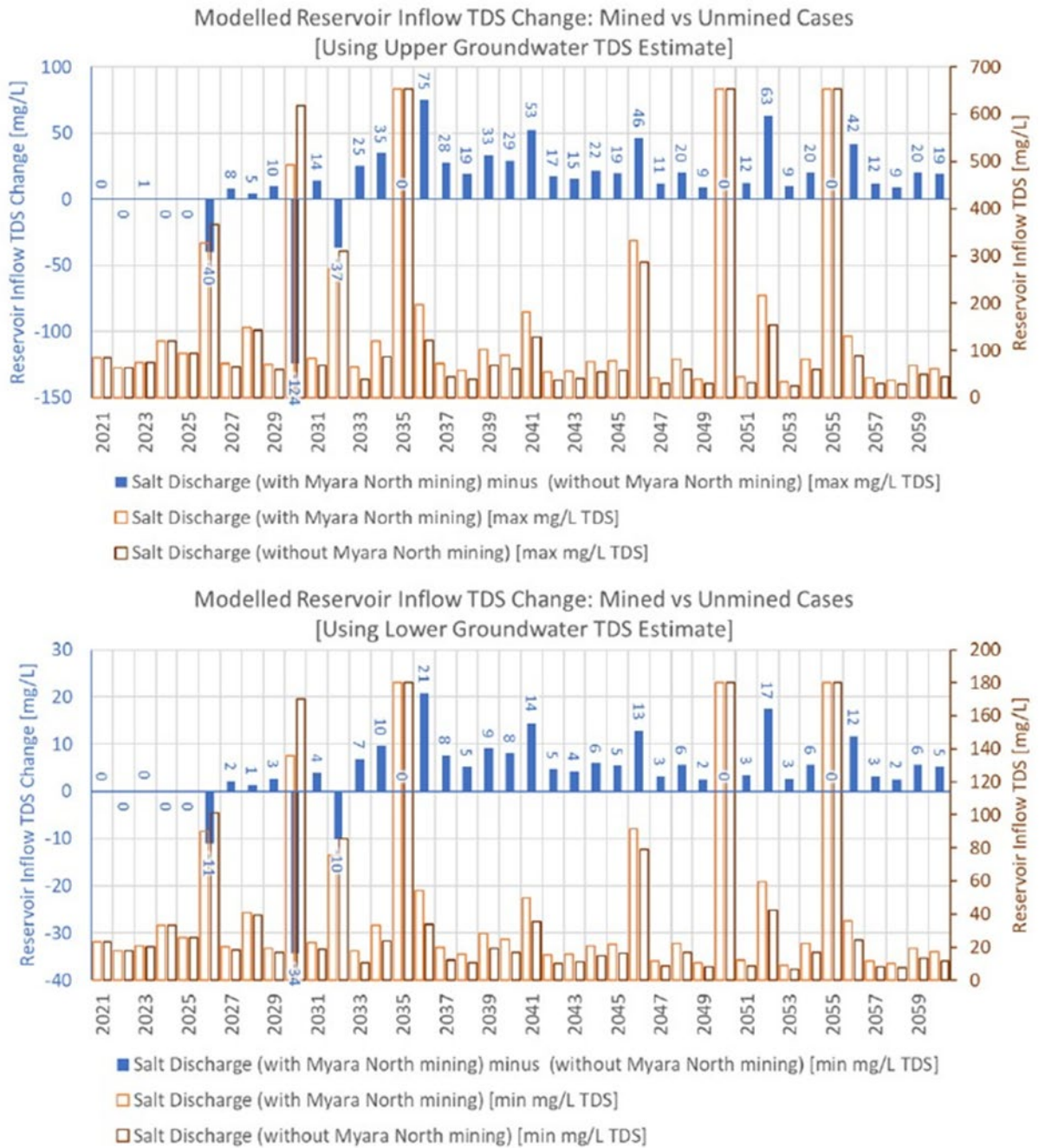


Chart 8-24 Modelled change to salinity inflow – Serpentine Dam

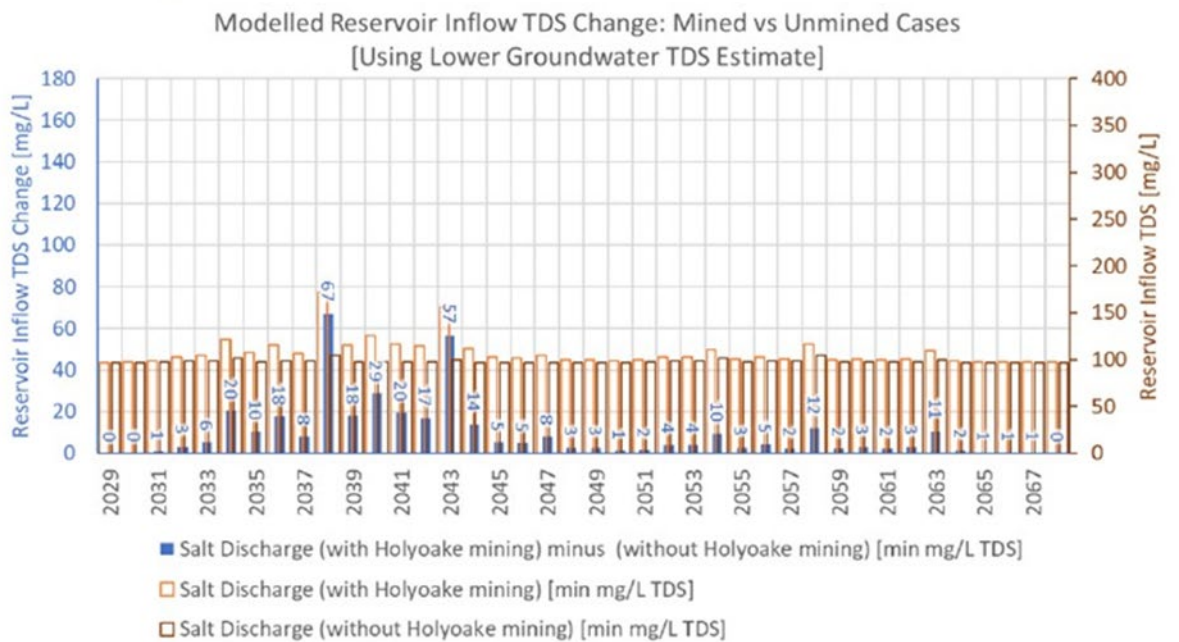
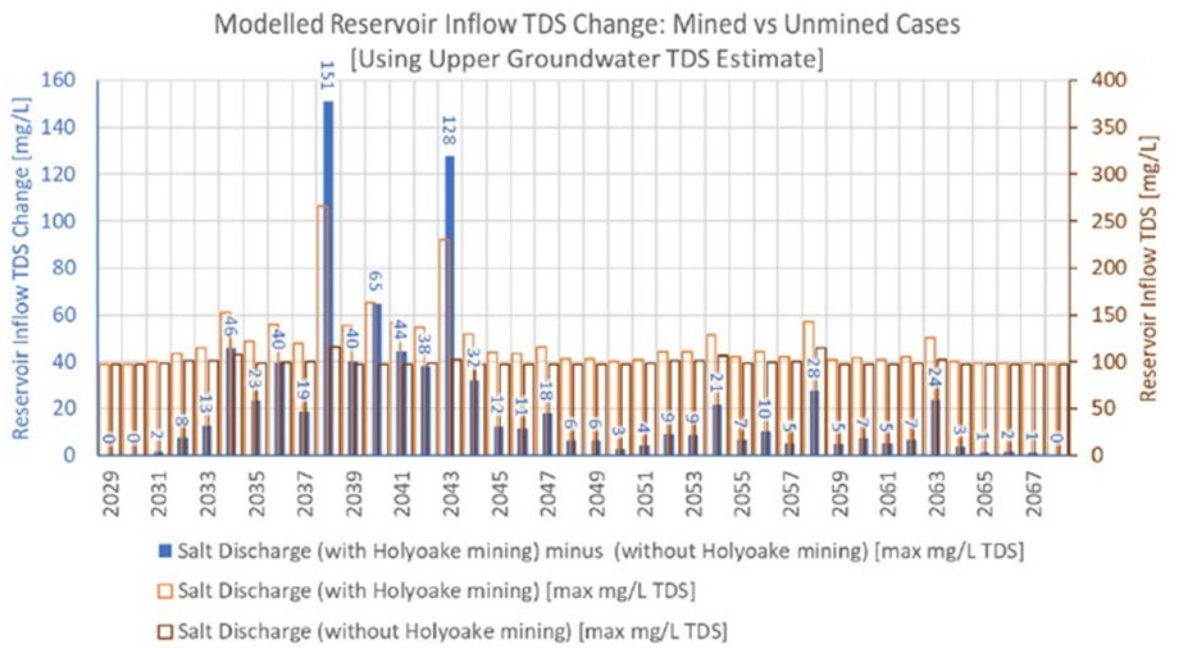


Chart 8-25 Modelled change to salinity inflow – South Dandalup Dam

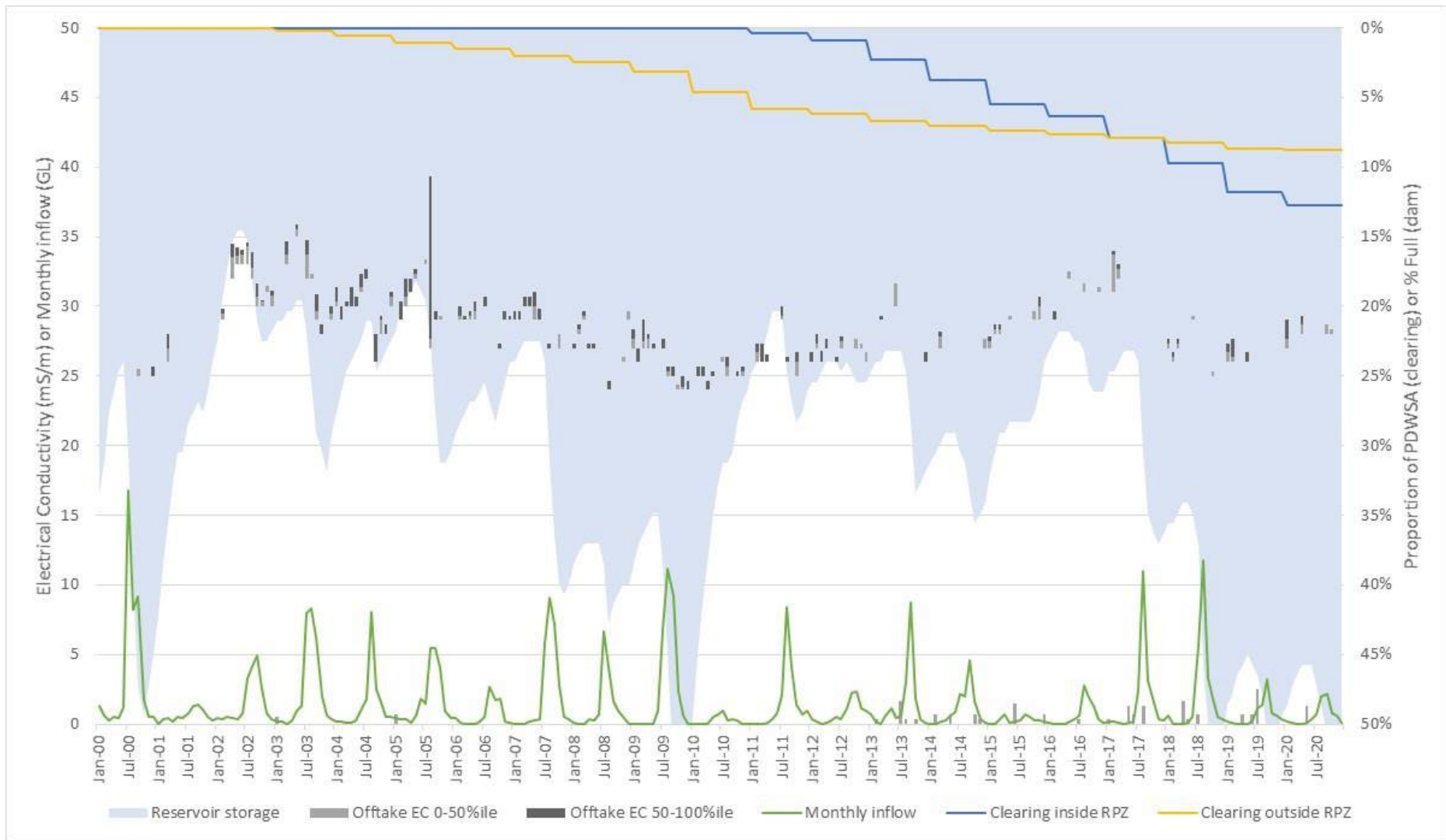


Chart 8-26 Monitored salinity in Serpentine Dam versus trends in reservoir storage, inflows, and mining over 2000-2020

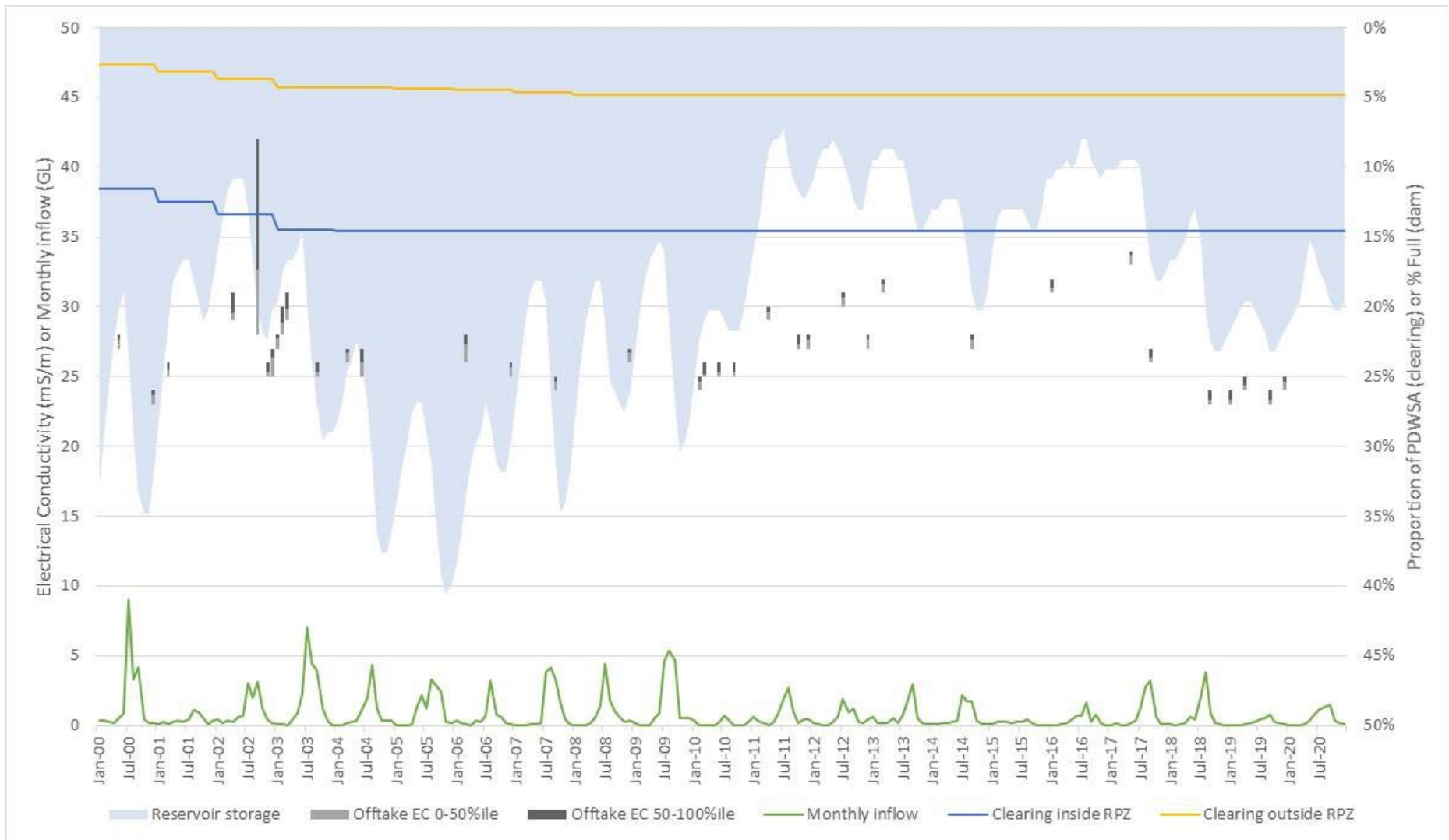


Chart 8-27 Monitored salinity in South Dandalup Dam versus trends in reservoir storage, inflows, and mining over 2000-2020

8.4.4.3 Impact to freshwater aquatic ecosystems

As detailed above, the Proposal is expected to result in limited changes to stream salinity and freshwater conditions are expected to be maintained in major tributaries throughout the Mine DE including Serpentine River, South Dandalup River, Upper Wungong Brook and the freshwater tributaries of Murray River.

Streamzone monitoring of mined and un-mined catchments was undertaken as part of the TMP, with surveys conducted by WRM in 2005, 2007, 2009, 2011, 2014 and 2019 (WRM 2021). Streamzone monitoring involved sampling and comparative analysis of macroinvertebrates, as indicators of potential impacts to aquatic biodiversity. Analyses included univariate and multivariate analysis of species-level metrics including total taxa richness, EPT⁷ richness, functional feeding groups and Bray-Curtis similarity (WRM 2021).

WRM (2019) concluded that the analyses did not indicate significant differences between the macroinvertebrate communities of sites in mined and un-mined catchments. There was a greater variation in total species richness and EPT taxa richness within the groups of sites in mined and un-mined catchments rather than between the groups, indicating that the fauna is more dependent on natural habitat characteristics and localised anthropogenic disturbance at each site.

Based on the expected limited changes to stream salinity and the findings of streamzone monitoring in the Huntly Mine, the Proposal is highly unlikely to cause a significant impact to aquatic biodiversity as a result of salinity.

8.4.5 Increased sediment from erosion of post-mining landforms

8.4.5.1 Effects of mining on Jarrah forest soils

The mine development stage involves stripping and stockpiling the superficial soils and blasting or ripping the caprock layer. Mining then involves removing the bauxite caprock and friable fragmental layers, which are transported to stockpiles, then crushed and conveyed to the Pinjarra Alumina Refinery. Following the completion of mining, rehabilitation is undertaken as described in Section 2.4.

The net effect of bauxite mining of Jarrah forest soils is the removal of an approximately 4-6 m thick layer of caprock and friable fragmental material, and its replacement with a seed rich topsoil and overburden placed over a ripped, friable substrate of sandy loams and clays. The total depth of friable material created is about 1.5 m, including topsoil, overburden and ripped substrate.

The establishment of a friable layer of topsoil, overburden and ripped substrate provides a comparable, though generally thicker, stratum than the topsoil and overburden present above the caprock prior to mining. The friable layer enables development of a dense root structure of Jarrah forest vegetation as occurs in the topsoil and overburden present prior to mining. Deeper rooted vegetation establishing within the friable layer is expected to re-colonise ancient root channels present in the underlying regolith materials, as have been used by successive generations of trees prior to mining (Dell et al 1983). There is expected to be a partial loss of soil water capacity due to the removal of the bauxite friable fragmental layer, which comprised about 2 m of loamy soils that previously were accessed by deep and medium rooted vegetation.

The roots of *Eucalyptus marginata* (Jarrah), the predominant canopy tree across the Northern Jarrah Forest and Mine DE, form a dense mass within the sandy gravel layer above the duricrust, with a lower density of vertical 'sinker' roots through the bauxite layer and mottled

⁷ EPT Richness estimates water quality by the relative abundance of three major orders of stream insects that have low tolerance to water pollution: *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies).

saprolite, terminating in a second mass of roots within the pallid clay saprolite around the groundwater table (Kimber 1974). The limited root density through the bauxite layer suggests that Jarrah obtain their water primarily above and below the bauxite layer, and that the bauxite layer provides a water transmission medium but not an important water storage medium for Jarrah.

The bauxite layer is overlain by sandy gravels, which exploration drilling indicate are present across all proposed mining areas, with a thickness ranging from 0.1 to 1.8 m (see Section 7.3.1.3). As the duricrust / caprock is buried at depth beneath the sandy gravel layer, it is not expected to provide an erosion protection function for the overlying sandy gravel soils.

Loss of the bauxite friable fragmental layer has not been observed to result in impaired growth or health of rehabilitation (see Section 2.4). Monitoring of rehabilitation has demonstrated the successful establishment and persistence of an LAI of 2-2.5, comparable to that of un-mined Jarrah forest. Monitoring has also indicated a floristic diversity of about 80 per cent to 100 per cent of un-mined forest, declining weed cover and sustained understorey coverage (see Section 2.4). During the 2010/11 drought and heat waves, Jarrah forest canopy die-off was observed at sites across the NJF, including un-mined forest and some areas of rehabilitation (see Section 2.4). Widespread die-off of rehabilitation did not occur nor was rehabilitation affected in greater proportion than un-mined forest. Browsers et al (2012) report that canopy dieback was more frequent on:

- rocky soils with low water holding capacity
- sites that were close to rock outcrops
- areas that received a slightly higher amount of annual rainfall compared to the surrounding landscape
- sites at high elevations or on steep slopes
- in areas that were generally slightly warmer than their surroundings.

The results of monitoring collectively demonstrate that Alcoa's rehabilitation establishes and persists, including during drought and heatwave events, indicating that the friable substrate over regolith containing ancient root channels is an effective growth medium. Accordingly, mine rehabilitation vegetation is expected to be sustained over the long term with resilience to climate change comparable to that of the un-mined Jarrah forest. Mine rehabilitation is therefore expected to provide long-term protection of soils from erosion and associated sediment discharge to streams and reservoirs.

8.4.5.2 Erosion during rehabilitation establishment

Mengler et al (2006) surveyed topsoil and overburden samples in rehabilitated mine pits at the Huntly Mine. The survey indicated predominantly sandy gravel texture, comprising an average of 60 per cent gravel (>2 mm diameter, range 38 per cent-78 per cent), 38 per cent sand (2-0.02 mm diameter, range 24 per cent-65 per cent) and 3 per cent silt and clay (<0.02mm diameters, range 0 per cent-6 per cent) for the Mine. Due to the predominant sandy gravel texture, the soils had calculated low erodibility coefficients (RUSLE equation K factors) averaging 0.009 (range 0.000-0.019).

The skeletal topsoil and overburden materials are distinct to most agricultural soils and mining waste due to the low combined clay and silt contents and very high gravel contents, which develop with time a protective surface layer of gravel covering 70 per cent - 80per cent of the land surface. The high porosity and coarse texture also enable rapid infiltration of rainfall within the topsoil, overburden and ripped regolith material. However, thinly applied topsoil and overburden can be mixed with finer grained pit floor materials during contour ripping, which can introduce more erodible (and potential dispersive) clayey material into the shallow subsurface surface. The regolith beneath the ripped zone generally comprises lower permeability sandy

loams and clays, therefore rainfall infiltration is limited to the water storage in the overburden and ripped zoned, accordingly surface runoff occurs following extended rainfall periods that fill up the permeable materials.

Gullies form in the rehabilitated landform through an erosion sequence (Mengler et al 2006). The fine-grained content is displaced from the coarser topsoil/overburden, depositing within the furrows and filling their volume such that surface water overflows and erodes through the fine-grained materials in downslope furrows. The gully that is initially created in the fine-grained materials concentrates flow and creates knickpoints that enable erosion of the coarser topsoil/overburden and underlying ripped regolith materials.

Analysis of gully erosion at the Huntly, Willowdale and Boddington bauxite mines suggested a minimum catchment of 0.3 ha for gully development, with gully volumes typically remaining small (20-100 m³) but potentially increasing for higher slopes (> 10°) and shallower topsoil/overburden placement (< 200 mm). Erosion was highest in the first two to three years following rehabilitation completion until rehabilitation establishes, though there was a lack of long-term data with which to compare the erodibility of rehabilitation to that of un-mined Jarrah forest (Mengler et al 2006). For the period at higher risk of erosion, the major triggers for gully erosion were identified as:

- directing excessive off-site runoff into the rehabilitation
- poor surface completion (e.g. ripping that does not adhere to contours) that concentrates flow or impairs infiltration
- insufficient depth of returned topsoil and overburden (< 200 mm combined).

Chart 8-28 presents slope analysis based on LiDAR within Huntly Mine disturbance areas, including historic mine regions, the current Myara mine region and the proposed Myara North DE. It is noted that the Myara North slopes are currently un-mined whereas the Myara and historic regions reflect the topographic effect of mining. The analysis indicates that approximately 92 per cent to 93 per cent of the disturbance areas within the Mine have slope less than 10° and are therefore likely to be subject to small volumes of gully erosion. The remaining 7 per cent to 8 per cent of disturbance areas may potentially be subject to higher gully volumes, based on the findings of Mengler et al (2006).

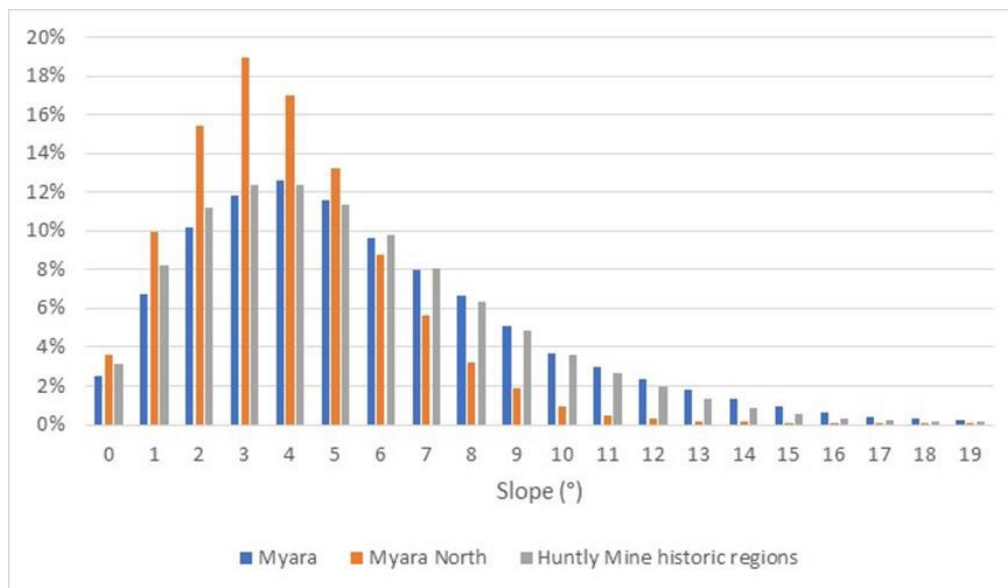


Chart 8-28 Proportion of slope class within Huntly Mine disturbance areas

8.4.5.3 Worst case erosion and loss of reservoir capacity

Table 8.11 presents estimated worst-case soil erosion rates for drinking water reservoirs that are subject to mining.

Erosion estimates are made using the Revised Universal Soil Loss Equation (RUSLE), with baseline erosion rates estimated from RUSLE parameters derived from the results of Viscarra-Roseel et al (2016). Baseline annual erosion rates are estimated to range from 0.71 to 1.80 t/ha/yr. The highest erosion rates are estimated for the Serpentine and South Dandalup pipehead dams due to the steeper terrain and location west within higher rainfall zones. Erosion rates for Upper Wungong Brook are based on Serpentine Dam, which has a comparable topography and rainfall regime. South Dandalup Dam has the lowest estimated erosion due to more gentle slopes.

Worst case erosion rates are estimated based on conservative assumptions as follows:

- soil erodibility is the highest recorded in Australia
- soils are 100 per cent exposed with no effective vegetation cover
- no soil erosion mitigation is undertaken.

Under these assumptions, worst case soil erosion rates are estimated to range from 27 to 98 t/ha/yr, exceeding baseline erosion rates by a factor of about 40.

The soil erosion rates are conservative compared to sediment loads reported by Smith et al (2011) from burnt catchments (0.017 to 50 t/ha/yr) and estimates by Blake et al (2020) for the NJF impacted by the 2016-Waroon Yarloop fire. Blake et al (2020) used the RUSLE to estimate erosion risk, which indicated an approximate ten-fold increase from in the order of 0.01-0.1 t/ha/yr before the fire to in the order of 0.1-1 t/ha/yr following the fire. Erosion risk was estimated to increase by two orders of magnitude over localised areas, to in the order of 1-10 t/ha/yr, with hot spots identified in forested headwaters associated with steep terrain and high fire intensity.

Adopting worst case soil erosion rates for mined areas and baseline erosion rates for un-mined areas, and assuming that all erosion is deposited in the reservoirs, it is estimated that it would take hundreds of years for worst-case erosion to completely fill reservoirs and several decades to reduce reservoir capacities by 10 per cent. By comparison, the time for rehabilitation to be completed is approximately 3-4 years from clearing and vegetation cover is effectively established by around 5 years. Actual sediment deposition rates into reservoirs are therefore expected to be a small proportion (less than 10 per cent) of the worst-case erosion rates presented in Table 8.11.

Table 8.11 Estimated worst case sediment rates to drinking water reservoirs

Catchment	Un-mined catchment (ha)	Erosion rate in un-mined catchment (t/ha/yr)	Erosion from un-mined catchment (kt/yr)	Mined catchment (ha)	Erosion rate in mined catchment (t/ha/yr)	Erosion from mined catchment (kt/yr)	Total erosion to catchment (kt/yr)	Estimated loss of reservoir capacity per year (per cent)	Time to fill reservoir (years)
Serpentine Dam	54,845	0.85	47	11,420	40	457	503	0.24	410
Serpentine Pipehead Dam	2,669	1.50	4	216	55	12	16	0.34	296
South Dandalup Dam	25,957	0.71	18	4,868	27	131	150	0.05	2,084
Wungong Brook	9,679	0.85	8	3,159	40	126	135	0.15	669
Canning Dam	80,237	0.85	68	106	40	4	72	0.05	1,874

8.4.6 Loss of the bauxite layer as a hydrological unit

Mining removes the bauxite layer including duricrust (caprock) and friable / fragmental unit. Across the Darling Plateau the bauxite layer is approximately four to six metres thick with the duricrust generally being one to two metres thick and absent in places, and the friable fragmental layer generally two metres or more thick and up to ten metres thick on some locations on the plateau (Hickman *et al* 1992). The bauxite layer is overlain by sandy gravels up to four metres thick (average 0.5 metres) and underlain by saprolite (mottled and pallid clays) about 20 to 30 m thick (Hickman *et al* 1992). The bauxite layer is thickest mid-slope, thinner in upper slopes and crests, and is generally absent in lower slopes and valley floors (Hickman *et al* 1992).

Exploration drilling over mid to upper slopes of the Mine DE (i.e. excluding lower slopes and valley floors where bauxite is absent) indicates that duricrust is present over approximately 55 to 70 per cent of proposed mining areas (i.e. absent over 30 to 45 per cent) and has a thickness ranging from 0.2 to 2.1 m (see Section 7.3.1.3).

The bauxite layer is overlain by sandy gravels, which exploration drilling indicate are present across all proposed mining areas, with a thickness ranging from 0.1 to 1.8 m (see Section 7.3.1.3). Where the duricrust is absent, the gravelly sands directly overlie the friable fragmental unit. As the duricrust is buried at depth beneath the sandy gravel layer (up to 1.8 m thick), it is not expected to provide an erosion protection function for the overlying sandy gravel soils.

The duricrust comprises a massive, cemented layer with numerous small macropores (up to one centimetre) from tree roots and intermittent large macropores (about one metre diameter) that can create a relatively high permeability within the otherwise cemented rock matrix (Ruprecht & Schofield 1993). Where the caprock has sufficiently high vertical permeability, it may reduce or prevent the presence of a perched aquifer and throughflow in the overlying sandy gravels (Ruprecht & Schofield 1993).

The small macropores are formed by roots (approximately one centimetre diameter or less) formed by Jarrah and other deeper-rooted vegetation, whereas large macropores comprise sandy gravel filled holes about one metre diameter that may cover about ten per cent of the caprock layer (Ruprecht & Schofield 1993). The macropores create a relatively high vertical permeability in the other cemented, low permeability matrix of the duricrust, with a measured hydraulic conductivity of approximately 2.4 m/d (Ruprecht & Schofield 1993).

The hydrological functions of the bauxite layer are expected to comprise the following:

- Vertical infiltration through the duricrust and friable fragmental layer, with infiltration into the underlying mottled sandy/silty clay saprolite that forms recharge to the groundwater table in the saprolite.
- Supporting seasonal shallow throughflow in the overlying sandy gravel layer, where the duricrust or (if duricrust is absent) friable fragmental layer has sufficiently low vertical permeability to create a seasonal perched aquifer.
- Potential seasonal throughflow in the friable fragmental layer, where the friable fragmental layer has sufficiently high horizontal permeability and the underlying mottled or pallid saprolite has sufficiently low vertical permeability to create a seasonal perched aquifer.

The roots of *Eucalyptus marginata* (Jarrah), the predominant canopy tree across the Northern Jarrah Forest and Mine DE, form a dense mass within the sandy gravel layer above the duricrust, with a lower density of vertical 'sinker' roots through the bauxite layer and mottled saprolite, terminating in a second mass of roots within the pallid clay saprolite around the groundwater table (Kimber 1974). The limited root density through the bauxite layer suggests that Jarrah obtain their water primarily above and below the bauxite layer, and that the bauxite

layer provides a water transmission medium but not an important water storage medium for Jarrah.

Upon mining, the bauxite layer is removed and the sandy gravel layer re-laid over the ripped mottled or pallid saprolite layer. The saprolite is ripped to about two metres depth and the sandy gravel layer is contour ripped and partially mixed with the ripped saprolite. The sandy gravel / ripped saprolite layer is expected to comprise a high to moderate permeability medium, which will enable seasonal throughflow when a seasonal perched aquifer forms above the underlying un-ripped saprolite. Water will infiltrate from the sandy gravel / ripped saprolite layer into the underlying mottled or pallid saprolite layer, at a higher rate for mottled saprolite and a lower rate for pallid saprolite. Accordingly, the created rehabilitation substrate is expected to support throughflow and groundwater recharge, however there will be a loss of the potential seasonal throughflow within the friable fragmental layer, if this layer was of sufficiently high permeability and the underlying saprolite of sufficiently low permeability to have created throughflow.

The loss of the bauxite layer was not observed to have had a measurable effect on streamflows monitored in mined catchments on the western high rainfall zone (Grigg 2017), which were comparable to tree thinning catchments and had contributions dominated by groundwater, or in mined catchments in the eastern IRZ (Croton et al 2011) where mining caused no measurable change on streamflow due to the presence of deeper groundwater tables. Accordingly, removal of the bauxite layer within the Mine DE is not expected to cause a significant impact to streamflow generation in the Mine DE.

8.4.7 Impacts from development of river crossings

8.4.7.1 Development of river crossings

The Proposal will involve construction of river crossings over the Serpentine and South Dandalup rivers, including:

- primary haul road crossing over the Serpentine River, to service the Myara North mine facilities
- conveyor, mine access road and primary haul road crossings over the South Dandalup River, to service the Holyoake mine facilities.

Indicative locations of the Serpentine and South Dandalup river crossings are presented in Figure 1-4 (Myara North) and Figure 1-5 (Holyoake). The Serpentine and South Dandalup river crossings are located within the RPZs of the Serpentine Dam and South Dandalup Dam, respectively, at a distance of approximately one kilometre upstream of each reservoir's top water level and several kilometres upstream of each reservoir's 2024 water level.

The Proposal will also involve construction of stream crossings for secondary haul roads within the Mine DE. Indicative locations of the secondary haul road crossings for streams are presented in Figure 1-4 (Myara North), Figure 1-5 (Holyoake) and Figure 1-6 (O'Neil).

Table 8.12 presents a preliminary construction sequence for the Serpentine and South Dandalup river crossings. The final construction sequence will be developed during detailed design and will be defined for the RIWI Act Beds and Banks Permit for each river crossing.

Table 8.12 Preliminary construction sequence for river crossings

Stage	Activities
Stage 1: Pre-works	<ul style="list-style-type: none"> • Construction plant, equipment and materials mobilise to site • All materials laydown, fuel storage, crib rooms and sewage facilities for river crossing construction will be located at a designated construction compound located outside of the RPZ (e.g. Myara, Kisler or McCoy mine facilities)

Stage	Activities
	<ul style="list-style-type: none"> • Install temporary drainage around perimeter of proposed construction area, including sumps where the construction area does not drain into the permanent drainage sumps (see below). • Install temporary containment measures at construction area including hydrocarbon booms, spill kits and hay bales. • Install sumps upstream of the river crossing to intercept a significant portion of the upstream runoff. • Clearing is undertaken for the haul road approach to the river crossing within the open upland vegetation (E, D, P, S, T, W, Y dominant vegetation types, see Section 5.3.4.2) up to the boundary of riparian vegetation (A and C dominant veg types) and thereafter any access or construction over the riparian vegetation is by pushing over vegetation rather than clearing, in order to prevent direct soil disturbance within the river valley floor.
<p>Stage 2: Permanent drainage sumps</p>	<ul style="list-style-type: none"> • Install permanent drainage sumps on either side of the proposed crossing. • Three stage sumps to be constructed on each side, comprising two HDPE lined sumps to enable capture of hydrocarbon spills, and a third sump for runoff storage and infiltration. • The three stage sumps will be sized to contain runoff over the crossing catchment (causeway and approach) from a one per cent AEP (one in 100 year) seven-day storm event. • A spillway with rock armour erosion protection will be installed on the third sump, to allow controlled release of runoff from a greater than one per cent AEP storm event.
<p>Stage 3: Culvert and embankment construction – scheduling</p>	<ul style="list-style-type: none"> • The pre-works and permanent drainage sumps will be scheduled for summer-autumn to avoid the river flow period and potential heavy rainfall in wet catchment conditions. • Once temporary and permanent drainage is installed and containment measures are established, main construction works will commence. • Main construction works will be scheduled for summer-autumn as far as practicable, however construction may extend into winter-spring depending on the timeframe of gaining approvals and the requirement to maintain ore supply to Pinjarra Refinery. • Options are presented for whether river bed is dry or flowing.
<p>Stage 3 - Option 1: Culvert and embankment construction when river bed is dry (summer-autumn)</p>	<ul style="list-style-type: none"> • Ensure construction commences when weather forecast shows seven days of no rain. • In a progressive manner and only opening lots that can be completed in a single shift, push over vegetation and cover with geofabric until the proposed culvert location within the river valley is reached • Where indicated by geotechnical investigation and design, excavate low strength material at proposed location for culvert footings. <ul style="list-style-type: none"> ○ excavation requirements for culvert footings to be confirmed by geotechnical investigation, but expected to be up to one metre depth, total volume up to 500 m³. ○ if material to be excavated is identified as acid sulfate soil (ASS), undertake management in accordance with approved ASS management plan (see Section 7.5). • Construct culvert/s over stream channel: <ul style="list-style-type: none"> ○ compact culvert footing subbase, install geofabric and gravel footings ○ install pre-cast culvert sections

Stage	Activities
	<ul style="list-style-type: none"> ○ install fauna crossing culverts, to maintain ecological linkages within the Mine DE and allow for fauna access to areas outside of the Mine DE ○ install rock armour erosion protection on upstream and downstream side of culvert/s. ● Construct earth embankment over crossing, using imported fill. ● Install rock armour erosion protection over crossing embankment. ● Install pedestrian access track along embankment perimeter.
<p>Stage 3 – Option 2: Culvert and embankment construction when river is flowing / valley floor is wet (winter-spring)</p>	<p>The below approach installs the new culvert adjacent to the flowing river channel, then diverts the river flow into this culvert once completed, before blocking the river channel installing the embankment.</p> <ul style="list-style-type: none"> ● Ensure construction commences when weather forecast shows seven days of no rain. ● In a progressive manner and only opening lots that can be completed in a single shift, push over vegetation and cover with geofabric until the proposed culvert location is reached ● Construct temporary infiltration pond at a suitable location away from work area where groundwater is at least two metres from the pond floor. The pond will be used to store any groundwater seepage from the valley floor that enters the work area, or turbid water diverted water from the river channel during construction of the culvert. ● Create access to downstream end of proposed culvert location, using progressive push over of vegetation described above. Place and compact gravel foundation to create access. ● Excavate a small pond to act as a drainage sump at the downstream end of the proposed culvert location and install rock pitching. ● Install pump within the rock pitched ponds to pump potentially turbid water to the infiltration pond. Pumps to be sized appropriately based on flow rates within the river channel. Any diesel pumps or generators will be double banded. ● Prepare culvert footings from the downstream end to the upstream end, including excavation of low strength materials (if required) and ASS management (if required), as described for Stage 3 Option 2 above. Hay bales installed along the length of the working area adjacent to the flowing stream. ● Excavate another small pond with rock pitching on upstream end of culvert and pump out to remove standing water. ● Install culvert sections as described for Stage 3 Option 1 above. Backfill over culvert with embankment material. ● On upstream side of new culvert, hand-dig a small channel between flowing river channel and pond installed on upstream side of culvert. Allow river water to flow from upstream pond, through new culvert to wash out disturbed fines, then discharge into pond on downstream side of culvert. Pump water from the downstream pond into infiltration pond. ● With pumps still operating, block the flowing river channel with hay bales near upstream pond to divert all river water through new culvert. ● Confirm diverted river water is flowing clear through the new culvert before installing a geofabric sock to complete block the existing river channel and divert all river water through the new culvert. ● Lay hay bales across river channel adjacent to downstream end of new culvert.

Stage	Activities
	<ul style="list-style-type: none"> Complete construction of earth embankment over completed culvert and diverted river, as per Stage 3 – Option 1 above.
Stage 4: Haul road / conveyor construction	<p>Primary haul road:</p> <ul style="list-style-type: none"> Construct haul road pavement over completed embankment, using suitable locally won materials that meet specification. Install causeway drainage structures including inverted culvert and temporary bunds, and rock armoured channels into three stage sumps (see Stage 2 above). Install haul road berms and pre-cast concrete crash barrier sections (approximately 1.5 m high). Install sealed pavement and kerbs. <p>Conveyor:</p> <ul style="list-style-type: none"> Install conveyor and access road over embankment. <p>At completion:</p> <ul style="list-style-type: none"> Remove any remaining temporary drainage controls around the embankment construction area and rehabilitate any bare ground remaining to restore native vegetation.

8.4.7.2 River crossing design

The Serpentine and South Dandalup river crossing designs are undergoing progressive development, with detailed designs to be prepared to the level required to support a RIWI Act Bed and Banks Permit application, should one be required. Table 8.13 presents key design elements for river crossings. The river crossings at the Serpentine River and South Dandalup River are expected to be comparable to the existing river crossing over Big Brook in the Myara mine region, as presented in Plate 8-1.

Table 8.13 Key design elements for river crossings

Design element	River crossing	Secondary haul road crossing
Drainage sumps	<ul style="list-style-type: none"> triple stage sumps first two sumps HDPE lined for hydrocarbon capture design capacity: one per cent AEP (one in 100 year) seven-day storm event 	<ul style="list-style-type: none"> single stage sumps design capacity: one per cent AEP (one in 100 year) 72 hour storm event
Pavement	<ul style="list-style-type: none"> asphalt seal over compacted gravel 	<ul style="list-style-type: none"> compacted gravel
Erosion protection	<ul style="list-style-type: none"> rock armour over embankment, culvert bed, inlets and spillways from drainage sumps 	<ul style="list-style-type: none"> rock armour over inlets and spillways from drainage sumps
Haul road edge treatment	<ul style="list-style-type: none"> pre-cast concrete panels approximately 1.5 m high 	<ul style="list-style-type: none"> earth berm approximately 1.5 m high

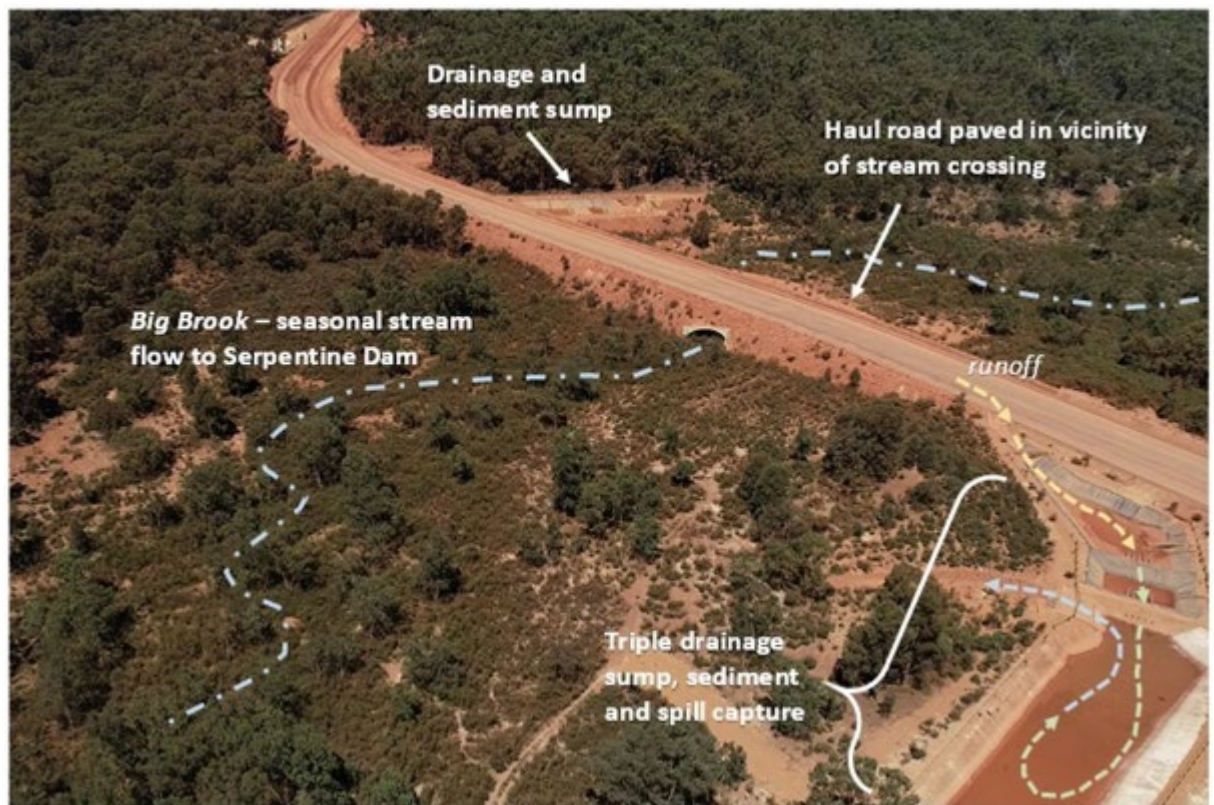


Plate 8-1 Existing Big Brook crossing, Myara mine region of Huntly Mine

8.4.7.3 Potential impacts during construction

Construction of a river crossing has potential to impact water quality through the following:

- major storm event and shallow groundwater conditions occurring during construction that exceeds the capacity of temporary drainage installed around the construction work area, causing a discharge of turbid water / sediment into the river downstream.
- accidental spills of diesel during refuelling of construction plant within the construction works area, causing groundwater contamination that could seep into the river downstream.
- excavation of culvert footings causing disturbance to acid sulfate soils (ASS), if present, causing oxidation and generation of acidic and metalliferous drainage.
- direct faecal deposition by construction personnel into bushland adjacent to the construction area, which could runoff with overland flow into the river downstream.

The permanent drainage sumps to be installed early during the construction phase will have a capacity of a one per cent AEP (one in 100 year) seven-day to storm event, therefore in the event of a storm event exceeding this intensity / duration there is potential for a loss of containment and discharge of turbid water into the river downstream. The likelihood of this event occurring is greater (though still less than one in ten in a given year) if the construction period extends into late winter and spring, during which the river valley floor may become saturated and subject to groundwater discharge (baseflow and throughflow) and saturated overland flow (see Section 8.3.3.3). The volume of turbid water and total sediment load from the discharge would be limited by the size of the construction area over the valley floor downslope of the permanent drainage sumps, which would be 100 to 200 metres wide and approximately a few hectares in extent. The discharge may result in coarse sediment deposition in the river channel downstream of the crossing and discharge of finer sediments into the reservoir a kilometre or more downstream.

Refuelling of large construction plant will be restricted to outside the valley floor, at a distance of at least 100 m from riparian vegetation. No refuelling of construction plant will occur over saturated ground such as may occur within the river valley floor during the winter-spring period. Fuel storage will be limited to designated construction compounds located outside of the RPZ and therefore well away from the river valley floor. Small quantities of diesel will be stored and refuelled within the pumps used to move water from the ponds to infiltration areas.

As discussed in Section 8.4.8, the majority of diesel spills and leaks, particularly those from major incidents and involving large volumes, are expected to be identified quickly and the contaminated soils excavated and disposed off-site at a licensed waste facility. Smaller spills and leaks may potentially be missed and the contaminants leach through the unsaturated zone. The smaller spills and leaks are expected to remain predominantly adsorbed to soil particles beneath the spill site. Diesel and particularly oil contain larger chain hydrocarbons that are weakly water soluble and readily adsorb to soils with organic matter and clay content. Small volumes of diesel and oil that escape detection and remediation are unlikely to result in substantial migration of hydrocarbons into the river channel and transport into the reservoir. Accordingly, the storage and handling of hazardous materials during construction or operations is expected to pose a low risk to water quality.

As presented in Section 7.4.2.2, excavation of sediments within valley floors will be limited to the immediate vicinity of the river/stream channel to create footings for culverts. The volume of sediment that may be removed is expected to be up to 500 m³ for a river crossing and less for a stream crossing, subject to confirmed final geotechnical design requirements. Apart from culvert footings, no trenches or other excavations will occur within the valley floors for river or stream crossings. The shallow excavation of valley floor sediments for culvert footings may disturb ASS, if present in the sediments. Disturbance to ASS, if present, may cause oxidation of ASS and generation of acid and metalliferous leachate. All river and stream crossings will be subject to geotechnical survey, including sampling for ASS. If ASS are identified as present in the sediments to be removed, then management will be undertaken in accordance with national guidelines to minimise disturbance to and impacts from ASS (see Section 7.5).

The risk posed by pathogens due to direct faecal deposition from the workforce is discussed in Section 8.4.10. Strict hygiene requirements will apply to the river crossing construction, including an enforced zero on-site waste disposal. All toileting and other waste disposal will occur at designated construction compounds located outside of the RPZ.

8.4.7.4 Potential impacts during operations

Operation of a river crossing has potential to impact water quality through the following:

- vehicle accident on causeway where the vehicle crests the concrete barriers and crashes off the causeway into the river, causing a rupture of a fuel tank and discharge of hydrocarbons into the river
- vehicle accident involving a sewage tanker servicing the Holyoake mine facilities, where the tanker crests the concrete barriers and crashes off the causeway into the river resulting in rupture of a tank and discharge of sewage sludge into the river
- major storm event and shallow groundwater conditions occurring that exceeds the capacity of permanent drainage sumps, causing a discharge of turbid water / sediment and any other contaminant residues in the sumps (e.g. hydrocarbons) into the river downstream
- major storm event and shallow groundwater conditions occurring that exceeds the capacity of permanent drainage sumps, occurring concurrent with a vehicle accident involving a major spill of fuel or sewage on the causeway, with the spill entering the sumps and then overflowing with major storm runoff into the river

- vehicle fire on causeway resulting in application of fire suppression (3F) foams and oily discharges from pyrolysis of tyres into the sumps, which overflows into the river if the spill occurs concurrent with a major storm event that exceeds the sump capacity.

Vehicle incident records for the Huntly Mine over the period of 2011 to 2020 provide a large sample of vehicle movements (estimated total 17.1 million kilometres of travel by the mine fleet) to estimate a representative accident rate per kilometre of travel. Over the 2011 to 2020 period (ten years) there were a total of six vehicle accidents (vehicle collisions with haul road berms) recorded at the Huntly Mine, or average of 0.6 accidents per year or 0.35 per million km of travel. These accidents were contained within haul roads and did not result in vehicles cresting the berm and crashing off the road. Over 2011 to 2020 there were a total of 23 vehicle fires recorded, or an average of 2.3 per year or 1.34 per million km of travel. No sewage tanker or fuel tanker accidents were recorded over 2011 to 2020, which is consistent with the much lower frequency of movements of those vehicles compared to the mine fleet.

There were a total of 620 reported incidents of loss of containment (spills) of hydrocarbons at the Huntly Mine over 2017-2022. The incidents averaged 103 per year, with an average spill volume of 132 litres. Based on a conservative estimate that all spills occurred on haul roads, the spill rate is estimated at 60.2 per million km of travel.

Assuming the entire Huntly Mine production of approximately 25 Mtpa was conveyed over the river crossing via a primary haul road and was carried in haul trucks with a 250 tonne load per truck, the river crossing would be subject to approximately 100,000 return trips or 200,000 one way crossings, as haul trucks comprise the predominant traffic on haul roads. Based on an approximate one km length of causeway draining into the crossing sumps, the total crossing travel is approximately 200,000 km per year and applying an average statistics from the Huntly Mine the incident rate over the causeway is estimated as:

- Approximately 0.07 vehicle accidents per year.
- Approximately 0.27 vehicle fires per year.
- Approximately 12 oil or coolant spills per year.

The cumulative likelihood of an incident occurring on the river crossing concurrent with a major storm event greater than one in 100 years that could exceed the sump capacity is considered remote, as the mine fleet would not operate in intense storm periods which would result in unsafe road conditions and temporary closure of the haul road network. A major storm event could conceivably occur immediately after an incident on the causeway and prior to completion of spill response activities and removal of all incident contaminants (e.g. fuels, tyre pyrolysis residue, 3F fire suppression foam) from the three stage sumps, however it would need to be concurrent in the week following the incident, which would have a cumulative likelihood of about in 100,000 for vehicle accidents, about five in 100,000 for vehicle fires, and about two in 1000 for an oil or coolant spill (average 132 litre volume).

The likelihood of a mine fleet vehicle, fuel or sewage tanker losing control (e.g. through a driver losing consciousness and/or a mechanical failure of steering and brakes) and approaching the causeway at high speed, cresting the concrete barriers and crashing off the causeway and into the river crossing is also considered remote. An incident of a vehicle crashing off a haul road was not recorded in the Huntly Mine over 2011 to 2020 and would have a likelihood less than 0.06 per million km of travel or less than 0.01 accidents per year over the causeway for a haul truck, and much lower for a fuel tanker or sewage tanker that have lower frequencies of crossings per year. In addition to a lower frequency of crossings, a fuel tanker or sewage tanker has a much smaller mass and tyres than a haul truck and would be far less likely to crest the approximately 1.5 m concrete barriers along the causeway.

Based on the assessed incident statistics and the proposed design capacity of the river crossing sumps, it is considered a remote event that a major discharge of hydrocarbons or fire suppression foam could occur from the causeway and enter the river downstream. The likelihood of a greater than one in 100 year storm event occurring at some point over a ten year operational lifetime of a river crossing is less than one in ten, and if occurring would result in an overflow of turbid water from the sumps that enters the river downstream with the major storm event flows in the wider catchment. The total volume of suspended sediment entering the river would be limited by the contributing catchment to the sumps, which would be approximately 2.5 hectares, and would not be expected to cause a noticeable impact at the offtake.

8.4.8 Contamination from spills and/or leaks from storage and handling of hazardous materials and waste

Impacts from a large volume diesel spill

The Mine is a diesel-only fuel site, with no storage or handling of unleaded petrol. Diesel is predominantly used for haul trucks, excavators and other large earthmoving equipment, and to a lesser extent for light vehicles. The storage and handling of diesel creates a potential hazard for spillage of diesel that may enter reservoirs. GHD (2023a) examined the effect of mining activity-related diesel spill incidents in the catchments, with the assumption that a 15 m³ fuel tanker load was directly discharged into a stream at a haul road crossing. This event is equivalent to a worst-case during construction (e.g. a major fuel spill during construction of a haul road or conveyor crossing of a waterway) or during operations (e.g. a mobile fuel tanker supplying heavy equipment in the field).

The modelled processes leading to decreased diesel concentrations were stream dilution, reservoir mixing and dispersion, and withdrawals from the dams. The modelled diesel spill incidents in Serpentine Main Dam and South Dandalup Dam were predicted to result in peak concentrations at the dam offtakes at up to 1 µg/L, whilst a mid-reservoir spill in Pipehead Dam was predicted to result in peak concentrations at the dam offtake at up to 5 µg/L. These concentrations did not exceed the ADWG health based guideline limits for components of diesel fuel. The ADWG notes that diesel contamination in drinking water has a taste and odour threshold of 5 µg/L. This could be reached, with the largest predicted peak diesel concentration of up to 5 µg/L for the Pipehead Dam.

A large volume diesel spill may result in water quality impacts in the stream zone downstream of the spill as well as the upper reservoir prior to substantial mixing and attenuation. Localised impacts within the stream zone may impact aquatic fauna that occur seasonally during stream flow, as well as the condition of riparian vegetation. Impacts within the upper reservoir may affect aquatic fauna that reside in the perennial waterbody, including native fish, freshwater crayfish and potentially populations of Carter's Freshwater Mussel (see Section 6.3.4).

Use of per- and polyfluoroalkyl substances (PFAS)

Alcoa has committed to using PFAS-free fire-fighting foams for the Myara North, Holyoake and O'Neil regions. All water supplies to construction and operations in the Myara North, Holyoake and O'Neil regions will be sourced from public drinking water sources, captured onsite stormwater or from licensed onsite water treatment facilities where approved for reuse on the Mine.

PFAS would be limited to minor quantities in materials such as workforce clothing, paper packaging, carpets or wire insulation, which are unlikely to be discharged to the environment as all wastes will be recycled or disposed of off-site at licensed waste facilities. Accordingly, the direct discharge of PFAS from construction and mining is expected to pose a low risk to drinking water quality.

The existing land uses and baseline monitoring program (Appendix B8.1 and Appendix B8.2) do not indicate the presence of substantial PFAS contamination within the Myara North, Holyoake or O'Neil regions. PFAS are relatively persistent and water-soluble compounds that readily mobilise through the unsaturated zone and into groundwater, which discharges into streams. It is therefore expected that any existing substantial PFAS contamination of the catchments would be detectable in stream flows. Due to the absence of existing substantial contamination, any hydrological changes from construction and mining (i.e. the clearing of vegetation causing groundwater mounding and increased stream flows) are not expected to mobilise substantial quantities of PFAS into reservoirs. Accordingly, the indirect mobilisation of historic PFAS from catchments due to construction and mining is expected to pose a low risk to water quality.

Other hazardous materials

Diesel is the predominant hazardous material used at the Mine, and to a lesser extent hydraulic and lubricating oils. Minor quantities of other hazardous materials include solvents, adhesives and other chemicals are used for vehicle and equipment maintenance or water treatment.

Haul trucks, some wheeled earthmoving equipment and light vehicles are refuelled at fuel bays. Planned maintenance of haul trucks, light vehicles and some earthmoving equipment is undertaken at workshops. The fuel bay and workshop buildings are located at mine facilities and have roofs and sealed floors, which are expected to capture spills or leaks during refuelling or maintenance. Diesel and oil storage tanks are located at mine facilities and are double-lined and above ground to minimise and detect leaks. Smaller quantities of hazardous materials stored at mine facilities inside buildings or on sealed floors.

Excavators, bulldozers and other earthmoving equipment are refuelled and maintained in the field. Refuelling and maintenance in the field have the potential to cause spills and leaks that contaminate soils. There is also potential for ongoing, low-level oil leaks from vehicles and equipment, and rare collisions that result in fuel or oil spills.

The majority of spills and leaks, particularly those from major incidents and involving large volumes, are expected to be identified quickly and the contaminated soils excavated and disposed off-site at a licensed waste facility. Smaller spills and leaks may potentially be missed and the contaminants leach through the unsaturated zone. The smaller spills and leaks are expected to remain predominantly adsorbed to soil particles beneath the spill site. Diesel and particularly oil contain larger chain hydrocarbons that are weakly water soluble and readily adsorb to soils with organic matter and clay content. Small volumes of diesel and oil that escape detection and remediation are unlikely to result in substantial migration of hydrocarbons that reach streams and can be transported into reservoirs. Accordingly, the storage and handling of hazardous materials during construction or operations is expected to pose a low risk to water quality.

8.4.9 Water quality deterioration in streams and reservoirs, including cumulative impacts from existing mining operations

8.4.9.1 Drinking water catchment protection

Alcoa will implement preventative risk management for the Proposal consistent with the multiple barrier approach specified by the ADWG. ADWG (Version 3.9, December 2024) notes that traditional preventive measures are incorporated as or within a number of barriers, including:

- catchment management and source water protection
- detention in protected reservoirs or storages
- extraction management
- coagulation, flocculation, sedimentation and filtration

- disinfection
- protection and maintenance of the distribution system.

Alcoa's preventative risk management framework prioritises catchment management and source water protection, as the first barrier to protecting drinking water and consistent with the first principle specified by the ADWG:

"The greatest risks to consumers of drinking water are pathogenic microorganisms. Protection of water sources and treatment are of paramount importance and must never be compromised."

Reservoir detention as a barrier

Reservoirs have potential to be effective barriers for drinking water contaminants however they can be subject to limitations. Accordingly, Alcoa's preventative risk framework does not rely on reservoir detention as a barrier but aims to prevent contaminant discharges into reservoirs.

The ADWG (Version 3.9, December 2024) notes the following with respect to reservoir detention:

"Detention of water in reservoirs can reduce the number of faecal microorganisms through settling and inactivation, including solar (ultraviolet) disinfection. Most pathogenic microorganisms of faecal origin (enteric pathogens) do not survive indefinitely in the environment. Substantial die-off of enteric bacteria will occur over three to four weeks. Enteric viruses and protozoa will survive for longer periods (weeks to months). Detention also allows suspended material to settle, which makes subsequent disinfection more effective and reduces the formation of disinfection by-products. Other preventive measures in reservoirs and storages include:

- *reservoir mixing or destratification to reduce growths of cyanobacteria (taste, odour and toxin production)*
- *excluding or restricting human, domestic animal and livestock access*
- *diversion of local stormwater flows."*

"Reservoirs are a valuable barrier for pathogen removal/inactivation and can contribute to the overall treatment target (expressed as LRVs) of a treatment train. When contributing to the LRV, it is essential that the pathogen removal performance of the reservoir be quantitatively evaluated for all relevant conditions. This will involve a site-specific evaluation of the fate and transport of pathogens in the reservoir.

Researchers have investigated the way in which pathogens move through reservoirs (Brookes et al 2004). Some pathogens are settled by gravity if water is static. They may also be inactivated by temperature, sunlight and predation at varying rates. Pathogen risk can be reduced if water is stored for long enough. If waters are very clear and shallow, factors such as temperature and sunlight can also influence how much pathogens are reduced. This is particularly the case for organisms which are sensitive to UV light, such as Cryptosporidium.

Under relatively low flow conditions, reservoirs can provide good removal when pathogen ingress occurs some distance from the offtake. However, in practice reservoir storage barriers can be compromised by:

- *waterfowl perching on offtake infrastructure*
- *public access, such as recreation close to water supply offtakes*
- *short circuiting through a combination of hydraulic forcing and temperature/density related buoyancy especially following rain events*
- *resuspension of sediments containing pathogens that are able to survive in the environment following rain-events and rapid inflows into reservoirs.*

To be confident in the ability of a reservoir to contribute to the LRV (through processes such as dilution, attenuation and settling) the following factors need to be understood:

- *the hydrodynamics of the reservoir*
- *sources of direct pathogen ingress (e.g. from public access, including recreation if allowed or frequently observed)*
- *the dynamics of water inflow (particularly high-volume inflow events such as floods or high flow managed releases).*

Risk management preventive measures that rely upon reservoir storage should assess the impacts of these variables. In particular, ingress close to offtakes and short-circuiting from more distant inflows should be carefully evaluated. Appropriate controls should be included to reduce ingress of pathogens and increase retention time. Controls should also aim to promote reductions of concentrations present in feeder streams. Possible controls include:

- *restricting or excluding public access (including recreational access)*
- *turbidity monitoring*
- *water extraction management.”*

While Serpentine Dam and South Dandalup Dam are large storage reservoirs that provide potential for extended detention and settling, the Serpentine Pipehead Dam is a small reservoir. The Water Corporation (pers. comm 2024) advise that the *“Pipehead does not provide a means of dilution as it has its own treatment challenge arising from a range of catchment related issues, including Alcoa’s mining operations. The Pipehead is central to the distribution of drinking water into the IWSS, therefore any impacts to the Pipehead would result in a direct impact to the distribution system.”*

In recognition of the importance of the Serpentine Pipehead Dam to the IWSS and the limited detention available in that reservoir, Alcoa has committed to avoiding further mining in the Pipehead Dam’s catchment and has selected the Proposal’s Mine DE to exclude the Serpentine Pipehead Dam PDWSA (see Section 8.5.1).

Multiple barriers for catchment protection

The Proposal incorporates multiple preventative mitigation measures or ‘barriers’ to prevent hazards to downstream drinking water reservoirs from occurring or reduce them to acceptable levels. Multiple barriers are established to control hazards relating to pathogens, sediment discharge and hydrocarbons and other chemicals. The barriers act to prevent and minimise the discharge of pathogens, sediment and hydrocarbons into downstream reservoirs, which are themselves barriers to contaminant transport before raw water is removed at the offtakes and entering the Water Corporation’s water treatment and distribution system.

Figure 8-21, Figure 8-22, Figure 8-23 and Figure 8-24 present a conceptual overview of the multiple barriers to pathogens from the mine workforce, sediment discharge and hydrocarbons. Details of the barriers are presented in the Drinking Water Risk Assessment (GHD 2025, Appendix B8.6), including photograph examples, potential failure mechanisms, fail-safes, performance evidence, residual failure likelihood and proposed improvements.

The DWRA review of the existing barrier network at the Mine (GHD 2025) indicates that some barriers are likely to fail under certain conditions and with multiple barrier failures, result in varying quantities of contaminants reaching the downstream reservoirs. Key conditions that can cause multiple-barrier failure include workforce behaviour in the case of discharge of pathogens, and major storm events during wet catchment conditions in the case of sediment and hydrocarbons.

Additional barriers and improvements to existing barriers are proposed to reduce the likelihood of barrier failure and potential for discharge of contaminants into reservoirs. The DWRA details the proposed improvements, with key components as follows:

- Avoidance of mining in the Serpentine Pipehead PDWSA
- Avoidance of mining within the RPZ of PDWSAs. Disturbance within the RPZ will be limited to three corridors for linear infrastructure.
- Workforce education and monitoring relating to pathogen risk
- Incident reporting and response (including waste bagging and removal) relating to pathogen discharge
- Application of risk-based Mine drainage controls in all disturbed areas, in accordance with Alcoa WA Mining and Haul Road Drainage Design Manual
- Rehabilitated mine pits to be designed and executed to prevent overflow during a 1 per cent Annual Exceedance Probably (AEP) storm event of 24 hour duration.

The Alcoa WA Mining and Haul Road Drainage Design Manual⁸ is a working document which is undergoing enhancements. Alcoa is conducting a detailed drainage management review that will incorporate learnings from historic and current drainage design, third party hydrological and engineering reviews and associated improvement plans. This will form a risk based mine drainage control tool that will be incorporated into the Manuals and executed.

The quantitative assessment of risks posed by discharge of hydrocarbons, pathogens and sediment/turbidity presented in Section 8.4.10.1 and Section 8.4.10.2 assume varying degrees of barrier failure. In the case of hydrocarbons and sediment/turbidity, the quantitative assessments assume catastrophic failure of barriers during major storm events and low reservoir water levels. The quantitative assessments undertaken as part of the DWRA (GHD 2025, Appendix B8.6) are therefore highly conservative and characterise the residual risk to the existing preventative risk management at the Huntly Mine, prior to the proposed barrier improvements to the mine.

⁸ <https://approdnoaaaaacomsa.blob.core.windows.net/australia/pdfs/Appendix%2016%20-%20Drainage%20Design%20Manual.PDF>

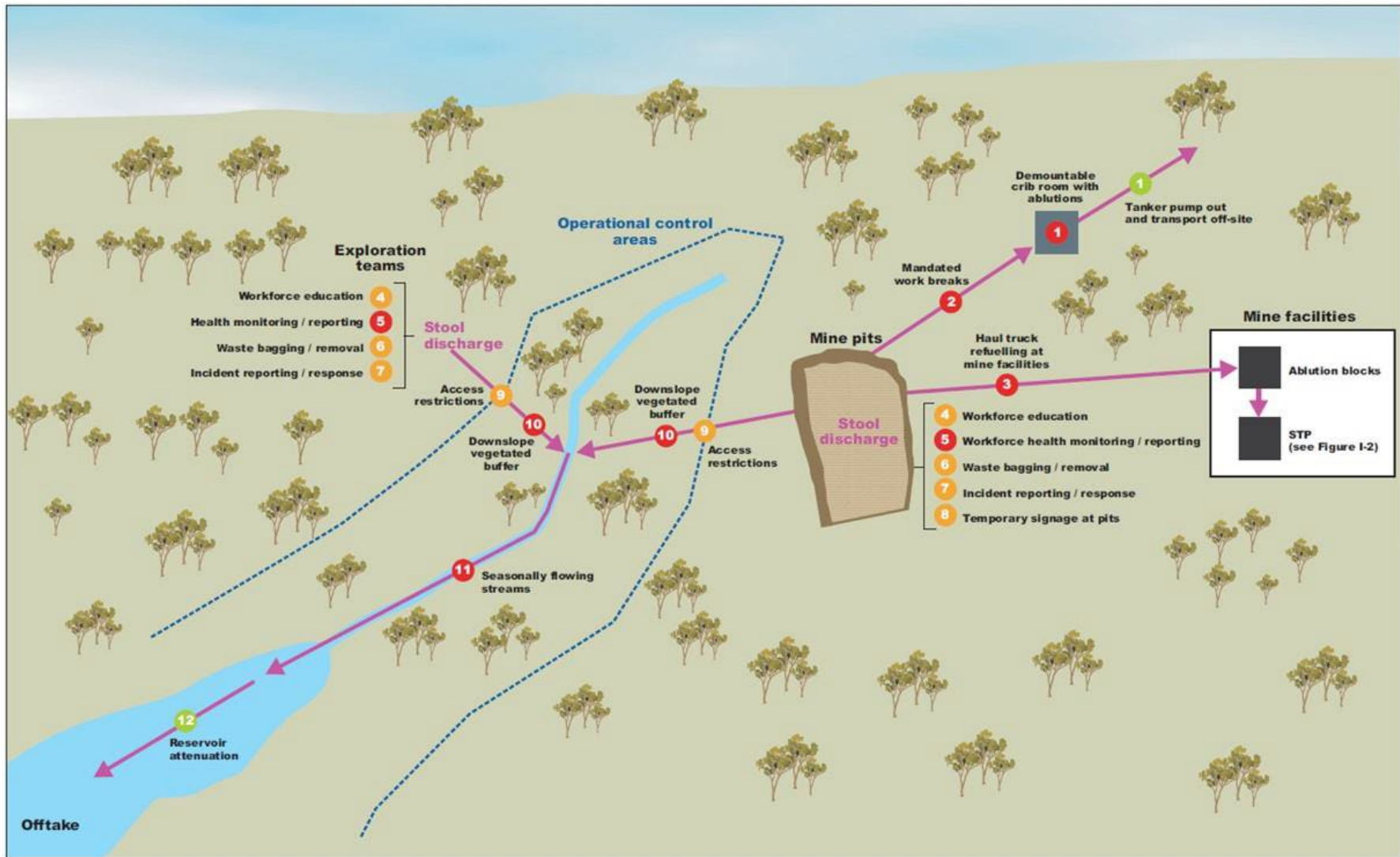


Figure 8-21 Preventative barriers to pathogen discharge and transport – workforce in the field - conceptual model

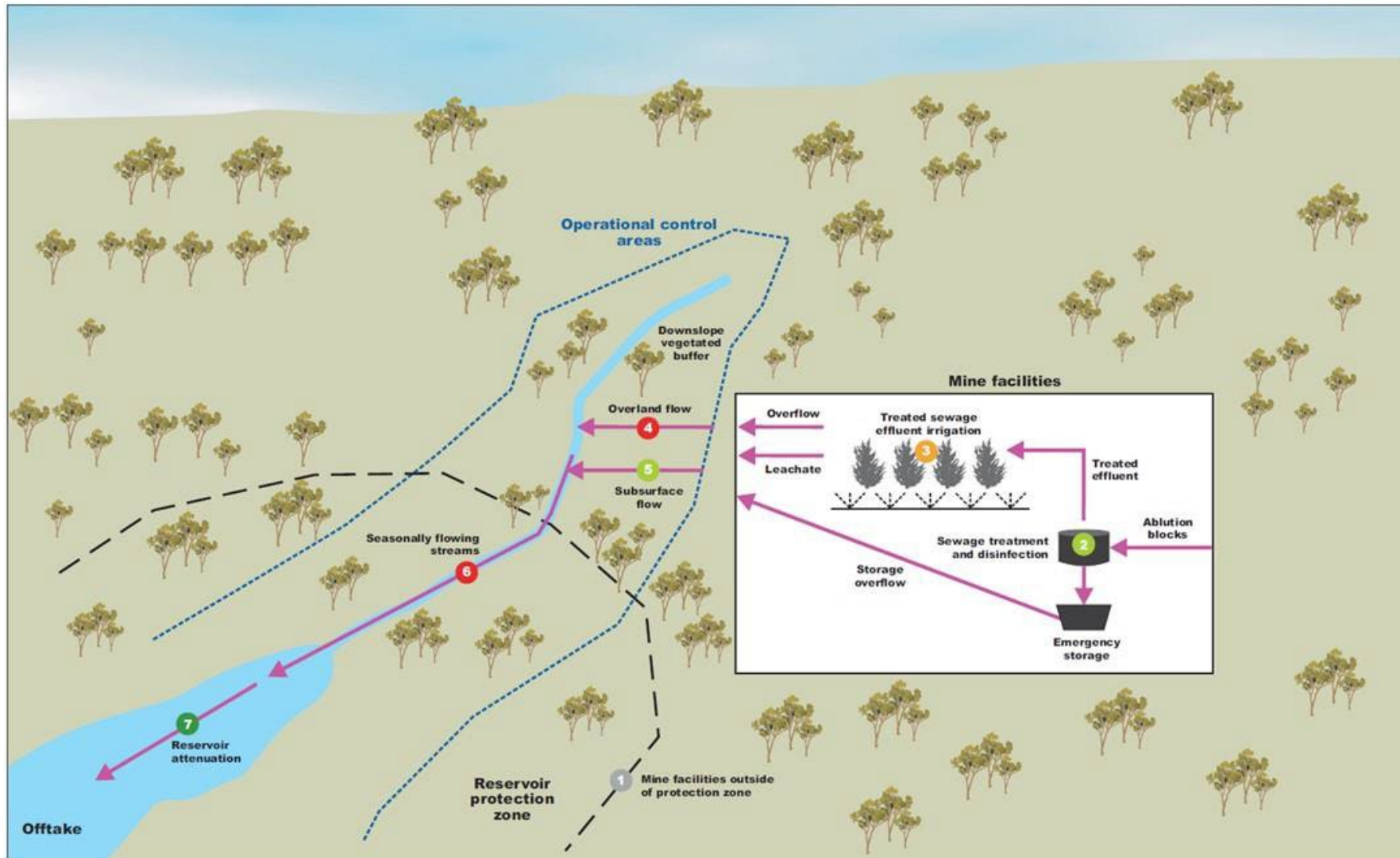


Figure 8-22 Preventative barriers to pathogen discharge and transport – workforce at mine facilities – conceptual model

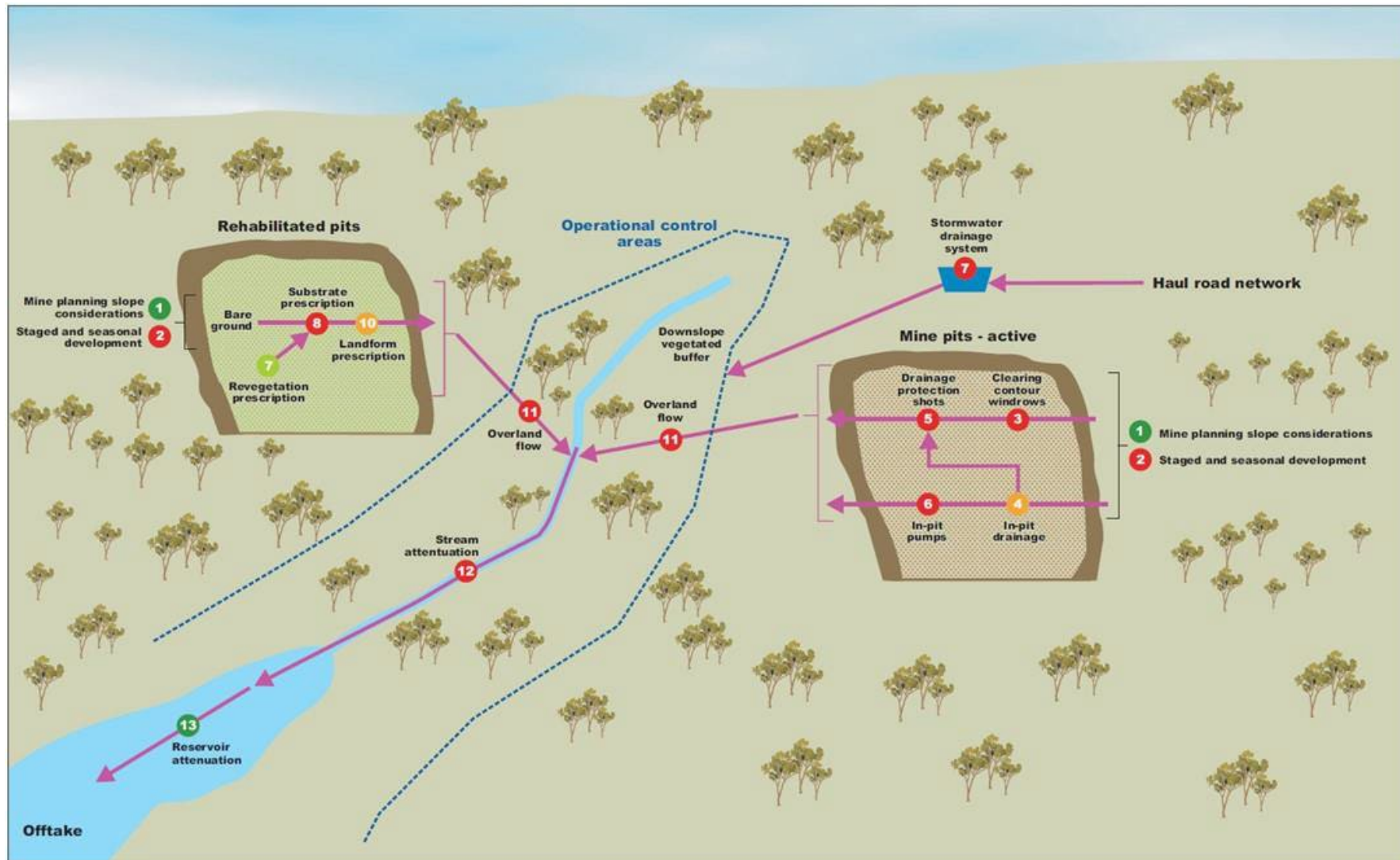


Figure 8-23 Preventative barriers to sediment discharge and transport – conceptual model

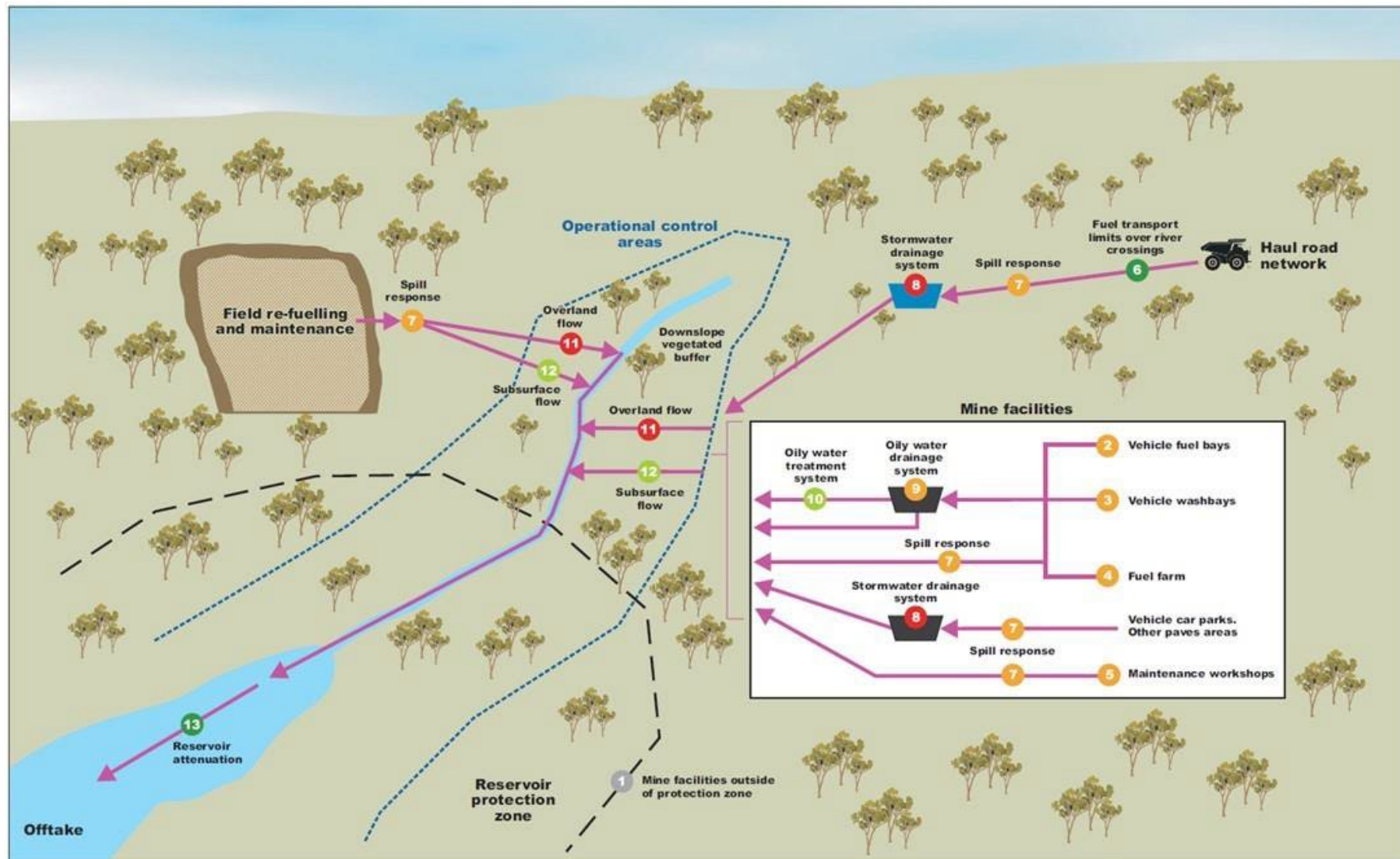


Figure 8-24 Preventative barriers to hydrocarbon discharge and transport – conceptual model

GHD (2025) conducted a Drinking Water Risk Assessment (DWRA) in accordance with contemporary guidance. The DWRA is presented in Appendix B8.6 and assessed in detail the following key hazards:

- pathogenic microorganisms
- turbidity
- hydrocarbons, PFAS and other hazardous materials
- wildfires
- long term erosion of rehabilitation.

The DWRA findings concerning hydrocarbons, PFAS and other hazardous materials are discussed in Section 8.4.8 and the findings to long-term erosion of rehabilitation are discussed in Section 8.4.5.

The findings to pathogens, turbidity and wildfires are discussed below.

8.4.9.2 Drinking water risk assessment – pathogens

The Australian Drinking Water Guidelines (NHMRC and NRMCC 2018) state that the greatest risks to consumers of drinking water are pathogenic microorganisms. GHD (2025) assessed pathogen hazards to PDWSAs through a source vulnerability assessment and a quantitative microbial risk assessment (QMRA).

The source vulnerability assessment concluded that human settlement and stock animal challenges of microbial risk aligned well with category 1 source waters for the Serpentine Dam, Serpentine Pipehead Dam and South Dandalup Dam. Some challenges presented from itinerant human activity could be regarded as category 1 or 2, however with the consideration of existing mitigation factors, the source water could be considered as a category 1 source. This was consistent with the current treatment applied to the source water. The assessment was verified with a desktop sanitary survey applied to sewage treatment systems and mobile work teams typically associated with construction, mining and rehabilitation activities. The worst-case outputs from this survey assessment produced medium or low-risk results, in line with the outcomes of the vulnerability assessment.

The QMRA was conducted to estimate impacts of pathogen inputs from the Proposal and other sources in the Serpentine Dam, Serpentine Pipehead Dam and South Dandalup Dam that could potentially become entrained in the source waters for drinking water supply. The QMRA examined the concentration of the reference pathogen *Cryptosporidium* through to potential exposure to the local population, estimated the risk of illness from such exposure, and expressed this risk as Disability Adjusted Life Years (DALYs). Pathogen inputs to the catchment were examined as hazardous events, including:

- sewage overflow during on-site treatment
- washout of treated effluent from an irrigation area
- subsurface leaching of treated effluent
- direct faecal deposition in a riparian zone by a staff member with asymptomatic cryptosporidiosis.

The worst case of each of these events was considered, with the assumption of steep terrain, little vegetation coverage, and heavy rainfall resulting in high rates of transport of contamination into the receiving reservoir. Hydrological modelling by GHD (2025) examined subsequent pathogen transport and survival through the reservoirs, and pathogen exposure and dose response estimates were applied to calculate the risk from the use of each dam as a source water. The risk was then compared with an acceptance threshold of 10^{-6} DALYs/person/year.

Table 8.14 and Table 8.15 summarise the QMRA outputs for Serpentine Dam and South Dandalup Dam, respectively. Outputs for the Serpentine Dam are also presented for the existing Huntly Mine (Myara region) operations within the PDWSA. As presented, the operation of a sewage treatment plant at the proposed Myara North or Holyoake mine facilities within the Serpentine Dam or South Dandalup Dam PDWSAs has a potential cryptosporidium dosage at reservoir offtakes that is well within the health risk thresholds.

However, direct faecal deposition within the Serpentine Dam or Serpentine Pipehead Dam PDWSAs has potential to result in exceedance of the 10^{-6} DALY threshold and within Serpentine Pipehead Dam to also result in peak cryptosporidium concentrations that pose an unacceptable high risk of short-term cryptosporidiosis epidemics. The Proposal Mine DE excludes the Serpentine Pipehead Dam PDWSA and so no pathogen hazards are considered for proposed mining associated with the Proposal in that reservoir. The elevated health risks for direct faecal deposition indicates that additional preventative control measures are required to reduce the risk to acceptable levels for the Serpentine Dam and South Dandalup Dam.

Alcoa have incorporated additional preventative controls for the Proposal to reduce the risk posed by pathogens, including avoidance of the RPZ and an Avoidance Zone around streams, as presented in Section 8.5.1.

A crash of a sewage tanker or a deliberate (illegal) discharge by a tanker operator that causes a pathogen discharge from the Proposal into a drinking water reservoir are not considered credible hazards. Sewage tanker operations would pose a likelihood of a tanker accident within a PDWSA at about one in 10,000 over the life of each mine region, or about one in 100,000 for a tanker accident over the approximately one kilometre causeway of the Serpentine River or South Dandalup River main channel (GHD 2025). These estimated likelihoods relate to any accident and not necessarily a catastrophic accident with sufficient damage to cause a rupture of the sewage tank, which would be an even lower likelihood and would be considered a very remote and freak event.

The hazard of a deliberate (i.e. illegal) discharge of sewage within a PDWSA is also not considered a credible hazard. All collection of sewage at the Huntly Mine is by a licensed waste contractor and requires waste tracking as a controlled waste under the Environmental Protection (Controlled Waste) Regulations 2004, which is a practice that would be continued for the Proposal. Any discharge of the collected sewage during transport off-site would thereby be recorded by the tracking system (i.e. a discrepancy between the generator and receiver records).

The ADWG notes that detention in reservoirs is a traditional preventative measure, reducing the number of faecal microorganisms through settling and inactivation, as well as settling suspended solids, which makes subsequent disinfection more effective. However, the ADWG notes that multiple barriers are required to protect drinking water, and that catchment management and source water protection provide the first barrier for protection. Accordingly, Alcoa will implement preventative risk management (see Section 8.5.1) to prevent discharge of pathogens into the reservoir, rather than relying on reservoir detention as a barrier.

Table 8.14 Cryptosporidium dose estimates from Proposal hazards – Serpentine Dam

Scenario	Hazard	Existing Huntly Mine (Myara region) operations			Proposed Huntly Mine (Myara North DE) operations		
		Peak concentration at offtake (oocysts/L)	Average concentration at offtake (oocysts/L)	Source water DALYs per person per year	Peak concentration at offtake (oocysts/L)	Average concentration at offtake (oocysts/L)	Source water DALYs per person per year
	Risk threshold	0.01 ⁹	n/a	10 ⁻⁶	0.01	n/a	10 ⁻⁶
1	Sewage overflow from mine facilities sewage treatment plant	~ 5 x 10 ⁻⁵	2.23 x 10 ⁻⁷	1.94 x 10 ⁻⁸	~ 1.5 x 10 ⁻⁵	3.63 x 10 ⁻⁷	3.16 x 10 ⁻⁸
2	Washout of treated effluent from an irrigation area	~ 10 ⁻⁵	3.34 x 10 ⁻⁷	2.90 x 10 ⁻⁸	~ 2 x 10 ⁻⁵	7.97 x 10 ⁻⁷	6.93 x 10 ⁻⁸
3	Subsurface leaching of treated effluent	~ 1 x 10 ⁻⁷	1.39 x 10 ⁻⁸	1.21 x 10 ⁻⁹	~ 1 x 10 ⁻⁷	3.41 x 10 ⁻⁸	2.95 x 10 ⁻⁹
4	Direct faecal deposition in a riparian zone by a staff member with asymptomatic cryptosporidiosis.	0.0002 to 0.001	1.45 to 2.62 x 10 ⁻⁵	1.26 to 2.28 x 10 ⁻⁶	0.0002 to 0.0004	1.66 to 2.71 x 10 ⁻⁵	1.44 to 2.35 x 10 ⁻⁶

⁹ Threshold at high risk of causing a short term epidemic of cryptosporidiosis

Table 8.15 Cryptosporidium dose estimates from Proposal hazards – South Dandalup Dam

Scenario	Hazard	Proposed Huntly Mine (Holyoake DE) operations		
		Peak concentration at offtake (oocysts/L)	Average concentration at offtake (oocysts/L)	Source water DALYs per person per year
	Risk threshold	0.05	n/a	10^{-6}
1	Sewage overflow from mine facilities sewage treatment plant	$\sim 5 \times 10^{-6}$	2.14×10^{-7}	1.86×10^{-8}
2	Washout of treated effluent from an irrigation area	$\sim 5 \times 10^{-6}$	4.31×10^{-7}	3.74×10^{-8}
3	Subsurface leaching of treated effluent	$\sim 11.5 \times 10^{-6}$	3.30×10^{-8}	2.86×10^{-9}
4	Direct faecal deposition in a riparian zone by a staff member with asymptomatic cryptosporidiosis.	0.0001 to 0.001	4.62 to 9.82×10^{-6}	4.02 to 8.53×10^{-7}

8.4.9.3 Drinking water risk assessment - turbidity

Turbidity risks during mining – empirical data on loss of hydraulic containment of mine drainage (drainage failures)

The *Catchment Risk Assessment Alcoa 2023-2027, Procedural assessment under MS 728 informing the environmental audit of Alcoa's 2023-2027 MMP* (Water Corporation undated) identifies three key risk factors that increase the likelihood of a loss of hydraulic containment from mine drainage (e.g. haul road and mine pit sumps, mine pit drainage shots) in a given area, that could result in sediment / turbid water entering downstream reservoirs:

- clearing more than 30 per cent of a subcatchment
- clearing in areas greater than 16 per cent slope
- clearing in areas with a topographic wetness index (TWI) exceeding nine (9), as an indicator of potential shallow groundwater

Analysis undertaken for the *Catchment Risk Assessment Alcoa 2023-2027* concluded that approximately 95 per cent of reported drainage failures¹⁰ in the Huntly Mine over 2017 to 2021 resulted from either profile saturation or steep slopes, or combination of both, with only 5% of drainage failures not able to be explained by these two factors (Water Corporation undated).

Alcoa reported a total of 227 drainage failures from 2017 to 2022 over the Huntly and Willowdale mines, or an average of approximately 45 failures per year over that five year period. A peak of 77 drainage failures was reported in 2021. Approximately 60 per cent of reported failures from 2017 to 2022 occurred in mine pits or drainage protection slots, approximately 26 per cent occurred in haul roads and sumps, and approximately 13 per cent occurred in pits undergoing rehabilitation. It is noted that there are over 1,900 haul road sumps in the Huntly Mine alone, which indicates that the reported drainage failures from haul roads and sumps comprised less than one per cent of the installed drainage assets.

Review of Water Corporation monitoring data from the Serpentine Dam indicates that the reported drainage failures over 2017 to 2020, did not cause any noticeable rise in turbidity from past levels. Data was requested but not available for 2021 onwards to enable a comparison of turbidity levels in the reservoir following the peak drainage failures reported in 2021.

The reason why the reported drainage failures over 2017 to 2020 (or previous drainage failures within the Huntly Mine) did not cause a noticeable rise in turbidity at the outlets of the Serpentine Dam or South Dandalup Dam may be one or more the following factors:

- the small proportion of drainage assets failing (i.e. compared to the total number within the PDWSA) and the small proportion of the catchment contributing turbid water into the reservoirs over the limited duration of the failures, compared to wider catchment inflows over each winter-spring period
- potential attenuation of turbidity in overland flow and stream flow through settling or filtering/attachment on vegetation, reducing the sediment load into the reservoirs
- the performance of the reservoirs as barriers for turbidity, through settling of sediment particularly of sand, silt and non-dispersive clay fractions.

It is unlikely that turbidity peaks occurred but were not captured in the Water Corporation monitoring data due to intervals in the monitoring (e.g. intervals range from weeks to a month) as hydrodynamic modelling indicates that elevated levels of turbidity at the offtake, if occurring, would have been for a duration of a few months or more following major turbidity discharges (GHD 2021), which would have been captured by the monitoring.

¹⁰ Drainage failure is defined in this document as unplanned loss of containment from drainage features such as sumps.

It is noted that the Catchment Risk Assessment Alcoa 2023-2027 analysis of loss of hydraulic containment is based on the past performance of mine drainage, which has been subject to substantial improvements over the past two years. This includes the substantial revision of the original Minesite Drainage Book (Croton 1990) to a new Drainage Design Manual in 2020 and 2022, with the latest version at Revision E in December 2023 (Worley Consulting 2023). This has increased the minimum design storm event capacities for mine drainage to:

- mine pits: minimum capacity design 1% AEP 24 hours.
- haul roads: minimum capacity design 1% AEP 72 hours.

Water balance modelling has indicated the storage design criteria can achieve catchment runoff volume containment for mine pits for more than 99% and haul roads for 90-95% assuming infiltration rates within expected range (Worley Consulting 2023). It is noted that saturated catchment conditions may occur that reduce the infiltration rates and thus performance against the design standards. Where lower infiltration rates are identified, Alcoa commits to targeted water handling to manage storage design capacity extent (and additional clearing for haul road storage only) and/or increased storage capacity, to target runoff volume containment (Worley Consulting 2023).

Turbidity risks during mining – empirical data on discharge of turbid water from mine drainage (turbidity events)

Data Analytics Australia (DAA 2023) conducted an analysis of turbidity events based on Alcoa recorded data in un-mined, mined and rehabilitated catchments. The study compiled 2016 to 2020 turbidity data and undertook initial high turbidity event verification for 2021-2022.

DAA conducted top level statistical analysis for 10 monitors (i.e. catchments) with 80 per cent turbidity data availability for May to September 2021, analysing correlation of high turbidity events (> 25 NTU) with catchment characteristics. The statistical analysis indicated the following:

- Positive correlation between open area (i.e. cleared but not rehabilitated) and number of high turbidity events, however it was not statistically significant ($R^2 = 0.42$ $p = 0.22$).
- Correlation of close to zero between total catchment clearing (i.e. including rehabilitated areas) and number of high turbidity events ($R^2 = 0.01$ $p = 0.97$).
- Significant correlation between mean catchment slope (positive, $R^2 = 0.56$ $p = 0.09$) and area of completed rehabilitation (negative, $R^2 = -0.57$ $p = 0.08$) and number of high turbidity events.

DAA (2023) conducted statistical modelling of 14 monitors between January 2021 and September 2022 to estimate a sequence of multivariate statistical models. The modelling indicated the following:

- Catchment slope and rainfall have a significant positive effect on likelihood of occurrence ($p < 0.001$) and number ($p = 0.011$ and < 0.001 , respectively) of high turbidity events.
- Open area (i.e. cleared but not yet rehabilitated) has a significant positive effect on likelihood of occurrence ($p = 0.022$) but not number ($p = 0.776$) of high turbidity events.
- Total cleared area (i.e. including rehabilitated areas) has no effect ($p = 0.474$) on likelihood of occurrence or number of high turbidity events.
- When both clearing and rehabilitation are considered, rehabilitation has a significant negative effect (p reduces from 0.131 to 0.023) on the likelihood of occurrence of high turbidity events.

DAA (2023) reported the best-fitting model to predict expected number of high turbidity events as follows:

- Risk increases with increasing area open and increasing catchment slope
- Risk decreases with increasing rehabilitation
- High turbidity events can be expected within uncleared catchments

DAA (2023) concluded that open areas (i.e. cleared but not rehabilitated) pose a risk of high turbidity events, but cleared areas that have been subsequently rehabilitated do not. The modelling results strongly suggest that selection of a threshold on catchment clearing to minimise risk of high turbidity events should consider rehabilitation. DAA (2023) also concluded that high turbidity events are predicted to increase more rapidly when the open area is over 30 per cent of the catchment.

Turbidity risks during mining – subcatchment scale assessment of historic and proposed mining

Given the risks identified from historic drainage failures and turbidity events relating to the extent of mine area open, a subcatchment scale assessment (GHD 2025) was undertaken of historic and proposed mining, including clearing and rehabilitation. The assessment used published DWER hydrographic subcatchments as well as more detailed subcatchments developed by DWER and the Water Corporation for assessment of Alcoa's MMP submissions.

Assessment of historic clearing and rehabilitation against the DWER hydrographic subcatchments indicated the following:

- As at the end of 2023, the Huntly Mine involved a total clearing of 17,950 ha, with 13,990 ha (77.9 per cent) rehabilitated. The mine area open at the end of 2023 was 3,960 ha. Approximately 30.9 per cent of the rehabilitation is up to ten years of age, 28.3 per cent is from 11-20 years of age, 24.9 per cent is from 21-35 years of age and 15.9 per cent is over 35 years of age.
- The Jarrahdale Mine involved a total clearing of 4,033 ha prior to 2000, all of which was rehabilitated with approximately 57.7 per cent aged 21-35 years and 42.3 per cent aged over 35 years.
- There is no mine area open within the Jarrahdale Mine.
- As at the end of 2023, total clearing within the Serpentine Dam PDWSA was 6,972 ha, with 4,015 ha (57.6 per cent) rehabilitated and a mine area open of 2,958 ha. Approximately 56.5 per cent of rehabilitate is aged up to ten years and approximately 40.5 per cent aged 11-20 years. The mine area open represents 4.5 per cent of the PDWSA catchment area.
- As at the end of 2023, total clearing within the South Dandalup Dam PDWSA was 2,159 ha, with 100 per cent rehabilitated and no mine area open. Approximately 42.3 per cent of the rehabilitation is from 11-20 years of age, 39.4 per cent is from 21-35 years of age and 18.3 per cent is over 35 years of age.
- As at the end of 2023, total clearing within the Wungong Dam PDWSA was 2,507 (all of which for the Jarrahdale Mine), with 100 per cent rehabilitated and no mine area open. Approximately 56.7 per cent of the rehabilitation is from 21-35 years of age and 43.3 per cent is over 35 years of age.

Assessment of proposed clearing against the DWER hydrographic subcatchments indicated the following:

- Clearing within the Serpentine Dam PDWSA is estimated to comprise 3,919 ha for the Proposal and 2,367 ha under other approvals. Combined with historic clearing, the total

disturbance within the PDWSA is estimated at 13,259 ha and the worst case mine area open (assuming no additional rehabilitation) is estimated at 9,244 ha or 13.0 per cent of the PDWSA catchment area.

- Clearing within the South Dandalup Dam PDWSA is estimated to comprise 2,214 ha for the Proposal and 17 ha under other approvals. Combined with historic clearing, the total disturbance within the PDWSA is estimated at 4,300 ha and the worst case mine area open (assuming no additional rehabilitation) is estimated at 2,123 ha or 6.8 per cent of the PDWSA catchment area.
- Subcatchment analysis using the published DWER hydrographic subcatchments indicated that the Proposal and other proposed clearing for the Huntly Mine is not expected to create a mine area open exceeding 30 per cent of any of subcatchment, as follows:
 - The worst case mine area open (assuming no rehabilitation from 2024 onwards) within the Serpentine Dam subcatchments is estimated at less than 30 per cent of the subcatchment areas, with 21.0 to 29.3 per cent for subcatchments 3064 (Serpentine River), 3065 (39 Mile Brook) and 3069 (Big Brook), 10.4 per cent for subcatchment 3066 (Big Brook) and less than ten per cent for the remaining seven subcatchments.
 - The worst case mine area open within the South Dandalup Dam subcatchments is estimated at less than ten per cent of the subcatchment areas.

However, subcatchment analysis using the more detailed subcatchments developed by DWER and Water Corporation indicated an increased risk of a mine area open exceeding 30 per cent of subcatchments for the Serpentine Dam. Details are presented in the DWRA (GHD 2025) in Appendix B8.6, with the mine area open by subcatchment presented in Figure 8-25 (existing as at 2023) and Figure 8-26 (worst case as at 2044).

Analysis of historic clearing and rehabilitation against the detailed subcatchments indicated that five (out of 53) subcatchments had a mine area open exceeding 30 per cent as of 2023. These subcatchments comprise a total of 2,466 ha or 3.7 per cent of the PDWSA, and are clustered within the Myara mine region (see Figure 8-25). Based on the empirical data, mining in these subcatchments would be at a higher likelihood of drainage failures and turbidity events that could result in turbidity discharges to Serpentine Dam.

Analysis of proposed clearing against the detailed subcatchments indicates that clearing under the Proposal and other approvals has potential to increase the number of Serpentine Dam subcatchments with a mine area open greater than 30 per cent from five to 18 (see Figure 8-26 and). These subcatchments comprise a total of 12,258 ha or 18.5 per cent of the Serpentine Dam PDWSA. The Proposal has potential to contribute to an increase in mine area open to greater than 30 per cent in nine of the 18 subcatchments. The remaining nine subcatchments will be impacted by proposed clearing under other approvals. The Proposal has potential to contribute:

- Less than five per cent of subcatchment area, in Big Brook 7, Mt Solus and Serpentine 48 subcatchments.
- Five to ten per cent of subcatchment area, in Big Brook 13 and Serpentine 53.
- Ten to 20 per cent of subcatchment area, in Serpentine River 40 and 45.
- More than 20 per cent of subcatchment area, in Serpentine River 44 and 52.

The analysis of mine open area with proposed clearing is a worst case, assuming no additional rehabilitation from 2024 to 2044, which will not be the actual case. The mine area open will therefore be less than the worst case, however estimates cannot be made for specific subcatchments at this stage.

The analysis undertaken using the detailed subcatchments for Serpentine Dam indicates a higher risk at smaller subcatchment scales. Accordingly, mining and rehabilitation will need to be carefully planned over those subcatchments to ensure that the actual open area remains below 30 per cent of the subcatchment area, to reduce the risk of turbidity discharges to Serpentine Dam.

Analysis of the more detailed subcatchments for the South Dandalup Dam indicated that as at the end of 2044, the worst case mine area open (assuming no rehabilitation from 2024 onwards) was less than 30 per cent for all subcatchments (see Figure 8-27).

Turbidity risks – topographic slope and topographic wetness index

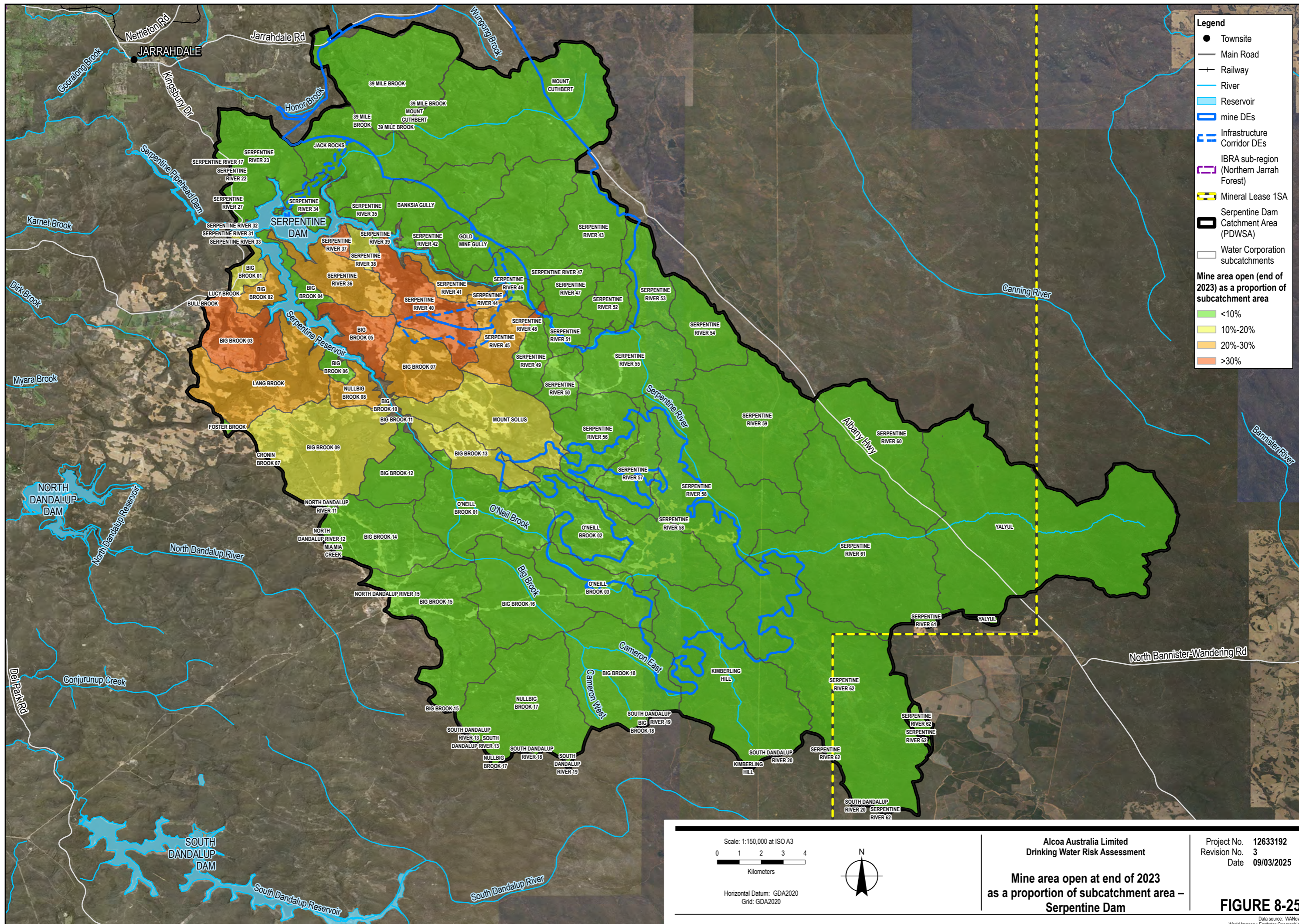
Further to the risk factors identified in the *Catchment Risk Assessment Alcoa 2023-2027* (Water Corporation undated) analysis was undertaken of the Mine DE against the following:

- topographic slope
- modelled TWI exceeding nine (9), as an indicator of potential shallow groundwater

The majority (21,896 ha or 91.6 per cent) of the DE comprises a topographic slope less than 16 per cent, with 21.4 per cent comprising a slope less than four per cent and 34.1 per cent comprising a slope of four to eight per cent.

The 1,997 ha (8.4 per cent) of the Proposal DE that comprises a topographic slope more than 16 per cent includes 1,215 ha (5.1 per cent) within an LDA or MDZ that could be subject to clearing. Based on the *Catchment Risk Assessment Alcoa 2023-2027* (Water Corporation undated), clearing within this 1,215 ha of the Proposal DE would pose an elevated risk of drainage failures. Accordingly, Alcoa propose additional avoidance measures (see Section 8.5.1) to reduce the risk of turbidity discharges to Serpentine Dam and South Dandalup Dam.

The area of modelled TWI greater than nine comprises approximately 6,281 (26.3 per cent) of the DE. Of this area, 4,144 ha (17.3 per cent of the DE) lies within an LDA or MDZ that could be subject to clearing. Based on the *Catchment Risk Assessment Alcoa 2023-2027* (Water Corporation undated), clearing within this 4,144 ha of the Proposal DE would pose an elevated risk of drainage failures. Where mining is proposed in areas with a modelled TWI greater than nine Alcoa proposed additional avoidance measures (see Section 8.5.1) to reduce the risk of turbidity discharges to Serpentine Dam and South Dandalup Dam.



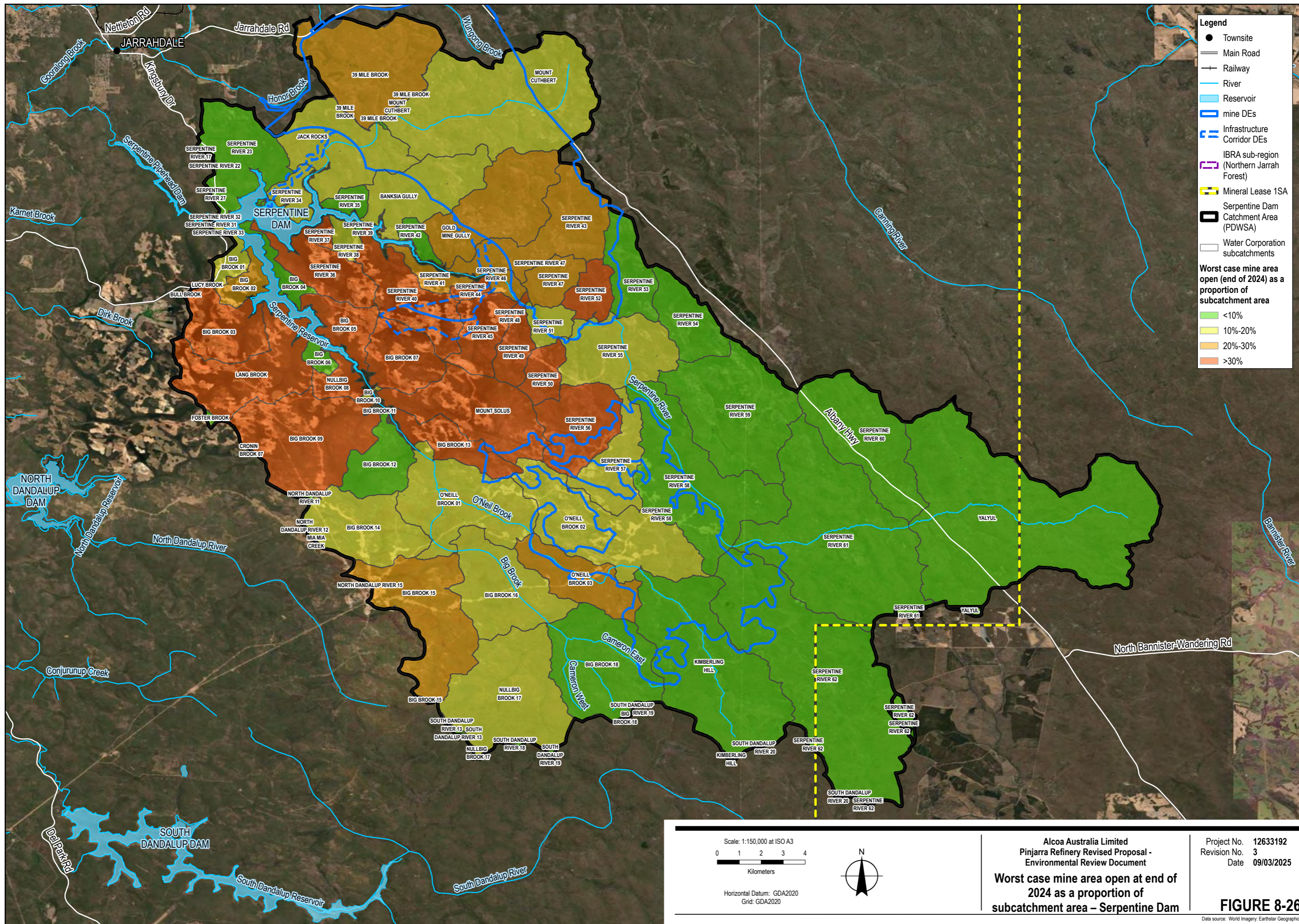
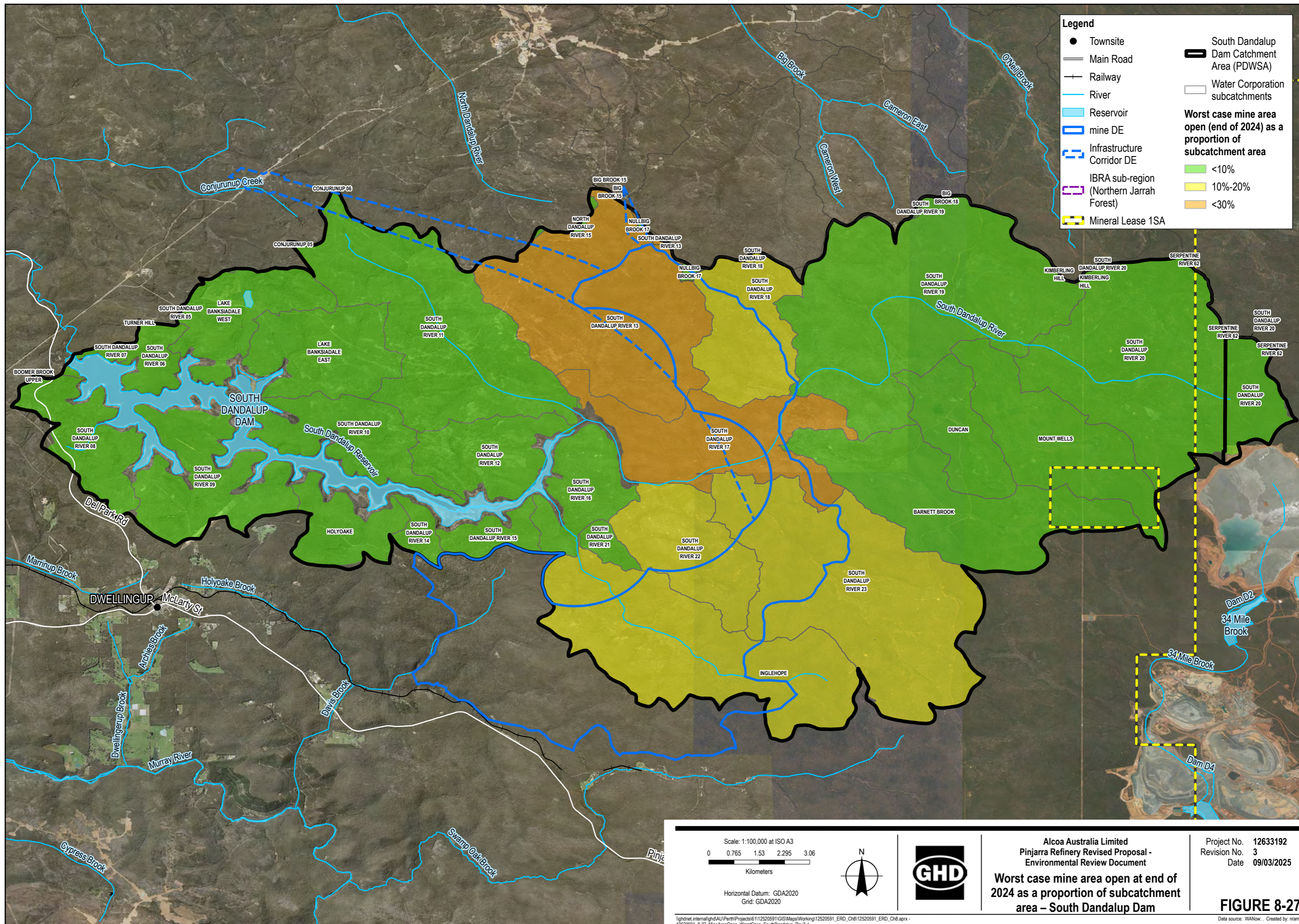


Table 8.16 Summary of detailed subcatchments with estimated worst case mine area open (as at 2044) exceeding 30 per cent of subcatchment area – Serpentine Dam

Subcatchment	Subcatchment area (ha)	Mine area open at end of 2023 as a proportion of subcatchment area (%)	Worst case mine area open at end of 2044 as a proportion on subcatchment area (%)	Clearing contribution of Proposal (ha)	Clearing contribution of Proposal as a proportion of subcatchment area (%)
BIG BROOK 03	822	42.3	45.9	nil	nil
BIG BROOK 05	505	33.4	33.9	nil	nil
BIG BROOK 07	750	27.4	38.1	24	3.2
BIG BROOK 09	1,831	18.3	32.8	nil	nil
BIG BROOK 13	574	19.7	37.1	34	6.0
LANG BROOK	1,415	23.1	30.7	nil	nil
MOUNT SOLUS	1,417	13.3	33.6	37	2.6
NULLBIG BROOK 08	271	27.2	33.2	nil	nil
SERPENTINE RIVER 36	731	22.2	31.6	nil	nil
SERPENTINE RIVER 37	99	32.1	32.1	nil	nil
SERPENTINE RIVER 40	999	33.7	56.4	187	18.7
SERPENTINE RIVER 44	103	26.3	50.7	25	24.4
SERPENTINE RIVER 45	616	29.7	53.9	75	11.8
SERPENTINE RIVER 48	41	31.9	40.9	1	3.0
SERPENTINE RIVER 49	356	6.4	31.4	nil	nil
SERPENTINE RIVER 50	349	8.8	48.8	nil	nil
SERPENTINE RIVER 52	376	0.0	30.1	113	30.1
SERPENTINE RIVER 53	1003	0.6	34.7	85	8.5
Total area	12,258			581	
Serpentine Dam PDWSA total area	66,423				



Turbidity risks – hydrodynamic modelling

GHD (2025) assessed turbidity as a water quality parameter in the Serpentine, South Dandalup and Pipehead PDWSAs. While not hazardous in itself, turbidity is able to reduce the efficacy of treatment processes in inactivating or removing pathogens, and the existing water treatment processes at the Pipehead Dam Water Treatment Plant (WTP) do not include a mechanism to reduce turbidity in the raw water. The ADWG notes that where the turbidity of a source exceeds 1 nephelometric turbidity units (NTU), adequate disinfection may be more difficult to maintain but may still be achievable.

Generally, the lower the turbidity of a source water, the more effective chlorination will be, and validation is required to demonstrate that disinfection of higher turbidity water is effective. The literature basis for turbidity as an indicator of disinfection efficacy was examined, including the demonstrated finding that turbidity-generating compounds such as clays, humic acids and fulvic acids do not affect disinfection. Where high turbidity (20 NTU) waters containing organic particles generated from wastewater were examined, these waters could still be effectively disinfected for chlorine-resistant viruses, but required longer chlorine contact times to factor in the chlorine demand from wastewater particulates. In practice, challenge testing can be performed to validate and optimise virus disinfection, where a source water is outside the tested range for disinfection parameters such as turbidity.

The hydrodynamic modelling (GHD 2023a) simulated the relative differences of large winter and summer inflow events on reservoir and withdrawal turbidity levels represented by 10 per cent and 1 per cent Average Exceedance Probability (AEP) events, equivalent to a return period of approximately 10 years and 100 years, respectively. The 10 per cent and 1 per cent AEP inflow events were assumed to occur in combination with either moderate (30 per cent) and high (75 per cent) failure rates in mine sediment controls. Turbidity was modelled as suspended sediment for scenarios of baseline (no-mining), existing mining and mining under the Proposal.

The modelled scenarios of major sediment releases are equivalent or greater to a worst-case sediment release during construction, such as a major washout of a construction area during construction of a haul road or conveyor crossing of a waterway. Such a washout event would occur over a relatively small footprint compared to the simulated major sediment release across the mining area during operations (thousands of hectares).

The predicted effects of these large inflow events and assumed sediment control failures on the reservoirs and offtake water quality were as follows:

- Increased concentrations of coarser suspended sediments (silt fractions) were of short duration due to the relatively rapid settling within reservoirs before reaching the offtake. Increased concentrations that occurred at the offtake were predominantly fine suspended sediments (clay fractions).
- For Serpentine Dam with moderate failure in mine sediment controls (see Chart 8-29), there was limited change in suspended sediment between the non-mining and mining scenarios for either winter or summer 10 per cent AEP events. Suspended sediment increases of up to ~0.5 mg/L and ~0.2-0.3 mg/L were simulated for moderate failure in mine sediment controls for the summer and winter 1 per cent AEP inflow events, respectively. The relatively higher increases for summer are due to the presence of thermal stratification and more limited mixing compared to winter.
- For Serpentine Dam with high failure of mine sediment controls (see Chart 8-30), there was also limited change in suspended sediment between the non-mining and mining scenarios for either winter or summer 10 per cent AEP events. Suspended sediment increases of up to ~1 mg/L and ~0.3-0.4 mg/L were simulated for high failure in mine sediment controls for the summer and winter 1 per cent AEP inflow events, respectively.

- For South Dandalup Dam with moderate and high failure of mine sediment controls (see Chart 8-31 and Chart 8-32), there was no material change in suspended sediment between the non-mining and mining scenarios for either winter or summer 10 per cent or 1 per cent AEP events. The lack of a material change is due to the relatively small proportion of the catchment that will be disturbed by the Proposal, which does not generate sufficient additional suspended sediment loads to cause a substantive increase.
- For Serpentine Pipehead Dam with moderate and high failure of mine sediment controls (see Chart 8-33 and Chart 8-34) there was no material change in suspended sediment between the non-mining and mining scenarios for either winter or summer 10 per cent or 1 per cent AEP events. The lack of a material change is due to a hydrodynamic barrier effect induced by the substantial IWSS inflows and outflows in proximity to the dam wall, which increases the duration of particle settling in the upper reservoir volume prior to transport to the dam wall. Additionally, the high inflows from the IWSS have low suspended sediment concentrations that are likely to dilute catchment-derived suspended sediments from inflow loading events.

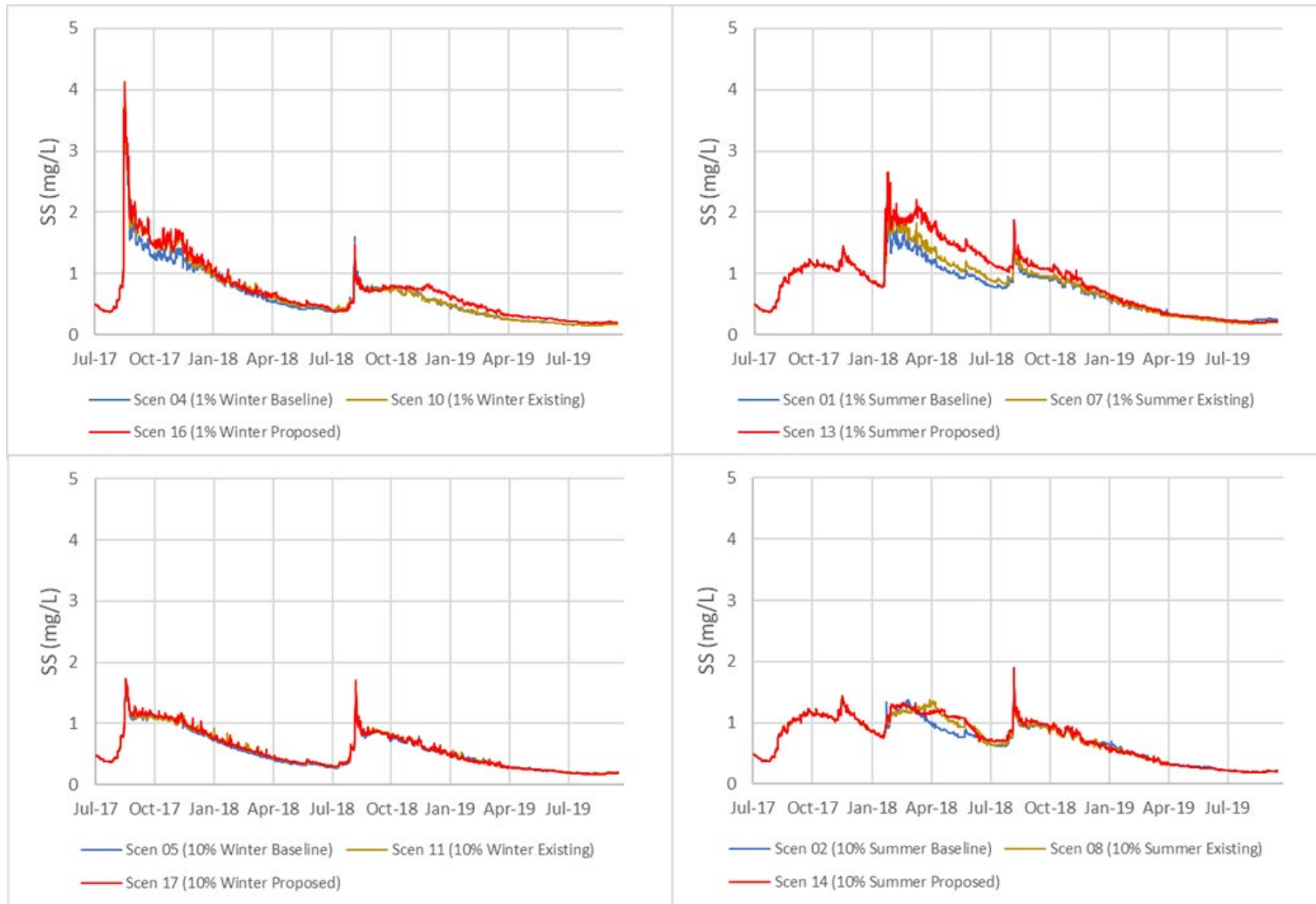


Chart 8-29 Simulated reservoir offtake suspended solids of winter and summer 1 per cent and 10 per cent AEP inflow event scenarios with moderate failure in mine sediment controls – Serpentine Dam

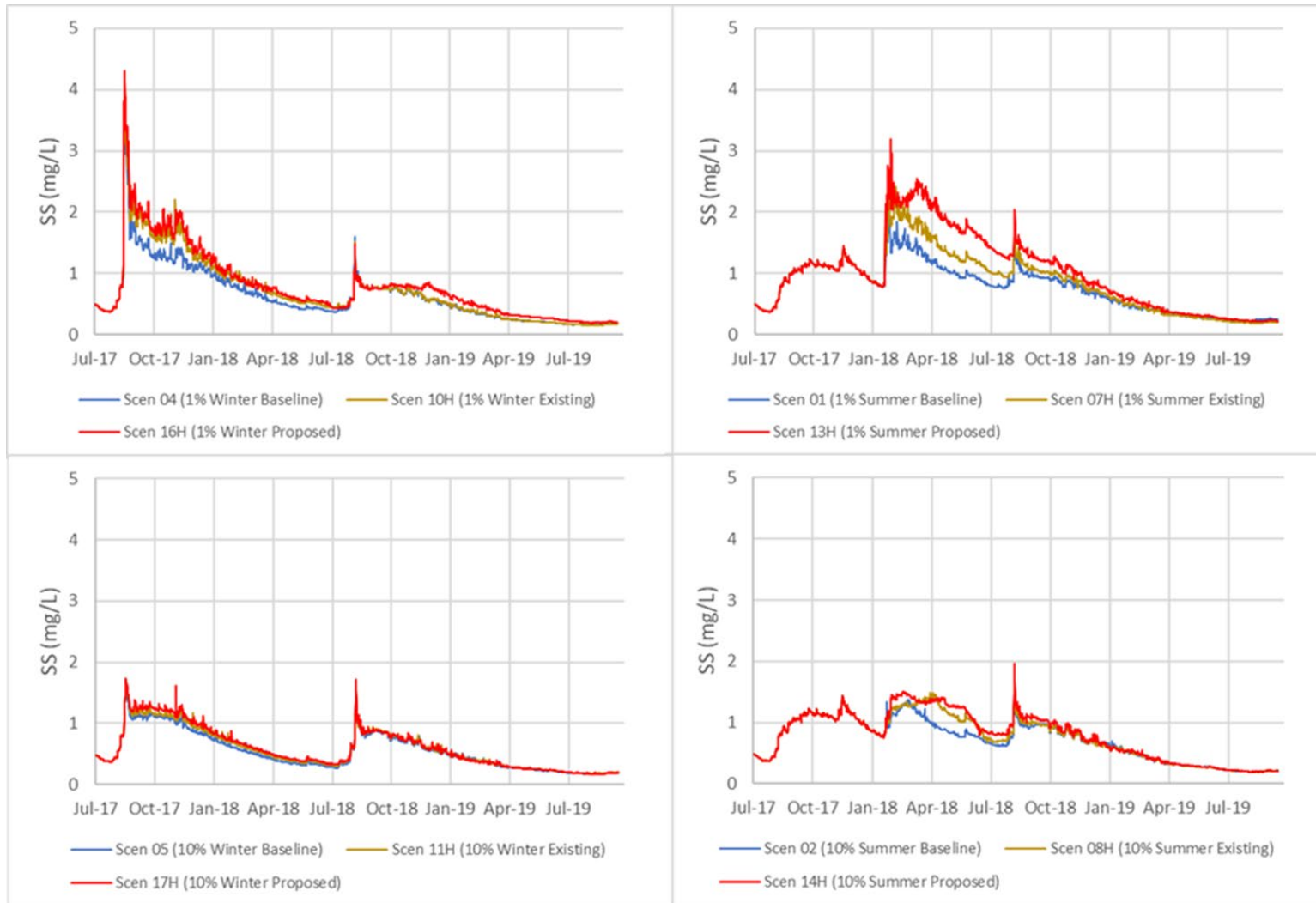


Chart 8-30 Simulated reservoir offtake suspended solids of winter and summer 1 per cent and 10 per cent AEP inflow event scenarios with high failure in mine sediment controls – Serpentine Dam

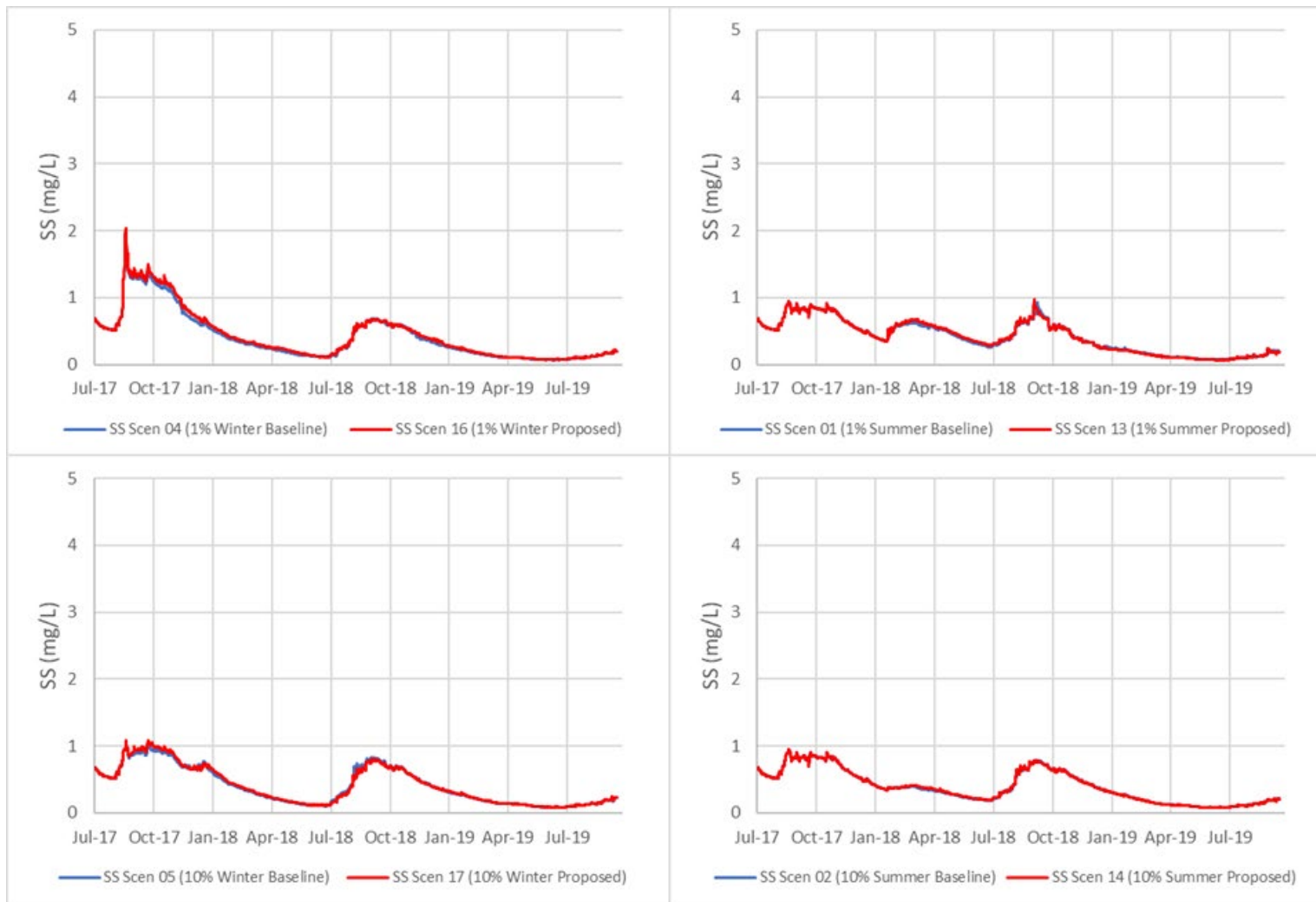


Chart 8-31 Simulated reservoir offtake suspended solids of winter and summer 1 per cent and 10 per cent AEP inflow event scenarios with moderate failure in mine sediment controls – South Dandalup Dam

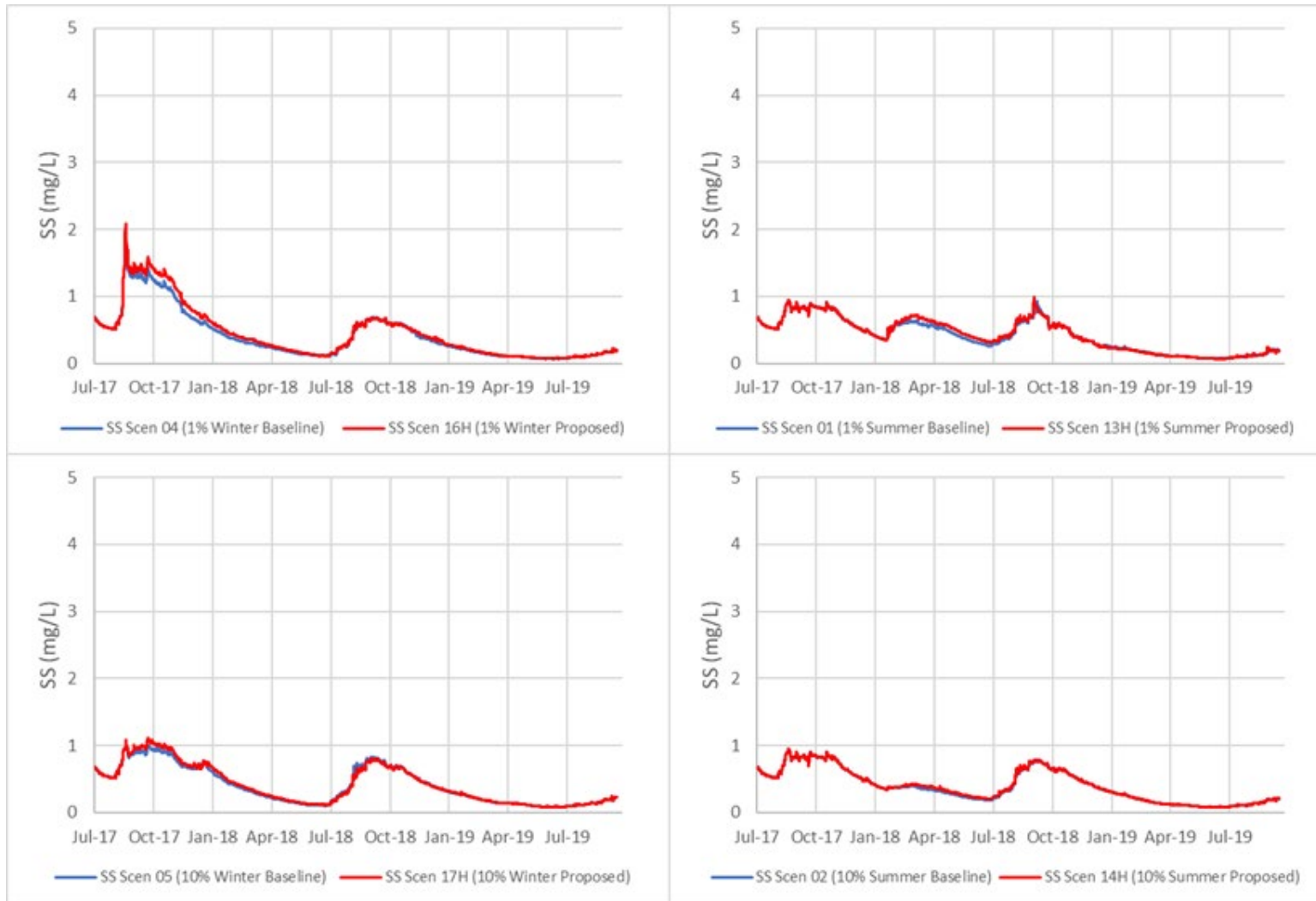


Chart 8-32 Simulated reservoir offtake suspended solids of winter and summer 1 per cent and 10 per cent AEP inflow event scenarios with high failure in mine sediment controls – South Dandalup Dam

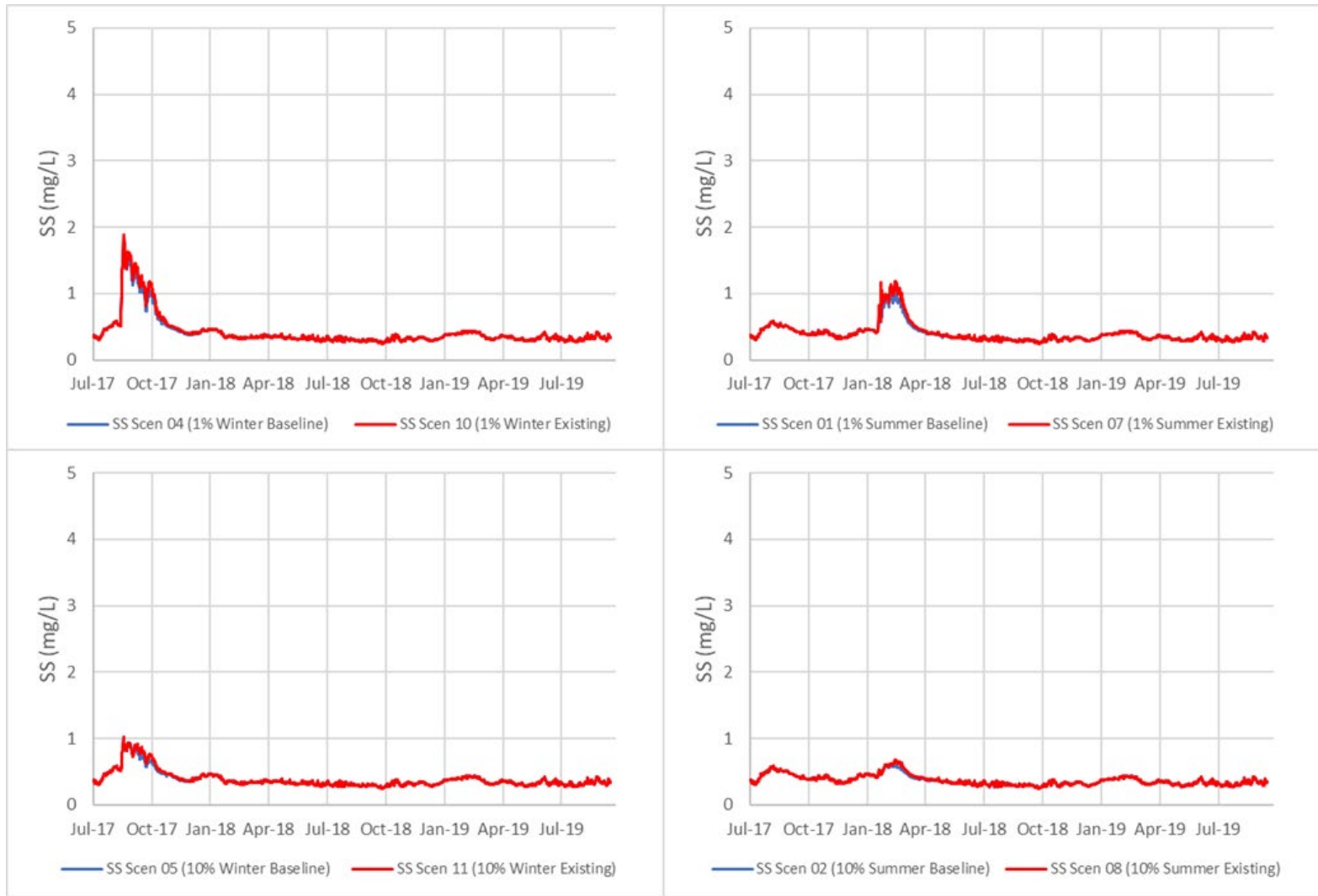


Chart 8-33 Simulated reservoir offtake suspended solids of winter and summer 1 per cent and 10 per cent AEP inflow event scenarios with moderate failure in mine sediment controls – Serpentine Pipehead Dam

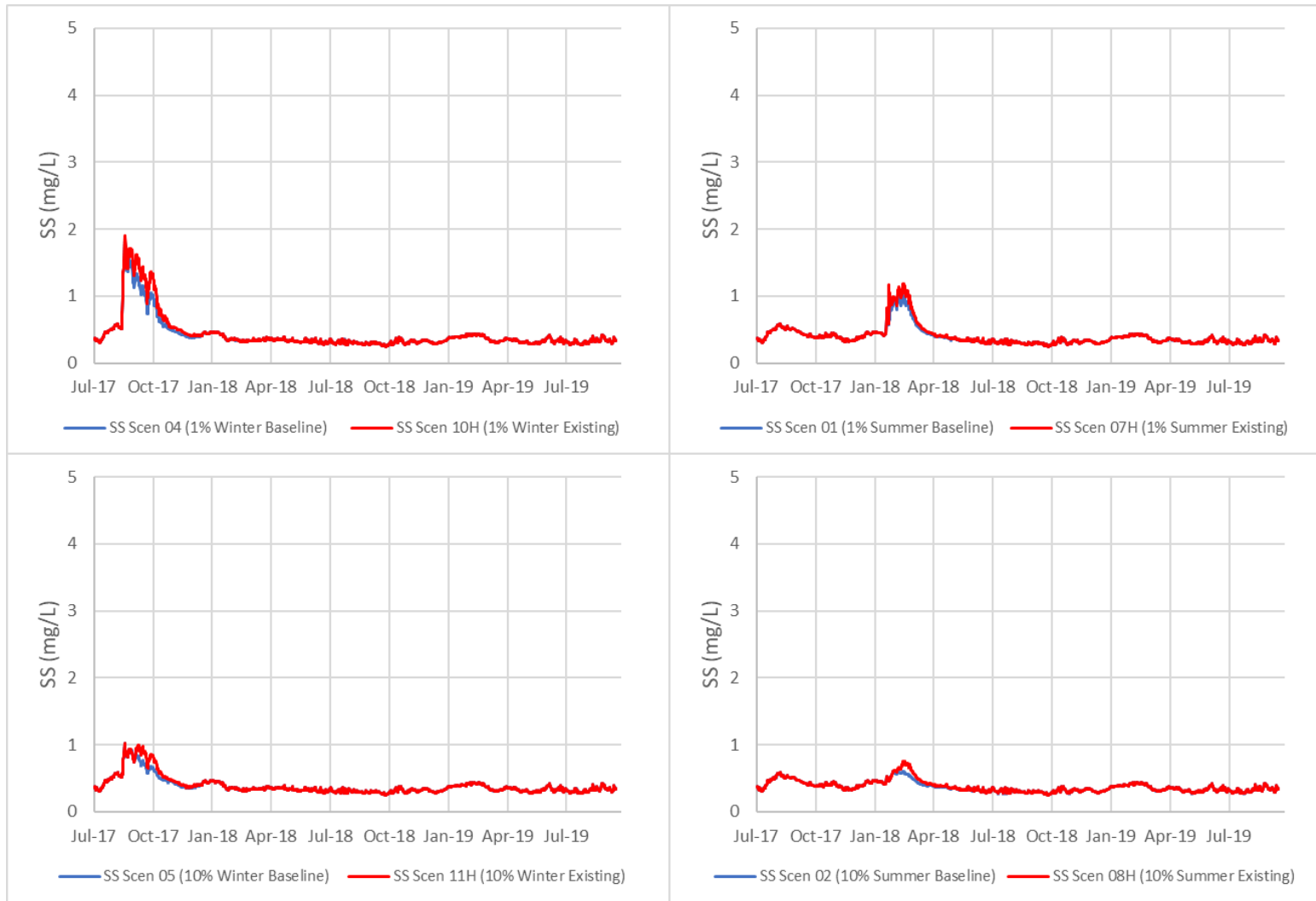


Chart 8-34 Simulated reservoir offtake suspended solids of winter and summer 1 per cent and 10 per cent AEP inflow event scenarios with high failure in mine sediment controls – Serpentine Pipehead Dam

The hydrodynamic modelling findings indicate that Serpentine Dam suspended sediment and therefore turbidity concentrations are sensitive to high levels of failure in mine sediment controls during a major storm (greater than a 10 per cent AEP or ten year return period) event, as the existing and proposed mining would comprise a sufficient proportion of the catchment. By contrast, the South Dandalup Dam has a lower sensitivity due to the relatively smaller proportion of the catchment subject to mining and the Serpentine Pipehead Dam has a lower sensitivity due to the hydrodynamic and dilution effects of the substantial IWSS inflows and withdrawals. GHD (2023a) noted that elevated levels of inorganic suspended sediments of up to 1 mg/L (equivalent to about 1-2 NTU) are not expected to affect disinfection efficacy.

8.4.9.4 Wildfire impacts to water quality

GHD (2023a) conducted a literature review of the impacts of bushfires within Australia and Western Australia. The evidence reviewed by Australian authors and the impact of the 2005 Perth Hills and 2016 Waroona-Yarloop fires suggests that the Serpentine Dam, Serpentine Pipehead Dam, South Dandalup Dam and Wungong Dam reservoirs may be susceptible to water quality impacts from bushfires. Such an event may include a high-intensity wildfire that covers a large proportion of a catchment, occurs over steep terrain and in the year before heavy rainfall events.

A major wildfire and heavy rainfall sequence may result in widespread ash deposition, runoff and erosion that generate substantial discharges of ash and sediment into the catchment's reservoir (GHD 2023a). Depending on the severity and location of fire and rainfall, there is potential for the scale of discharges to exceed the attenuating capacity of the reservoir and cause elevated contaminant levels at the offtake that exceed drinking water quality criteria (GHD 2023a).

There remains the potential for major wildfire events to occur throughout the NJF, irrespective of the Proposal. Such events include the 2003 Mount Cooke, 2005 Perth Hills and 2015 Boddington (Lower Hotham) fires which occurred away from bauxite mining and rehabilitation (see Section 5.3.4.9 and Chart 5-5). The increased prevalence of wildfires over the past two decades is expected to have been in part due to a reduction in prescribed burning since the 1990s. The reduction in prescribed burning was due to a variety of reasons independent of bauxite mining and rehabilitation, including (GHD 2023a):

- climate variability (e.g. increasing frequency of high fire risk days in which burning cannot be scheduled)
- land-use changes and population growth (e.g. urban and rural air quality constraints, landowner objections)
- resource constraints.

Climate change is expected to extend the period at which vegetation is flammable, increasing the frequency and scale of forest fires in the Jarrah forest, though drying may also reduce the rate of fuel accumulation (see Section 5.4.4.4). Analysis undertaken for south-east Australia, which is predicted to undergo similar drying and warming as is forecast for the South West region, suggests a potential for increased cumulative forest fire danger index and increased number of high and very high fire risk days (see Section 5.4.4.4). Accordingly, there is potential for the frequency of wildfires to increase in the future.

Alcoa collaborates with DBCA in planning an annual prescribed burn program, and funds the DBCA burns conducted within and surrounding mining and rehabilitation areas. Prescribed burns are conducted by a combination of aerial and ground methods and occur adjacent to mining operations and infrastructure. Mining operations temporarily cease in the vicinity of burns during and for a period after prescribed burns, for safety reasons (i.e. heat, smoke, falling dead trees). Following DBCA inspection and clearance of burnt areas, mining operations recommence. Alcoa has operated in the NJF for over fifty years and has mature experience in

managing operations during prescribed burning and collaborating with DBCA to plan prescribed burns around mine operations and infrastructure.

Alcoa's operations and infrastructure are less sensitive to smoke impacts compared to urban and rural land uses, which are a key constraint to DBCA's prescribed burn operations in the NJF. For example, Alcoa can temporarily suspend or relocate operations away from impacted areas, whereas urban and rural land uses are relatively fixed. Mine infrastructure and equipment are relatively resilient to smoke impacts compared to domestic properties, agricultural crops and stock animals. Accordingly, the Huntly Mine operations are able to accommodate smoke impacts from prescribed burns that would otherwise result in prescribed burns being delayed or cancelled due to public health risks or neighbouring landowner disputes. This provides more flexibility to DBCA in conducting prescribed burns within mining regions, subject to constraints posed by urban or rural land uses in the vicinity.

The integration of rehabilitation areas into forest prescribed burns utilises a fire risk matrix based on fuel ages in rehabilitated areas and adjacent unmined forests. Rehabilitation up to approximately six years of age has relatively low fuels with a discontinuous litter layer which provides opportunities to conduct prescribed burning in the surrounding un-mined forest. Rehabilitation from approximately six to 15 years requires fire exclusion to protect the crowns of young canopy tree saplings, which have not yet separated from the shrub layer. From approximately 15 years onwards, rehabilitation tends to form a two-tiered fuel structure, trees have developed a thick bark layer that provides greater protection and prescribed burning can be reintroduced within the rehabilitation and surrounding un-mined forest (Grant et al 1998, Grant et al 2007).

Though past rehabilitation prescriptions have generated high yet patchy fuel accumulation in the understorey, past prescribed burns conducted within mining regions have successfully reduced fuel levels and have not resulted in wildfires spreading outside of mining regions. This is in part due to the varying fuel loads in rehabilitation that occupy relatively small areas of the landscape and are interspersed by fire breaks created by open mine pits, mine infrastructure and the negligible fuel loads of newly established rehabilitation. Fire behaviour in prescribed burns is substantially affected by the fuel loads in the surrounding un-mined forest, which form the majority of the landscape.

Alcoa rehabilitation prescriptions require the reinstatement of forest access tracks and roads to DBCA approval, which enable forest management including prescribed burns and fire response activities. Alcoa's mine road network and the re-instated forest access tracks enable prescribed burn operations to be conducted within mine regions during mining and rehabilitation stages. During emergency fire events, Alcoa's mine road network and mine facilities can be used to provide access and emergency response management.

It is expected that the transition of mining into the Myara North and Holyoake mine regions and the re-entering of the O'Neil mine region will continue to enable DBCA's prescribed burning program to be effectively planned, funded and implemented, as has been demonstrated within the Huntly Mine to date. Accordingly, the Proposal is expected to maintain and support the State Government's program to limit fuel accumulation in the NJF, thereby reducing the likelihood of large wildfires occurring in the PDWSAs that lie within the mine regions.

8.4.10 Impacts to public health

8.4.10.1 Risk assessment in accordance with WQPN 77

The DWRA (GHD 2025) for the Proposal included a risk assessment in accordance with Water Quality Protection Note (WQPN) 77 *Risk assessment process for public drinking water source areas* (DWER 2022). The risk assessment was undertaken at the reservoir offtake point, prior to

treatment, as specified in WQPN 77, and thus considered preventative strategies including catchment management, source water protection and reservoir detention.

The risk assessment adopts likelihood and consequence ratings recommended in WQPN 77, including default Catastrophic consequence for any discharge of pathogens and Major for any discharge of turbidity or hydrocarbons.

Table 8.17 presents a summary of the risk findings, with a detailed risk assessment table in accordance with WQPN 77 presented in the DWRA in Appendix B8.6.

The assessed likelihood of Possible for hazards resulting in an exceedance of drinking water quality criteria at the offtake that could pose a risk to human health (in the event of the reservoir being used) is informed by the following considerations (GHD 2025)

- QMRA indicates that the Serpentine Main Dam and South Dandalup Dam are likely to perform as barriers to potential pathogen discharges from the Proposal including during storm events. The Serpentine Pipehead Dam is excluded as a barrier, given its small size and the advice of Water Corporation.
- Increased disturbance within the Serpentine Main Dam PDWSA from an existing 6,972 ha in 2023 (mine area open of 2,958 ha with rehabilitation up to 20 years of age), to up to 14,007 ha in 2034. This represents an increase from approximately 10.5 per cent to 21.2 per cent of the PDWSA catchment area.
- Increased disturbance within the South Dandalup Dam PDWSA from an existing 2,159 ha in 2023 (fully rehabilitated more than 10 years of age), to up to 4,301 ha in 2034. This represents an increase from approximately 7.0 per cent to 14.0 per cent of PDWSA catchment area.
- The historic level of reported drainage failures representing a small proportion of installed assets (and by correlation catchment area), in the case of haul roads being less than one per cent of the installed drainage assets in a given year.
- The lack of observed elevated turbidity in the Serpentine Dam or South Dandalup Dam during mining operations, including years of reported drainage failures in the Serpentine Dam. However, reservoir turbidity data was not available for 2021 when there was a peak of reported drainage failures.
- The potential for low frequency major storm events (e.g. 1% AEP / 1 in 100 year interval or greater) in wet catchment conditions to result in a large scale of drainage failures and turbidity discharges that has previously been recorded at the Huntly Mine.
- The historic level of reported drainage failures may not reflect the performance of mine drainage under the new Mine Drainage Design Manual including additional design capacity to retain runoff. However, there is a lack of performance data for the new Mine Drainage Design Manual given its recent implementation, and there remains potential for drainage failures to occur due to catchment moisture conditions and challenges with implementation.
- The lack of observed hydrocarbons, chlorinated hydrocarbons, herbicides or pesticides in streamflow monitoring within mined catchments of the Huntly Mine.
- The effect of climate change and increased drought and bushfire and uncertainty on the degree of impact on the condition of mine rehabilitation relative to un-mined forest. However, there has been a lack of observed widespread die-off in the canopy of mine rehabilitation, or surrounding un-mined forest, during recent drought events. A study of the 2010-11 drought indicates a die-off risk for forest on sandy and gravelly soils or shallow soils over granite bedrock on upper slopes, rather than on clayey soils or mid-slopes as is typical for mine rehabilitation.

- Studies and reservoir monitoring indicating that mining is likely to cause a small variation in streamflow (order of a few percent) and salinity (up to ten per cent), with reservoir water quality remaining fresh and well within the range of good palatability. Streamflow yield is expected to slightly increase with mining compared to no mining, thereby increasing reservoir levels and associated dilution / settling capacity.

Based on the adopted consequence being Catastrophic for pathogens and Major for hydrocarbons and turbidity (as recommended by WQPN 77), the maximum risk for these hazards is Very High. Salinity hazards have a consequence of Moderate and the maximum risk is Moderate.

Based on the adopted preventative strategies (see Section 8.5.1 and 8.5.2), the likelihood of hazards resulting in an exceedance of drinking water quality criteria at the offtake that could pose a risk to human health (in the event of the reservoir being used) is reduced to Rare or Unlikely. However, due to the adopted consequence being Catastrophic for pathogens and Major for hydrocarbons and turbidity, the residual risk for these hazards remains High. The residual risk for salinity remains Moderate.

8.4.10.2 Summary of risk assessment findings

The findings of the DWRA presented in Appendix B8.6 and discussed in Sections 8.4.7, 8.4.8 and 8.4.9 are summarised in Table 8.18 with respect to the potential for impacts to public health.

Table 8.17 Summary of drinking water risk assessment in accordance with WQPN 77

Activity	Hazard	Hazardous event	Likelihood	Consequence	Maximum risk	Residual likelihood	Residual risk
Sewage Treatment Plant (mine facilities)	Pathogens	STP malfunction causing raw sewage overflow discharging via overland flow into creek	Possible	Catastrophic	Very High	Rare	High
Sewage Treatment Plant (mine facilities)	Pathogens	Treated effluent irrigation during storm event causing discharge via overland flow into creek	Possible	Catastrophic	Very High	Rare	High
Sewage Treatment Plant (mine facilities)	Pathogens	Treated effluent irrigation during storm event causing discharge via subsurface flow into creek	Possible	Catastrophic	Very High	Rare	High
Mining workforce in the field	Pathogens	Staff / contractor faecal release in the field, which may runoff with overland flow into creek	Possible	Catastrophic	Very High	Rare	High
Tankering sewage sludge from Sewage Treatment Plant	Pathogens	Sewage tanker rollover due to vehicle accident on mine access road, causing raw sewage / sewage sludge discharge into creek	Rare	Catastrophic	High	Rare	High
Tankering sewage sludge from Sewage Treatment Plant	Pathogens	Sewage tanker rollover due to vehicle accident on haul road, causing raw sewage / sewage sludge discharge into a creek	Rare	Catastrophic	High	Rare	High
Tankering sewage sludge from Sewage Treatment Plant	Pathogens	Deliberate dumping of tanker load within PDWSA, causing raw sewage / sewage sludge discharge into creek	Rare	Catastrophic	High	Rare	High
Fuel storage at mine facilities	Hydrocarbons	Leakage from fuel storage tanks, causing groundwater contamination that flows into streams, is transported to the reservoir and results in an exceedance of drinking water criteria at the offtake	Possible	Major	Very High	Rare	High
Refuelling at mine facilities	Hydrocarbons	Spills or leaks during vehicle refuelling, causing groundwater contamination that flows into streams, is transported to the reservoir and results in an exceedance of drinking water criteria at the offtake	Possible	Major	Very High	Rare	High
Vehicle washing at mine facilities	Hydrocarbons	Contaminated washwater causing groundwater contamination that flows into creek, is transported to the reservoir and results in an exceedance of drinking water criteria at the offtake	Possible	Major	Very High	Rare	High
Vehicle and equipment maintenance at mine facilities	Hydrocarbons	Spills or leaks of oils and chemicals during maintenance, causing groundwater contamination that flows into creek, is transported to the reservoir and results in an exceedance of drinking water criteria at the offtake	Possible	Major	Very High	Rare	High
Refuelling in the field	Hydrocarbons	Spills or leaks during vehicle refuelling, causing groundwater contamination that flows into creek, is transported to the reservoir and results in an exceedance of drinking water criteria at the offtake	Possible	Major	Very High	Rare	High
Mine fleet operations	Hydrocarbons	Mechanical failure (e.g. blown hose) results in a discharge of hydraulic oil, that flows directly or via groundwater into creek, is transported to the reservoir and results in an exceedance of drinking water criteria at the offtake	Possible	Major	Very High	Rare	High
Mine fleet operations	Hydrocarbons	Vehicle fire causing discharge of engine/hydraulic oil and oils from tyre pyrolysis, that flows directly or via groundwater into creek, is transported to the reservoir and results in an exceedance of drinking water criteria at the offtake	Possible	Major	Very High	Rare	High
Mine fleet operations	Hydrocarbons	Vehicle accident causing discharge of fuel and/or engine/hydraulic oil, that flows directly or via groundwater into creek, is transported to the reservoir and results in an exceedance of drinking water criteria at the offtake	Possible	Major	Very High	Rare	High
Mine fleet operations	Organic chemicals - various	Vehicle fire or accident causing discharge of non-PFAS fire suppression chemicals that flows directly or via groundwater into creek, is transported to the reservoir and results in an exceedance of drinking water criteria at the offtake	Possible	Major	Very High	Rare	High
Mine pit development, mining, rehabilitation (prior to completion)	Sediment / turbidity	Multiple overflows of mine drainage controls, causing discharge of turbid water into the reservoir that in aggregate result in an exceedance of drinking water criteria at the offtake	Possible	Major	Very High	Rare	High

Activity	Hazard	Hazardous event	Likelihood	Consequence	Maximum risk	Residual likelihood	Residual risk
Primary haul roads within RPZ	Sediment / turbidity	Multiple overflows of haul road drainage controls, causing discharge of turbid water into the reservoir that in aggregate result in an exceedance of drinking water criteria at the offtake	Possible	Major	Very High	Rare	High
Rehabilitation (post completion)	Sediment / turbidity	Increased leaf area index and/or uniform stand density increasing wildfire intensity or restricting prescribed burn operations over the long term, enabling wildfire over a large proportion of the catchment that cause discharge of sediment that in aggregate result in an exceedance of drinking water criteria at the offtake	Possible	Major	Very High	Unlikely	High
Rehabilitation (post completion)	Sediment / turbidity	Increased leaf area index reducing groundwater recharge, stream flow and reservoir yield over the long term, reducing dilution of sediment discharges that in aggregate result in an exceedance of drinking water criteria at the offtake	Rare	Major	High	Rare	High
Rehabilitation (post completion)	Sediment / turbidity	Removal of caprock and friable bauxite layer affecting root structure and access to soil moisture, combined with declining rainfall with climate change, resulting in decline in vegetation condition over the long term, increasing erosion, and discharge of turbid water into the reservoir that in aggregate result in an exceedance of drinking water criteria at the offtake	Possible	Major	Very High	Unlikely	High
Mine pit development, mining, rehabilitation (prior to completion)	Salinity	Clearing of vegetation causing increased groundwater mounding and discharge of saline water into streams that in aggregate increases salinity in the reservoir to an unpalatable level at the offtake.	Unlikely	Moderate	Moderate	Rare	Moderate

Table 8.18 Potential impacts to public health arising from the Proposal

Potential impact	Summary of assessment of potential impacts to public health
Increases in stream salinity as a result of mining-induced saline groundwater discharge	<ul style="list-style-type: none"> Groundwater modelling indicates that the Proposal has potential to result in small changes in salinity inflows to reservoirs, which are expected to fall well within the threshold of freshwater quality. Modelling results are comparable to a previous study using the LUCICAT catchment model (Dixon et al 2019). Historic salinity monitoring in Serpentine Dam, South Dandalup Dam and Wungong Dam do not indicate substantial increases in salinity as a result of mining of between 7 and 20 per cent of the catchment. The Proposal is therefore unlikely to cause a significant impact to drinking water quality due to changes in stream salinity.
Increased sediment from erosion of post-mining landforms	<ul style="list-style-type: none"> The results of monitoring demonstrate that Alcoa's rehabilitation establishes and persists, including during drought and heat wave events, indicating that the friable substrate over regolith containing ancient root channels is an effective growth medium. Accordingly, mine rehabilitation vegetation is expected to be sustained over the long term with resilience to climate change comparable to that of un-mined Jarrah forest. Mine rehabilitation is therefore expected to provide long term protection of soils from erosion and associated sediment discharge to streams and reservoirs.
Contamination from spills and/or leaks from storage or handling of hazardous materials and waste	<p>Diesel spills</p> <ul style="list-style-type: none"> Diesel is the predominant hazardous material used at the Huntly Mine, and to a lesser extent hydraulic and lubricating oils. Hydrodynamic modelling indicates that a worst-case spill from a 15 m³ fuel tanker direct into stream without any spill response would be subject to substantial attenuation such that peak concentrations at the Serpentine Dam or South Dandalup Dam offtakes would be up to 1 µg/L. A worst case spill of 15 m³ within the Serpentine Pipehead Dam catchment would result in peak concentrations of up to 5 µg/L at the offtake. Diesel comprises small quantities (<1 per cent total) of aromatic hydrocarbons that have drinking water health limits range from 1-800 µg/L. Accordingly a worst-case diesel spill event is highly unlikely to result in offtake water quality that exceeds drinking water health criteria. However, there is potential for a worst-case diesel spill to result in offtake water quality that exceeds the threshold for taste and odour, which are substantially lower. <p>PFAS</p> <ul style="list-style-type: none"> Alcoa have committed to using PFAS-free fire-fighting foams for the Myara North, Holyoake and O'Neil regions. All water supplies to construction and operations in the Myara North, Holyoake and O'Neil regions will be sourced from public drinking water sources, captured onsite stormwater or from licensed onsite water treatment facilities where approved for reuse on the Mine. Accordingly, the direct discharge of PFAS from construction and mining is expected to pose a low risk to drinking water quality. The existing land uses and baseline monitoring program do not indicate the presence of substantial PFAS contamination within the Proposal Mine DE. Accordingly, the potential indirect mobilisation of historic PFAS from catchments due to construction and mining is expected to pose a low risk to water quality. <p>Other hazardous materials and wastes</p> <ul style="list-style-type: none"> The majority of spills and leaks of hazardous materials, particularly those from major incidents and involving large volumes, are expected to be identified quickly and the contaminated soils excavated and disposed off-site at a licensed waste facility. Small volumes of diesel and oil that escape detection and remediation are unlikely to result in substantial migration of hydrocarbons that reach streams and can be transported into reservoirs. Accordingly, the storage and handling of hazardous materials during construction or operations is expected to pose a low risk to water quality. All construction and operational wastes will be disposed off-site at licensed waste facilities and expected to pose a low risk to drinking water quality. On-site sewage treatment and disposal is addressed under pathogenic microorganisms (see below).
Water quality deterioration in streams and reservoirs, including cumulative impacts from existing mining operations	<p>Preventative risk management</p> <ul style="list-style-type: none"> Alcoa implements preventative risk management at the Mine, which incorporates multiple barriers to prevent hazards to downstream drinking water reservoirs from occurring or reduce them to acceptable levels. The barriers act to prevent and minimise the discharge of contaminants into downstream reservoirs, which are themselves barriers to contaminant transport before raw water being removed at the offtakes and entering the Water Corporation's water treatment and distribution system. Some existing barriers are likely to fail under certain conditions and with multiple barrier failures result in varying quantities of contaminants reaching the downstream reservoirs. Key conditions that can cause multiple-barrier failure include workforce behaviour in the case of discharge of pathogens, and major storm events during wet catchment conditions in the case of sediment and hydrocarbons. Additional barriers and improvements to existing barriers are proposed to reduce the likelihood of barrier failure and potential for discharge of contaminants into reservoirs (see Section 8.5). <p>Pathogenic microorganisms</p> <ul style="list-style-type: none"> Pathogenic microorganisms generally represent the greatest risks to consumers of drinking water. Source vulnerability assessment concluded that human settlement and stock animal challenges of microbial risk aligned well with category 1 source waters for the PDWSAs. Some challenges presented from itinerant human activity could be regarded as category 1 or 2, however with the consideration of existing mitigation factors, the source water could be considered a category 1 source. This was consistent with the current treatment applied at the source water. Quantitative microbial risk assessment indicates that of a sewage treatment plant at the proposed mine facilities has a potential cryptosporidium dosage at reservoir offtakes that is well within health risk thresholds. However, direct faecal deposition within the Serpentine Dam or Serpentine Pipehead Dam PDWSAs has potential to result in exceedance of the 10-6 DALY threshold and within Serpentine Pipehead Dam to also result in peak cryptosporidium concentrations that pose an unacceptably high risk of short-term cryptosporidiosis epidemics. The elevated health risks for direct faecal deposition indicates that additional preventative control measures are required to reduce the risk to acceptable levels. <p>Turbidity</p> <ul style="list-style-type: none"> Hydrodynamic modelling findings that Serpentine Dam suspended sediment and therefore turbidity concentrations are sensitive to high levels of failure in mine sediment controls during a major storm (greater than a 10 per cent AEP or ten year return period) event, as the existing and proposed mining would comprise a sufficient proportion of the catchment. The South Dandalup Dam has a lower sensitivity due to the relatively smaller proportion of the catchment subject to mining and the Serpentine Pipehead Dam has a lower sensitivity due to the hydrodynamic and dilution effects of the substantial IWSS inflows and withdrawals.

Potential impact	Summary of assessment of potential impacts to public health
	<ul style="list-style-type: none"> • Hydrodynamic modelling indicates that a 1 per cent AEP inflow event that results in moderate failure of mine sediment controls has the potential to increase suspended sediment by ~0.5 mg/L (summer inflow event) and ~0.2-0.3 mg/L (winter inflow event). A 1 per cent AEP inflow event that causes high failure of mine sediment controls has the potential to increase in suspended sediment by ~1 mg/L (summer inflow event) and ~0.3-0.4 mg/L (winter inflow event). • The modelled inflows that may increase suspended sediment concentrations by 0.3-1 mg/L at the offtake would occur infrequently, at less than 10 per cent of years, and would require a high failure rate in mine sediment controls (i.e. 75 per cent release of all sediment volumes from all sumps and drainage shots in the mine region) which has not previously occurred at the Huntly Mine. • Literature review indicates that elevated levels of inorganic suspended sediments of up to 1 mg/L (equivalent to about 1-2 NTU) at the offtake are not expected to affect disinfection efficacy. <p>Bushfires</p> <ul style="list-style-type: none"> • Large scale wildfires occurring with PDWSAs have the potential to cause a significant impact to reservoir water quality through deposited ash and sediment. Wildfires are expected to occur within the NJF irrespective of the Proposal and may potentially increase in likelihood and/or intensity with the effects of climate change. The Proposal is expected to continue enabling DBCA's prescribed burning program to be effectively planned, funded and implemented, as has been demonstrated within the Huntly Mine to date. The Proposal is expected to maintain and support the State Government's program to limit fuel accumulation in the NJF, thereby reducing the likelihood of large wildfires occurring in mine regions.

8.4.11 Service interruption of the public drinking water supply

8.4.11.1 Proportion of IWSS catchments covered by Alcoa operations

A summary of Alcoa's WA mining operations (Huntly and Willowdale mines and former Jarrahdale Mine) within the catchments of dams connected to the IWSS is presented in Table 8.19 and Figure 8-28.

As presented, Alcoa's WA mining operations as of 2023 have disturbed a total of 21,219 ha or approximately 9.8 per cent of the combined 216,638 ha catchment of the ten PDWSAs. Approximately 16,340 ha or 77.0 per cent of this disturbance has been rehabilitated, of which 4,245 ha (26.0 per cent) is aged ten years or older and 12,095 ha (74.0 per cent) is aged less than ten years. The area open as of 2023 totalled 4,879 ha or 2.2 per cent of the combined PDWSA catchment.

The disturbance within the ten PDWSAs is forecast to increase by 11,689 ha to a total 32,908 ha as of the completion of the Proposal and other clearing under the MMP around 2044. Under worst case, the total area open in 2044 is forecast to remain at 4,879 ha, as rehabilitation is expected to match clearing on an annual basis aggregated over the ten PDWSAs, although the rehabilitation within individual PDWSAs or subcatchments cannot be estimated at this stage and depends on a range of priorities. For example, some topsoil and overburden materials from clearing in the South Dandalup PDWSA may be prioritised for rehabilitation in the Serpentine PDWSA, therefore the open area may increase in the South Dandalup PDWSA and decrease in the Serpentine PDWSA though the total open area will remain constant across the PDWSAs.

As of the completion of the Proposal and other clearing under the MMP around 2044 the extent of rehabilitation will increase from 16,340 ha to 28,029 ha, incorporating an additional 11,689 ha matching the forecast clearing over the same period. In 2044 the rehabilitation is estimated to comprise 16,340 ha (58.3 per cent) aged ten years or old and 11,689 ha (41.7 per cent) aged less than ten years. Accordingly, there is expected to be a slight decrease in the extent and proportion of rehabilitation aged less than ten years compared to the extent as of 2023, as the current rehabilitation matures across the PDWSAs.

As presented in Table 8.19 and Figure 8-28, the majority of open area as of 2023 (4,776 ha or 97.9 per cent) is in four PDWSAs, being the Serpentine Dam (60.6 per cent), North Dandalup Dam (11.2 per cent), Samson Brook Dam (12.5 per cent) and Stirling Dam (13.5 per cent). This will remain the case with the Proposal and other clearing under the MMP, such that the remaining six of ten PDWSAs are forecast to have very limited areas open as of 2044.

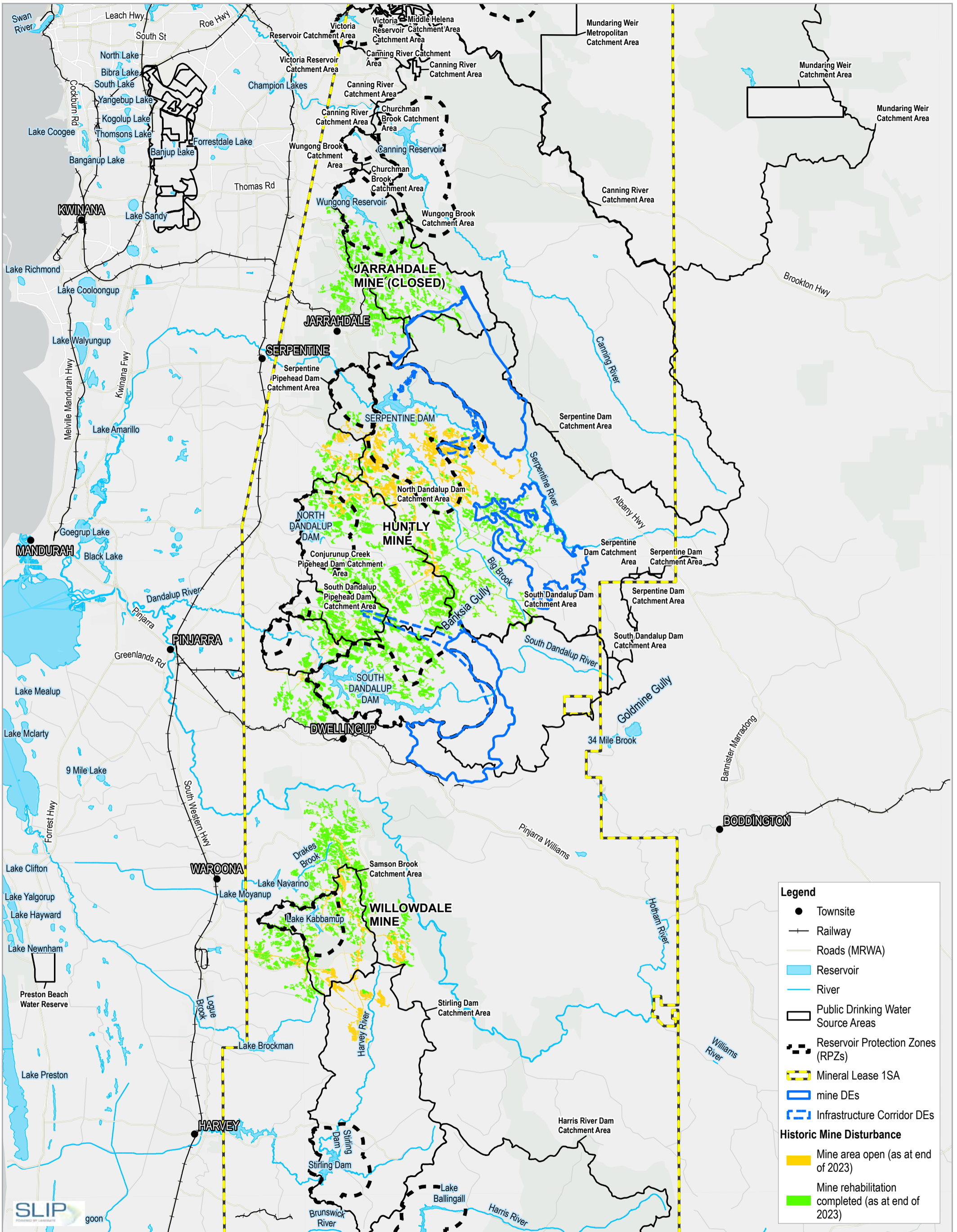
8.4.11.2 Impact to inflow capacity of the IWSS

There is no publicly available information for forecast inflows to the ten PDWSAs and the breakdown of inflows by PDWSA, however given historic trends published for the IWSS (see Section 8.3.2.5), forecast inflows for Serpentine Dam (DWER 2017a) and North Dandalup Dam (DWER 2017b), it is expected that inflows into the IWSS will continue to decline with the effects of declining rainfall and groundwater levels across the Darling Plateau. Historic inflows vary substantially across the PDWSAs depending on the catchment size and the catchment extent within the western high rainfall zone versus eastern IRZ.

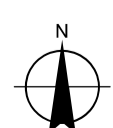
Table 8.19 Summary of clearing and rehabilitation of Alcoa WA mining operations within PDWSAs connected to the IWSS

PDWSA	Reservoir capacity (maximum storage) (GL)	Catchment area (ha)	WA Mining Operations	Clearing (at end of 2023) (ha)	Rehab (at end of 2023) (ha)	Rehab up to ten years of age (at end of 2023) (ha)	Mine area open (at end of 2023) ha)	Area open proportion of catchment (%)	Clearing for Proposal (2026-2044) (ha)	Proposed clearing outside DE (2024-2044)	Total disturbance (ha)	Worst case area open (at end of 2044) (ha)*	Worst case area open as proportion of catchment area (%)
Serpentine Dam	138	66,423	Huntly Mine, Jarrahdale Mine	6,972	4,015	2,270	2,958	4.5	3,919	2,367	13,259	9,244	13.9
Serpentine Pipehead Dam	3	2,883	Huntly Mine	170	98	98	72	2.5	0	0	170	72	2.5
South Dandalup Dam	208	31,327	Huntly Mine	2,159	2,177	nil	nil	0.0	2,124	17	4,300	2,123	6.8
South Dandalup Pipehead	0.08	3,802	Huntly Mine	574	556	nil	18	0.5	0	11	584	28	0.7
North Dandalup Dam	75	15,155	Huntly Mine	4,457	3,908	1,512	549	3.6	227	255	4,939	1,031	6.8
Conjurunup Pipehead	0.2	3,920	Huntly Mine	1,653	1,622	nil	31	0.8	102	7	1,762	140	3.6
Wungong Dam	60	12,845	Huntly Mine	2,507	2,507	nil	0	0.0	297	0	2,804	297	2.3
Canning Dam	90	72,823	Huntly Mine	35	35	nil	0	0.0	30	0	65	30	0.0
Samson Brook Dam	8	7,460	Willowdale Mine	2,007	1,399	342	608	8.2	0	343	2,350	951	12.7
Stirling Dam	57	25,331	Willowdale Mine	684	23	23	661	2.6	0	1,991	2,675	2,652	10.5
Total	639	216,638		21,219	16,340	4,245	4,879	2.3	6,699	4,990	32,908	4,879*	2.3

* Note: the total open area across all ten PDWSAs in 2044 is estimated to match that of 2023, as the aggregate rehabilitation is expected to match aggregate clearing on an annual basis, although rehabilitation within individual PDWSAs cannot be estimated at this stage and depends on a range of priorities. The worst case area open for individual PDWSAs therefore assumes that topsoil and overburden soil collected from clearing over 2024-2044 within that PDWSA is used to rehabilitate clearing in other PDWSAs.



Scale: 1:350,000 at ISO A3
 0 2 4 6 8
 Kilometres



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50

Alcoa of Australia Limited
 Pinjarra Refinery Revised Proposal -
 Environmental Review Document

Project No. 12633192
 Revision No. 3
 Date 09/03/2025

**Overview of Alcoa WA mining operations
 within Public Drinking Water
 Source Areas**

FIGURE 8-28

Data source: Light Gray Base: Esri, TomTom, Garmin, Foursquare, FAO, MET/NASA, USGS.

The Proposal is expected to have the greatest effect on inflows to Serpentine Dam, as the total disturbance within the PDWSA is forecast to increase from 10.5 percent to 20.0 per cent of its catchment over 2023-2044. The Proposal has potential to increase inflows over the mining period to 2044 by a few GL/year compared to a no mining scenario, and decrease inflows over the post-rehabilitation period to the 2060s and 2080s by about one GL/year compared to a no-mining scenario (see Section 8.4.3.1 and Section 8.4.3.4). Based on the findings of numerical modelling (see Section 8.4.3.1 and Section 8.4.3.4) and catchment stream monitoring (see Section 8.4.3.1), rainfall trends and antecedent groundwater levels are expected to have the greatest effect on inflows into Serpentine Dam.

The Proposal is expected to have a moderate effect on inflows to South Dandalup Dam, with the total disturbance within the PDWSA forecast to increase to 13.7 per cent of its catchment as of 2044. The Proposal has potential to increase inflows over the mining period by up to one GL/year, and decrease inflows over the post-rehabilitation period to the 2060s and 2080s by up to one GL/year compared to a no-mining scenario (see Section 8.4.3.4).

The Proposal is expected to have a minor effect on inflows to other eight PDWSAs due to the small extent of disturbance within the catchment areas.

Other Alcoa WA mining operations are expected to have a moderate effect on inflows to the North Dandalup, Samson Brook and Stirling Dam and a minor effect on inflows to the other PDWSAs.

The aggregated effect of Alcoa's WA mining operations on inflow capacity of the IWSS is expected to comprise an increase in inflow capacity over the mining period up to 2044, and a decrease in inflow capacity over the post-rehabilitation period compared to a no-mining scenario. The findings of numerical modelling and catchment studies suggest that the increases and decreases during the mining and post-rehabilitation stages, respectively, will be approximately balanced and that inflows into the IWSS will be dominated by future rainfall trends with the effects of mining being a relatively small contributing factor.

8.4.11.3 Impacts to typical supply and contingency supply

As presented in Table 8.17, the Proposal is unlikely to result in an exceedance of drinking water quality criteria at reservoir offtakes due to spills of hazardous materials, sewage treatment plant operation or release of sediment from mined areas. Post-mining rehabilitated landforms are expected to be subject to low levels of erosion with vegetation that persists in vigour and condition and is comparable in resilience to that of un-mined forest.

There remains potential for large scale wildfires to occur in the PDWSAs that may result in the drinking water becoming impacted for an extended duration. In such an event there is a potential requirement for the reservoir to be taken off-line, such as occurred for the Samson Brook Dam following the Waroona-Yarloop fire in 2016. However, as presented in Section 8.4.9.4 the Proposal is not expected to increase the likelihood of severity of wildfires occurring in the mine regions.

The Proposal incorporates commitments to avoid mining in the RPZ and minimise mining in areas identified as at risk of causing a loss of containment from mine drainage. This is expected to substantially reduce the risk of a catastrophic loss of containment that could cause sufficient suspended sediment discharge into the Serpentine Dam or South Dandalup Dam and potentially result in elevated turbidity at the offtake such that the reservoir would need to be taken off-line.

There remains potential for a very rare storm event exceeding the one percent AEP (one in 100 year) design capacity of mine drainage controls to result in a catastrophic loss of containment from mine drainage within one or more PDWSAs connected to the IWSS. Such a rare event may dictate the one of more reservoirs being taken offline as a risk prevention measure. A large

diesel spill that enters the reservoir (e.g. a freak fuel tanker accident) is unlikely to cause an impact to public health but may dictate an individual reservoir being taken offline.

Such a catastrophic sediment release or diesel spill event that results in a shutdown to a reservoir causing an impact to typical supply or contingency supply to the IWSS would be a very rare or remote event.

8.4.12 Water supply for mining and refining

8.4.12.1 Huntly Mine

The existing Mine operations in the Myara mine region consume approximately 1 GL/yr. Alcoa currently holds three water abstraction licence (SWL 63409, 83356, 153635) issued under the RIWI Act, which have a combined allocation of 0.6 GL/yr. The licences enable abstraction from South Dandalup Dam and Marrinup Brook and expire in 2034. A minor proportion of the Mine water demand is met through harvested stormwater and recycled treated water from the oily water system in the Myara and McCoy mine facilities.

Temporary construction water supply will be required for approximately 18 months to provide 1.6 GL/year, prior to installation of permanent water storage facilities. Water will be sourced from the Serpentine Dam via a to be constructed pumping station and pipeline. A temporary water supply will be via pipeline extended from existing water storage at Myara.

For the Myara North mine region (circa 2026-2034), mining is expected to consume up to approximately 3 GL/year of water, primarily for dust suppression on haul roads and minor water demand for mine facilities (e.g. ablutions, vehicle washing). This water will be sourced from the Serpentine Dam. For the Holyoake mine region (circa 2028-2045) the water demand is expected to be comparable to the existing Mine operations in the Myara mine region, this water is anticipated to be sourced from the South Dandalup Dam. For the O'Neil mine region (circa 2026-2032) water will be tankered from McCoy using water sourced from the South Dandalup Dam and treated stormwater run-off from mine facilities.

The estimated water demand is residual to implementing water recycling measures as presented in Table 8.20.

Table 8.20 Water recycling measures to reduce water demand for Huntly Mine

Facility	Stormwater harvesting	Recycled oily water	Estimated water demand reduction (ML/year)
Catchments	Light vehicle roads, parking areas, roof water and general surface run off	Fuel bay, heavy and light vehicle washdown bays, concrete hydrocarbon storage beds, contractors' yard oily water sump and mobile maintenance workshops	
Myara	<ul style="list-style-type: none"> Collected in sumps around facilities area, diverted through humeceptors and culverts to single sump and pumped back into the reservoir 	<ul style="list-style-type: none"> Collected in sump at the ultraspin unit, trucked back to McCoy Dissolved Air Flotation (DAF) plant, treated, tested and pumped back to reservoir 	120
McCoy	<ul style="list-style-type: none"> Collected in sumps around facilities area, diverted through humeceptors and culverts to single sump and pumped back into the reservoir 	<ul style="list-style-type: none"> Collected in sump at DAF plant, treated, tested and pumped back to reservoir 	80
Kisler	<ul style="list-style-type: none"> As for Myara 	<ul style="list-style-type: none"> As for McCoy 	120
Myara North / Holyoake	<ul style="list-style-type: none"> As for Myara 	<ul style="list-style-type: none"> As for McCoy 	120
Total			440

Alcoa is investigating and/or implementing other water efficiency measures for the Huntly Mine including:

- trials of alternative surfacing for haul road pavements. including ferricrete and cement and bitumen modified materials
- pump out from roadside sumps into water carts and reuse on the haul road network, where practical without impacting operations
- heat mapping of haul roads to guide water cart operations
- flow control on water cart spray bars driven by travelling speeds and gradients
- ongoing training of water cart operators.

Water demand residual to water recycling and efficiency measures will be sourced from public drinking water sources, captured onsite stormwater or from licensed onsite water treatment facilities where approved for reuse on the Mine.

The abstraction of 1 to 3 GL/yr for mining represents:

- approximately 1.2 per cent to 3.7 per cent of the Water Corporation’s combined 80.7 GL/yr licence allocation for the Serpentine Dam and South Dandalup Dam
- approximately 0.3 per cent to 0.8 per cent of the estimated 380 GL/yr water demand on the IWSS in 2030 (Water Corporation 2009).

The abstraction of 1 to 3 GL/yr from the Serpentine Dam or South Dandalup Dam is expected to be subject to the Water Corporation’s licence allocation and environmental release requirements for the dams, and no additional impact is expected to downstream hydrological regimes or water quality.

8.4.12.2 Pinjarra Refinery

Water demand and efficiency under the Pinjarra Refinery Efficiency Upgrade

The PREU involved an increase in Refinery net water demand from 6.13 to 7.4 GL/yr. Water supply was one of four environmental factors assessed by the EPA for the PREU (EPA 2003).

The Refinery gross water demand at 3.5 Mtpa was a total of 12 GL/yr, approximately 3.5 kL per tonne of alumina product. The gross water demand was predominantly due to evaporative and cooling tower losses, liquor loss to residues, and dust suppression (Table 8.21) (Environ 2003). The gross water demand was met through approximately 5.9 GL/yr of rainfall harvesting and process inputs, and the remaining 6.13 GL/yr net demand was supplied by make-up water (Environ 2003).

Table 8.21 Refinery water balance at 3.5 Mtpa

Water inputs	GL/yr	Water outputs	GL/yr
Rainfall residue	3.70	Liquor loss with mud and sand	3.13
Rainfall	1.08	Natural evaporation	2.9
Water in bauxite	0.9	Cooling tower blowdown and windage	2.8
Water in caustic	0.19	Cooling evaporation of RSA1	1.3
Make up water	6.13	Loss due to irrigation (dust suppression)	1.05
		Other losses	0.82
Total input	12.0	Total output	12.0

Upgrade of the Refinery to 4.2 Mtpa under the PREU required an increase in gross water demand to 14.9 GL/yr with a net water demand increase to 7.4 GL. In preparation for the PREU Alcoa conducted a detailed water audit to better understand the Refinery water circuit and investigate opportunities for improvement. The investigation focussed on reducing evaporation losses including the option to use covers on the water storage lake. Covering the water storage lake was found to be unviable due to the significant engineering risk and exposure to high wind conditions (Environ 2003). Alcoa also investigated additional water supplies including:

- treated wastewater from the Water Corporation's Mandurah Wastewater Treatment Plant (preferred option)
- capturing excess vapour from digestion blow-off tanks
- additional surface water harvesting structures for winter peak stream flows
- Cattamarra aquifer, through improved understanding of aquifer extent and yield.

Alcoa committed the PREU to be subject to a Water Use Minimisation Program including:

- current water conservation initiatives
- identification of opportunities and targets for continuous improvement by means of operational change, use of best practicable technology and maximisation of water reuse/recycling.

Alcoa also committed to refer new water supply proposals with a potential for environmental impact to the EPA.

The EPA (2003) assessed the additional water demand for the PREU with regard to Alcoa's commitments and that additional abstraction, if required, would be regulated under the RIWI Act. The EPA (2003) concluded that the additional water demand could be managed to meet the EPA's objectives.

In 2015 MS 646 was altered to increase the refinery's production output to 5 Mtpa, at the same time the regulation of water usage was removed from MS 646, as it is regulated under the RIWI Act.

Existing water consumption

The Refinery utilises multiple sources of water to sustain operations and execute required operational controls to appropriately manage environmental risks. Alcoa employs a refinery water sourcing strategy hierarchy which preferentially sources the following water sources in order of prioritisation to minimise environmental impacts:

1. externally supplied lower quality water not suitable for other uses (i.e. agriculture, human consumption) but usable in the refinery Bayer process
2. reuse of Extra Good Condensate Return (EGCR) water derived from the refinery Bayer process
3. internally harvested surface water from within the existing Refinery footprint (i.e. rainfall runoff captured from sealed surfaces by the refinery closed circuit storm sewer network and direct rainfall capture across the Refinery's residue storage areas and associated water storage assets)
4. externally licenced surface water abstraction licences
5. externally licenced groundwater abstraction licences

Identified higher prioritised water sources which provide the best environmental and sustainability outcomes are generally available in insufficient quantities to be solely relied upon and therefore use of lower prioritised water sources (i.e. groundwater and surface water) is necessary.

Alcoa currently hold three groundwater and three surface water abstraction licenses issued under the RIWI Act (Table 8.23). Groundwater is abstracted from production bores in the confined Cattamarra aquifer, which meets the majority of Refinery water demand. Surface water

is abstracted from detention dams on Barritt Brook and Oakley Brook to the north-east and south-east of the residue area, and from a lower pumpback dam on Oakley Brook downstream of the Refinery. The total abstraction varies year to year depending on rainfall (Table 8.22, Rockwater 2021c).

Supplementary metered water sources include:

- recovery bores drilled in the superficial formations to intercept alkaline discharge beneath the residue area
- recycled water from the Pinjarra townsite wastewater treatment plant (WWTP)
- Occasional purchases from the Water Corporation's IWSS (when repairs are required to the Refinery's potable water facility).

Supplementary metered sources supplied a total of 0.67 GL in 2017/18, 0.62 in 2018/19, 0.55 in 2019/20 and 0.58 in 2020/21 (Table 8.22, Rockwater 2021c).

Additional water is provided from unmetered onsite sources including water contained in the caustic soda, rainfall-runoff, the refinery sewerage system and direct rainfall captured in residue and water storage assets. Stormwater runoff from the Refinery has the potential to come into contact with alkaline materials. As a result, the Refinery is designed to be a zero discharge site, with potentially contaminated stormwater being collected and directed to the storm lake from where it is pumped into the residue area for use in the process water system. The residue area has base drainage systems that collect residue leachate and rainfall infiltration, which is then transferred to the lined cooling pond or ROWS pond for use as process makeup water. The additional water from unmetered onsite sources makes up the remaining component of the Refinery gross water demand.

Table 8.22 Annual total metered water supply – Pinjarra Refinery

Source	Volume (GL) 2017/18	Volume (GL) 2018/19	Volume (GL) 2019/20	Volume (GL) 2020/21
Production bores (Cattamarra aquifer)	5.27	4.73	4.13	6.40
Surface water	3.71	2.30	2.11	1.08
Subtotal – abstraction	8.98	7.03	6.24	7.48
Superficial formations and superficial aquitard – alkaline recovery	0.21	0.25	0.20	0.20
Pinjarra WWTP (grey water)	0.43	0.37	0.35	0.38
Scheme water	0.03	0.00	0.00	0.00
Subtotal – supplementary water	0.67	0.62	0.55	0.58
Total	9.66	7.65	6.79	8.06

Table 8.23 Pinjarra Refinery water licence summary

License	Type	Source	Allocation (GL/yr)	Expiry
GWL 98936	Groundwater	Cattamarra Coal measures	4.00	2026
GWL 167867	Groundwater (drought provision licence)	Cattamarra Coal measures	2.50	2026

License	Type	Source	Allocation (GL/yr)	Expiry
GWL 150586	Groundwater	Superficial Aquifer	0.40 (alkaline recovery)	2026
Subtotal - groundwater			6.50	
SWL 98937	Surface water	Oakley Brook	3.00	2033
SWL 98940	Surface water	Oakley Brook	1.20	2033
SWL 98939	Surface water	Barritt Brook / Tate Gully	1.00	2033
Subtotal – surface water			5.20	

Future water consumption

GWL 167867 is a groundwater drought provision licence granted under the RIWI Act to supplement water use for industrial purposes at the Refinery during dry years where rainfall levels are insufficient resulting in shortfalls in water supply from rainfall dependant surface water sources¹¹ for the Refinery. GWL 167867 is expected to expire in 2026 and Alcoa estimate an approximate 3-3.5 GL/yr shortfall in water supply depending on rainfall/drought years, upon upgrade of the Refinery to 5.25 Mtpa.

Alcoa is investigating a range of potential options to meet any shortfalls in water requirements, all options under review will involve water efficiency initiatives and may include alternative supply options in addition to current surface water and groundwater entitlements (see Table 8.24).

Table 8.24 Potential options to meet water demand for Pinjarra Refinery at 5.25 Mtpa production

Water management strategy	Options to be investigated
Alternative process technologies	<ul style="list-style-type: none"> • use of fin fan coolers • vapour recovery from calciners • mechanical vapour recompression (trial underway at Wagerup).
Water efficiency improvement in existing process technologies	<ul style="list-style-type: none"> • water demand reduction in Residue Filtration Facility • efficiency of sprinkler dust depression systems at residue area • alternative dust suppression technologies/materials at residue area • improve integrity of potable water plant and Refinery water ring main
Reduction in evaporative losses	<ul style="list-style-type: none"> • floating covers, emulsions and other options to reduce losses from storage ponds/dams • alternative management of alkaline water circuits (e.g. empty ponds in summer)
Alternative water supplies	<ul style="list-style-type: none"> • increased volume of secondary treated wastewater from Water Corporation's Pinjarra Waste Water Treatment Plant (WWTP) • secondary treated wastewater from Water Corporation's Gordon Road WWTP • construction additional sealed areas at Refinery to increase rainfall capture (e.g. diversion of carpark runoff)

¹¹ Rainfall dependant water sources for the Refinery include groundwater production bores, surface water sources, rainfall water captured across the Refinery's RSA (and associated water storage assets), the Pinjarra WWTP and water collected from raw materials during the Bayer process.

Water management strategy	Options to be investigated
	<ul style="list-style-type: none"> • other lower quality water sources for dust suppression at residue area • third-party suppliers
Water entitlements	<ul style="list-style-type: none"> • review of surface water and groundwater licences

8.4.13 Potential disturbance to the Peel-Yalgorup System Ramsar site

8.4.13.1 Peel-Yalgorup System catchment

The Mine DE lies predominantly (22,756 ha or 95.2 per cent) within the catchment of the Peel-Inlet, a component of the Peel-Yalgorup System Ramsar site, as presented in Table 8.25 and Figure 8-29. The majority of the Mine DE (20,200 ha or 84.6 per cent) lies within regulated catchments of drinking water dams, primarily the Serpentine Dam and South Dandalup Dam, which divert all or most of the catchment inflows for public drinking water supply. Approximately 2,536 ha (10.6 per cent) of the Mine DE lies in un-regulated catchments of Gooralong Brook, Davis Brook and Swamp Oak Brook, which are tributaries of the Serpentine and Murray rivers that discharge into the Peel Inlet. Gooralong Brook covers a small north-west portion of the Myara North DE, and Davis Brook and Swamp Oak Brook cover the southern portion of the Holyoake DE. Approximately 1,108 ha (4.6 ha) of the Mine DE lies outside of the catchment of the Peel-Yalgorup System.

As presented in Figure 8-29, the Peel Yalgorup System catchment has substantial areas cleared for agriculture, including cropping and animal grazing, as well as urban development. Dryland cropping over the upper catchment of the Murray River within the semi-arid zone has resulted in salinisation of the river, rendering the water quality unsuitable for potable or irrigation uses and hence the river remains un-regulated. Extensive agricultural development over the lower catchments of Murray River and Serpentine River, on the Swan Coastal Plain, has resulted in high nutrient loads and eutrophication of the Peel-Harvey Estuary (Hale and Butcher 2007). Along with river diversions, agricultural land use poses a key threat to the environmental values of the Peel-Yalgorup Ramsar site (Hale and Butcher 2007).

8.4.13.2 Inflows to the Peel-Yalgorup System

The Peel-Harvey Estuary component of the Peel-Yalgorup System has an average inflow of 380 GL/yr, with a standard deviation of 150 GL/yr (Peel-Harvey Catchment Council 2019).

The South Dandalup Dam and Conjurunup Pipehead Dam divert 100 per cent of catchment inflows for public drinking water supply, with zero release to downstream waters. The Serpentine Dam and North Dandalup Dam release water downstream for environmental uses according to allocation statements.

Releases from the Serpentine Dam and Serpentine Pipehead Dam to the Serpentine River downstream of the Pipehead Dam are managed according to the Serpentine allocation statement (DWER 2017a), which allows for the release of 0.8 gegalitres per year (GL/yr) for 'low-inflow' years (inflow to dam less than 30 GL) and 0.86 GL/yr for 'standard' years (inflow to dam greater than 30 GL). Accordingly, for average inflows of approximately 14 GL/yr, as was recorded over 2008-2015 (DWER 2017a), Serpentine Dam would divert more than 94 per cent of inflow from the Serpentine River catchment upstream, with less than six per cent released downstream. For inflows exceeding 30 GL/yr, the dam would divert more than 97 per cent, with less than three per cent released downstream.

Releases North Dandalup Dam to North Dandalup River downstream are managed according to the North Dandalup allocation statement (DWER 2017b), which allows for the release of

0.46 GL/yr for 'low-inflow' years (less than 30 GL) and 0.51 GL/yr for 'standard' years (inflow greater than 30 GL). Accordingly, for average inflows of approximately 8 GL/yr, as was recorded over 2008-2015 (DWER 2017b), North Dandalup Dam would divert more than 95 per cent, with less than five per cent released downstream. For inflows exceeding 30 GL/yr, the dam would divert more than 98 per cent, with less than two per cent released downstream.

Based on the allocation statements, the total downstream releases from the Serpentine Dam and North Dandalup Dam are expected to average a total of 1.26 GL/yr based on the expected continuing decline in catchment inflows.

There is no active gauging station on Gooralong Brook, however the station at nearby Vardi Road on Wungong Brook (station 616041) indicates flows since 2010 have averaged 1.60 GL/year for an approximate 7,950 ha catchment¹², or a yield of about 0.20 ML/ha/yr. Gooralong Brook has a total catchment area of approximately 5,155 ha and assuming a similar catchment yield as Wungong Brook are expected to average a total of 1.04 GL/yr.

Similarly, there is no active gauging station on Davis Brook or Swamp Oak Brook, however the station at nearby Yarragil Brook (station 614044) indicates flows since 2010 have averaged 0.33 GL/year for an approximate 8,000 ha catchment¹³, or a yield of about 0.04 ML/ha/yr. Davis Brook and Swamp Oak Brook have a total catchment area of approximately 13,670 ha and assuming a similar catchment yield as Yarragil Brook are expected to average a total of 0.56 GL/yr.

The total flow downstream to the Serpentine and Murray rivers from Serpentine Dam, North Dandalup Dam, Gooralong Brook, Davis Brook and Swamp Oak Brook is therefore expected to average a total of approximately 2.86 GL/yr. This total downstream flow represents approximately 0.75 per cent of the average total inflow into the Peel-Harvey Estuary, however only a fraction of the downstream flow is expected to reach the Peel-Harvey Estuary, due to water abstraction by downstream users, evaporative losses, and potential losses to groundwater.

8.4.13.3 Potential impacts on water yield and quality to the Peel-Yalgorup System

Impacts to water yield

Modelling for the Proposal and previous studies indicates that the Proposal may cause a variation in catchment inflows by approximately five to ten per cent, with an increase in stream flow during mining and a reduction in stream flow as rehabilitation establishes (see Section 8.4.3).

Assuming a conservative scenario that Proposal causes substantially reduced inflows into Serpentine and North Dandalup dam reservoirs that resulted in a reduced release downstream (i.e. inflows dropped from a 'standard' year to a 'low-inflow' year due to the effects of the Proposal), the reduction in releases to the Serpentine and North Dandalup rivers would be approximately 0.11 GL/yr (the difference between the releases allowed for a 'standard' year and 'low inflow' year).

Assuming a conservative scenario that the Proposal caused a ten per cent reduction in catchment flows from the unregulated catchments of Gooralong Brook, Davis Brook and Swamp Oak Brook, this would reduce flows by approximately 0.16 GL/yr. This is considered highly conservative due to the very small area of the Gooralong Brook catchment covered by the Mine DE.

A conservative estimate of the total downstream flow reduction possible due to the Proposal is therefore 0.26 GL/yr. This represents approximately 0.07 per cent of the average total inflow into

¹² Bureau of Meteorology, Hydrologic Reference Stations: <http://www.bom.gov.au/water/hrs/>

¹³ Ibid.

the Peel-Harvey Estuary. In the worst case of a low inflow year (lower standard deviation, at 230 GL/yr) for the Peel-Harvey Estuary, a 0.26 GL/yr reduction would represent 0.11 per cent of the total inflow. Only a fraction of the downstream flow is expected to reach the Peel-Harvey Estuary as noted above, thus the reduction to inflow at the Peel-Harvey Estuary would be less. The reduced streamflow is a conservative estimate and does not account for the increase in total downstream flow that may occur due to the Proposal increasing catchment stream flows during the mining stage prior to establishment of rehabilitation.

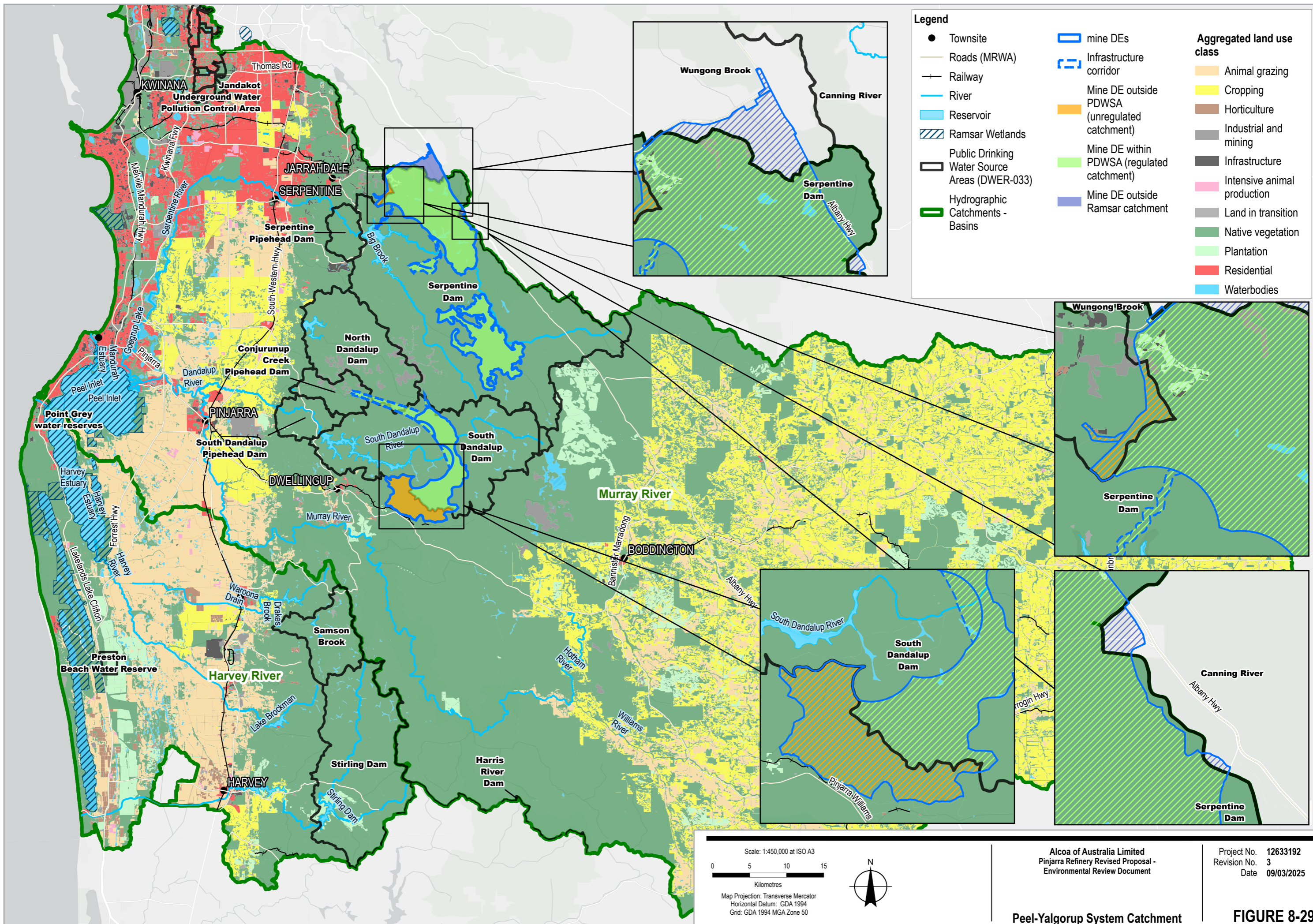
Impacts to water quality

Assuming a conservative scenario that the Proposal causes increase salinity of flows to the downstream rivers to rise by up to ten per cent, flows would remain fresh (i.e. less than 500 mg/L total dissolved salts or TDS) and the slightly elevated salinity of flows arising from the Mine DE would not be expected to cause a measurable change in salinity at the Peel-Harvey Estuary, which has a salinity ranging from 17,000 to 35,000 mg/L TDS (close to seawater) due to the opening of the Dawesville Channel (Peel-Harvey Catchment Council 2019).

As presented in Section 8.4.7, 8.4.8 and 8.4.9, the Proposal is unlikely to cause substantial impacts to water quality in drinking water reservoirs, including from turbidity or chemicals such as hydrocarbons or PFAS. Given that the majority of the Mine DE (89 per cent) lies within the catchments of drinking water reservoirs, the high water quality standards dictated for drinking water and the associated impact avoidance and mitigation commitments (see Section 8.5) to protect drinking water catchments, and the small proportion of water releases from drinking water dams to downstream rivers, the Proposal is highly unlikely to generate sufficient contaminant discharges to the Serpentine and Murray rivers downstream of the dams such that there would be a measurable impact to water quality in the Peel-Harvey Estuary. Accordingly, the Proposal is expected to have a negligible impact to the Peel-Yalgorup System Ramsar site.

Table 8.25 Overview of Mine Development Envelope area within catchments of the Peel-Yalgorup System

Catchment	Receiving waters	Myara North DE (ha)	Holyoake DE (ha)	O'Neil DE (ha)	Mine DE total (ha)	Proportion of Mine DE (%)
Regulated (dammed) catchments flowing into the Peel-Yalgorup System						
Serpentine Dam	Serpentine River, Peel Inlet	9,397	20	5,571	14,988	62.7
South Dandalup Dam	Murray River, Peel Inlet	0	4,795	0	4,795	20.1
North Dandalup Dam	Murray River, Peel Inlet	0	309	0	309	1.3
Conjurunup Pipehead Dam	Murray River, Peel Inlet	0	128	0	128	0.5
Regulated catchment subtotal total		9,397	5,252	5,571	20,220	84.6
Un-regulated catchments flowing into the Peel-Yalgorup System						
Gooralong Brook	Serpentine River, Peel Inlet	204	0	0	204	0.9
Davis Brook	Murray River, Peel Inlet	0	1739	0	1,739	7.3
Swamp Oak Brook	Murray River, Peel Inlet	0	592	0	592	2.5
Un-regulated catchment subtotal		204	2,332	0	2,536	10.6
Total within Peel-Yalgorup catchment		9,601	7,584	5,571	22,756	95.2
Catchments outside the Peel-Yalgorup catchment						
Wungong Brook	Canning River, Swan-Canning Estuary	1,046	0	0	1,046	4.4
Canning Dam	Canning River, Swam-Canning Estuary	61	0	0	61	0.3
To outside Peel-Yalgorup catchment		1,108	0	0	1,108	4.6
DE total		10,705	7,624	5,571	23,900	



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Peel-Yalgorup System Catchment **FIGURE 8-29**

Data source: Light Gray Base: Esri, TomTom, Garmin, Foursquare, METINASA, USGS
 Light Gray Base: Esri, TomTom, Garmin, Foursquare, FAO, METINASA, USGS

8.4.14 Cumulative impacts

8.4.14.1 Mining, timber salvage and other forest industries

Mining

The cumulative impact of current and future mining in the Serpentine Dam PDWSA have been incorporated into the hydrological and hydrodynamic modelling presented in Section 8.4.3 and Section 8.4.9.

The Newmont Boddington Goldmine and Worsley Bauxite Mine both lie in the un-regulated catchment of the Murray River and will not cause any cumulative impact to the Serpentine Dam, South Dandalup Dam and Wungong Dam PDWSAs. Alcoa's Willowdale Mine lies predominantly in the catchment of the Harvey River as well as the un-regulated catchment of the Murray River. The Huntly Mine transition to the Holyoake mine region will increase disturbance within the un-regulated catchment of the Murray River by an estimated 755 ha, or 0.10 per cent of the catchment (see Section 8.4.2). The disturbance in the Holyoake mine region is a small portion of the disturbance of Newmont Boddington Goldmine and Worsley Bauxite Mine and negligible compared to the clearing for agriculture in the upper and lower catchments of the Murray River.

Timber salvage

The WA Government has announced an end to native forest logging in 2024 and thus timber harvesting will not occur within PDWSAs during the life of the Myara North, Holyoake and O'Neil regions (circa 2026-2044). Historic timber harvesting is expected to have caused a larger disturbance to LAI within the NJF, with annual clearing about an order of magnitude greater than that of mining, however harvesting is relatively distributed across the forest and surface water catchments. Given the distribution of timber harvesting between catchments and the demonstrated regrowth that occurs in a comparable timeframe (or less) to that of mining, it is likely that there would be limited changes to stream salinity in any one drinking water catchment, and that freshwater quality will be maintained. Historic salinity monitoring data for the Serpentine Dam, South Dandalup Dam and Wungong Dam do not indicate that timber harvesting has caused significant salinisation, as salinity is well within freshwater quality (see Section 8.4.3).

Historic timber harvesting had potential for spills or leaks of diesel and oils during harvesting operations, which involved refuelling and potentially maintenance of harvesting equipment and heavy vehicles. There was also potential for low level oil leaks from vehicles and equipment, and rare collisions that resulted in fuel or oil spills. As with mining, the majority of spills and leaks, particularly those from major incidents and involving large volumes, are expected to have been identified quickly and the contaminated soils excavated and disposed off-site at a licensed waste facility. As with mining, small volumes of diesel and oil that escape detection and remediation were unlikely to result in substantial migration of hydrocarbons that reached streams and were transported into reservoirs.

Baseline monitoring for the Myara North, Holyoake and O'Neil regions indicates a lack of hydrocarbon or other chemical contamination (see Section 8.3.2.3 and Section 8.3.3.4), which indicates that historic timber harvesting did not cause significant contamination in these regions.

8.4.14.2 Rehabilitation

The impact of mine site rehabilitation on long-term erosion and vegetation resilience are discussed in Section 2.4.

8.4.14.3 Climate change and fire

The effects of climate change on the fire regime and the impacts of fire on water quality are presented in Section 5.4.4.4 and Section 8.4.9.

8.5 Mitigation

8.5.1 Impact avoidance and preventative risk management

Alcoa have developed an integrated impact avoidance framework for the Mine component of the Proposal, which avoids impacts across multiple key environmental factors. The impact avoidance framework is outlined below and commenced during planning of the Mine DE. Alcoa will continue to implement impact avoidance during the design, construction and operation phases of the mine component of the Proposal.



Figure 8-30 Integrated impact avoidance framework for Mine component of the Proposal

The impact avoidance framework has been developed with consideration to the principles of preventative risk management and multiple barriers as specified in the ADWG, and the findings of studies including the *Catchment Risk Assessment Alcoa 2023-2027*, *Procedural assessment under MS 728 informing the environmental audit of Alcoa's 2023-2027 MMP* (Water Corporation undated).

Table 8.26 Avoidance strategy for inland waters

Avoidance strategy elements	Drinking water quality and public health	GDEs and riparian habitat values	Carters Freshwater Mussel and other aquatic fauna	Farm dams and recreational uses	Peel Yalgorup System Ramsar Site
Inland waters guidance					
<ul style="list-style-type: none"> The greatest risks to consumers of drinking water are pathogenic microorganisms. Protection of water sources and treatment are of paramount importance and must never be compromised (ADWG Version 3.9 2024). The drinking water system must have, and continuously maintain, robust multiple barriers appropriate to the level of potential contamination facing the raw water supply (ADWG Version 3.9 2024). Catchment management and source water protection provide the first barrier for the protection of water quality (ADWG Version 3.9 2024). The RPZ is a key barrier in the approach to protecting reservoir and drinking water quality (Drinking Water Source Protection Plans, Serpentine Dam Serpentine Dam, South Dandalup Dam, DoW 2005 and 2007). Serpentine Pipehead Dam is central to the distribution of drinking water into the IWSS (Water Corporation, pers comm. 2024). The ecological character of the Peel-Yalgorup System, including services and values, will be maintained or enhanced to achieve long-term positive outcomes (Peel-Yalgorup System Ramsar Site Management Plan, PHCC 2009). 					
Objectives					
<ul style="list-style-type: none"> Avoid mining and limit infrastructure development within an RPZ. Avoid sewage treatment and disposal facilities and fuel storage facilities within an RPZ. Avoid mining and infrastructure within the Serpentine Pipehead Dam PDWSA. Maintain buffers to streams as key receptors and pathways to water contamination. Minimise the likelihood of a loss of hydraulic containment from mine drainage (drainage failures) and elevated turbidity in streams (turbidity events). Minimise the likelihood of saline water discharge into streams and reservoirs. 					
Selection of Development Envelope					
<ul style="list-style-type: none"> Mine DE was amended post-referral to avoid the Serpentine Pipehead Dam PDSWA. 	ü				ü
<ul style="list-style-type: none"> Mine DE was amended post-referral to avoid the RPZ of PDWSAs, with the exception of three linear infrastructure corridors within defined LDAs of the Serpentine Dam and South Dandalup Dam RPZs (see Figure 8-31.1 and Figure 8-31.2). The Proposal will not involve any mining, secondary haul roads or development of mine facilities within the RPZ of any PDWSA. 	ü				ü
<ul style="list-style-type: none"> Myara North DE was amended post-referral to avoid approximately 96 per cent of Gooralong Brook catchment. Holyoake DE was amended post referral to avoid approximately 92 per cent of Swamp Oak Brook catchment. 				ü	ü
Avoidance Zones within Development Envelope					
<ul style="list-style-type: none"> Avoidance Zone covers approximately 1,644 ha of mapped riparian and swamp vegetation, being approximately 82 per cent of the mapped riparian and swamp vegetation within the DE (see Figure 8-31.1, Figure 8-31.2 and Figure 8-31.3). 	ü	ü	ü	ü	ü

Avoidance strategy elements	Drinking water quality and public health	GDEs and riparian habitat values	Carters Freshwater Mussel and other aquatic fauna	Farm dams and recreational uses	Peel Yalgorup System Ramsar Site
<ul style="list-style-type: none"> Avoidance Zone covers 174 km of mapped stream lines (order 1, 2 and 3), being approximately 80 per cent of the mapped streams within the DE. Low Disturbance Area covers a further 38 km of mapped stream lines, being approximately 17 per cent of the mapped stream lines within the DE. Disturbance within the LDA will be limited to linear infrastructure crossings. A total of seven km of stream lines are mapped within the Development Zone, being approximately 3 per cent of mapped stream lines within the DE. Avoidance Zone incorporates a 100 m buffer to mapped riparian and swamp vegetation (A and C dominant vegetation types) with the exception of waterway crossings whereby these areas will be designated as an LDA, to mitigate potential indirect impacts from the Proposal to these areas. The avoided streams represent seasonal water sources that has potential to contain un-mapped river pools that may support Carter's Freshwater Mussel and other aquatic fauna. 					
Preclearance investigations and targeted avoidance					
<ul style="list-style-type: none"> Open areas limited to no more than 30 per cent of a subcatchment. The exception is clearing within the Myara North infrastructure corridor that extends within existing cleared subcatchments of the Myara mine region. Should existing clearing within these subcatchments result in open areas exceeding 30 per cent, then rehabilitation will be prioritised to ensure no net increase in the mine area open, reconciled to the end of each rehabilitation season (May-April) (i.e. for each hectare cleared in that subcatchment, at least one hectare of rehabilitation is completed within the same rehabilitation season). 	ü	ü	ü	ü	ü
<ul style="list-style-type: none"> Clearing for mine pits limited to areas with an average slope less than or equal to 16 per cent (based on the Landgate derived slope dataset) prior to mining. 	ü	ü	ü	ü	ü
<ul style="list-style-type: none"> Where mining is proposed in areas that CSIRO has modelled as TWI greater than nine, groundwater investigation undertaken as described in the Water Resource Management Plan (WRMP) (Alcoa 2024) to inform which of Alcoa's standard drainage controls will be implemented. In areas subject to a groundwater investigation, mine pits designed to maintain a 2 m separation between the predicted groundwater surface and planned pit floor. 	ü	ü	ü	ü	ü
<ul style="list-style-type: none"> Groundwater investigation undertaken in each subcatchment (at a first order stream scale) where mining is proposed, at least 24 months prior to clearing of mine pits in that catchment, to identify the depth and salinity of groundwater. Where groundwater salinity is recorded at greater than 500 mg/L TDS, further investigation will be undertaken including collection of at least 18 months of baseline groundwater level data and at least six months of baseline stream salinity data, and predictive modelling of groundwater rise and discharge into streams. Mine pits will be designed to maintain the predicted stream salinity within the range of the baseline salinity recorded in the subcatchment stream. Should the groundwater investigation and mine pit design for a subcatchment with a recorded groundwater salinity greater than 500 mg/L TDS indicate that mining within that subcatchment cannot maintain stream salinity within the baseline range, then mining will be avoided in that subcatchment. 	ü	ü	ü	ü	ü
<ul style="list-style-type: none"> Groundwater investigation undertaken in each subcatchment (at a first order stream scale) where mining is proposed, at least 24 months prior to clearing of mine pits in that catchment, to identify the depth of groundwater. Predictive modelling undertaken of groundwater rise and potential waterlogging (i.e. groundwater within one metre of the surface) for more than six months a year during mining in the subcatchment. Mine pits designed to maintain groundwater levels to avoid waterlogging for more than six months per year to any mapped site vegetation types within the subcatchment. 		ü			

Avoidance strategy elements	Drinking water quality and public health	GDEs and riparian habitat values	Carters Freshwater Mussel and other aquatic fauna	Farm dams and recreational uses	Peel Yalgorup System Ramsar Site
<ul style="list-style-type: none"> Should the groundwater investigation and mine pit design for a subcatchment indicate that mining within that subcatchment cannot maintain waterlogging to six months or less per year, then mining avoided in that subcatchment unless empirical data is available that demonstrates the affected site vegetation types are tolerant to the predicted duration of waterlogging. 					

8.5.2 Impact reduction

Alcoa is experienced in preventing and managing impacts to the inland waters of the Murray River and Pinjarra locality NJF, having operated the Refinery since 1972 and the Huntly Mine since 1976¹⁴. Alcoa's environmental management of its Refineries and Mine sites incorporates the mitigation hierarchy consistent with Western Australian guidance, which is in order of priority:

- Impact avoidance
- Impact minimisation
- Rehabilitation.

Table 8.27 presents a summary of the avoidance and minimisation for impacts to inland waters, with discussion provided below.

Water Resources Management Plan

Alcoa have developed a Water Resources Management Plan (WRMP) for the Huntly and Willowdale mines. The plan was developed to meet 2023-2027 Mining and Management Program (MMP) conditions.

The WRMP specifically addresses management of the risks and potential impact of bauxite mining activities on key environmental values of Inland Waters including:

- ecosystem health:
- wetlands, wild rivers, spring and pools
- ecosystems supporting significant flora, vegetation and fauna species/ communities
- ecosystems supporting significant amenity, recreation and cultural values
- beneficial uses:
 - drinking water supplies
 - significant current or potential water supplies
 - Inland Waters with high levels of recreation
 - Inland Waters with significant cultural and aesthetic values.

This WRMP aims to comply with the *Public Health Act 2010* for Drinking Water Quality Management in the ADWG (NHMRC, NRMCC, 2011) to safeguard drinking water quality.

In support of the WRMP, Alcoa has developed a robust framework comprising:

- a suite of management plans and guidelines tailored to address potential risks
- implementation of management actions to minimise impacts to water quality and flow regimes
- multiple monitoring programs to track environmental performance and measure progress against management targets
- an adaptive management approach through the application of learning from monitoring outcomes and management actions.

Environmental management system

Alcoa operates the Refinery and Mine through a mature environmental management system that is to international standards, and which undergoes continual improvement. Alcoa's preventative risk management framework at the Mine involves multiple barriers to prevent and reduce hazards to drinking water reservoirs.

¹⁴ Between 1972 and 1976, bauxite was supplied to the Refinery from the Del Park mine west of Huntly Mine.

Alcoa has operated in the NJF for over five decades including substantial operations within the South Dandalup, North Dandalup, Serpentine and Wungong PDWSAs. To date there has not been a substantial rise in salinity, a catastrophic sediment release or a catastrophic diesel spill from Alcoa's operations that has required remedial actions in a reservoir or for a reservoir to be taken off-line.

Alcoa is committed to working with the Water Corporation and DWER to ensure Mine operations continue to protect beneficial uses for public drinking water supply and recreational values and protect water dependent ecosystems to contribute to maintaining the ecological integrity of the NJF.

The Pinjarra Alumina Refinery has been regulated under Part V of the EP Act since 1983 and subject to a State Government endorsed LTRMS¹⁵ since 1997. Water abstraction is rigorously managed through water licensing and an operating strategy, including comprehensive monitoring of water quality in the superficial and confined aquifers. Alcoa has undertaken continual improvement at the Refinery to improve protection for inland waters, including water efficiency initiatives (Section 8.4.12.2), and improved design of the Refinery residue area (Section 8.4.13.2).

8.5.3 Rehabilitation

Rehabilitation is a critical component to Alcoa's environmental management system and protects inland waters through ensuring stable and non-polluting landforms. Alcoa's rehabilitation has performed over more than three decades against the completion criteria approved by DBCA to meet the objective of a self-sustaining jarrah forest ecosystem that meets multiple forest uses (see Section 2.4). The completion criteria have evolved in response to research and practice, with ongoing publication of research findings in the scientific literature.

The effectiveness of rehabilitation in mitigating turbidity risks was demonstrated through statistical analysis of turbidity event data (DAA 2023) (see Section 8.4.9.3). DAA (2023) concluded that open areas (i.e. cleared but not rehabilitated) pose a risk of high turbidity events (> 25 NTU) downstream, but cleared areas that have been subsequently rehabilitated do not.

Alcoa's success in implementing and evolving its rehabilitation program provides confidence in our capacity to adapt as the objective for rehabilitation changes into the future. This will include new State Government objectives for the NJF with the cessation of timber harvesting and introduction of the 2024-2033 FMP and the potential requirement for enhanced resilience to future climate change. Alcoa remains committed to collaborating with DBCA and other agencies to ensure Huntly Mine rehabilitation achieves outcomes that protect the inland waters values of the NJF.

Alcoa has developed a Rehabilitation Management Plan and Schedule (RMPS) for the Huntly and Willowdale mines, in accordance with 2023-2027 MMP approval conditions. The RMPS specifically addresses potential impacts of rehabilitated areas to the environmental values of the surrounding forest and associated water resources, prior to handback of rehabilitation to the State. The purpose of the RMPS is to:

- document management of rehabilitated areas to minimise impacts to environmental values
- demonstrate how rehabilitation is prioritised within PDWSAs through a detailed rehabilitation schedule.

The RMPS addresses management of the environmental values including water sources, water dependent ecosystems and PDWSAs.

¹⁵ Long Term Residue Management Strategy (Alcoa 2016)

The RMPS aligns with current Rehabilitation Completion Criteria (Department of State Development 2015). It should be noted that the Rehabilitation Completion Criteria is currently under revision with DBCA (as per the MMP approval condition 23). The RMPS will be updated as a result of this review and will further incorporate outcomes of ongoing research programs and enhancements to rehabilitation activities.

The RMPS is supported by Alcoa's Rehabilitation Design Manual (RDM), which provides a scientific based framework outlining Alcoa's rehabilitation design process. The RDM provide detailed descriptions of the rehabilitation methodologies, accompanied by the associated processes and procedures. Additionally, it defines the protocols for monitoring and reporting to ensure adherence to completion criteria standards.

Table 8.27 Minimisation of potential impacts to inland waters

No.	Increases in stream salinity as a result of mining-induced saline groundwater discharge	Industry standard, best practice and certainty of effectiveness
8-1	Where salinity risk has been identified through previous data, rehabilitation will be completed as soon as practicable after mining has been completed.	Established practice at Huntly Mine, commencement timeframes may vary due to a range of factors, moderate certainty
8-2	Rehabilitation within the Mine Development Envelope will be undertaken as presented in Section 2.4	Established practice at Huntly Mine, high certainty
Increased water supply for alumina refining		Industry standard, best practice and certainty of effectiveness
8-3	Investigate a range of water supply options including water efficiency initiatives to meet the Pinjarra Alumina Refinery’s water requirements.	High certainty
8-4	Huntly Mine – Water minimisation practices being investigated to reduce the water demand for the Huntly Mine.	Best practice options under investigation, moderate certainty
8-5	Huntly Mine – monitoring as required under water supply agreement and water abstraction licences	Established practice at Huntly Mine, high certainty
8-6	Pinjarra Alumina Refinery – Monitoring in accordance with Part V Environmental Licence for the Refinery and the Surface and Groundwater Operating Strategy	Established practice at Refinery, high certainty
Increased sediment from erosion of post-mining landforms – Mine Development Envelope		Industry standard, best practice and certainty of effectiveness
8-7	Haul roads, conveyors, and other infrastructure planned to limit crossing of mapped swamp and stream zones, to the minimum required for safe mining, as far as practicable. If disturbance to mapped swamp and stream zones cannot be avoided, minimise disturbance within swamp and stream zones, as far as practicable.	Established practice at Huntly Mine, high certainty
8-8	Rehabilitation within the Mine Development Envelope will be undertaken as presented in Section 2.4.	Established practice at Huntly Mine, high certainty

8-9	Rehabilitated mine pits to be designed and executed to prevent overflow during a 1 per cent 24hr AEP event	Best practice, site constraints to execution may vary, moderate certainty
8-10	Application of risk-based Mine drainage controls in all disturbed areas, in accordance with updated Alcoa WA Mining and Haul Road Drainage Design Manual.	Best practice, manuals under development, moderate certainty
8-11	Rehabilitation within the Mine Development Envelope will be undertaken as presented in Section 2.4.	Established practice at Huntly Mine, high certainty
8-12	Visual inspections of rehabilitated areas for stability, as per Rehabilitation Management Plan and Schedule (Alcoa 2024) .	Established practice at Huntly Mine, high certainty
	Development of Serpentine and South Dandalup river crossings	Industry standard, best practice and certainty of effectiveness
8-13	River crossings constructed during periods of no river flow and dry catchment conditions as far as practicable.	Best practice, schedule may be affected by approvals timeframe, moderate certainty
8-14	In the event that the river crossing is constructed during a period of river flow, then impoundment of river water will be limited to the duration required to construct and stabilise culverts, prior to the river water being diverted through the culverts. No impoundment of river water will occur following completion of construction of the river crossing.	Established practice at Huntly Mine, high certainty
8-15	Disturbance of riparian vegetation (A and C dominant vegetation types) for construction of river crossings limited to push over and covering of vegetation, to prevent direct soil disturbance.	Established practice at Huntly Mine, high certainty
8-16	Clearing for embankment and culvert construction to not commence until seven days of forecast no rain.	Best practice, high certainty.
8-17	Construction emergency response plan prepared and implemented for construction area management to stabilise and secure the site in the event of forecast rain 20 mm or greater during construction.	Best practice, moderate certainty

8-18	All refuelling of river crossing construction equipment to be at least 100 m from mapped riparian vegetation and on dry ground.	Best practice, high certainty.
8-19	All fuel storage, ablutions and waste disposal for river crossing construction to be located at designated construction compound outside of RPZ.	Best practice, high certainty.
8-20	Specific inductions provided to construction team and warning signs installed at construction site with respect to pathogen risk, hygiene requirements and zero human waste discharge on site.	Best practice, high certainty.
8-21	Speed limit of 30 km/hr over river crossing causeways at all times, clearly signed at approach to crossings.	Established practice at Huntly Mine, high certainty
8-22	Limit of 15,000 litre hydrocarbon volume to be transported across crossings, clearly signed at approach to crossings.	Established practice at Huntly Mine, high certainty
8-23	Triple stage sumps installed, including dual HDPE lined sumps for hydrocarbon capture. Sumps sized to contain runoff from one per cent AEP (one in 100 year), seven-day storm event.	Best practice, high certainty.
8-24	Crossing sumps regularly inspected and maintained in a 'storm ready state'. Sump water to be subject to testing for BTEX, PAH and TPH prior to controlled discharge and only discharged subject to tested hydrocarbons below detectable limits.	Established practice at Huntly Mine, high certainty
8-25	Spill response equipment maintained at all times adjacent to triple stage sumps.	Established practice at Huntly Mine, high certainty
	Contamination from spills and/or leaks from storage and handling of hazardous materials and waste – Mine Development Envelope	Industry standard, best practice and certainty of effectiveness
8-26	Construction and operational vehicles and equipment will use PFAS free fire-fighting foams	Best practice, foam alternatives available, high certainty
8-27	All construction and operational wastes (except treated sewage and oily water) will be transported off-site for recycling or disposal at a licensed waste facility.	Established practice at Huntly Mine, high certainty
8-28	Construction compounds and mine facilities will be located outside of designated RPZs	Established practice at Huntly Mine, high certainty

8-29	Bulk fuel tankers to construction compounds or mine facilities will not cross the Serpentine River main channel.	Established practice at Huntly Mine, high certainty
8-30	Haul trucks, heavy vehicles and light vehicles will be refuelled as far as practicable at designated fuel bays.	Established practice at Huntly Mine, high certainty
8-31	Mobile fuel tankers that service heavy equipment in the field will be limited to 15 m ³ capacity.	Established practice at Huntly Mine, high certainty
8-32	Planned maintenance of operations and construction vehicles and equipment will occur within workshops, as far as practicable. On site workshops will be located at mine facilities.	Established practice at Huntly Mine, high certainty
8-33	Storage of all hydrocarbon and chemicals within the Mine Development Envelope will be undertaken within appropriately sized secondary containment in accordance with <i>Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 1997</i> as applicable to specific materials as per the Environmentally Hazardous Materials Management Plan ¹⁶ . Storage will take into consideration the requirements of WQPN 56 Tanks for fuel and chemical storage near sensitive water resources (DWER 2018).	Industry standard, high certainty
8-34	Hazardous materials and wastes will be stored at designated construction compounds or other storage facilities in accordance with <i>Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 1997</i> as applicable to the specific materials. Storage will take into consideration the requirements of WQPN 56 Tanks for fuel and chemical storage near sensitive water resources (DWER 2018) and WQPN 65 Toxic and hazardous substances (DoW 2015).	Industry standard, high certainty
8-35	All wastes will be temporarily stored in designated containers and compounds prior to transport off-site for recycling or disposal at a licensed waste facility.	Established practice at Huntly Mine, high certainty

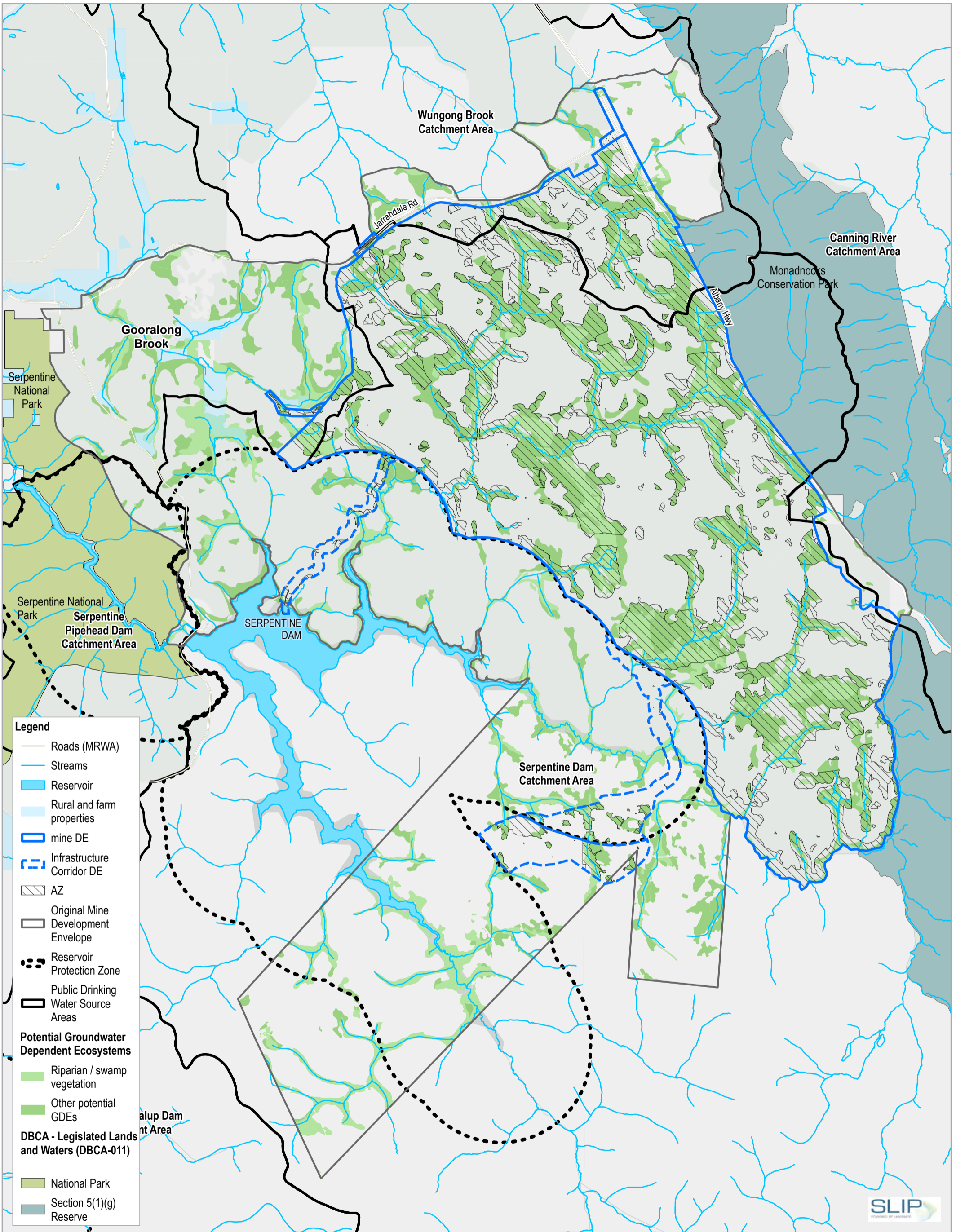
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<https://appprodnoaaaaacomsa.blob.core.windows.net/australia/pdfs/Environmentally-Hazardous-Materials-Management-Plan.pdf>

8-36	Construction and operations will have an emergency response plan that includes the requirements of WQPN 10 <i>Containment spills – emergency response plan</i> (DWER 2020).	Industry standard, high certainty
8-37	Spill response equipment will be maintained at the designated construction compound during construction or mine facilities during operations in accordance with the Huntly Mine Emergency Response Plan.	Industry standard, high certainty
8-38	Staff will be trained in spill response and clean up to enable effective and efficient clean up of any spills which may occur	Industry standard, high certainty
8-39	All spills or leaks will be reported and remediated as soon as practicable, in accordance with the WRMP.	Established practice at Huntly Mine, high certainty
8-40	Incident reporting and investigation will be conducted in accordance with the WRMP to reduce the likelihood of similar incidents occurring.	Established practice at Huntly Mine, high certainty
8-41	Contaminated areas within the Huntly Mine will be identified at closure and remediated in accordance with the Huntly Mine Closure Plan (Appendix D1).	Industry standard, high certainty
8-42	Inspection of spill locations after clean up is completed to ensure all contaminated soil is removed and managed accordingly.	Established practice at Huntly Mine, high certainty
	Contamination from spills and/or leaks from storage and handling of hazardous materials and waste – Refinery Disturbance Footprint	Industry standard, best practice and certainty of effectiveness
8-43	All construction wastes will be transported off-site for recycling or disposal at a licensed waste facility.	Industry standard, high certainty
8-44	Construction vehicles and equipment will be refuelled at designated fuel bays. Fuel bays and fuel storage will be constructed in accordance with <i>Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 1997</i> and Part V licence requirements.	Industry standard, high certainty
8-45	Hazardous materials and wastes will be stored at a designated construction compound in accordance with <i>Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 1997</i> and Part V licence requirements as applicable to the specific material.	Industry standard, high certainty

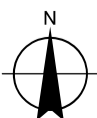
8-46	Planned maintenance of construction vehicles and equipment will occur within off-site workshops, as far as practicable.	Industry standard, high certainty
	Potential impacts to public health	Industry standard, best practice and certainty of effectiveness
	<i>See controls for Water quality deterioration in streams and reservoirs below</i>	
	Potential for service interruption of the public drinking water supply	Industry standard, best practice and certainty of effectiveness
	<i>See controls for Water quality deterioration in streams and reservoirs below</i>	
	Water quality deterioration in streams and reservoirs (for example, turbidity, salinity, pathogens, hydrocarbons, PFAS, nutrients, pesticides), including cumulative impacts from existing mining operations – Mine Development Envelope	Industry standard, best practice and certainty of effectiveness
8-47	Sewage Treatment Plant located at mine facilities outside of designated RPZs	Established practice at Huntly Mine, high certainty
8-48	Induction packages – the workforce will be made aware of RPZ access requirements and controls to prevent potential impacts on public health	Established practice at Huntly Mine, high certainty
8-49	Incident reporting and response of all accidental waste discharges in accordance with Alcoa procedures.	Established practice at Huntly Mine, high certainty
8-50	Waterway crossings constructed as far as practicable during periods of low river flow and dry catchment conditions.	Established practice at Huntly Mine, program constraints may require construction in winter/spring, moderate certainty
8-51	Waterway crossings will be constructed in a manner which facilitates their removal, rehabilitation and reinstatement of pre-disturbance water flows after use.	Established practice at Huntly Mine, high certainty
8-52	Mine drainage to be designed and executed with minimum capacity of: <ul style="list-style-type: none"> • Mine pits: 1 per cent AEP 24 hours • Haul roads: 1 per cent AEP 72 hours 	Best practice, site constraints to execution may vary, moderate certainty

8-53	Application of risk-based Mine drainage controls in all disturbed areas, in accordance with Alcoa Drainage Management Manual.	Best practice, manuals under development, moderate certainty
8-54	Rehabilitation within the Mine Development Envelope will be undertaken as presented in Section 2.4.	Established practice at Huntly Mine, high certainty
8-55	Construction of mine facilities and infrastructure will be in accordance with the WRMP	Best practice, high certainty



- Legend**
- Roads (MRWA)
 - Streams
 - Reservoir
 - Rural and farm properties
 - mine DE
 - Infrastructure Corridor DE
 - AZ
 - Original Mine Development Envelope
 - Reservoir Protection Zone
 - Public Drinking Water Source Areas
 - Potential Groundwater Dependent Ecosystems**
 - Riparian / swamp vegetation
 - Other potential GDEs
 - DBCA - Legislated Lands and Waters (DBCA-011)**
 - National Park
 - Section 5(1)(g) Reserve

Scale: 1:75,000 at ISO A3
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 Kilometres



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50

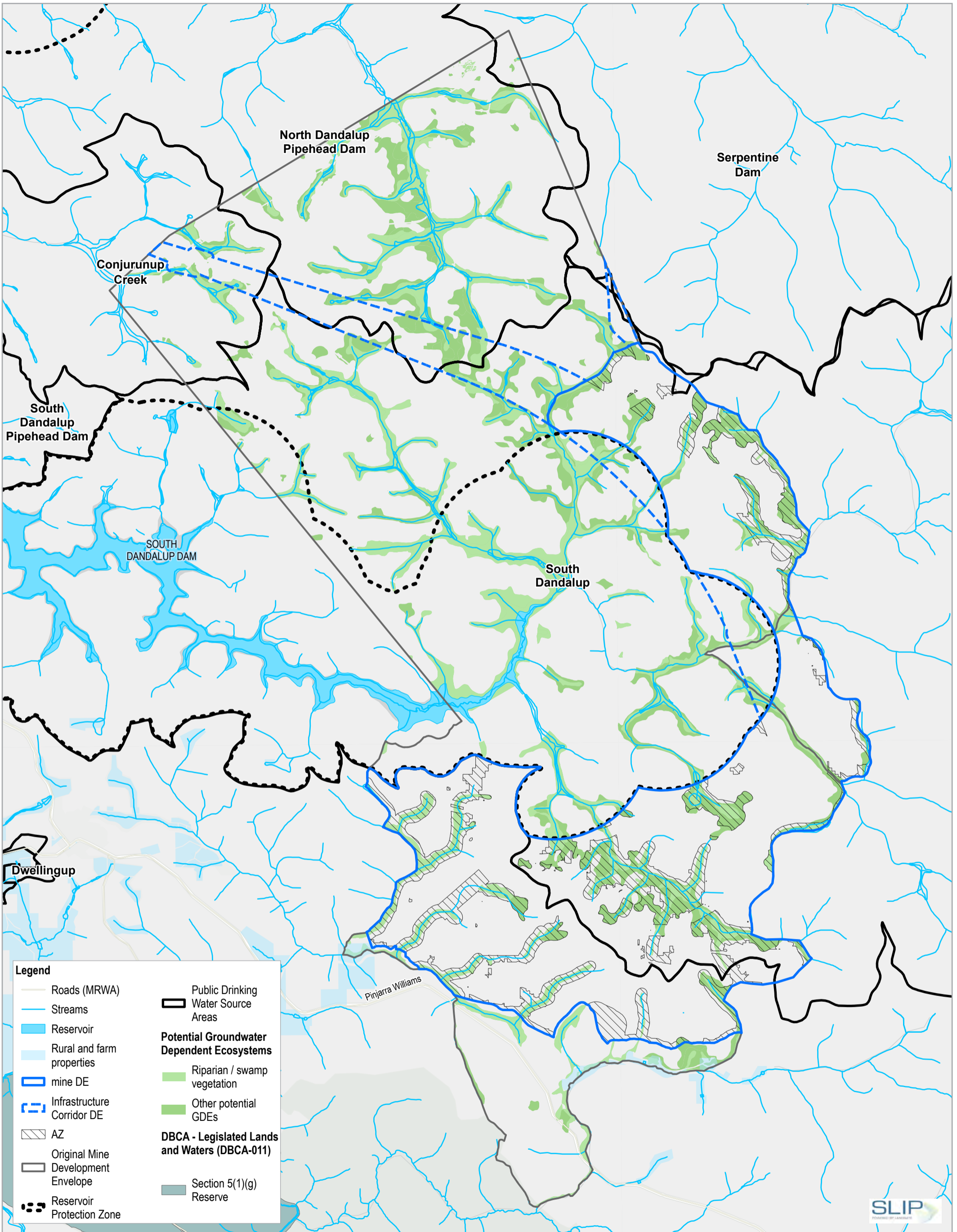
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 Revision No. 3
 Date 09/03/2025

Inland Waters Impact Avoidance -
 Myara North

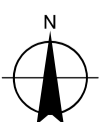
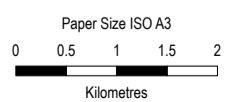
FIGURE 8-31.1

Data source: Light Gray Base: Esri, TomTom, Garmin, Foursquare, METINASA, USGS. Created by: rrama



Legend

Roads (MRWA)	Public Drinking Water Source Areas
Streams	Potential Groundwater Dependent Ecosystems
Reservoir	Riparian / swamp vegetation
Rural and farm properties	Other potential GDEs
mine DE	DBCA - Legislated Lands and Waters (DBCA-011)
Infrastructure Corridor DE	Section 5(1)(g) Reserve
AZ	
Original Mine Development Envelope	
Reservoir Protection Zone	



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50

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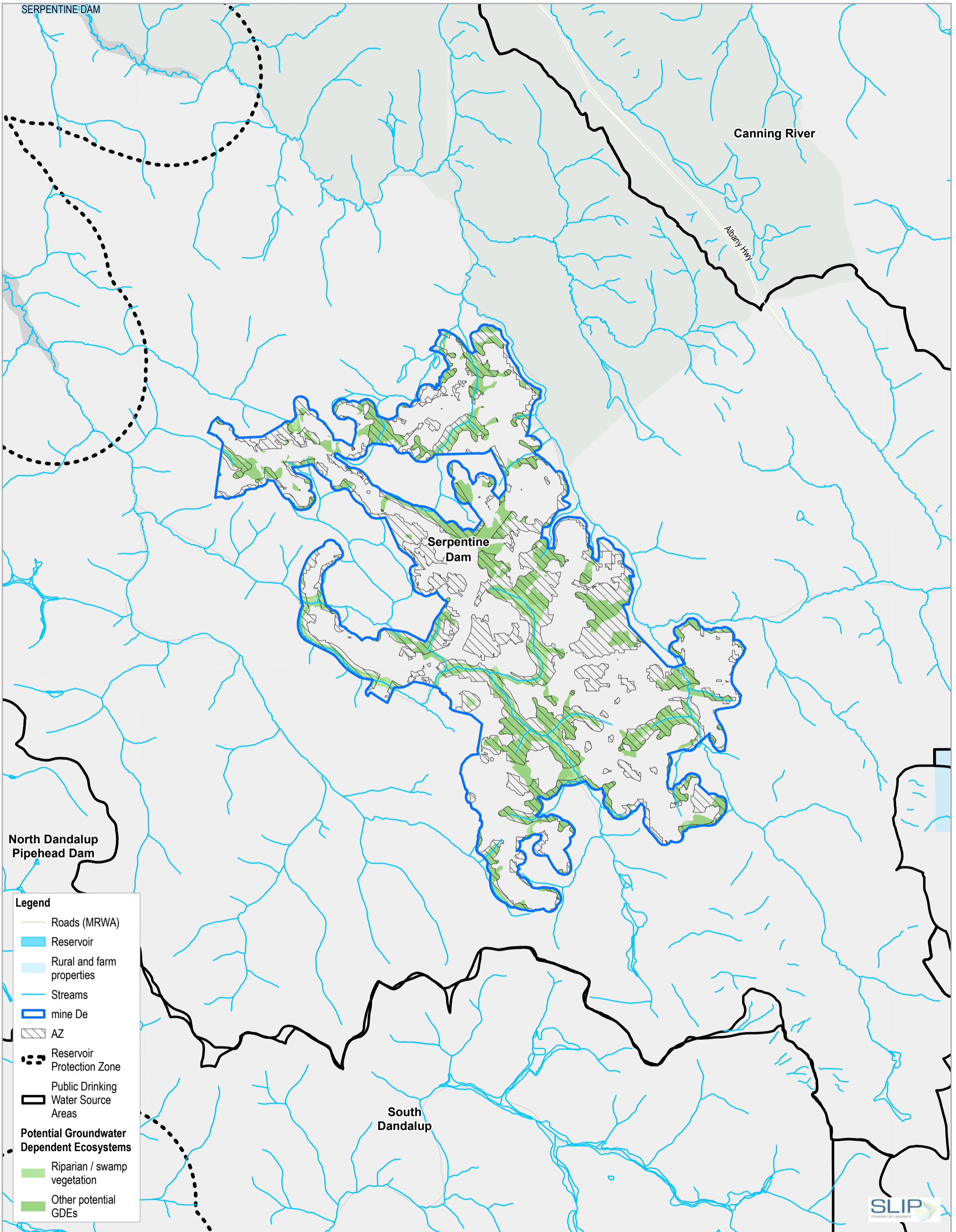
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**Inland Waters Impact Avoidance -
 Holyoake**

FIGURE 8-31.2

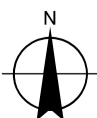
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- Legend**
- Roads (MRWA)
 - Reservoir
 - Rural and farm properties
 - Streams
 - mine De
 - AZ
 - Reservoir Protection Zone
 - Public Drinking Water Source Areas
 - Potential Groundwater Dependent Ecosystems**
 - Riparian / swamp vegetation
 - Other potential GDEs

Scale: 1:75,000 at ISO A3
 0 0.5 1 1.5 2
 Kilometres



Map Projection: Transverse Mercator
 Horizontal Datum: GDA 1994
 Grid: GDA 1994 MGA Zone 50

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Inland Waters Impact Avoidance -
 O'Neil

FIGURE 8-31.3

8.6 Assessment and significance of residual impacts

Table 8.28 and Table 8.29 present an assessment of residual impacts to inland waters and their significance for the Mine and Refinery components of the Proposal, respectively. As presented, the Proposal is unlikely to cause significant residual impacts to inland waters.

Alcoa implements preventative risk management involving multiple barriers to prevent and reduce hazards to drinking water reservoirs and has proposed additional barriers to further avoid and minimise hazards. These include:

- amendment of the DE to avoid the Serpentine Pipehead Dam PDWSA and RPZ of other PDWSAs with the exception of linear infrastructure crossings
- avoidance of mining within 100 m of mapped riparian and swamp vegetation, through designated Avoidance Zone
- avoidance measures to minimise the likelihood of a loss of hydraulic containment from mine drainage, including limits on open area, avoiding mining in high slope areas, and maintaining a minimum separation of mine pits from groundwater.

River crossings within the RPZs of the Serpentine and South Dandalup PDWSAs will be subject to specific management measures to prevent impacts during construction or operations, and if required, will be subject to regulation through a Bed and Banks Permit under the RIWI Act.

Mitigations to protect water quality, including surface and groundwater monitoring and a TARP, are contained in Alcoa's WRMP.

The effectiveness of rehabilitation, including resilience during drought and heat waves and effectiveness at preventing high turbidity events downstream, has been demonstrated through long-term research and monitoring, and is at a high level of confidence.

Alcoa has operated in the NJF for over five decades including substantial operations within the South Dandalup, North Dandalup, Serpentine and Wungong PDWSAs. To date there has not been a substantial rise in salinity, a catastrophic sediment release or a catastrophic diesel spill from Alcoa's operations that has required remedial actions in a reservoir or for a reservoir to be taken off-line.

As described in Section 1, the Proposal is a significant amendment of the PREU and accordingly this ERD assesses the potential impacts of the Proposal in the context of the PREU, including the combined effects on the environmental factors previously assessed by the (EPA 2003) which include water supply, part of the inland waters factor. The residual impact of Refinery water supply presented in Table 8.29 is the combined effect of the Proposal and the PREU as the approved proposal.

8.7 Environmental outcomes

Table 8.30 presents proposed environmental outcomes with respect to inland waters. These environmental outcomes are supported by environmental management objectives detailed in the Water Resources Management Plan (Appendix C3). The proposed environmental outcomes:

- reflect specific and measurable environmental states
- have a clear boundary, size, extent, or limit
- are consistent with the EPA's objective to protect maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.

Table 8.30 identifies where another statutory decision-making process can mitigate the potential environmental impacts of the Proposal on the environment to be consistent with the EPA's factor objective. As presented, amendment to existing Part V environmental licences for the

Huntly Mine and Pinjarra Refinery are expected to regulate outcomes relating to water quality, existing RIWI Act licences are expected to regulate outcomes relating to water abstraction, and requirements under the *Contaminated Sites Act 2003* are expected to regulate outcomes with respect to mine facilities contamination. Details of how the Part V environmental licence and RIWI Act licence decision-making process can mitigate impacts on the environment are presented in Section 2.2.3.

Table 8.28 Residual impacts to inland waters – Huntly Mine

Potential environmental impact	Residual impact	Likelihood of significant impact
Increases in stream salinity as a result of mining-induced saline groundwater discharge	<ul style="list-style-type: none"> Proposal has potential to result in small changes in salinity inflows to reservoirs, which are expected to fall well within the threshold of freshwater quality and drinking water palatability. Groundwater investigation will be undertaken in subcatchments with elevated groundwater salinity, to inform mine pit design to avoid salinity impacts to streams. Rehabilitation will be prioritised in areas at risk of shallow groundwater rise and saline groundwater. 	Unlikely
Increased sediment from erosion of post-mining landforms	<ul style="list-style-type: none"> Mine rehabilitation vegetation is expected to be sustained over the long term with resilience to climate change comparable to that of un-mined Jarrah forest. Mine rehabilitation is expected to provide long term protection of soils from erosion and associated sediment discharge to streams and reservoirs. Analysis of turbidity event data for the Huntly Mine indicates that rehabilitation is effective at reducing the incidence of high turbidity events downstream. 	Unlikely
Contamination from spills and/or leaks from storage or handling of hazardous materials and waste	<ul style="list-style-type: none"> The likelihood of a vehicle accident on a river crossing that could result in a major discharge of hydrocarbons or fire suppression foam into the Serpentine or South Dandalup rivers has been assessed as remote. A worst-case diesel spill event involving 15 m³ direct discharge to a stream is highly unlikely to result in offtake water quality that exceeds drinking water health criteria. However, there is potential for a worst-case diesel spill to result in offtake water quality that exceeds the threshold for taste and odour, which are substantially lower. Storage and handling of fuels, oil and other hazardous materials and wastes will predominantly occur at the mine facilities, outside of designated RPZs and with established barriers to contaminant discharge and transport. Small diesel or oil spills that escape detection and remediation are unlikely to result in substantial migration of contaminants that reach streams and can be transported into reservoirs. Accordingly, the storage and handling of hazardous materials is expected to pose a low risk to water quality. 	Unlikely
	<ul style="list-style-type: none"> Alcoa has committed to using PFAS-free fire-fighting foams. All water supplies to construction and operations in the Myara North and Holyoake regions will be sourced from public drinking water sources, captured 	Unlikely

Potential environmental impact	Residual impact	Likelihood of significant impact
	<p>onsite stormwater or from licensed onsite water treatment facilities where approved for reuse on the Mine.</p> <ul style="list-style-type: none"> The existing land uses and baseline monitoring program do not indicate the presence of substantial PFAS contamination within the Myara North or Holyoake regions. Accordingly, the potential indirect mobilisation of historic PFAS from catchments due to construction and mining is expected to pose a low risk to water quality. 	
	<ul style="list-style-type: none"> All construction and operational wastes will be disposed off-site at licensed waste facilities and expected to pose a low risk to water quality. On-site sewage treatment and disposal is addressed under pathogenic microorganisms (see below). 	Unlikely
Water quality deterioration in streams and reservoirs, including cumulative impacts from existing mining operations	<ul style="list-style-type: none"> Alcoa implements preventative risk management at the Mine, which incorporates multiple barriers to prevent hazards to downstream drinking water reservoirs from occurring or reduce them to acceptable levels. The barriers act to prevent and minimise the discharge of pathogens, sediment and hydrocarbons into downstream reservoirs, which are themselves barriers to contaminant transport prior to raw water being removed at the offtakes and entering the Water Corporation's water treatment and distribution system. Some barriers are likely to fail under certain conditions and with multiple barrier failures result in varying quantities of contaminants reaching the downstream reservoirs. Alcoa has committed to additional avoidance measures to reduce the likelihood of a loss of hydraulic containment from mine drainage, including limits on open area, avoiding mining in high slope areas, and maintaining a minimum separation of mine pits from groundwater. 	Unlikely
	<ul style="list-style-type: none"> Source vulnerability assessment concluded that human settlement and stock animal challenges of microbial risk aligned well with category 1 source waters for the PDWSAs. This was consistent with the current treatment applied at the source water. Quantitative microbial risk assessment indicates that a sewage treatment plant at the proposed mine facilities has a potential cryptosporidium dosage at reservoir offtakes that is well within health risk thresholds. Direct faecal deposition within the Serpentine Dam PDWSA has potential to result in exceedance of health risk thresholds. 	Unlikely

Potential environmental impact	Residual impact	Likelihood of significant impact
	<ul style="list-style-type: none"> Additional preventative measures will be implemented for the Serpentine Dam and South Dandalup Dam PDWSAs to reduce the risk of direct faecal deposition, including exclusion of mining from the RPZ and workforce inductions on pathogen risk and procedures. 	
	<ul style="list-style-type: none"> Alcoa will implement risk-based Mine drainage controls in all disturbed areas, in accordance with Alcoa's WA Mining and Haul Road Drainage Design Manual. Rehabilitated mine pits will be designed and executed to prevent overflow during a 1 per cent 24hr AEP event. Haul road sumps will be designed and executed to prevent overflow during a 1 per cent 72hr AEP event. Serpentine Dam turbidity concentrations are sensitive in the event of a catastrophic failure in mine sediment controls during a major storm event (greater than a 10 per cent AEP or ten-year return period). South Dandalup Dam has a comparatively low sensitivity. The predicted elevated turbidity levels at the offtake in the event of a catastrophic failure of mine sediment controls are not expected to affect disinfection efficacy. A major storm event that causes catastrophic failure in mine sediment controls is unlikely to occur during mine operations and has not previously occurred at the Huntly Mine since commencement of operations in the 1970s. 	Unlikely
	<ul style="list-style-type: none"> The Proposal is expected to enable DBCA's prescribed burning program to be effectively planned, funded and implemented, as has been demonstrated within the Huntly Mine to date. The Proposal is expected to maintain and support the State Government's program to limit fuel accumulation in the NJF, thereby reducing the likelihood of large wildfires occurring in mine regions that could impact water quality. 	Unlikely
Impacts to public health	<ul style="list-style-type: none"> See above 	
Service interruption of the public drinking water supply	<ul style="list-style-type: none"> The aggregated effect of Alcoa's WA mining operations on inflow capacity of the IWSS is expected to comprise an increase in inflow capacity over the mining period up to 2044, and a decrease in inflow capacity over the post-rehabilitation period compared to a no-mining scenario. The increases and decreases during the mining and post-rehabilitation stages, respectively, are expected to be approximately balanced and inflows into the IWSS are expected 	Unlikely

Potential environmental impact	Residual impact	Likelihood of significant impact
	<p>to be dominated by future rainfall trends with the effects of mining being a relatively small contributing factor.</p> <ul style="list-style-type: none"> • There remains potential for large scale wildfires to occur in the PDWSAs that may result in the drinking water becoming impacted for an extended duration. In such an event there is a potential requirement for the reservoir to be taken off-line, however the Proposal is not expected to increase the likelihood of severity of wildfires occurring in the mine regions. • There remains potential for a very rare storm event exceeding the design capacity of mine drainage controls to result in a catastrophic loss of containment from mine drainage within one or more PDWSAs connected to the IWSS. Such a rare event may dictate one of more reservoirs being taken offline as a risk prevention measure. • A large diesel spill that enters the reservoir (e.g. a freak fuel tanker accident) is unlikely to cause an impact to public health but may dictate an individual reservoir being taken offline. This would be a very rare or remote event. • Such catastrophic sediment release or diesel spill events that result in a shutdown to the Serpentine Dam, South Dandalup Dam or Wungong Dam have not occurred to date at the Huntly Mine or Jarrahdale Mine and are highly unlikely to occur. 	
Water supply for mining and refinery	<ul style="list-style-type: none"> • Mining will require 1-3 GL/yr of water supplied from public drinking water sources, captured onsite stormwater or from licensed onsite water treatment facilities where approved for use on the Mine. • The abstraction of 1 to 3 GL/yr for mining represents: <ul style="list-style-type: none"> • approximately 1.2 per cent to 3.7 per cent of the Water Corporation's combined 80.7 GL/yr licence allocation for the Serpentine Dam and South Dandalup Dam • approximately 0.3 per cent to 0.8 per cent of the estimated 380 GL/yr water demand on the IWSS in 2030 (Water Corporation 2009). • Additional abstraction from public drinking water sources for mining is expected to be subject to the Water Corporation's licence allocation and environmental release requirements for the dams, and no additional impact is expected to downstream hydrological regimes or water quality. 	Unlikely
Potential disturbance to Peel-Yalgorup System Ramsar site	<ul style="list-style-type: none"> • A conservative estimate of the total downstream flow reduction possible due to the Proposal during the post-rehabilitation stage is 0.26 GL/yr. This represents 	Unlikely

Potential environmental impact	Residual impact	Likelihood of significant impact
	<p>approximately 0.07 per cent of the average total inflow into the Peel-Harvey Estuary. The actual reduction to inflow the Peel-Harvey Estuary is expected to be less due to losses (e.g. abstraction) on the Serpentine and Murray rivers downstream. This does not account for the increase in total downstream flow that may occur due to the Proposal increasing catchment stream flows during the mining stage.</p> <ul style="list-style-type: none"> The Proposal is unlikely to cause substantial impacts to water quality in drinking water reservoirs, including from salinity, sediment, hydrocarbons or PFAS. Given that the majority of the Mine DE lies within the catchments of drinking water reservoirs, the high water quality standards dictated for drinking water and the associated impact avoidance and mitigation commitments to protect drinking water catchments, and the small proportion of water releases from drinking water dams to downstream rivers, the Proposal is highly unlikely to generate sufficient contaminant discharges to the Serpentine and Murray rivers such that there would be a measurable impact to water quality in the Peel-Harvey Estuary. Accordingly, the Proposal is expected to have a negligible impact to the Peel-Yalgorup System Ramsar site. 	

Table 8.29 Residual impacts to inland waters – Refinery Development Envelope

Potential environmental impact	Residual impact	Likelihood of significant impact
Increases in stream salinity as a result of mining-induced saline groundwater discharge	Not applicable	Not applicable
Increased sediment from erosion of post-mining landforms	Not applicable	Not applicable
Contamination from spills and/or leaks from storage or handling of hazardous materials and waste	Not applicable.	Not applicable
Water quality deterioration in streams and reservoirs, including cumulative impacts from existing mining operations	Not applicable	Not applicable
Impacts to public health	Not applicable	Not applicable
Service interruption of the public drinking water supply	Not applicable	Not applicable
Water supply for mining and refinery	<ul style="list-style-type: none"> Alcoa estimate an approximate 3-3.5 GL/yr water supply shortfall depending on rainfall/drought years upon upgrade of the Refinery to 5.25 Mtpa. Alcoa is investigating a range of options to meet any shortfall in fresh water requirements as the Refinery production rate is incrementally increased towards 5.25 Mtpa. All options under review will involve water efficiency initiatives and may include alternative supply options in addition to current surface and groundwater entitlements. Water abstraction from the PREU, as the approved proposal, will continue to be licenced under the RIWI Act and managed under the Operating Strategy for the Refinery, and subject to this regulation is not expected to result in significant impacts to hydrological regimes or water quality. This residual impact represents the combined effect of the Proposal with the PREU as the approved proposal. 	Unlikely

Potential environmental impact	Residual impact	Likelihood of significant impact
Potential disturbance to Peel-Yalgorup System Ramsar site	Not applicable	Not applicable

Table 8.30 Proposed environmental outcomes – inland waters

Potential environmental impact	Environmental outcome	Other statutory approval that will assure outcome	Monitoring of outcomes
Increases in stream salinity as a result of mining-induced saline groundwater discharge	No Proposal-related exceedance of salinity criteria (defined in WRMP) within stream inflows to drinking water reservoirs, Davis Brook or Swamp Oak Brook.	n/a	Salinity monitoring in Serpentine River, 39 Mile Brook and South Dandalup River
	In any three (3) rehabilitation season period (May-April) commencing after the date of approval, the hectares of rehabilitation of active areas within the Huntly Mine is equal to or greater than the hectares of disturbance of native vegetation for active areas.	n/a	Annual reporting of clearing extent Annual reporting of rehabilitation extent and performance against completion criteria
Changes to surface water regimes as a result of Proposal-related operations	No mining within 100 m of mapped riparian and swamp vegetation.	n/a	Annual reporting of clearing extent
	Open areas limited to no more than 30 per cent of a subcatchment, with the exception of the Myara North ICDE. Should existing clearing within the Myara North ICDE subcatchments result in open areas exceeding 30 per cent, then rehabilitation will be prioritised to ensure no net increase in the mine area open, reconciled to the end of each rehabilitation season period (May-April) (i.e. for each hectare cleared in that subcatchment, at least one hectare of rehabilitation is completed within the same rehabilitation season).	n/a	Annual reporting of clearing extent Annual reporting of rehabilitation extent and performance against completion criteria

Potential environmental impact	Environmental outcome	Other statutory approval that will assure outcome	Monitoring of outcomes
	Clearing for mine pits limited to areas with an average slope less than or equal to 16 per cent (based on the Landgate derived slope dataset) prior to mining.	n/a	Annual reporting of clearing extent
	Where mining is proposed in areas that CSIRO has modelled as TWI greater than nine, groundwater investigation undertaken as described in the Water Resource Management Plan (WRMP) to inform which of Alcoa's standard drainage controls will be implemented. In areas subject to a groundwater investigation, mine pits designed to maintain a 2 m separation between the predicted groundwater surface and planned pit floor.	n/a	Implementation of management plan
Increased sediment from erosion of post-mining landforms	In any three (3) rehabilitation season period (May-April) commencing after the date of approval, the hectares of rehabilitation of active areas within the Huntly Mine is equal to or greater than the hectares of disturbance of native vegetation for active areas.	n/a	Annual reporting of clearing extent Annual reporting of rehabilitation extent and performance against completion criteria
	Commencement of decommissioning of areas cleared for long-term infrastructure occurs within 18 months of these areas no longer being required by either Alcoa or the landowner.	n/a	Annual reporting of rehabilitation extent
Contamination from spills and/or leaks from storage or handling of hazardous materials and waste	No Proposal-related contamination exceeding ecological or human health guideline criteria (defined in WRMP) within stream inflows to drinking water reservoirs, Davis Brook or Swamp Oak Brook.	n/a	Streamflow water quality monitoring defined in WRMP
	Bulk fuel tankers to construction compounds or mine facilities will not cross the Serpentine River main channel.	n/a	Vehicle tracking logs

Potential environmental impact	Environmental outcome	Other statutory approval that will assure outcome	Monitoring of outcomes
	No construction or operational waste disposal areas located within the Mine Development Envelope, with the exception of mine facilities treated sewage effluent irrigation area.	Environmental licence under Part V of EP Act	Annual reporting of waste disposal
	No soil or water contamination exceeding ecological or health guideline criteria within the mine facilities footprint following decommissioning.	Contaminated Sites Act 2003	Detailed site investigation, remediation action plan and validation report upon facilities decommissioning
Impacts to public health	No Proposal-related turbidity levels exceeding criteria (defined in the WRMP) in stream inflows to drinking water reservoirs.	n/a	Streamflow turbidity monitoring defined in WRMP
	No Proposal related disturbance in Serpentine Pipehead Dam PDSWA	n/a	Annual reporting of clearing extent
	Sewage Treatment Plant located at mine facilities outside of the RPZ of any PDWSA	n/a	n/a
	No bauxite extraction withing the RPZ of any PDWSA	n/a	Annual reporting of clearing extent
Contamination of surface water and/or groundwater with potential acid sulfate soil (PASS) compounds due to soil and sediment removal at waterway crossings	PASS study is undertaken in any PASS areas and if required, management plans developed.	n/a	Implementation of management plan
Potential disturbance to Peel-Yalgorup System Ramsar site	No Proposal-related contamination exceeding ecological or human health guideline criteria (defined in WRMP) within stream inflows to drinking water reservoirs, Davis Brook or Swamp Oak Brook.	n/a	Streamflow water quality monitoring defined in WRMP