
APPENDIX K

Water Assessment

HVO Continuation Project

Water Assessment

Prepared for HV Operations Pty Ltd

December 2022

HVO Continuation Project

Water Assessment

HV Operations Pty Ltd

H190408 RP9

December 2022

Version	Date	Prepared by	Approved by	Comments
1	1 November 2022	Claire Corthier and Kate Holder	Nicole Armit	Draft for HVO review
2	28 November 2022	Kate Holder	Nicole Armit	Final
3	14 December	Kate Holder	Nicole Armit	Updated final

Approved by

Nicole Armit

Director

14 December 2022

Ground floor 20 Chandos Street

St Leonards NSW 2065

PO Box 21

St Leonards NSW 1590

This report has been prepared in accordance with the brief provided by HV Operations Pty Ltd and has relied upon the information collected at the time and under the conditions specified in the report. All findings, conclusions or recommendations contained in the report are based on the aforementioned circumstances. The report is for the use of HV Operations Pty Ltd and no responsibility will be taken for its use by other parties. HV Operations Pty Ltd may, at its discretion, use the report to inform regulators and the public.

© Reproduction of this report for educational or other non-commercial purposes is authorised without prior written permission from EMM provided the source is fully acknowledged. Reproduction of this report for resale or other commercial purposes is prohibited without EMM's prior written permission.

Executive Summary

ES1 Project introduction and overview

Hunter Valley Operations (HVO) is a multi-pit open cut mining complex approximately 24 kilometres north-west of Singleton in the Hunter Valley of New South Wales. HVO comprises two mine sites separated by the Hunter River, HVO North (approved under development consent DA 450-10-2003) and HVO South (operating under Project Approval 06_0261). While the two mine sites are approved under separate development consents, they are operated as one complex with fully integrated environmental management systems.

The HVO Continuation Project (the Project) broadly comprises the continuation of mining at HVO North and HVO South, from the current approved mining completion dates of 2025 and 2030 respectively, to the end of 2050 at HVO North and 2045 at HVO South. The continuation of mining across the HVO Complex will increase resource recovery from the existing operation, predominantly by mining through previously mined areas and to the extent of existing mining tenements and extracting coal from deeper seams at HVO North. At HVO South an extension to the life of the mine is proposed to facilitate improved mine sequencing outcomes and reduction in mining rate. The Project proposes a reduced mining disturbance area at HVO South compared to what is approved for extraction, with the previously approved coal extraction in the Riverview South East Extension area and South Lemington Pits 1 and 2 proposed to be removed from mine plan (and future approvals) for the Project. The approved shorter rail loop option associated with the Lemington Coal Preparation Plant has also been removed from the Project.

A number of infrastructure upgrades and changes are also required to facilitate the Project (and are included as part of it), including realignment of part of Lemington Road and improvements to Lake James and Parnells Dam.

To enable the Project to proceed, two new State significant development consents are required; one for HVO North and one for HVO South, under Part 4, Division 4.1 of the NSW *Environmental Planning and Assessment Act 1979*. The Project will seek to maintain separate development consents for HVO North and South, as is currently the case. Given that the two mine sites operate as one complex, one Environmental Impact Statement (EIS) has been prepared to support the two development applications required for the Project.

This water assessment forms part of the EIS and provides an assessment of the potential impacts of the Project on water resources and water-dependent assets. It also presents an assessment of the potential incremental impacts of the continuation of HVO North and HVO South given separate development consents are being sought for each operation, where practical. The water assessment is an overarching report documenting and summarising the findings of the different water-related technical assessments conducted for the Project, including:

- the groundwater impact assessment prepared by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE 2022), attached in Appendix A of this report;
- the surface water impact assessment prepared by Engeny Water Management (Engeny 2022), attached in Appendix B of this report;
- the aquatic ecology and groundwater dependent ecosystems (GDEs) assessment prepared by Eco Logical Australia (ELA 2022), attached in Appendix M of the EIS; and
- the geochemical assessment prepared by Environmental Geochemistry International Pty Ltd (EGi 2022a), attached in Appendix C of this report.

The water assessment documents the methods and results of the assessments listed above, initiatives to avoid and minimise impacts and additional mitigation and management measures proposed to address residual impacts not able to be avoided.

The potential impacts of the Project on water resources are generally consistent with the existing approved operations, given that the Project predominantly comprises mining through previously mined areas and to the extent of existing mining tenements. Some minor changes in impacts are predicted, including changes to timing as per the proposed changes to the project life and mining schedule.

The Project involves continued operations within portions of catchments that are currently or have been historically subject to extensive mining or impacts associated with mining, or areas of approved future mining. The existing operation has a well-established water management system (WMS) in place to minimise surface water impacts and operates in accordance with existing water access licences (for surface water and groundwater take) and environment protection licence 640, as well as the Hunter River Salinity Trading Schedule (HRSTS) to manage excess water.

The existing WMS will continue to be used to manage runoff with all water captured in active mining areas and mine surface runoff directed to the WMS. The existing approved clean water diversions will continue to divert runoff around the WMS. There are no new creek diversions proposed or required as part of the Project, and there are no proposed changes to water access licences or HRSTS credits.

The Project proposes the following key changes at HVO North which are relevant to impacts on water resources:

- Realignment of Lemington Road and construction of a new Hunter River bridge crossing, which will significantly improve the flood immunity of this road adjacent to the Hunter River, reducing road closures in flooding events.
- Improved flood protection levee for North Pit TSF (up to 0.1% Annual Exceedance Probability (AEP)) as per Glencore's operating standard.
- Improved flood protection for the Carrington West Wing levee (up to 0.1% AEP).
- An increase in the capacity of Parnells Dam (Dam 9W) from approximately 1 gigalitre (GL) to approximately 4 GL.
- Installation of the approved barrier wall in the Carrington West Wing area, following mining in that area but prior to backfilling with overburden and interburden material. The proposed approach will be consistent with the approved construction methodology of the existing Carrington Pit barrier wall.
- Reducing the number of final voids that will remain post closure from three to one final void at HVO North, resulting in a reduction in catchment area draining to the void and total void surface area when compared to the currently approved operation.

At HVO South, there are limited changes proposed that will affect water resources, given that while changes to the approved mine sequencing are proposed, mining within the two primary open cut pits, Riverview and Cheshunt, will remain generally within the same footprint and will mine the same seams as approved. Changes proposed that are relevant to water resources are:

- construction of the Cheshunt and Riverview Pit flood protection levees;
- enlargement of Lake James (Dam 15S) from approximately 0.7 GL to approximately 2 GL; and
- removal of coal extraction from the mine plan in the Riverview South East Extension, South Lemington Pit 1 and South Lemington Pit 2 mining areas.

Notably, the final void will remain largely the same as that currently approved at HVO South.

ES2 Water resources

Surface water resources in the vicinity of the HVO Complex include the Hunter River, Wollombi Brook and other minor watercourses such as Farrells Creek and Parnells Creek. The Hunter River, and highly connected alluvial groundwater within 40 m of the river bank, is managed under the NSW *Water Sharing Plan (WSP) for the Hunter Regulated River Water Source 2016*. The tributaries to the Hunter River are managed under the *WSP for the Hunter Unregulated and Alluvial Water Sources 2022*.

The *WSP for the North Coast Fractured and Porous Rock Groundwater Sources 2016* applies to the Permian groundwater resources within the Project area.

The main groundwater resources that could be impacted by the Project include:

- alluvial aquifers, occurring mainly along the Hunter River and Wollombi Brook; and
- Permian groundwater systems:
 - thin and variably permeable regolith, with limited saturated thickness;
 - interburden aquitards; and
 - low to moderately permeable coal seams.

The proposed mine plan will intercept groundwater and result in changes to the existing groundwater and surface water environment. However, the HVO Complex already comprises active and approved open cut pits and the potential for the Project to result in a significant incremental impact on water resources is low.

Water receptors include:

- downstream water users accessing surface water via water access licences and basic landholder rights;
- third-party landholder bores located upstream and downstream of the HVO Complex, typically installed in the alluvium; and
- ecosystems that potentially rely on surface water and/or groundwater:
 - river red gum communities (including in the Carrington Billabong area) that opportunistically access shallow groundwater recharged by leakage from the Hunter River and Wollombi Brook, and rely on flooding for germination;
 - stygofauna occurring principally in alluvial sediments along the Hunter River and its tributaries;
 - aquatic ecosystems; and
 - Warkworth Sand Woodland communities which rely principally on rainfall infiltration and a seasonal perched watertable observed to occur after large rainfall events.

The ecological surveys conducted for the Project observed that all vegetation stands were in low to moderate condition. In addition, the aquatic ecosystems surveyed as part of the aquatic ecology and GDE assessment (Appendix M to the EIS) are considered to be in poor ecological condition, based on the macroinvertebrate community and water quality (the ecological condition of the Hunter River is classed as poor to moderate). Macroinvertebrate communities were dominated by taxa that are robust and tolerant of pollution and poor environmental conditions.

ES3 Assessment approach

The various water technical studies considered the requirements of the NSW Government, including legislation, regulations, policies and guidelines. In relation to the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), a referral was submitted to the Department of Climate Change, Energy, the Environment and Water (DCCEEW) for the Project regarding potential impacts to listed threatened species and ecological communities, and water resources, to determine if it is a controlled action under the EPBC Act. At the time of EIS submission, DCCEEW's determination is still pending. Notwithstanding, the water technical studies considered the expectations of the Independent Expert Scientific Committee for Coal Seam Gas and Large Coal Mine Development (IESC).

The water technical assessments have been informed by extensive groundwater, surface water, ecological and geochemical monitoring and historical assessments for the existing operations.

The surface water impact assessment (Engeny 2022) included:

- Assessment of the Project WMS performance using a GoldSim water balance model, consistent with the water balance model used for the existing operations.
- Streamflow impact assessment based on flow sequencing analysis (for the Hunter River and Wollombi Brook) and an Australian Water Balance Model for the ephemeral watercourses. The streamflow impact assessment was based on estimated changes in catchment areas and changes in surface water-groundwater interaction.
- Surface water quality assessment based on outcomes of the water balance model and streamflow analysis (including assessment of potential impacts of approved HRSTS discharges).
- Flooding impact assessment using a hydraulic model of the Hunter River, in accordance with the methods recommended in Australian Rainfall and Runoff 2019 (Ball et al 2019).

The groundwater impact assessment has been informed by numerical groundwater flow modelling (AGE 2022), which was conducted using the existing HVO groundwater model which was updated to predict changes to groundwater levels and fluxes due to the Project.

The assessment of potential impacts on groundwater quality has been informed by the geochemical assessment (EGi 2022a) and the groundwater flow modelling.

An assessment of potential impacts of the final void and post closure impacts of the Project has been informed by:

- final void hydrology and salt balance modelling developed by Engeny (2022) to predict the pit lake recovery for the HVO North and South voids;
- groundwater modelling conducted for the Project; and
- hydrogeochemical modelling to predict pit lake water quality characteristics.

The aquatic ecology and GDE assessment conducted by ELA for the Project (Appendix M to the EIS) is based on the outcomes of the groundwater modelling (AGE 2022), streamflow impact assessment and surface water quality assessment (Engeny 2022). ELA (2022) conducted a risk assessment based on the ecological value, potential impact and risk magnitude of the Project on aquatic ecology, aquifer ecosystems and GDEs. The risk assessment was also used to identify management and mitigation measures.

ES4 Assessment findings

The assessments show the Project can operate within and meet the requirements of the water regulatory framework. Key results are summarised below.

ES4.1 Surface water impacts

Key outcomes of the surface water impact assessment and aquatic ecology assessment are summarised as follows:

- Impacts on Hunter River and Wollombi Brook streamflow will be negligible.
 - In addition, a decrease in the duration of dry periods is predicted at Wollombi Brook due to the removal of previously approved mining in the South Lemington Pit 1 and 2 areas from the Project.
- Minor changes in streamflow is predicted for three ephemeral watercourses during operations. The minor changes to streamflow due to the Project mainly relates to small reductions in catchment areas associated with mining extending between the existing West and Mitchell Pits to Carrington Pit, and changes in surface water-groundwater interaction. The predicted change in streamflow will have a minor impact on the number of dry days, as many of these ephemeral watercourses are dry (on average) for more than half of the year under current conditions. Post mining, potential streamflow impacts are expected to be negligible.
- Potential impacts on surface water downstream users will be negligible as no changes in streamflow regimes are predicted in the Hunter River, given it is a regulated system and HVO holds sufficient entitlement for the predicted reduction in streamflow due to the Project.
- No impacts are predicted on the aquatic ecology of the Hunter River, particularly as flow will be mitigated through regulated releases from Glenbawn Dam, and only minor impacts to the aquatic ecology in the tributaries to the Hunter River are expected.
- The proposed WMS for the Project is predicted to maintain a sufficient water supply for the operation and discharge capacity to preventing flooding of operational areas of the mine.
- Potential impacts on surface water quality are expected to be minimal and will continue to be mitigated through an appropriately sized, designed and operated WMS, including release from sediment dams in accordance with their design and discharge of mine water in accordance with approved environment protection licence limits and HRSTS credits. Modelling indicates that the impact of approved HRSTS discharges will have a negligible impact on water quality. Concentrations of key analytes are predicted to remain within the existing ranges observed in the Hunter River.
- The flood modelling for the Project indicates minor flooding impacts to properties not owned by the JV partners. The Project is predicted to result in minor additional flood level changes ranging between 20–50 mm, but generally less than 30 mm, at 15 properties (being contiguous landholdings) not owned by the HVO JV. The impact is predicted to be minor, as the properties are already subject to flooding, and the maximum modelled change in flood affected area is estimated to be 0.15% of the total property for any individual property. In addition, the predicted change in flooding will not have an impact on the use of the land (agricultural (grazing and cropping) or crown land).

- The main public infrastructure in the vicinity of HVO prone to flooding impacts is Lemington Road. Currently, Lemington Road at Moses Crossing becomes inundated during events smaller than 10% AEP, and has been closed for an average of 60 days per year since 2010. The proposed realignment and new Hunter River bridge crossing of Lemington Road will significantly improve the flood immunity of this road adjacent to the Hunter River. The new Hunter River crossing will exceed 10% AEP flood immunity during the Project and post closure.
- Velocity impacts are generally predicted to be localised around Project infrastructure (levees, Lemington Road, South Lemington Pit 1). The magnitude of velocities in these areas generally remain within the existing ranges experienced and remain a low likelihood of causing scour (<2 metres per second).
- There are no broad scale changes to flood hazard categories forecast as a result of the Project. Small changes in road inundation durations were forecast; however, the small changes are not expected to have an impact on use of the land or public safety or emergency management. Overall, there is a significant benefit to the local community through improved immunity and access of the realigned Lemington Road.

ES4.2 Groundwater impacts

Key outcomes of the groundwater impact assessment and GDE assessment are summarised as follows:

- No impact is predicted at privately-owned groundwater bores.
- Construction of the approved Carrington West Wing barrier wall will limit the long-term drawdown in the Hunter River alluvium and the potential for seepage from the backfilled mine areas to the alluvium. The potential impact on water quality is minor to negligible.
- Groundwater modelling predicts a short-term increase in groundwater drawdown in the alluvium in the Carrington West Wing area (noting this area is already approved for coal extraction under the existing development consent at HVO North) prior to construction of the barrier wall. Following installation of the approved barrier wall, groundwater levels are predicted to recover. During the short-term peak drawdown period, saturation in the alluvium will remain due to leakage from the Hunter River.
- Minimal drawdown (less than 0.5 m) is predicted in the Hunter River alluvium near mapped river red gum communities and dewatering will not occur. This predicted drawdown will be buffered by leakage through the riverbed. Therefore, no significant impact is predicted.
- No additional drawdown in the Wollombi Brook alluvium is predicted. In contrast, the avoidance measure of removing mining in the South Lemington Pit 1 and 2 areas from the mine plan is predicted to result in a reduction in potential drawdown in the Wollombi Brook alluvium (in comparison to the approved operations).
- No changes to the environmental, community and cultural values are predicted due to the Project.

ES4.3 Final void

Key outcomes of the final void assessment are:

- the predicted long-term watertable and pit lake level will be depressed, with groundwater flow directions towards the voids;
- the Hunter River alluvium is predicted to remain saturated due to the strong hydraulic connection with the Hunter River;

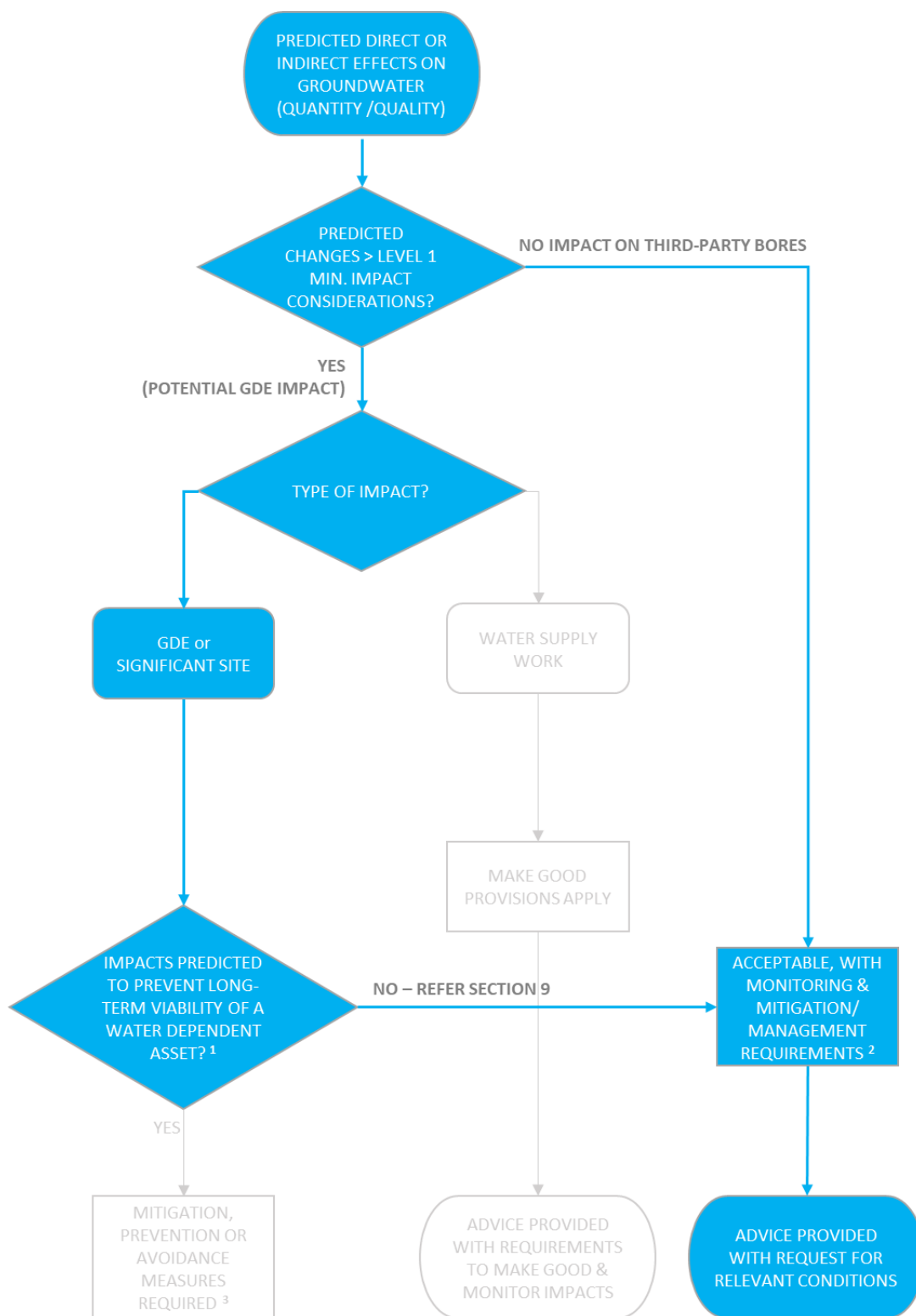
- evaporation will be the dominant loss from the voids and the voids are predicted to remain groundwater sinks;
- the long-term pit lake level is considerably deeper than the base of the alluvium and the base of weathering, therefore the risk of seepage from the pit lakes to shallow groundwater is negligible;
- the risk of spill from the pit lakes is negligible;
- the runoff area contributing to the voids is sufficiently small so that evaporation dominates, and the voids remain as strong long-term groundwater sinks thereby attracting seepage from the surrounding strata (at a very low rate); and
- infiltration of rainfall in the backfilled mine areas will gradually flow towards the pit lakes, as evidenced by the groundwater particle tracking completed as part of the groundwater impact assessment (Appendix A), and the risk of seepage from the backfilled mine areas migrating through the existing and proposed barrier walls to the Hunter River alluvium is negligible.

Given the depth and change from three voids to one void, the HVO North void for the Project will act as a stronger sink than the currently approved Carrington void evaporative sink. In addition, the surface water and groundwater modelling indicate the HVO South void will also act as a stronger evaporative sink than the currently approved HVO South void.

Consistent with the predicted drawdown during operations, the post mining incremental alluvial drawdown is not predicted to have a significant impact on GDEs or surface water resources.

The predicted cumulative drawdown is very conservative as the long-term predicted watertable is compared to a model where mining effects cease in 2009, effectively allowing groundwater levels to recover in the baseline model. The predicted cumulative alluvial drawdown (post mining) exceeds the NSW aquifer interference policy level 1 minimal impact considerations in a small area; however, the aquatic ecology and GDE assessment (ELA 2022) demonstrates that the predicted change in watertable will not prevent the long-term viability of the ecosystem. This is illustrated in Figure ES1.

River red gums and Bull Oak Grassy Woodland of the Central Hunter Valley (plant community type 1692) vegetation that opportunistically use shallow groundwater will continue to have access to shallow alluvial groundwater. In addition, the Project is predicted to have a negligible impact on Hunter River flow and flooding regime post mining. Therefore, river red gum communities will continue to rely on flooding for germination.



1. Assessment as per Serov et al 2012, with consideration of uniqueness, ecological/cultural value and timeframe of the impact.
2. Conditions of approval may include requirements for adaptive management to monitor and mitigate or remediate impacts that exceed level 1 thresholds.
3. Where there are no suitable or practical mitigation or prevention options, the proponent may be asked to avoid impacts by modifying the proposed activity.

Figure ES1 Overview of Project assessment against the NSW Aquifer Interference Policy minimal impact considerations process

ES4.4 Water licensing

HVO holds considerable water entitlement in the relevant surface water and groundwater sources in the Project area, which is sufficient to account for the predicted direct and indirect takes.

The integrated WMS includes storages located on non-minor and minor streams, and storages located off stream that are required for the future approved operation and Project operation. Where storages are located on minor streams (as defined by the *Water Management (General) Regulation 2018* (WM Regulation) spatial data set) and capture water to prevent contamination of a water source, they are considered excluded works under Schedule 1, item 3 of the WM Regulation and so the take is exempt. Other storages located on minor streams in the Project WMS can be accounted for within HVO's available harvestable right volume. The *Water Management Act 2000* requires all water take from non-minor streams to be licensed. Therefore, the catchment runoff captured by storages (existing and proposed) in the Project WMS has been calculated.

ES5 Monitoring, management and mitigations

Following Project approval, the WMP will be reviewed and updated, including review of the existing surface water, groundwater and ecological monitoring, so that WMP performance criteria and verification of assessment findings can be assessed. The majority of the proposed management and mitigation measures listed in the water-related assessments are consistent with the existing mitigation measures in place at HVO. This is appropriate and to be expected given the generally small incremental impact due to the small additional disturbance and changes to timing associated with the Project.

In addition to review and extension of the existing WMP and associated monitoring, HVO will expand the existing groundwater monitoring network to include additional monitoring bores within the zone of predicted short-term incremental drawdown in the Carrington West Wing alluvium area (south of the proposed barrier wall). A network of eight nested monitoring bores will be installed in this area, with separate bores screened with the alluvium and Permian strata. The bores will be installed approximately one year prior to mining commences in the remnant paleochannel to allow collection of background groundwater level trends prior to the effects of mining.

In addition, piezometers will be installed downstream of the Carrington West Wing barrier wall, consistent with the approach used for the existing Carrington Pit barrier wall. The purpose of the piezometers would be to monitor for changes in salinity (as EC) and pressure.

The locations and designs of the additional groundwater monitoring locations will be determined in consultation with DPE Water during updates to the WMP.

In accordance with condition 25 of the HVO North development consent (DA 450-10-2003), HVO will develop a low permeability barrier monitoring and management plan following Project approval and in consultation with the NSW Government.

The dedicated monitoring and management plan would include the following:

- identification and design of additional groundwater monitoring bores mentioned above;
- monitoring requirements and methodologies, including monitoring of groundwater levels/pressures and salinity at a suitable frequency, and sampling for comprehensive laboratory water quality analysis at a suitable frequency, to evaluate the efficacy of the Carrington West Wing barrier wall;
- summary of the Carrington West Wing barrier wall construction methodology and design requirements;
- identification of other monitoring requirements or adjustments, such as at the Hunter River and/or river red gum stands;

- selection of trigger levels, and appropriate action response plan(s), for groundwater level and salinity in the Hunter River alluvium south of the Carrington West Wing barrier wall so that adequate management of groundwater level and quality is achieved; and
- summarising reporting commitments that will evaluate multiple lines of evidence for assessing potential impacts at receptors.

TABLE OF CONTENTS

Executive Summary	ES.1
1 Introduction	1
1.1 Background	1
1.2 Project overview	4
1.3 Project terminology	6
1.4 Purpose of this report	6
1.5 Assessment requirements	8
1.6 Water study areas	8
2 Project context	11
2.1 Existing water management	11
2.2 Key water affecting activities of the Project	15
3 Regulatory and policy context	22
3.1 Legislation overview	22
3.2 Relevant NSW policies	22
3.3 Relevant guidelines	29
4 Description of the environment	31
4.1 Data availability	31
4.2 Climate	31
4.3 Hydrological setting	32
4.4 Geological setting	37
4.5 Geochemistry	40
4.6 Hydrogeological setting	41
4.7 Water receptors	45
5 Conceptual model	52
5.1 Existing conditions	52
5.2 Conditions during mining	55
5.3 Post mining conditions	56
6 Assessment approach	59
6.1 Introduction	59
6.2 Avoidance and mitigation measures	59
6.3 Assessment criteria	60
6.4 Assessment methods	67

6.5	Cumulative impacts	67
6.6	Peer review	68
7	Surface water impact assessment	69
7.1	Introduction	69
7.2	WMS performance	69
7.3	Streamflow impacts	69
7.4	Surface water quality	70
7.5	Flooding assessment	70
8	Groundwater impact assessment	73
8.1	Introduction	73
8.2	Watertable drawdown	73
8.3	Saturated thickness changes	79
8.4	Groundwater inflows	81
8.5	Groundwater quality	81
9	Potential impacts on water dependent ecosystems	83
9.1	Groundwater dependent vegetation	83
9.2	Aquifer ecological communities	83
9.3	Aquatic ecology	84
10	Final void assessment	85
10.1	Introduction	85
10.2	Final pit lake recovery	85
10.3	Post closure groundwater levels and flow direction	87
10.4	Potential impacts on water-dependent assets	91
10.5	Water quality	93
10.6	Climate change	94
11	Water licensing	96
11.1	NSW water legislation and policies for licensing water take	96
11.2	Approach to licensing	97
11.3	Water licensing strategy	100
12	Risk assessment	108
12.1	Risk assessment and management framework	108
12.2	Risk evaluation	109
13	Monitoring, mitigation and management	113
13.1	Water management strategy	113
13.2	Mine material management	113
13.3	Erosion and sediment control measures	113
13.4	Monitoring program	114

13.5	River red gum health monitoring and management	118
13.6	Management plans	118
13.7	Groundwater model validation	119
13.8	Residual risk assessment	120
14	Conclusions	121
14.1	Surface water impacts	121
14.2	Groundwater impacts	122
14.3	Final void	122
14.4	Water licensing	125
	References	126

Appendices

Appendix A	Groundwater Impact Assessment	A.1
Appendix B	Surface Water Impact Assessment	B.1
Appendix C	Geochemistry Assessment	C.1
Appendix D	Regulatory overview	D.1
Appendix E	Supporting assessment requirements	E.1
Appendix F	Peer review reports	F.1

Tables

Table 1.1	Study areas for each technical assessment	8
Table 2.1	HVO WMS water classification	11
Table 3.1	Relevant legislation and regulations	22
Table 3.2	Summary of Hunter Regulated River WSP water requirements and entitlements	25
Table 3.3	Summary of entitlements held by HVO in the Hunter Regulated River Water Source	26
Table 3.4	Summary of Hunter Unregulated and Alluvial WSP water requirements and entitlements	27
Table 3.5	Summary of entitlements held by HVO in the Hunter Unregulated and Alluvial Water Sources	28
Table 3.6	Sydney Basin North Coast Groundwater Source water entitlement summary	29
Table 3.7	Relevant guidelines	29
Table 4.1	Data sources	31
Table 4.2	Summary of main geological units in the Project area	38
Table 6.1	Water affecting activities, potential effects, impacts on receptors, and assessment methods	61
Table 6.2	Minimal impact considerations for 'highly productive' alluvial aquifer	64
Table 6.3	Minimal impact considerations for 'less productive' porous rock water source	65
Table 6.4	Surface water assessment criteria	67

Table 7.1	Estimated change in water quality concentrations due to HRSTS discharge following mixing (Engeny 2022)	70
Table 8.1	Predictive uncertainty analysis results discussion terminology	78
Table 10.1	Comparison of approved and proposed (indicative) final void catchment areas	85
Table 11.1	Summary of HVO water licensing requirements by water source and method used to estimate take	98
Table 11.2	Project WMS – storages on non-minor streams	101
Table 12.1	Glencore risk assessment matrix	108
Table 12.2	Classification of likelihood	108
Table 12.3	Classification of consequence	109
Table 12.4	Assessment of unmitigated potential impacts or events	110
Table 13.1	Assessment of residual risk of potential impacts or events	120

Figures

Figure 1.1	Locality plan	2
Figure 1.2	Local context	3
Figure 1.3	Proposed conceptual layout	5
Figure 1.4	Assessment approach and inter-relationships of the water studies	7
Figure 1.5	Water study area	10
Figure 2.1	Key existing water management aspects	14
Figure 2.2	Key Project water management aspects	18
Figure 2.3	Final landform	21
Figure 3.1	Water sharing plans and water source areas	24
Figure 4.1	Mean monthly rainfall and evaporation (SILO data)	32
Figure 4.2	Surface water context	34
Figure 4.3	Environmental and community values (adapted from ANZG 2018)	36
Figure 4.4	Geological setting	39
Figure 4.5	Groundwater monitoring network	43
Figure 4.6	GW271031 hydrograph	44
Figure 4.7	Water receptors	46
Figure 4.8	Receptor conceptual diagram - Hunter River and River Red Gums	49
Figure 4.9	Warkworth Sands monitoring bore hydrograph	50
Figure 4.10	Receptor conceptual diagram – Warkworth Sands and Wollombi Brook	51
Figure 5.1	Conceptual model	54
Figure 5.2	Ephemeral creek generic conceptual diagram	55
Figure 5.3	Carrington West Wing mining area and western paleochannel conceptual diagram	58
Figure 6.1	AIP minimal impact considerations process (adapted from DPI Water 2012a)	66
Figure 8.1	Hunter River alluvium – maximum incremental drawdown during operations	74

Figure 8.2	Hunter River alluvium - maximum cumulative drawdown during operations	76
Figure 8.3	Wollombi Brook alluvium - maximum cumulative drawdown during operations	77
Figure 8.4	Cumulative Hunter River alluvial drawdown – likelihood of 2 m drawdown extent (AGE 2022)	79
Figure 8.5	Predicted aquifer alluvial saturation – 2020 to 2050	80
Figure 10.1	HVO North pit lake recovery and salinity (Engeny 2022)	86
Figure 10.2	HVO South pit lake recovery and salinity (Engeny 2022)	87
Figure 10.3	Post mining watertable and particle tracking	88
Figure 10.4	Maximum cumulative alluvial drawdown post mining (AGE)	90
Figure 10.5	Final voids conceptual diagram	92
Figure 10.6	Groundwater model sensitivity – post mining watertable and groundwater flow direction (particle tracking)	95
Figure 11.1	Surface water take from Hunter Regulated River Water Source (high security)	100
Figure 11.2	Surface water take (median) from the Jerrys Water Source (Hunter Unregulated River) associated with the WMS	102
Figure 11.3	Surface water take (median) from the Singleton Water Source (Hunter Unregulated River) associated with the WMS	103
Figure 11.4	Groundwater take from the Hunter Regulated River Alluvial Water Source (downstream and upstream management zones)	104
Figure 11.5	Groundwater take from the alluvium associated with the Lower Wollombi Brook and Singleton Water Sources (Hunter Unregulated River)	105
Figure 11.6	Groundwater take from the Sydney Basin-North Coast Groundwater Source	106
Figure 13.1	Proposed additional groundwater monitoring – Carrington West Wing area	117
Figure 14.1	Overview of Project assessment against the AIP minimal impact considerations process	124
Figure D.1	Licensing requirements by source (surface water vs groundwater) (DPE Water 2022b)	D.5
Figure D.2	Groundwater dependent ecosystem level of dependence on groundwater	D.10

1 Introduction

1.1 Background

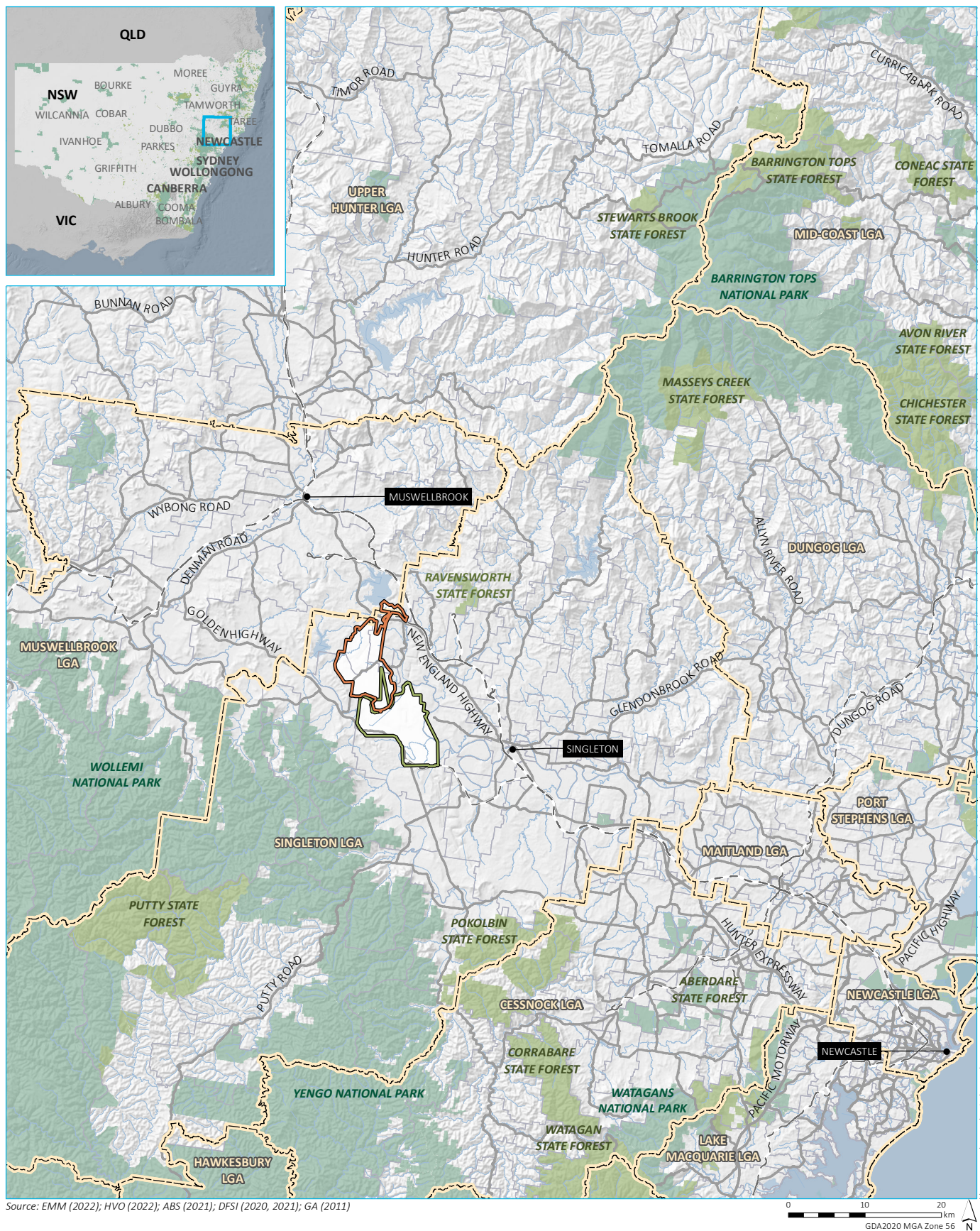
Hunter Valley Operations (HVO) is a multi-pit open cut mining complex approximately 24 kilometres (km) north-west of Singleton in the Hunter Valley of New South Wales (NSW) (Figure 1.1). HVO comprises two mine sites separated by the Hunter River, HVO North and HVO South. While the two mine sites are approved under separate development consents, they are operated as one complex with fully integrated environmental management systems.

The existing HVO North operation comprises the approved mining areas of West Pit, Mitchell Pit and Carrington Pit, as shown in Figure 1.2. It operates under development consent DA 450-10-2003 which allows extraction of up to 22 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal until 12 June 2025.

HVO South operates under Project Approval (PA) 06_0261 and comprises the approved mining areas of Riverview Pit and Cheshunt Pit, where mining activities currently take place, and the Riverview South East Extension and South Lemington Pits 1 and 2. PA 06_0261 allows the extraction of up to 20 Mtpa of ROM coal until 24 March 2030.

Mining across HVO is undertaken using dragline and truck and shovel methods. ROM coal from HVO North and South is currently processed at the Hunter Valley (HV) Coal Preparation Plant (CPP) and/or the Howick CPP (both at HVO North), from which product coal is predominantly transported via overland conveyor to the HV load point (HVLN) or Newdell LP and via rail to the Port of Newcastle for export. The Lemington CPP (LCPP) and associated rail loop, which is approved under PA 06_0261 and would process and rail coal from HVO South, is yet to be constructed.

HVO is owned by subsidiary companies of Yancoal and Glencore, as participants in the unincorporated HVO Joint Venture (JV). HV Operations Pty Ltd is the appointed manager of the JV.

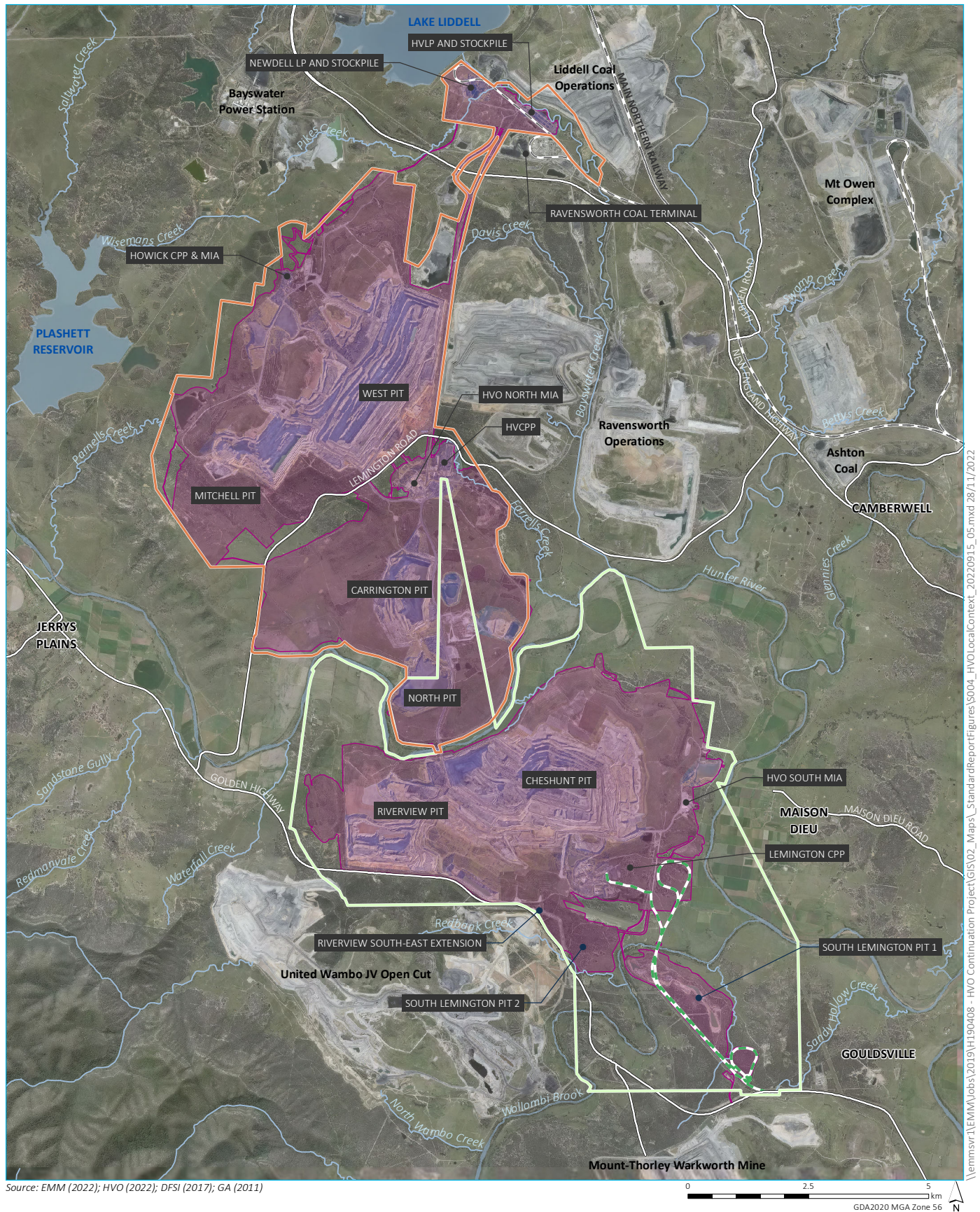


KEY

- Existing HVO North development consent boundary (DA 450-10-2003)
- Existing HVO South project approval boundary (PA 06_0261)
- Rail line
- Major road
- Named watercourse
- Named waterbody
- Suburb boundary
- Local government area
- NPWS reserve
- State forest

Locality plan

HVO Continuation Project
Water Assessment
Figure 1.1



KEY

- Existing HVO North development consent boundary (DA 450-10-2003)
- Existing HVO South project approval boundary (PA 06_0261)
- Existing and approved disturbance area
- South Lemington Rail Loop and haul route (approved, not yet constructed)

- Existing environment
- Rail line
- Major road
- Named watercourse
- Named waterbody

Local context

HVO Continuation Project
Water Assessment
Figure 1.2

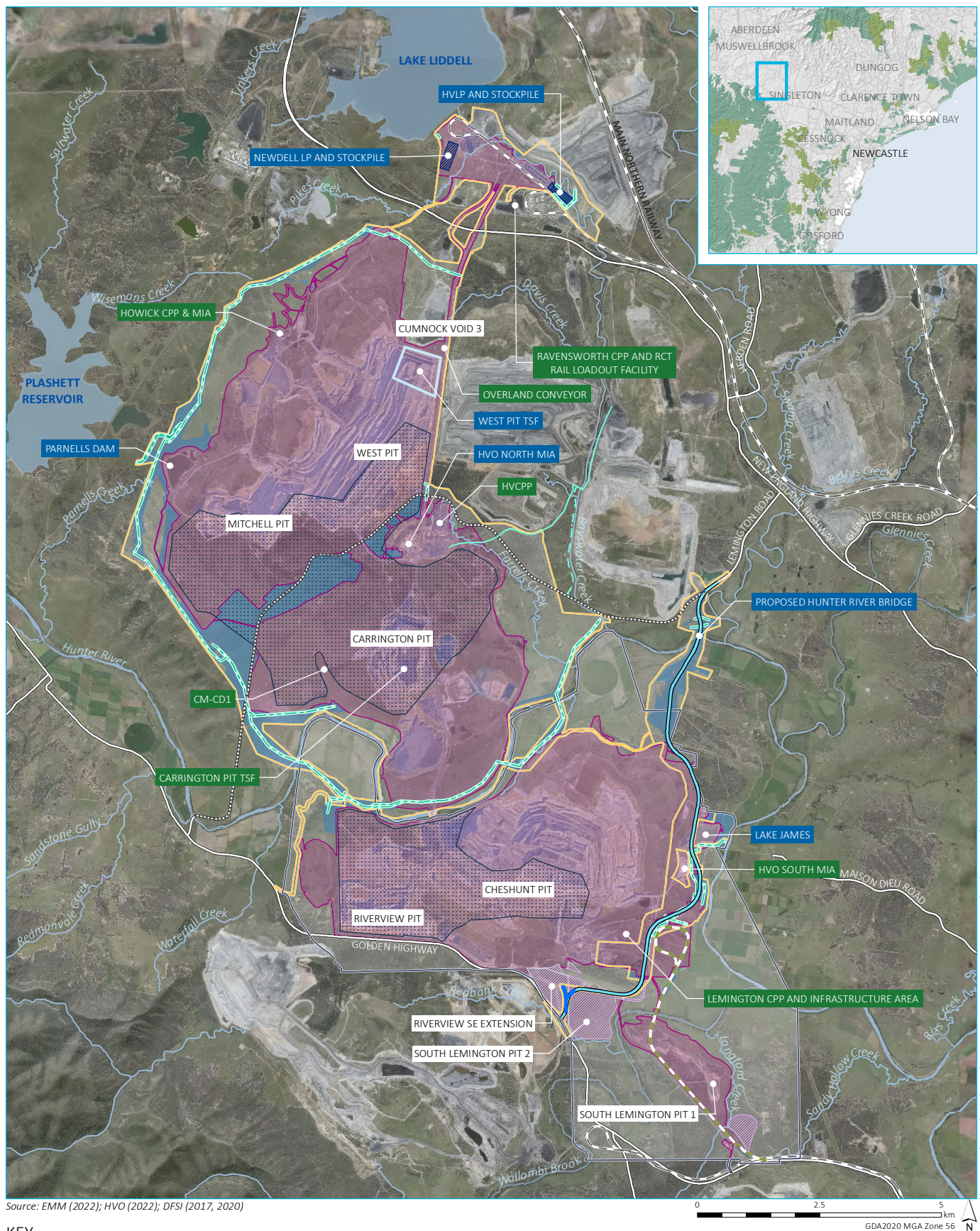
1.2 Project overview

The HVO Continuation Project (the Project) broadly comprises the continuation of the life of HVO North and HVO South, from the current approved mining completion dates of 2025 and 2030 respectively, to the end of 2050 at HVO North and 2045 at HVO South. The continuation of mining across the HVO Complex will increase resource recovery from the existing operation, predominantly by mining through previously mined areas and to the extent of existing mining tenements and extracting coal from deeper seams at HVO North.

At HVO South an extension to the life of the mine is proposed to facilitate improved mine sequencing outcomes and reduction in mining rate. The Project proposes a reduced mining footprint at HVO South compared to what is approved for extraction, with the previously approved coal extraction in the Riverview South East Extension area and South Lemington Pits 1 and 2 proposed to be removed from mine plan (and future approvals) for the Project. However, some rehabilitation works will be required to be undertaken in the South Lemington Pit 1 area, as part of the mine closure process. The approved shorter rail loop option associated with the LCPP has also been removed from the Project.

A number of infrastructure upgrades and changes are also required to facilitate the Project (and are included as part of it), including realignment of part of Lemington Road, relocation of transmission and telecommunication lines, an upgrade of the Newdell LP including construction of a new product stockpile and train loading bin, an upgrade of the HVLP product stockpile including an extension to the existing coal stockpile, and improvements to Lake James and Parnells Dam.

The Project description is provided in Chapter 4 of the EIS (EMM 2022a). The proposed conceptual layout of the Project, inclusive of both HVO North and South, is provided in Figure 1.3.



KEY

- HVO North proposed development consent boundary
- HVO South proposed development consent boundary
- Existing and approved disturbance area
- Previously approved area not retained
- Existing HVO elements to be maintained
- South Lemington Rail Loop (approved, not yet constructed)

- Proposed HVO Continuation Project elements
- Lemington Road realignment
- Indicative location of public road closure
- Haul route to Ravensworth Operations
- Transmission line relocation
- Alternative Golden Highway intersection
- Proposed mining area
- Product stockpile
- Additional disturbance area
- West Pit TSF

- Existing environment
- Rail line
- Major road
- Ravensworth Operations access road
- Named watercourse
- Named waterbody
- NPWS reserve (refer to inset)
- State forest (refer to inset)

Proposed conceptual layout

HVO Continuation Project
Water Assessment
Figure 1.3

1.3 Project terminology

The following key terms are used throughout this assessment to describe the Project:

- HVO Complex – comprises both HVO North and HVO South operations.
- Project area – the area that is the subject of the two development applications, ie the proposed development consent boundary for HVO North and the proposed development consent boundary for HVO South.

1.4 Purpose of this report

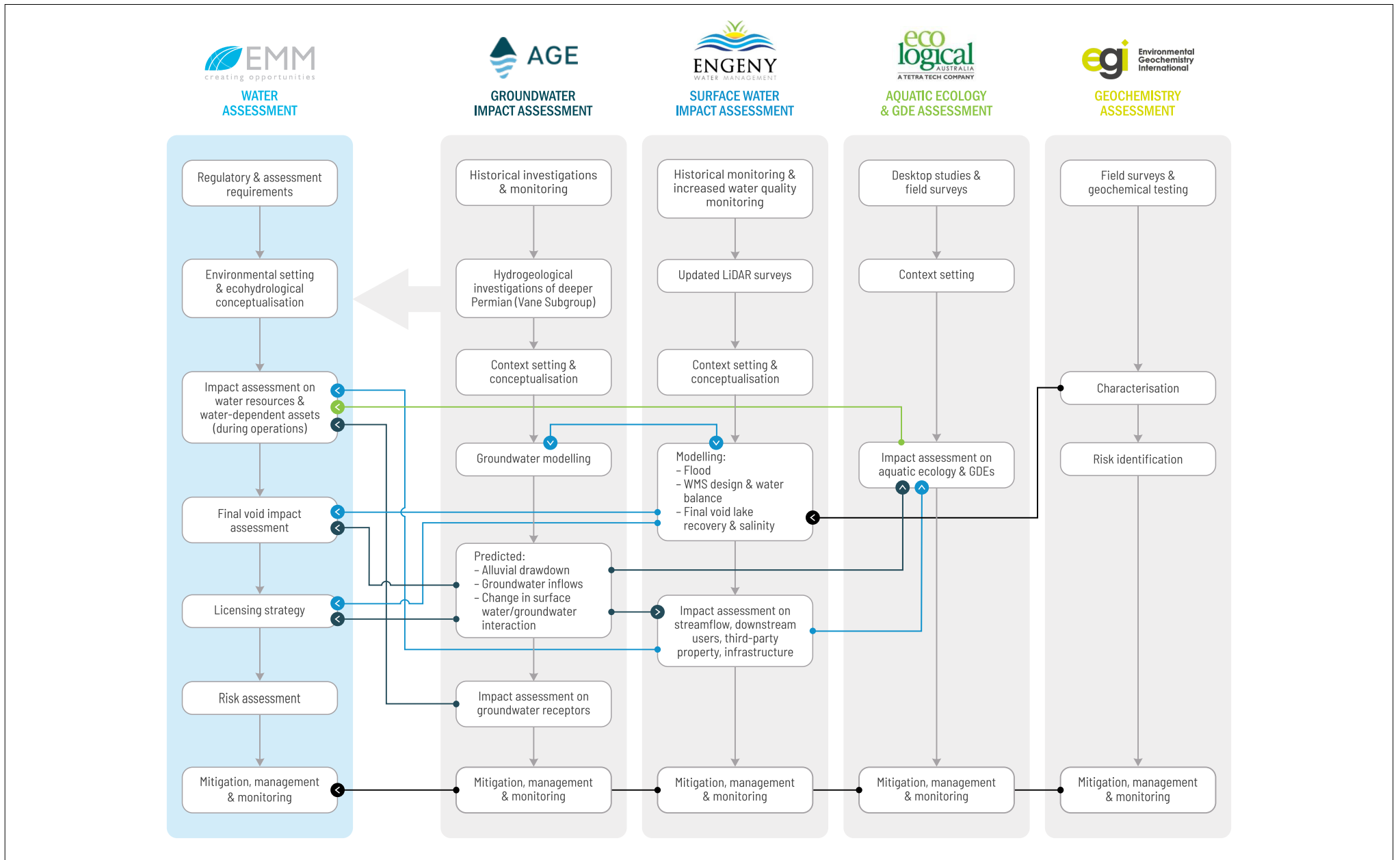
To enable the Project to proceed, two new State significant development (SSD) consents are required; one for HVO North and one for HVO South, under Part 4, Division 4.1 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). The Project will seek to maintain separate development consents for HVO North and South, as is currently the case. Given that the two mine sites operate as one complex, one Environmental Impact Statement (EIS) has been prepared to support the two development applications required for the Project.

This water assessment forms part of the EIS and provides an assessment of the potential impacts of the Project on water resources and water-dependent assets. It also assesses the potential incremental impacts of the continuation of HVO North and HVO South given separate development consents are being sought for each operation. The water assessment is an overarching report documenting and summarising the findings of the different water-related technical assessments conducted for the Project, including:

- the Groundwater Impact Assessment (GIA) prepared by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE 2022), attached in Appendix A of this report;
- the Surface Water Impact Assessment (SWIA) prepared by Engeny Water Management (Engeny 2022), attached in Appendix B of this report;
- the Aquatic Ecology and Groundwater Dependent Ecosystems (GDEs) Assessment prepared by Eco Logical Australia (ELA 2022), attached in Appendix L of the EIS; and
- the Geochemical Assessment prepared by Environmental Geochemistry International Pty Ltd (EGi 2022a), attached in Appendix C of this report.

The water assessment documents the methods and results of the assessments listed above, initiatives to avoid and minimise impacts and additional mitigation and management measures proposed to address residual impacts not able to be avoided.

Figure 1.4 illustrates the inter-relationships between the water-related studies and the role of this overarching water assessment.



Assessment approach and inter-relationships of the water studies

HVO Continuation Project

Water Assessment

Figure 1.4

1.5 Assessment requirements

The water related assessments have been prepared in accordance with requirements of the NSW Department of Planning and Environment (DPE). These were set out in the Secretary's Environmental Assessment Requirements (SEARs) for the Project, issued on 11 March 2021. Appendix B of the EIS lists the requirements and where they are addressed in the technical reports. Appendix A (GIA), Appendix B (SWIA) and Appendix M to the EIS (aquatic ecology and GDE assessment) also list the individual requirements relevant to the technical studies and where they are addressed in those reports.

1.6 Water study areas

Each technical assessment (as discussed in Section 1.4) focused on a particular area that was relevant to the subject matter. For example, the study area for the GIA is larger than that considered in the water balance. The Study area for each technical assessment is listed in Table 1.1. The combination of these study areas is the overall Study area for this water assessment report.

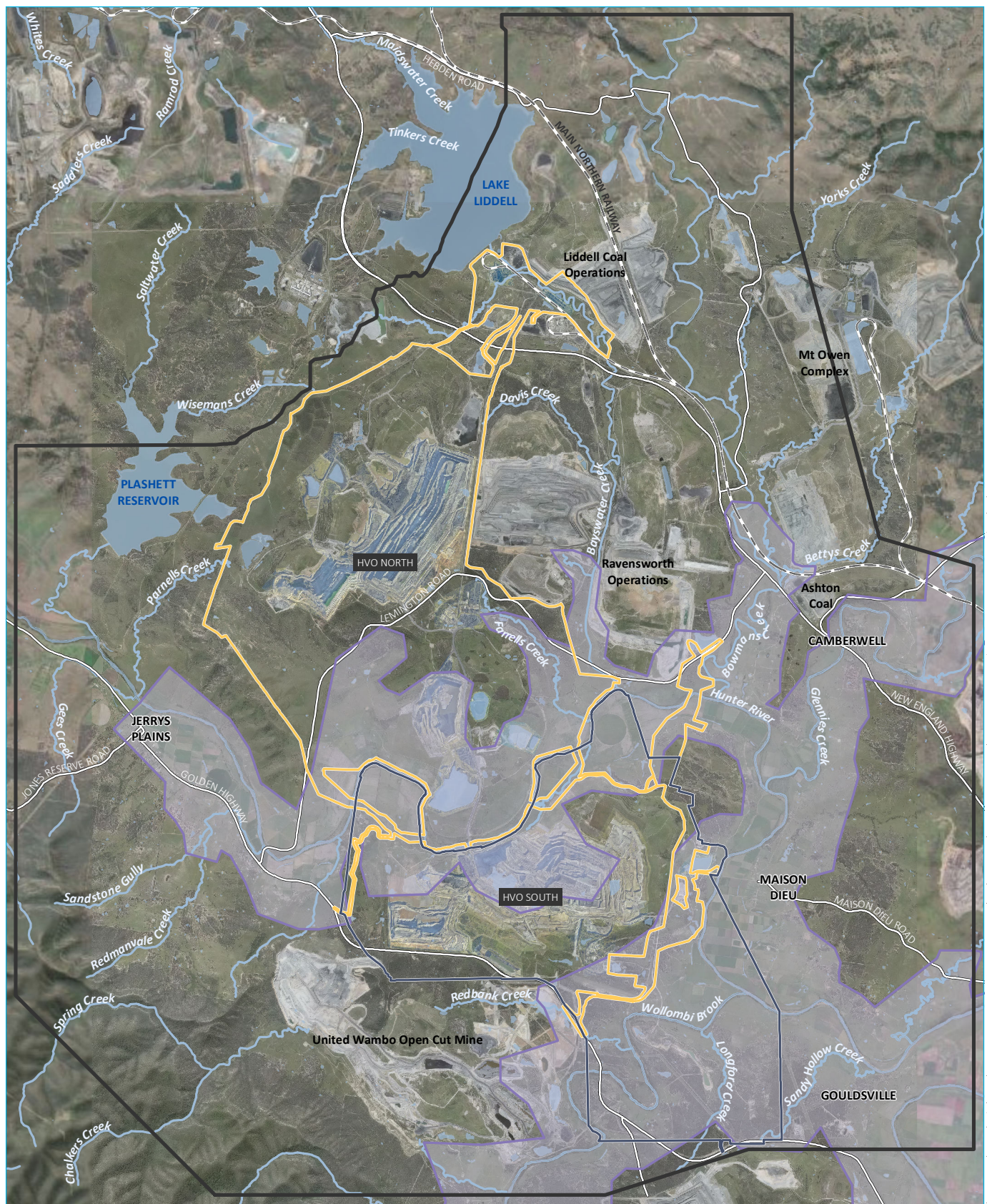
The proposed development consent boundaries and study areas are illustrated in Figure 1.5.

Table 1.1 Study areas for each technical assessment

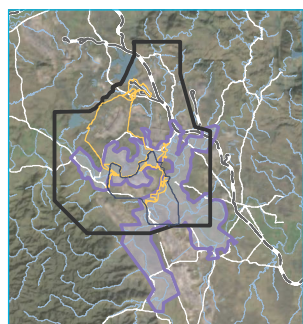
Technical assessment	Study area
Water management system and water balance model	HVO North and HVO South proposed development consent boundaries (Figure 1.5).
Streamflow impact assessment and water quality assessment	The Hunter River in the Project area and associated tributaries: • Parnells Creek; • Farrells Creek; • Pikes Creek; • Bayswater Creek; • Wollombi Brook; and • unnamed tributaries draining into Hunter River and Wollombi Brook in the Project area. Refer to Figure 1.5.
Flooding	Floodplain of the Hunter River and Wollombi Brook (Figure 1.5). Model downstream boundary: • approximately 3 km downstream of Singleton. Upstream boundaries: • Hunter River – approximately 2 km upstream of the Liddell gauge; • Bowmans Creek – at the confluence of Bowmans Creek and the Hunter River; • Glennies Creek – approximately 5 km upstream of the confluence with the Hunter River; and • Wollombi Brook – in the vicinity of the Warkworth Gauge, approximately 6.5 km upstream of the confluence with the Hunter River.
Groundwater model	Combination of the most recent groundwater models completed for the Glendell Continuation Project (AGE 2019) and HVO South Mod 5 (AGE 2017) (Figure 1.5)
Geochemistry characterisation	HVO North and HVO South proposed development consent boundaries (Figure 1.5)

Table 1.1 Study areas for each technical assessment

Technical assessment	Study area
Aquatic ecology and GDE assessment	Hunter River in the Study area including survey locations from approximately 6 km upstream of Parnells Creek confluence and downstream of the Wollombi Brook confluence (Figure 1.5). Surveys were also conducted at locations within the Study area; • Bayswater Creek upstream; • Farrells Creek; • Bowmans Creek, just upstream of the confluence with the Hunter River; and • Wollombi Brook near HVO South and Warkworth Bridge.



Source: EMM (2022); HVO (2022); DFSI (2017); GA (2011)



KEY

- HVO North proposed development consent boundary
- HVO South proposed development consent boundary
- Groundwater model extent
- Flood model boundary

- Existing environment
- Rail line
- Major road
- Named watercourse
- Waterbody

0 2.5 5 km
GDA2020 MGA Zone 56

Water study areas

HVO Continuation Project
Water Assessment
Figure 1.4

\\lemmsvr1\EMM\Jobs\2019\H190408 - HVO Continuation Project\GIS\02_Maps\WaterAssessment\WA002_WaterStudyAreas_20220928_02.mxd 28/11/2022

2 Project context

2.1 Existing water management

2.1.1 Water management system

The HVO Complex currently operates under an integrated water management system (WMS) across HVO North and South, in accordance with the approved water management plan (WMP). The integrated mine WMS also facilitates approved water transfers with other mining operations (Mount Thorley-Warkworth (MTW) via the South Lemington Pit 1 Void), Wambo, Liddell Coal Operations (LCO; via LPs), and Ravensworth Operations (via the Cumnock Void 3 tailings decant return)). Water to support operations is also sourced from the Hunter River under relevant water access licences (WALs).

Key water management components at the HVO Complex include water storages, licensed discharge points, Hunter River pumping stations, approved flood protection levees, and low permeability barrier walls at HVO North, which have been constructed in the eastern arm of the paleochannel in the Carrington Pit area and in the Alluvial Lands. The purpose of these barrier walls is to limit the groundwater drainage from the mined areas and potential for seepage from the backfilled areas towards the Hunter River. Construction of another barrier walls is also approved in the Carrington West Wing area in the western arm of the paleochannel; however, this barrier wall has not been constructed due to the Carrington West Wing pit not being mined to date. The diversion of an Unnamed Tributary (Unnamed Tributary 1) to the west of Carrington West Wing is also approved; however, similarly to the barrier wall, this has not yet been diverted due to mining operations not commencing in the Carrington West Wing.

The existing WMS for the HVO Complex consists of a network of infrastructure (dams, pipelines, contour banks) to control the movement of water around the HVO Complex. Water is shared between HVO South and HVO North via pipelines across the Hunter River bridge. HVO uses sufficient water storage capacity to provide minimise against drought and flood interruptions and prevent off site discharge except in accordance with the EPL.

Water is managed according to type whether it be mine water, sediment water or clean water (Table 2.1).

Table 2.1 HVO WMS water classification

Water category	Description
Clean	Runoff from undisturbed or rehabilitated areas.
Sediment	Runoff from disturbed areas (does not include water captured in mining pit areas or runoff from mine infrastructure areas where the water has been in contact with coal). Runoff draining away from pits where overburden stockpile areas have been shaped but without established ground cover.
Mine	Runoff from areas exposed to coal or water used in coal processing or from coal stockpile areas. Runoff draining into pits from the active/unshaped overburden that forms the low wall.

The WMS is designed to:

- minimise water abstraction from the Hunter River to meet water supply deficits (through existing entitlement);
- minimise impacts to the environment and neighbours;
- provide adequate water to facilitate the processing of coal and dust suppression to minimise interference with mining production, preferentially use of mine water for coal preparation and dust suppression;
- recycle on-site water; and
- control discharge of water to the environment in accordance with statutes and regulations.

Where possible, surface water is diverted away from disturbed areas at the HVO Complex via clean water diversions to minimise impact to the receiving environment.

The surface water monitoring program, under the WMP, includes monitoring surface water quality at a number of locations both upstream and downstream of the HVO Complex. The WMP monitors compliance with approval conditions and contains mechanisms for ensuring impacts to surface water resources are minimised.

Key existing water management components are identified in

Figure 2.1. Further discussion on the existing and proposed water management infrastructure for the Project is provided in Appendix B.

2.1.2 Tailings

Fine rejects (tailings) have been emplaced in various approved tailings storage facilities (TSFs) across the complex. Currently, tailings are emplaced within approved TSFs in Carrington Pit as well as Cumnock Void 3 (Dam 22W) under agreement with Ravensworth Operations to utilise the void capacity. Tailings from the Howick CPP are currently pumped via a pipeline to Cumnock Void 3, while tailings from the HVCPP are pumped via a pipeline to the Carrington Pit TSF.

Intermittent deposition of tailings occurs in the Dam 6W TSF and Central TSF (Dam 28N) as part of ongoing management towards decommissioning. The South East TSF (Dam 27N) is capped. Prior to TSFs reaching capacity a detailed closure plan is developed for the individual facility to determine effective closure requirements including capping depth.

Tailings areas are shown on

Figure 2.1.

2.1.3 Discharge of excess water

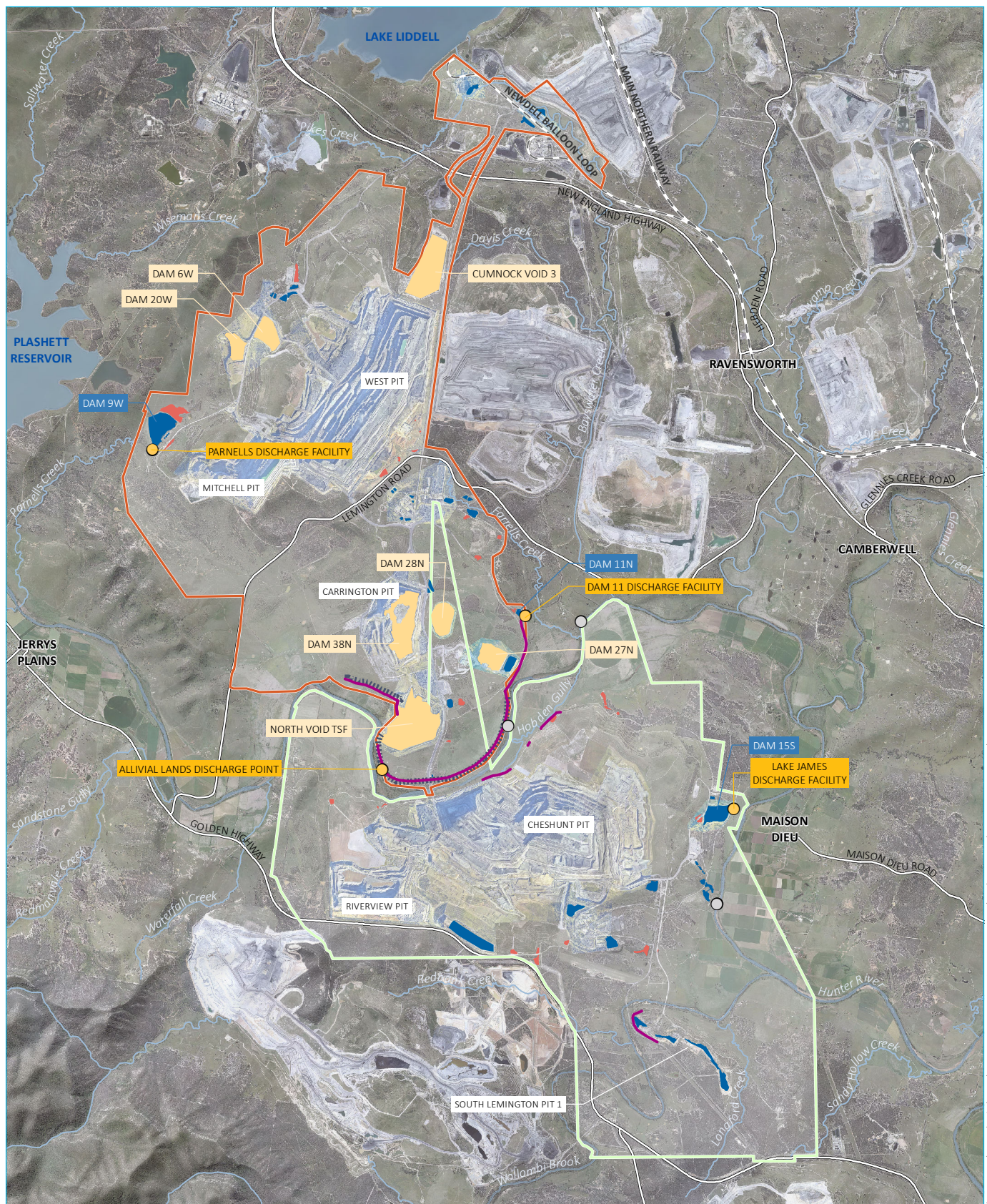
HVO holds approval to release water from the complex via licensed discharge points into the Hunter River under environment protection licence (EPL) 640 and the Hunter River Salinity Trading Scheme (HRSTS). Discharges are only allowed during high and flood flow periods in the Hunter River (refer to Appendix B for further detail).

EPL 640 also includes licensed discharge from the Alluvial Lands. This discharge point has specific discharge parameters and is not regulated under the HRSTS. Discharge parameters are in accordance with EPL 640.

2.1.4 Pollution reduction program

In 2019, following change in operation at HVO, Glencore conducted a review of water management infrastructure to identify improvements and works to bring the operation up to Glencore's operating standards. The outcome of the review identified a number of upgrades to water containment systems to bring it to a modern standard. The upgrades include increases to stormwater containment storage volumes, additional pipelines/transfer systems, monitoring systems, spillway upgrades and drainage improvements. The changes are scheduled to occur in priority order according to risk. The schedule covers a period from 2019 (works already completed) to 2024 and includes commitments from HVO in the order of \$60 million funding.

The upgrade projects have been incorporated into a pollution reduction program (PRP). Key infrastructure identified as part of the PRP relevant to the Project is proposed to be in place prior to the commencement of the Project.



Source: EMM (2022); HVO (2022); DFSI (2017)

KEY

- Existing HVO North development consent boundary (DA 450-10-2003)
- Existing HVO South project approval boundary (PA 06-0261)
- Levee
- Low permeability barrier wall

- Hunter River pump station
- HRSTS discharge facility
- Sediment dam
- Mine water storage
- Tailings dam

- Existing environment
- Rail line
- Major road
- Named watercourse
- Named waterbody

Key existing water management aspects

HVO Continuation Project
Water Assessment
Figure 2.1

2.2 Key water affecting activities of the Project

2.2.1 HVO North key elements

Key Project elements (that differ to the approved operations) with the potential to affect water resources and water-dependent assets at HVO North comprise:

- Extending the mine life from the current approval of June 2025 until the end of 2050, including extending mining from the Bayswater seam in the Carrington Pit area to the base of the Barrett seam, and increasing the mining extent in a small area between the existing West and Mitchell Pits to Carrington Pit.
- The proposed realignment and new Hunter River bridge crossing of Lemington Road as part of the Project will significantly improve the flood immunity of this road adjacent to the Hunter River, reducing road closures in flooding events. This is discussed further in Section 7.5.
- Tailings management will mostly remain as approved with emplacement within approved TSFs, including Dam 6W TSF and Carrington In-Pit TSF at HVO North, and the Cumnock Void TSF at Ravensworth Operations. Proposed operations also include additional tailings infrastructure, relocation and/or re-processing of tailings from existing TSFs, emplacement of tailings within the northern extent of West Pit and at LCO.
- Water management will mostly continue as approved, including continuation of the ability to transfer water to and from other mining operations where permitted. The proposed changes/upgrades are summarised as follows:
 - improved flood protection levee for North Pit (up to 0.1% Annual Exceedance Probability (AEP)) as per Glencore's operating standard;
 - additional mine/sediment water containment dams as required, as mining progresses;
 - clean water diversion as required, as mining progresses, including an extension of the Mitchell clean water diversion;
 - Parnells Dam enlargement from approximately 1 GL to 4 GL, new spillway, refurbishment of existing HRSTS discharge facility (no change to EPL/HRSTS approval);
 - improved flood protection for the Carrington West Wing levee (up to 0.1% AEP); and
 - installation of the approved barrier wall in the Carrington West Wing area, as described in Section 2.2.3ii.
- The proposed rehabilitation will be progressive, with the post mining land use to comprise a mixture of grazing and native habitat areas (as approved). The proposed changes to the approved rehabilitation comprise:
 - flood levees will be left in place, with the exception of the Carrington West Wing levee, which will be partially removed and incorporated into the final landform, and the Riverview Levee.
- Only one final void will remain at HVO North representing a reduction in the number of voids that will remain post mining compared to existing approved operations (ie from three to one).

2.2.2 HVO South key elements

Key Project elements (that differ to the approved operations) with the potential to affect water resources and associated water-dependent assets at HVO South comprise:

- Extending the mine life from the current approval of March 2030 until the end of 2045; however, the rate of mining will decrease from that currently approved.
- The disturbance area is proposed to be reduced compared to the approved operations due to the removal of the approved mining at South Lemington Pit 1 and 2, and the Riverview South East Extension area and the short rail loop option.
- Water management integrated with HVO North will continue as approved. The proposed changes/upgrades are summarised as follows:
 - construction of Cheshunt and Riverview flood protection levees; and
 - Lake James enlargement (from approximately 0.7 GL to 2 GL).
- The proposed rehabilitation will be progressive, with the natural landform designs supporting final land use objectives including agriculture and native habitat (as approved). Minor changes to the final landform design are proposed due to rescheduling and or infrastructure relocations.
- As approved, one final void will remain at HVO South. Some changes to the final void catchment and dimensions due to rescheduling are proposed.

2.2.3 Proposed water management

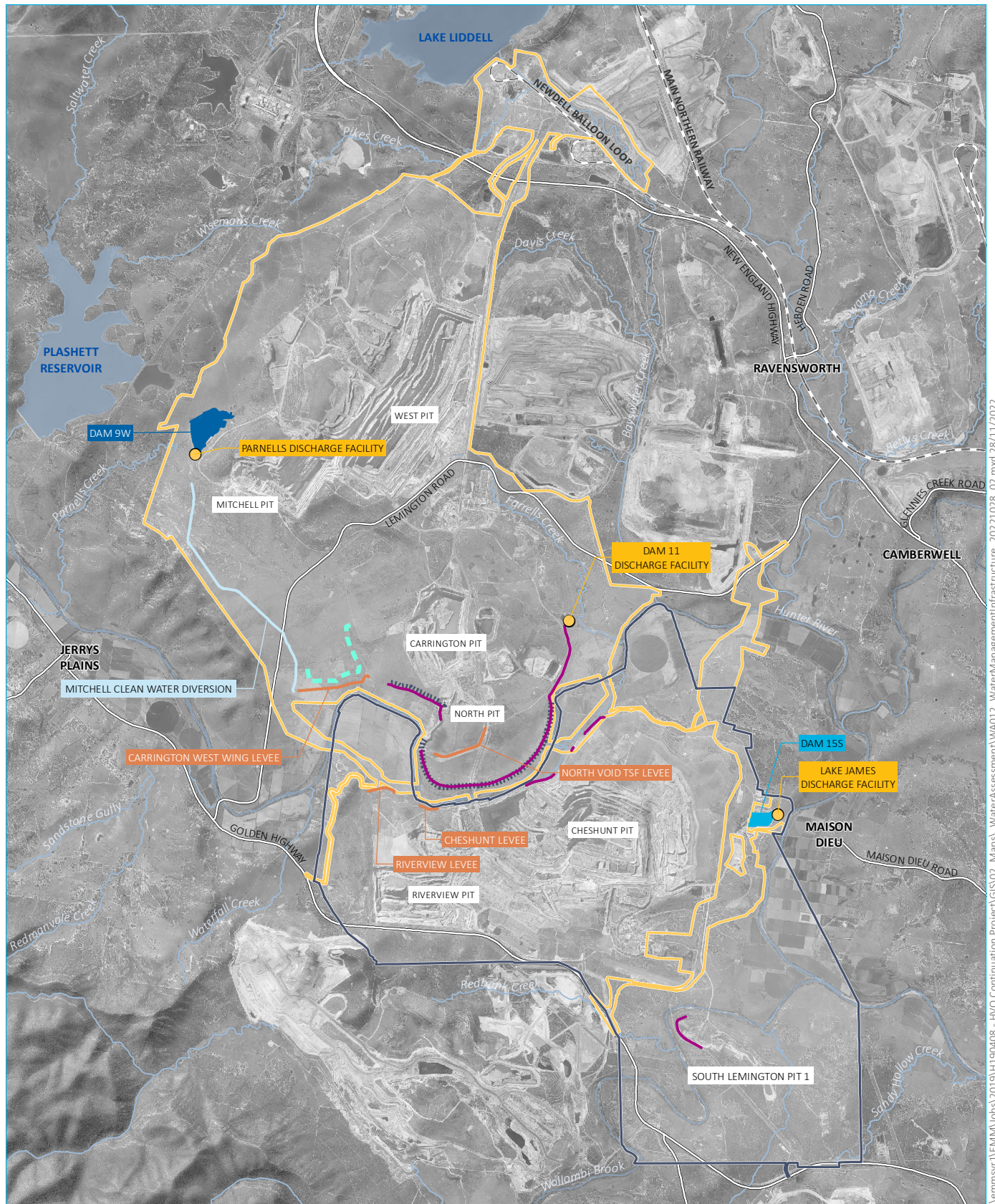
i Proposed WMS

The WMS for the Project is described in detail in the SWIA in Appendix B and a summary is provided here. The WMS for the Project will mostly remain similar to the existing WMS (described in Section 2.1.1) with some additional considerations, infrastructure and upgrades:

- The integrated nature of the WMS supports the WMP objectives (listed in Section 2.1.1). The Project will maintain the fully integrated WMS. As such, potential impacts are presented in the SWIA for the HVO Complex.
- In general, the Project will mine areas within existing approved disturbance boundaries, including mining previously disturbed areas. Consequently, the incremental impact of the Project on adjacent surface water systems is generally expected to be minor or negligible.
- The proposed WMS infrastructure for the Project also includes:
 - new storages to manage water in accordance with the WMP objectives, which will progressively change with the mine plan with time, the majority of which are required under the existing approval however the sequence and schedule has been adjusted for the Project;
 - new drains and flood protection levees; and
 - upgrades to existing water storages (including Parnells Dam and Lake James).
- No changes to existing approvals or licences for the discharge of mine water under the HRSTS are planned.

- Once mining at HVO South ceases, the HVO South void will be available for water storage.
- No changes to existing water sharing arrangements between HVO and LCO and/or MTW are proposed as part of the Project. The Project includes the construction of a pipeline to send tailings to LCO for deposition in the existing pit voids. The portion of recovered decant water attributable to HVO tailings would be returned to HVO for reuse. During wet periods, the decant water may be temporarily held at LCO to improve management of excess inventory at HVO.

Key aspects of the WMS changes for the Project are presented on Figure 2.2. Conceptual WMS stage plans and design criteria are presented in the SWIA (Appendix B). Water management schematics for the Project are also presented and discussed in the SWIA (Appendix B).



Source: EMM (2022); HVO (2022); DFSI (2017); GA (2011)

KEY

- HVO North proposed development consent boundary
- HVO South proposed development consent boundary
- HRSTS discharge facility
- Existing levee
- ▤▤▤▤ Existing low permeability barrier wall

Water management infrastructure upgrade

- Clean water diversion
- Levee
- ▤▤▤▤ Low permeability barrier wall
- Lake James capacity increase
- Parnells Dam capacity increase

Existing environment

- - - Rail line
- Major road
- Named watercourse
- Named waterbody

Key Project water management aspects

HVO Continuation Project
Water Assessment
Figure 2.2

ii Carrington West Wing barrier wall

As currently approved, a barrier wall is to be constructed in the western arm of the paleochannel in the Carrington West Wing area to limit groundwater migration from the Hunter River (and associated alluvium) into the HVO North mining areas and potential migration of water from the backfilled HVO North pit to the Hunter River alluvium.

The barrier wall location and timing for the revised Project mine plan were considered as part of the Project design, and a suitable alternative approach has been identified to meet the same objectives listed in the development consent. The proposed adjustment to the barrier wall location and timing has been discussed with DPE and DPE Water during consultation as part of the EIS.

The proposed approach will be consistent with the approved construction methodology of the existing Carrington Pit barrier wall (approved by the then NSW Department of Planning in 2008 and constructed in 2010):

- following mining in the Carrington West Wing area, emplacement of clayey material on the highwall benches that intercept the Hunter River alluvium prior to backfilling the pit with overburden and interburden waste material;
- the barrier wall will be keyed into the Permian, consistent with the approach of the Carrington Pit barrier wall;
- designed to meet the existing development consent specification of a permeability of 1×10^{-8} metres per second (m/sec), equivalent to 1×10^{-3} metres per day (m/day);
- the objectives of the barrier wall will remain unchanged:
 - limit groundwater inflow from the Hunter River alluvium into the mined area;
 - limit potential drawdown in the alluvium due to groundwater inflows into the mined area; and
 - limit the potential for seepage from the backfilled pit to the alluvium;
- the location of the proposed barrier differs slightly to the barrier presented in HVO North Mod 3 in 2010, as it will be constructed on the benches of the highwall that intercept alluvium, rather than excavating a trench across the inferred extent of the paleochannel alluvium.

The proposed approach has other benefits when compared to the barrier wall as per the current approval:

- by constructing the barrier wall on the highwall rather than excavating a trench closer to the Hunter River, the proposed location will result in reduced ground disturbance;
- by constructing the barrier wall after mining in the area and prior to backfill, the proposed timing will result in:
 - lower noise impacts associated with construction activities (such as noise from mining equipment) as the activity will be conducted below natural ground level, with the highwall acting as a sound barrier, limiting the potential for noise to travel beyond the mine area;
 - greater control of isolating the paleochannel alluvium, as the extent of the alluvium will be exposed in the highwall, ensuring that the clayey material is placed across the full extent; and
 - eliminating the potential for disturbance of the barrier wall during mining and associated risk of affecting the integrity of the barrier wall.

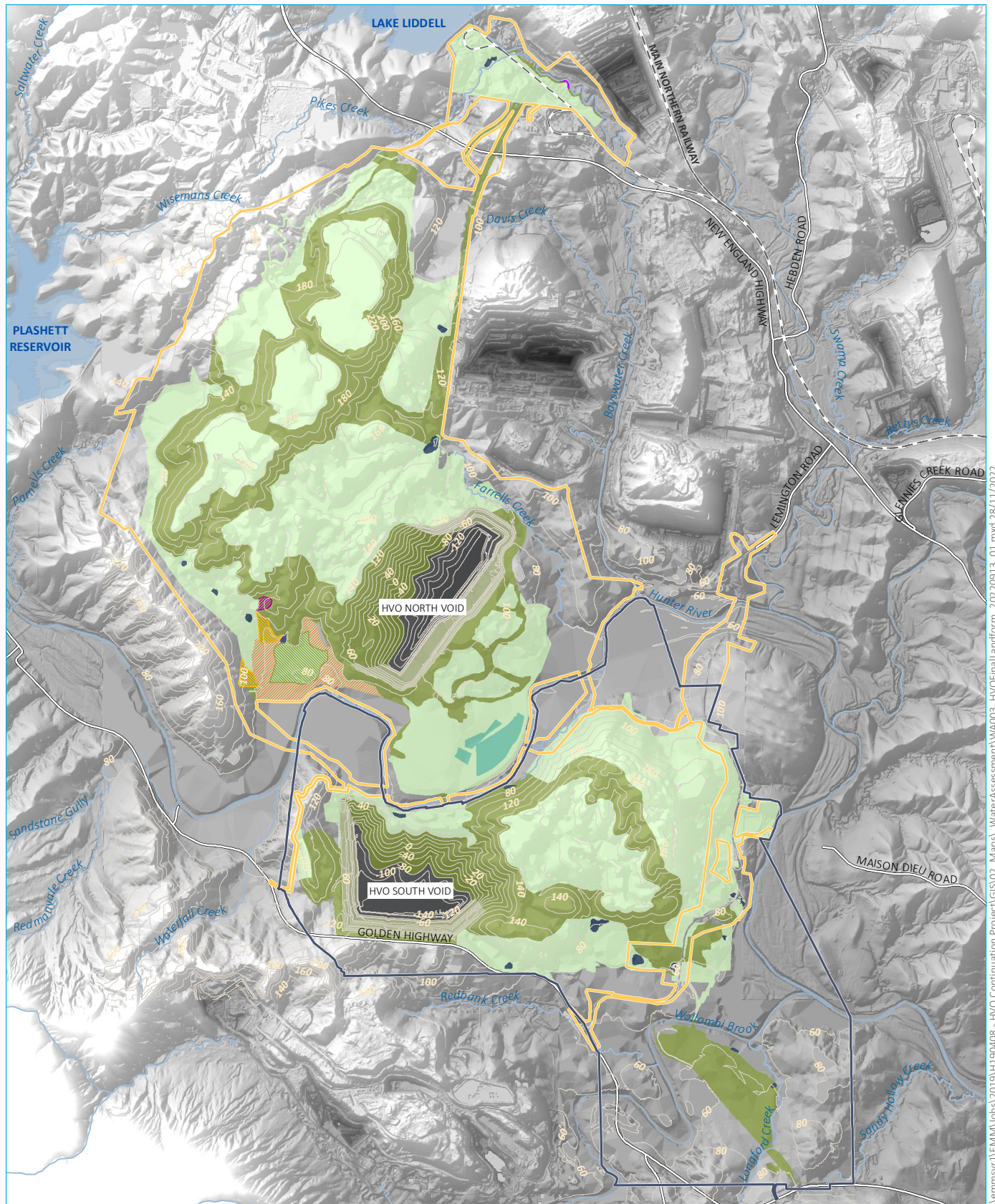
The proposed location of the Carrington West Wing barrier wall is shown on Figure 2.2.

2.2.4 Final voids

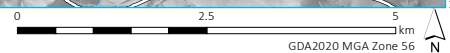
The Project has been designed to optimise resource recovery and operational efficiencies at the HVO Complex whilst avoiding and minimising environmental and social impacts; ultimately resulting in final voids. The proposed final voids and final landform is shown on Figure 2.3. Both final voids are predicted to be long-term sinks in which no water is expected to be released from the void to the receiving environment. A discussion on the predicted pit lake recovery is provided in Chapter 10 and Appendix B. The proposed final voids at HVO North and HVO South are briefly described below:

- **HVO North:** The approved final landform at HVO North includes three final voids, one in West Pit, one in Mitchell Pit and one in Carrington Pit. The Project will reduce the number of final voids that will remain post mining at HVO North, from the three approved to a single void within the Carrington area, as shown in Figure 2.3. This will result in a reduction of the total pit lake surface area at HVO North when compared to the currently approved operation.
- **HVO South:** Consistent with the current Project approval, one final void will remain at HVO South, in the south-western corner of Riverview Pit. The proposed final void dimensions will be smaller than currently approved due to mine sequencing refinement and infrastructure relocation.

In terms of use, the conceptual rehabilitation and closure strategy for the Project identifies the final voids as pit lakes; however, the voids have been designed so that other potential beneficial uses have not been precluded, as discussed further in Appendix T of the EIS.



Source: EMM (2022); HVO (2022); DFSI (2017); GA (2011)



KEY

- HVO North proposed development consent boundary
- HVO South proposed development consent boundary
- Predicted 20 m contour
- Existing environment
- Rail line
- Major road
- Named watercourse
- Named waterbody

- Final land use domain**
- Domain A | Native ecosystem
 - Domain A - Sub domain Ka | Other - Native ecosystem - partial vegetation on highwall benches
 - Domain B | Agriculture - grazing
 - Domain B - Sub domain Kb | Other - Agriculture - alluvial land
 - Domain G | Water storages
 - Domain J | Pit Lake

- Existing commitments maintained by the Project (indicative location)**
- Class 2 - DA 450-10-2003 MOD3
 - Class 3 - DA 450-10-2003 MOD3
 - Class 4 - DA 450-10-2003 MOD3
 - Central Hunter Box-Ironbark Woodland - DA 450-10-2003 MOD3
 - Swamp Oak Floodplain Forest - DA 450-10-2003 MOD5

Final landform

HVO Continuation Project
Water Assessment
Figure 2.3

3 Regulatory and policy context

An overview of the regulatory framework and guidelines relevant to the water assessments is provided in Sections 3.1 to 3.3. Further description and the requirements of the legislations, policies and guidelines are included in Appendix D.

3.1 Legislation overview

The primary water related statutes that apply to the Project are the *Water Act 1912* (Water Act), *Water Management Act 2000* (WM Act), *Protection of the Environment Operations Act 1997* (POEO Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The provisions of each Act are applied in accordance with their attendant regulation.

Table 3.1 lists the legislation relevant to the Project to assess potential impacts on water resources and water-dependent assets.

Table 3.1 Relevant legislation and regulations

Legislation	Authority	Relevant to
<i>Environmental Planning and Assessment Act 1979</i>	Department of Planning and Environment (DPE) – Planning and Assessment	All water assessments
<i>Water Management Act 2000</i>	DPE Water Natural Resources Access Regulator (NRAR)	All water assessments
<i>Water Management (General) Regulation 2018</i>	DPE Water	Water licensing and approvals
<i>Protection of Environment Operations Act 1997</i>	NSW Environment Protection Authority (EPA)	All water assessments
<i>Environment Protection and Biodiversity Conservation Act 1999</i>	Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW) Commonwealth Office of Water Science Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) – Section 505D	All water assessments
<i>Biodiversity Conservation Act 2016</i>	DPE Biodiversity, Conservation and Science Division	Aquatic and GDE assessment
<i>Fisheries Management Act 1994</i>	Department of Primary Industries	Aquatic and GDE assessment

3.2 Relevant NSW policies

3.2.1 Overview

The water assessments of the Project are required to consider the following policies and plans to characterise and assess potential impacts on water resources:

- relevant water sharing plans (WSPs);
- Aquifer Interference Policy (AIP; 2012);

- State Groundwater Dependent Ecosystems Policy (2002);
- Strategic Regional Land Use Policy (2012);
- Strategic Regional Land Use Plan – Upper Hunter (2012);
- Non-Urban Water Metering Policy (2020); and
- Flood Risk Management Manual (2022).

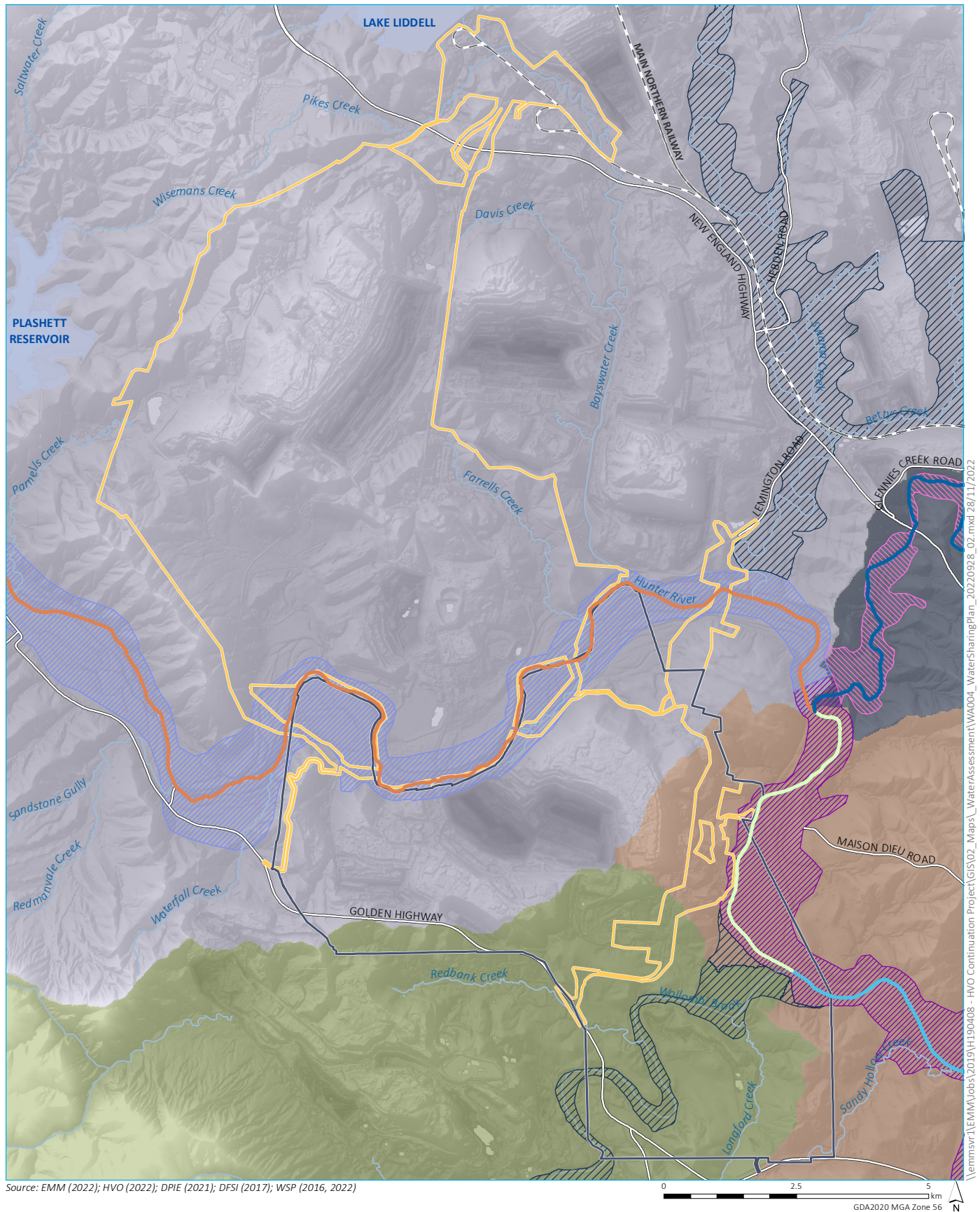
The relevant WSPs are key documents dictating the assessment of the potential impacts of the Project on water resources and are described in Sections 3.2.2. Other relevant policies and plans are further detailed in Appendix D.

3.2.2 Water sharing plans

WSPs are statutory documents dictating the management and sharing of water sources. The WSPs set the water management vision and objectives, management rules for WALs, what water is available within the various water sources, and procedures for dealing in licences and water allocations, water supply works approvals and the extraction of water. WSPs are designed to establish sustainable use and management of water resources and are periodically reviewed (every 10 years).

Each WSP documents the water available and how it is shared between environmental, extractive, and other uses. The WSPs outline the water availability for extractive uses within different categories, such as: local water utilities, domestic and stock, basic rights and WALs.

The Study area is within the catchments of the Hunter River and its tributaries. Three WSPs apply to the groundwater and surface water resources in the Study area and are described in subsequent sections. Figure 3.1 shows the WSP and water sources for the Hunter River, tributaries and alluvium.



KEY

- HVO North proposed development consent boundary
- HVO South proposed development consent boundary

Hunter Unregulated and Alluvial Water Sources 2022 WSP

Unregulated River Water Sources

- Glennies Water Source
- Jerrys Water Source
- Lower Wollombi Brook Water Source
- Singleton Water Source

Hunter Regulated River Alluvial Water Source Management Zone

- Downstream Glennies Creek

- Glennies Creek
- Upstream Glennies Creek
- Other alluvium

Hunter Regulated River 2016 WSP

- Management Zone 1B (Hunter River from Goulburn River Junction to Glennies Creek Junction)
- Management Zone 2A (Hunter River from Glennies Creek Junction to Wollombi Brook Junction)
- Management Zone 2B (Hunter River from Wollombi Brook Junction to downstream extent of the Hunter River)
- Management Zone 3A (Glennies Creek)

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody

Water sharing plan and water source areas

HVO Continuation Project
Water Assessment
Figure 3.1

The *WSP for the Hunter Regulated River Water Source 2016* (Hunter Regulated River WSP) covers the surface flows and highly connected alluvial aquifers within 40 m of the river banks of the Hunter River and Glennies Creek. The Hunter River is a regulated river, which are gazetted streams that have flows controlled by state-owned water storages. The Hunter River is regulated by releases from Glenbawn Dam upstream of HVO and Glennies Creek Dam further downstream. These storages are operated by WaterNSW to supply bulk, raw water for irrigation, towns and stock and domestic needs as far downstream as Maitland.

The long-term average annual extraction limit for the Hunter Regulated River is 217,000 ML/year.

The Hunter Regulated Water Source is divided into management zones, defined from the confluence of Glennies Creek with the Hunter River. The Project area encompasses multiple management zones:

- Zone 1B: Hunter River from Goulburn River junction to Glennies Creek junction;
- Zone 2A: Hunter River from Glennies Creek junction to Wollombi Brook junction; and
- Zone 2B: Hunter River from Wollombi Brook junction to Oakhampton rail bridge.

Table 3.2 presents a summary of the total entitlement shares in the Hunter Regulated River zones relevant to the Project area. Table 3.3 summarises the entitlements held by HVO in the various entitlement categories in the Hunter Regulated River Water Source.

Table 3.2 Summary of Hunter Regulated River WSP water requirements and entitlements

Entitlement category	Zone 1A (from Glenbawn Dam to Goulburn River Junction)	Zone 1B (from Goulburn River junction to Glennies Creek junction)	Zone 2A (from Glennies Creek junction to Wollombi Brook junction)	Zone 2B (from Wollombi Brook junction to Oakhampton rail bridge)	Zone 3A (Glennies Creek)
Basic landholder rights (from WSP¹)					
Domestic and stock (ML/year)	1,628	964	141	2,234	548
Water access licences (from WSP¹)					
Domestic and stock (ML/year)	672	101	27	855	181
Major utility (ML/year)	0	36,000	0	0	0
Local water utility (ML/year)	5,800	32	0	0	5,000
Regulated river (High security) (unit shares)	5,182	5,128	2,809	6,971	1,650
Regulated river (General security) (unit shares)	46,925	29,475	3,053	43,298	5,793
Supplementary (unit shares)	4,441	40,166	505	3,289	117

Table 3.2 Summary of Hunter Regulated River WSP water requirements and entitlements

Entitlement category	Zone 1A (from Glenbawn Dam to Goulburn River Junction)	Zone 1B (from Goulburn River junction to Glennies Creek junction)	Zone 2A (from Glennies Creek junction to Wollombi Brook junction)	Zone 2B (from Wollombi Brook junction to Oakhampton rail bridge)	Zone 3A (Glennies Creek)
Water access licences (from NSW Water Register²)					
Domestic and stock (ML/year)	1,820				
Major utility (ML/year)	36,000				
Local water utility (ML/year)	10,832				
Regulated river (High security) (unit shares)	21,740				
Regulated river (General security) (unit shares)	128,642				
Supplementary (unit shares)	48,519.22				

Notes: 1. Sourced from the Hunter Regulated River WSP.

2. Total share components were obtained from NSW water register (WaterNSW) for financial year 2021/22.

Table 3.3 Summary of entitlements held by HVO in the Hunter Regulated River Water Source

Entitlement category	Zone 1A (from Glenbawn Dam to Goulburn River Junction)	Zone 1B (from Goulburn River junction to Glennies Creek junction)	Zone 2A (from Glennies Creek junction to Wollombi Brook junction)	Zone 2B (from Wollombi Brook junction to Oakhampton rail bridge)	Zone 3A Glennies Creek
Domestic and stock (ML/year)	0	8	0	16	0
Regulated river (High security) (unit shares)	0	3,183	1,506	0	0
Regulated river (General security) (unit shares)	0	5,244	1,393	613	0
Supplementary (unit shares)	0	98	302	128	0

ii Hunter Unregulated and Alluvial Water Sources 2022

The *WSP for the Hunter Unregulated and Alluvial Water Sources 2022* (Hunter Unregulated and Alluvial WSP) applies to watercourses and alluvial groundwater in the vicinity of the HVO Complex, with the exception of the Hunter River. It also applies to the Hunter River alluvial groundwater at a distance greater than 40 m from the river banks.

The Hunter unregulated river has the following water sources of relevance to the Project area (refer Figure 3.1):

- Jerrys Water Source;
- Lower Wollombi Brook Water Source;
- Singleton Water Source; and
- Glennies Water Source.

The alluvial groundwater source (Hunter Regulated River Alluvial Water Source) has the following management zones of relevance to the Project area (refer Figure 3.1):

- Upstream Glennies Management Zone (MZ);
- Glennies MZ; and
- Downstream Glennies MZ.

Table 3.4 presents a summary of the total entitlement shares in the water sources of relevance to the Project area. Table 3.5 summarises the entitlements held by HVO in the various entitlement categories in the Hunter Unregulated River and Alluvial Water Sources.

Table 3.4 Summary of Hunter Unregulated and Alluvial WSP water requirements and entitlements

Entitlement category	Hunter Regulated River Alluvial Water Source			Jerrys Water Source	Lower Wollombi Brook Water Source	Singleton Water Source	Glennies Water Source
	D/S Glennies Creek MZ	Glennies Creek MZ	U/S Glennies Creek MZ				
Basic landholder rights (from WSP ¹)							
Domestic and stock (ML/year)	116			459	306	344	565
Harvestable rights (ML/year)	N/A			4,869	2,913	2,947	3,743
Water access licences (from WSP ¹)							
Domestic and stock (ML/year)	0	0	0	10	53	13	0
Major utility (ML/year)	0	0	0	7,700	0	0	0
Local water utility (ML/year)	4,095	0	843	0	0	0	0
Unregulated river (unit shares)	N/A			2,097 (2,044 in the Jerrys MZ)	6,625.2	1,170	446
Aquifer (unit shares)	7,130	10	15,960	1,241	3,745	230	10

Table 3.4 Summary of Hunter Unregulated and Alluvial WSP water requirements and entitlements

Entitlement category	Hunter Regulated River Alluvial Water Source			Jerrys Water Source	Lower Wollombi Brook Water Source	Singleton Water Source	Glennies Water Source
	D/S Glennies Creek MZ	Glennies Creek MZ	U/S Glennies Creek MZ				
Water access licences (from NSW Water Register ²)							
Domestic and stock (ML/year)	0			10	53	13	0
Major utility (ML/year)	0			7,700	0	0	0
Local water utility (ML/year)	4,938			0	0	0	0
Unregulated river (unit shares)	N/A			2,097	6,663	1,170	446
Aquifer (unit shares)	24,118			1,246	3,745	230	10

Notes: 1. Sourced from the Hunter Unregulated and Alluvial WSP.
2. Total share components were obtained from NSW water register (WaterNSW) for financial year 2021/22.

Table 3.5 Summary of entitlements held by HVO in the Hunter Unregulated and Alluvial Water Sources

Entitlement category	Hunter Regulated River Alluvial Water Source			Jerrys Water Source (Jerrys MZ)	Lower Wollombi Brook Water Source	Singleton Water Source	Glennies Water Source
	D/S Glennies Creek MZ	Glennies Creek MZ	U/S Glennies Creek MZ				
Unregulated river (unit shares)	N/A			705	88	0	0
Aquifer (unit shares)	289	0	448	120	144	225	0

iii North Coast Fractured and Porous Rock Groundwater Sources 2016

The *WSP for the North Coast Fractured and Porous Rock Groundwater Sources 2016* (North Coast WSP) applies to hard rock aquifers (porous or fractured). The water source of relevance to the Project area is the Sydney Basin-North Coast Groundwater Source. The LTAAEL for this water source is 90,000 ML/year.

Table 3.6 presents a summary of the total entitlement shares in the Sydney Basin-North Coast Groundwater Source and entitlements held by HVO.

Table 3.6 Sydney Basin North Coast Groundwater Source water entitlement summary

Entitlement category	Total shares held in the water source	Share component held by HVO
Basic landholder rights ¹		
Domestic and stock (ML/year)	5,087	
Water access licences ²		
Domestic and stock (ML/year)	0	0
Local water utility (ML/year)	1,300	0
Aquifer (unit shares)	67,484.5	5,560

Notes: 1. Sourced from the North Coast WSP

2. Total share components were obtained from NSW water register (WaterNSW) for financial year 2021/22

3.3 Relevant guidelines

The guidelines used in the technical water assessments are presented in Table 3.7.

Table 3.7 Relevant guidelines

Guidelines	Developed by	Relevant to
Information guidelines for proponents preparing coal seam gas and large coal mining development proposals.	Commonwealth of Australia 2018	All water assessments
Significant Impact Guidelines 1.3: Coal Seam Gas and Large Coal Mining Development – Impacts on Water Resources.	DoE 2013	All water assessments
Guidelines for the preparation and review of groundwater assessments for major projects in NSW: - Guidelines for Groundwater Documentation for SSD/SSI projects (DPE Water 2022b); - Minimum Requirements for Groundwater Modelling (DPE Water 2022c); - Cumulative Groundwater Impact Assessment Approaches (DPE Water 2022d); and - Groundwater Assessment Toolbox.	DPE Water 2022	GIA
Australian Groundwater Modelling Guidelines	National Water Commission (Barnett et al. 2012)	GIA
Uncertainty analysis – Guidance for groundwater modelling within a risk management framework (IESC explanatory note)	Middlemis and Peeters (2018)	GIA
Characterisation and modelling of geological faults (IESC explanatory note)	Murray and Power (2021)	GIA
Australian and New Zealand Guidelines for Fresh and Marine Water Quality	ANZG 2018	All water assessments
Information guidelines for assessing groundwater dependent ecosystems	IESC (Doody et al. 2019)	Water assessment (this report) Aquatic ecology and GDE assessment

Table 3.7 **Relevant guidelines**

Guidelines	Developed by	Relevant to
Risk Assessment guidelines for groundwater dependent ecosystems	NSW DPI Office of Water (Serov et al. 2012)	Water assessment (this report) Aquatic ecology and GDE assessment
Water and river flow objectives	DECCW 2006	SWIA
Australian Rainfall and Runoff (ARR 2019)– a Guide to Estimation	Commonwealth of Australia, Geoscience Australia (Ball et al. 2019)	SWIA

4 Description of the environment

4.1 Data availability

There is a significant history of mining within and surrounding the HVO Complex where numerous investigations and studies have been conducted since the 1950s. There is therefore a low level of residual uncertainty compared to less developed areas and the Project's environmental setting and conceptual model are considered robust.

Table 4.1 describes the main sources and previous studies used to describe the environmental setting and inform the conceptual model.

Table 4.1 Data sources

Setting	Public data	Site-specific data and studies
Land use	DPIE's eSPADE information system	HVO Continuation Mine Closure and Rehabilitation Strategy (EMM 2022b)
Topography	Digital Elevation Model (DEM) LiDAR data (5 m grid)	Airborne LiDAR survey
Climate	- Bureau of Meteorology (BoM)'s climate stations 061191 & 061086 - Scientific Information for Land Owners (SILO) Australian climate gridded data	- HVO's climate stations (2014 – now) - Cheshunt Weather Station - Corp Weather Station
Soil, geology (including geological structures)	- DPIE's eSPADE information system - Bioregional assessment (McVicar et al. 2015) - Hunter coalfield 1:100,000 geology map	- PFS study report (GCAA 2019) - Exploration drilling across HVO, United Operations, Ravensworth Operations - HVO geological models and geotechnical assessments
Surface water	- WaterNSW's real time database - Bioregional assessment (McVicar et al 2015)	Site specific monitoring network
Groundwater	- Bioregional assessment (McVicar et al 2015) - WaterNSW's real time database	- Carrington West Wing Extension for HVO North (MER 2010) - HVO South Modification 5 (AGE 2017) - Site specific monitoring network
GDEs	- BoM's National Atlas of Groundwater Dependent Ecosystems (the GDE Atlas) - NSW Fisheries Spatial Portal and BioNET - Landsat imagery – Glovis website - Water Sharing Plans	HVO Continuation Aquatic ecology and GDE assessment (Appendix L of the EIS, ELA 2022) Previous HVO EIS assessments: - Groundwater assessment (AGE 2017) - River Red Gum Rehabilitation and Restoration Strategy (Umwelt 2021) - SLR (2019)
Water users	- Water Sharing Plans - NSW Water Register	HVO water licence register

4.2 Climate

The regional climate of the Project area is characterised by hot summers and mild dry winters.

The SWIA report (Appendix B) provides a comparison of the different station data and demonstrates the SILO dataset is an adequate representation of the long-term climate in the Project area.

The mean annual rainfall is 656 mm, with the highest monthly rainfall typically occurring in January and the lowest monthly rainfall occurring in July. Figure 4.1 compares the mean monthly evaporation and rainfall from the SILO data drill. Rainfall is relatively consistent throughout the year, although slightly lower in winter than in summer. Evaporation exceeds rainfall throughout the year and a soil moisture deficit is likely (especially in the summer months). Annual average evaporation is 1,544 mm.

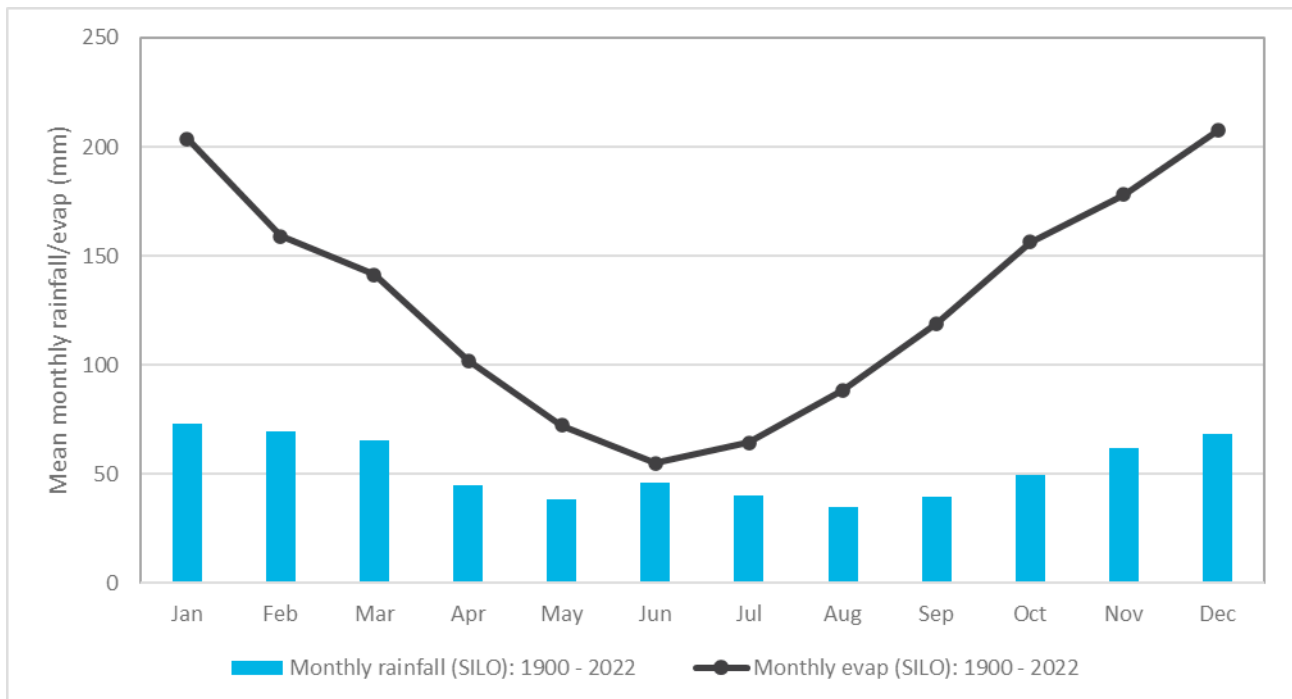


Figure 4.1 Mean monthly rainfall and evaporation (SILO data)

A review of rainfall trends shows:

- rainfall was below average between 2000 and 2006;
- a wetter period followed between 2007 and 2016;
- a significant drought was recorded between 2016 and 2019; and
- rainfall has been above the long-term average since 2020.

4.3 Hydrological setting

4.3.1 Watercourses and catchments

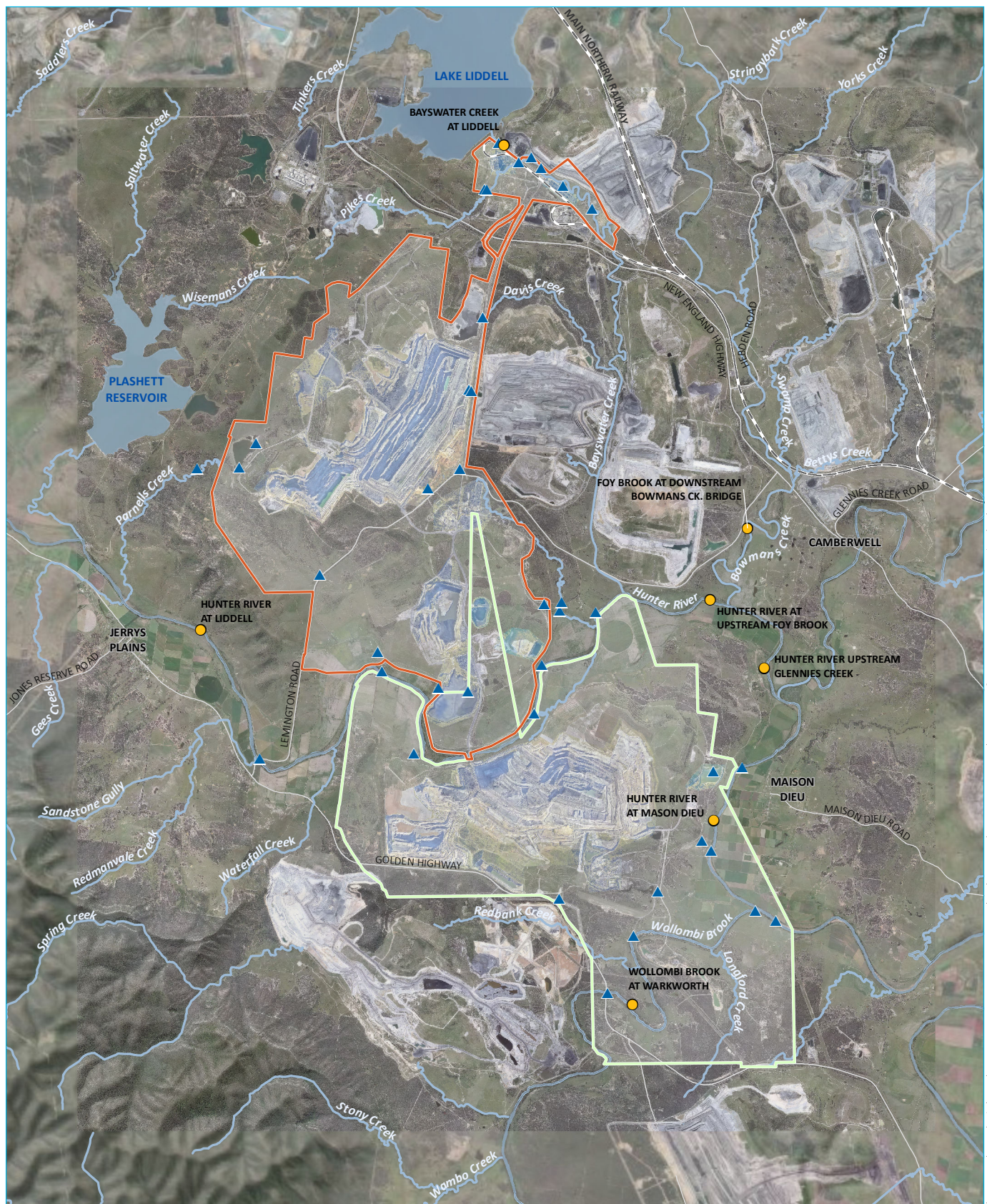
The HVO Complex is within the Hunter River Basin catchment and is drained by the Hunter River, Wollombi Brook and tributary drainage channels, including Parnells Creek, Farrells Creek, Bayswater Creek and Hobden Gully (Figure 4.2). As discussed in Section 3.2.2, the Hunter River is a regulated river, regulated by releases from Glenbawn Dam and Glennies Creek Dam. The Hunter River flows in an easterly direction between the HVO North and HVO South, then flows in a southerly direction.

Other minor watercourses in the vicinity of the Project are ephemeral, flowing after rainfall events. There are also several unnamed tributaries within the Project area. Streamflow analysis indicates many of the ephemeral watercourses are dry (on average) more than half the year.

Engeny (2022) conducted flow regime analysis for the Hunter River based on data from the Maison Dieu gauge (gauge 210128), located near HVO South (Figure 4.2). The flow duration curve analysis shows the Hunter River is perennial with daily flows typically exceeding 100 ML/day 90% of the time (Appendix B).

The flow duration curve analysis at the Warkworth gauge (210004) shows that Wollombi Brook stops flowing (ie is dry) 14% of the time and daily flows typically exceed 100 ML/day only 30% of the time at Warkworth (Engeny 2022).

Further descriptions of individual watercourses and catchments are provided in the SWIA in Appendix B.



Source: EMM (2022); HVO (2022); DFSI (2017); GA (2011)

KEY

- | | |
|---|--|
| Existing HVO North development consent boundary (DA 450-10-2003) | --- Existing environment |
| Existing HVO South project approval boundary (PA 06_0261) | --- Rail line |
| ● WNSW stream gauge | --- Major road |
| ▲ HVO surface water monitoring location | --- Named watercourse |
| | Named waterbody |

0 2.5 5 km
GDA2020 MGA Zone 56

Surface water context

HVO Continuation Project
Water Assessment
Figure 4.2

4.3.2 Surface water monitoring

Extensive monitoring at watercourses and within the HVO WMS has been occurring in the Project area since 2011, in accordance with the WMP.

The surface water monitoring program is described in the WMP (HVO 2018) and Appendix B. Monitoring locations are presented in Figure 4.2.

4.3.3 Surface water quality

i Hunter River basin

Water quality is generally poor due to typically high salt concentrations in the Hunter River basin. This is largely due to the geology of the area and groundwater discharge contributing to the high salinity in the Hunter River catchment (McVickar et al 2015).

The HRSTS was introduced in 1995 to minimise the impact of saline water discharges from industry. There are three key salinity monitoring stations located on the Hunter Regulated River: Denman, Glennies Creek and Singleton (McVickar et al 2015).

Salinity levels are typically low in the north-east of the Hunter River basin. Along the Hunter Regulated River, the mean salinity (as EC) between the 1995 and 2013 varied from around 600 microsiemens per centimetre ($\mu\text{S}/\text{cm}$) at Denman to 750 $\mu\text{S}/\text{cm}$ at Glennies Creek, to 640 $\mu\text{S}/\text{cm}$ at Singleton. A high variability was observed, particularly at low flows when baseflow discharges dominate the streamflow response (McVickar et al 2015).

ii Local setting

The HVO surface water monitoring program was extended for the Project in 2018 following a review of the available historical monitoring data conducted by Engeny (Engeny 2018a). Sufficient water quality monitoring data (greater than two years of monthly sampling, ie 24 samples) have been collected to adequately analyse data and trends for pH, electrical conductivity (EC), total suspended solids (TSS) and total dissolved solids (TDS), as well as nutrients and a range of metals/metalloids.

Detailed statistical analyses as set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) has been conducted as part of the SWIA (Appendix B). Recorded ranges in pH, EC and TSS have been compared to ANZG (2018) default guideline values and Blue Book (Landcom 2004). Further statistical analysis conducted by Engeny (2022) is provided in Appendix B. Review of water quality trends to site-specific trigger values is conducted as part of the Annual Reviews.

Historical water quality data (2011 to 2022) for the Hunter River, Wollombi Brook and the ephemeral creeks, generally complies with relevant water quality objectives for pH, EC and TSS for the 80th percentile, with the following observations:

- the 80th percentile TSS is somewhat higher than the Blue Book value for the ephemeral creeks;
- pH is generally neutral to alkaline, and the 80th percentile at the Hunter River can be above the ANZG (2018) default guideline value; and
- EC is below the ANZG (2018) default guideline value and is generally higher in the Hunter River than Wollombi Brook and ephemeral creeks.

In addition to routine parameters, surface water quality monitoring has been undertaken regarding nutrients and metals/metalloids in all clean water systems, the sediment water system and mine water system for the complex. The statistical analysis for metals and nutrients at each monitoring location is detailed in Appendix D of the SWIA (Engeny 2022).

4.3.4 Environmental and community values

An environmental and community value is defined in the national water quality guidelines (ANZG 2018) as a particular value or use of the environment that is important for a healthy ecosystem or for public benefit, health, safety or welfare, and requires protection from the effects of stressors. The term ‘beneficial use’ is also often used to describe the same term. Environmental and community values recognised by the national water quality guidelines (ANZG 2018) and listed in the NSW *Guidelines for Groundwater Documentation for SSD/SSI Projects* are listed in Figure 4.3.

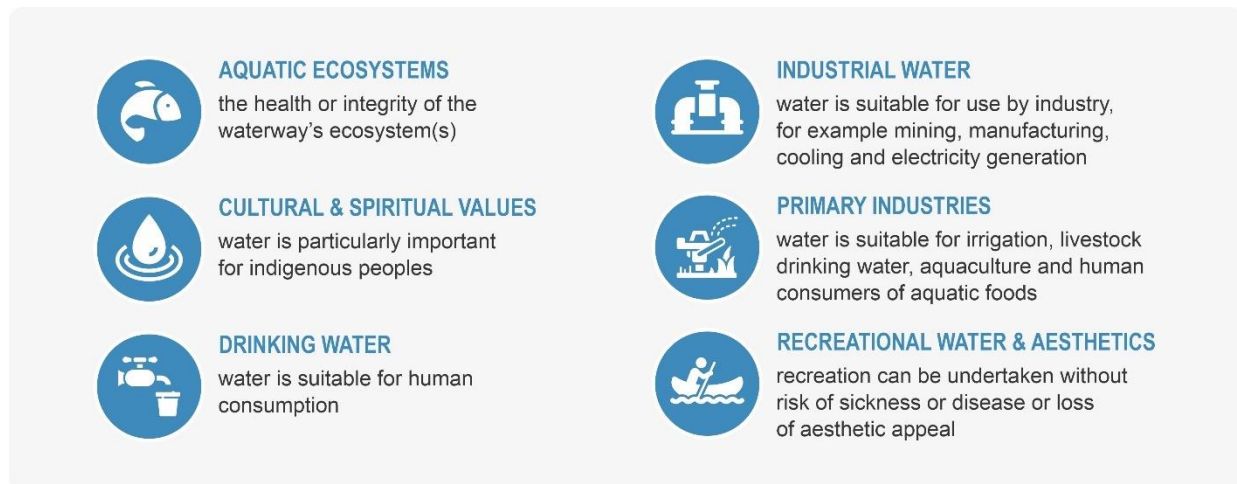


Figure 4.3 Environmental and community values (adapted from ANZG 2018)

The NSW Government has river flow and water quality objectives for different catchments in the NSW for use in developing plans and actions affecting river health. In the Hunter River catchment, the river flow and water quality objectives relevant to the Study area relate to “uncontrolled streams” (ie unregulated watercourses) and “major regulated rivers”¹.

The water quality objectives for “uncontrolled streams” and “major regulated rivers” relate to the protection of:

- aquatic ecosystems;
- visual amenity;
- primary and secondary contact recreation;
- livestock water supply;
- irrigation water supply;
- homestead water supply; and
- aquatic foods (cooked).

The NSW river flow objectives are:

- protect natural water levels in pools of creeks and rivers and wetlands during periods of no flow;
- protect natural low flows;

¹ https://www.environment.nsw.gov.au/ieo/Hunter/report-02.htm#P178_22807

- protect or restore a proportion of moderate flows, ‘freshes’ and high flows;
- maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems;
- mimic the natural frequency, duration and seasonal nature of drying periods in naturally temporary waterways;
- maintain or mimic natural flow variability in all rivers;
- maintain rates of rise and fall of river heights within natural bounds;
- maintain groundwaters within natural levels, and variability, critical to surface flows or ecosystems;
- minimise the impact of in-stream structures;
- minimise downstream water quality impacts of storage releases;
- ensure river flow management provides for contingencies; and
- maintain or rehabilitate estuarine processes and habitats.

The Hunter River catchment has undergone extensive modification in the Study area. It is generally considered as having low to medium instream value. There are some medium and high value areas, particularly in the upper regions of the regulated river. The regulated river has generally low diversity and no vital habitat value. The sub-catchments of the Hunter River are generally considered as under medium or high environmental stress. They have relatively poor bank condition, bed condition and riparian vegetation (DPI Water 2017). Within the Project area, the Hunter River and its tributaries are considered as having Poor Ecological Value (Appendix M to the EIS, ELA 2022).

The Hunter River supports a variety of uses including irrigation, town water supply, mining and power generation. Downstream of the HVO Complex, the town of Singleton relies on the river for its industries and water supply.

Landholders also access water through basic landholder rights and/or through WALs (refer Section 3.2.2 and 4.7.1 for further discussion).

In addition to environmental, social and economic value, the Hunter River also has cultural value for Aboriginal people. Aboriginal names for the Hunter River include *Coquun*, *Myan*, *Coonanbarra*, *Terrybong* or *Gingamboon*, depending on the point of its course (Wafer 2014); *Terrybong* appears to be the *Wonnarua* name for the Hunter River within the Project area (Gardner 1854). Derived from the *Awabakal* language, Wollombi means ‘meeting of the waters’ (NSW Geographical Names Board n.d.).

4.4 Geological setting

The surface geology in the Study area is presented in Figure 4.4.

The coal seams at HVO are contained within the Late Permian Wittingham Coal Measures which are further subdivided into the Vane subgroup and the Jerrys Plains subgroup. The coal measures are stratified sequences dipping in a general west to south-easterly direction and outcrop over most of the mapped extent.

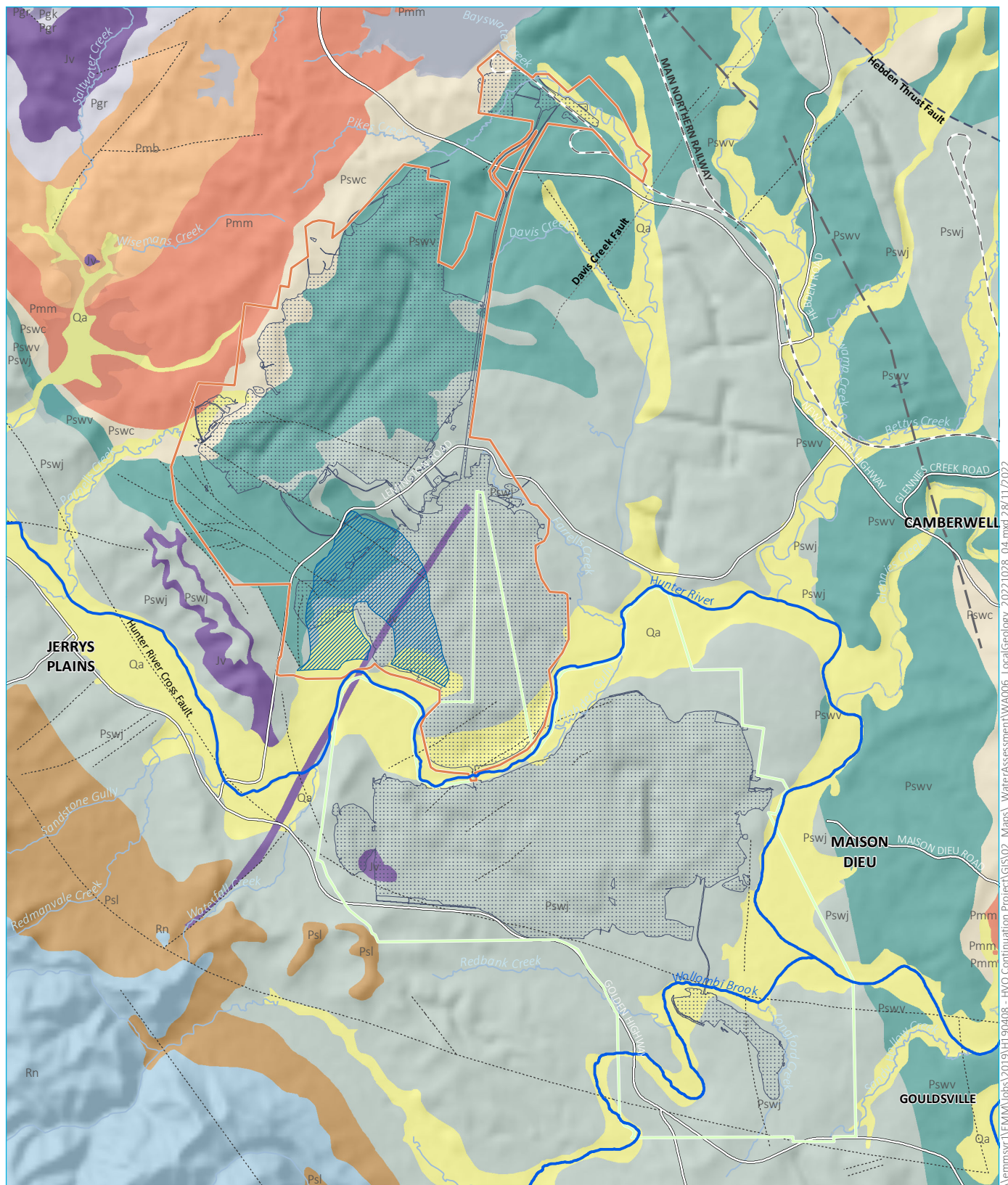
In the Project area, most of the younger Permian and Triassic units overlying the Wittingham Coal Measures have been eroded. Consequently, the Permian Wittingham Coal Measures, forming the bedrock, is now unconformably overlain by thin meandering lineaments of Quaternary alluvial sediments deposited along the Hunter River floodplain and its tributaries.

A weathering profile is typically present as a thin heterogeneous layer of unconsolidated weathered material (regolith) grading through weathered rock to fresh bedrock. The depth of weathering varies in the area and can extend to 50 m below surface (AGE 2022).

The main geological units present within the Project area are summarised in Table 4.2. Further discussion is provided in Appendix A.

Table 4.2 Summary of main geological units in the Project area

Geological unit	Description
Quaternary/Tertiary alluvium	The Quaternary alluvium occurring along the Hunter River and Wollombi Brook floodplains contains two main depositional units, a surficial fine-grained sediment (clay, silt and sand) overlying a coarser basal material (sand and gravel). The alluvial sediments are generally confined to the current course of the Hunter River and some tributaries near the confluence with the Hunter River.
Paleochannel alluvium	An ancient river meander carved into the Permian sediments at HVO and infilled with alluvial sediments forming a paleochannel to the north of the Hunter River near Carrington Pit (Figure 4.4). The paleochannel was formed during the Tertiary period and consists of silt, sand and gravel. MER (2010) discusses the investigations conducted in the paleochannel area to define the geometry, lithology and hydrogeological properties of the paleochannel. Exploration drilling and groundwater monitoring installations, and associated monitoring, and resulted in a robust conceptual understanding of the paleochannel. The depositional environment for the unconsolidated paleochannel alluvium was characterised by frequent flooding and resulting deposition of gravelly sandy material with silts and clays. Colluvial deposits are also present from hill slope runoff and sheet wash from surrounding hard rock (MER 2010). The alluvium thickness varies and ranges from 11 to 18 m, pinching out at the channel perimeter. The bottom 3 to 6 m generally comprises fine to coarse gravel contained within a silty-clayey matrix that is overlain by clay 2 to 8 m in thickness. This clay is overlain by relatively thin surficial sands, silts, clays and loams (MER 2010).
Aeolian deposits	Cenozoic dune sands and associated high level sand deposits mapped in the state geology dataset is locally referred to as 'Warkworth Sands' in the Project area. The feldspathic quartz aeolian sands are approximately 3 m (1 to 6 m) thick and form a thin capping on the underlying Permian bedrock. The fine-grained sands overlie a low permeability base of residual clay associated with the underlying strata (AGE 2022).
Permian Wittingham Coal Measures - Jerrys Plains subgroup - Vane subgroup	The Permian strata, underlying the Quaternary alluvium, comprise sequences of coal seams separated by layers of sandstone, siltstone, tuffs and conglomerate and are generally referred to as overburden and interburden in the context of mining. In the Project area, the regular layered sedimentary sequence dips gently to the south-east. The Jerrys Plains subgroup outcrops in HVO North, gradually thickens from its outcrop towards the south and is up to 300 m thick at HVO South. It is underlain by the Archerfield Sandstone consisting of a massive light brown or honey coloured well-sorted quartz lithic sandstone which marks the change into the underlying Vane subgroup. Mining at both HVO North and HVO South has intersected the Jerrys Plains subgroup. The Vane subgroup comprises six coal seams with the Lemington seam at the top and the Hebden seam at the base. The interburden consists of sandstone and siltstone. Mining at the Mitchell /West Pit at HVO North is currently approved to mine to the base of the Barrett seam. The Project proposes to extend mining to the base of the Barrett seam in the Carrington area.



KEY

- Hunter River and Wollombi Brook
- Other named watercourse
- Former extent of paleochannel
- Previous mining disturbance
- Existing HVO North development consent boundary (DA 450-10-2003)
- Existing HVO South project approval boundary (PA 06_0261)

Geology - Hunter coalfield 100K

- Qa - Quaternary Alluvium
- Jv - Jurassic Volcanics
- Rn - Narrabeen Group
- Psl - Wollombi Coal Measures

- Pswj - Wittingham Coal Measures, Jerrys Plains Subgroup
- Pswv - Archerfield sandstone, Vane Subgroup
- Pswc - Wittingham Coal Measures, Saltwater Creek Formation
- Pmm - Maitland Group, Mulbring Siltstone
- Pmb - Maitland Group, Branxton Formation
- Pgr - Greta Coal Measures, Rowan Formation
- Pgk - Greta Coal Measures, Skeletal Formation
- Water

Geological feature

- Anticline
- Thrust fault
- Fault

Existing environment

- Rail line
- Major road

Geological setting

HVO Continuation Project
Water Assessment
Figure 4.4

4.4.1 Structural geology

In the Hunter Coalfield, a group of small thrust faults running parallel to subparallel to the Hunter-Mooki thrust fault and a series of northerly trending folds displaces the Permian sequences. The Project area is incised by a series of faults that trend in a north-west to south-east direction.

The main mapped structures in the Project area are:

- The Hunter River Cross Fault: little is documented on the fault, but historical information suggests it is narrow with a maximum displacement of approximately 10 m.
- The Muswellbrook Anticline (west of HVO).
- The Bayswater Syncline north-west of Singleton (north and east of HVO).
- The Hunter Valley Dyke: a north-east trending volcanic intrusion adjacent to the Carrington Pit. The dyke is likely to exhibit lower permeability due to its thickness (greater than 40 m) and localised alteration of geology, but also localised fracturing which enhances groundwater storage.
- The 'Block Fault Zone': a zone of faults north-east of the Project area up to 250 m to 300 m wide with typical fault displacements of less than 12 m.
- The Davis Creek Fault that strikes in a north easterly orientation adjacent to the Ravensworth Operations east of HVO North and continues through to LCO. At LCO there were observations of distinct groundwater pressure differences on either side of the fault structure. The fault is therefore thought to act as a barrier to groundwater flow (AGE 2022).

Geological structures are discussed further in Appendix A.

4.5 Geochemistry

This section provides a summary of the geochemical assessment completed for the Project (Appendix C; EGi 2022). The objectives of the geochemistry work were to assess the potential for acid rock drainage, salinity and metal/metalloid leaching (including neutral mine drainage) of the proposed mine materials; identify any geochemical issues; and provide recommendations for materials management and any follow up test work if required.

Results of geochemical testing indicate the vast majority of overburden/interburden materials represented by the samples tested is:

- non-acid forming (NAF);
- of low sulphur content;
- has an excess of acid neutralising capacity; and
- low leachable salinity.

Potential acid forming (PAF) materials are estimated to comprise only 3% of overburden/interburden. Thin pyritic zones of elevated sulphur were identified generally close to coal seams, but dilution and mixing during mining should be sufficient to mitigate any acid rock drainage generation.

Overburden/interburden samples tested indicate the material is a potential source of buffering to help mitigate any acid rock drainage from PAF materials. Sandstone and siltstone tended to have higher acid neutralising capacity than other lithologies and are also the most common lithologies.

Given the expected high proportions of NAF (approximately 97% of overburden/interburden intervals tested were classified NAF) relative to PAF (approximately 3%), operational blending of NAF and PAF overburden/interburden together with the excess alkaline leachate from NAF materials is expected to be a robust approach to controlling acid rock drainage from PAF materials.

The majority of coal samples tested were PAF. Approximately half of immediate seam roof, floor and partings materials is also likely to be PAF, with NAF materials estimated to be 52%. These materials are generally thin (less than 0.3 m) and are expected to report to the raw coal process stream, however if they were to report to overburden/interburden then dilution and mixing during mining would be sufficient to negate acid rock drainage risk from these materials.

Kinetic NAG testing indicated that the PAF samples tested were relatively fast reacting and, despite varying acid neutralising capacity, lag times of one month or less were indicated.

Sulphur speciation testing suggests that the total sulphur in non-coal overburden/interburden samples and in rejects samples is likely to be mainly pyritic, and that coal samples and tailings samples are likely to include a higher proportion of non-pyritic sulphur forms.

The results of water and peroxide extraction tests indicate that significant metal/metalloid release from materials represented by the samples tested would only be associated with generation of acid rock drainage. The solubility of metals/metalloids will largely be determined by pH and therefore prevention of acid generation will effectively control metal/metalloid leaching.

Extracts from low sulphur NAF materials indicated that drainage from these materials is likely to be slightly saline to moderately saline and is unlikely to contain significant metal/metalloid concentrations, but elevated sulphate may occur from NAF materials with significant pyrite.

As observed in the surface water quality monitoring data, water quality within the mine water system is generally neutral to alkaline, with salinity up to 5,170 mg/L TDS.

Extracts show that metal/metalloid release associated with any acid rock drainage generated from pyritic overburden materials would include aluminium (Al), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), strontium (Sr) and zinc (Zn), and possibly arsenic (As) at low pH (less than 3).

4.6 Hydrogeological setting

4.6.1 Hydrogeological units

The main hydrogeological units within the Project area can be defined as follows based on the geological units and their ability to store and transmit water:

- alluvial aquifers, occurring along the major creeks and rivers, mainly the Hunter River; and the paleochannel, forming shallow unconfined aquifers in the Project area;
- Permian groundwater systems:
 - thin and variably permeable weathered rock at the surface (regolith). They generally do not form aquifers due to limited saturated thickness;
 - non coal interburden aquitards; and
 - low to moderately permeable coal seam aquifers, generally confined.

4.6.2 Groundwater monitoring

There is an extensive groundwater monitoring network at HVO that spans the various mining areas, targeting various lithologies including the alluvium and deeper Permian units. Groundwater monitoring commenced in 1995. Monitoring locations and frequency have been revised and updated over the operating years and in accordance with the WMP. Groundwater monitoring is also undertaken at surrounding mines including Ravensworth Operations, LCO, Mt Owen Complex, Integra, MTW, and United-Wambo. In addition, there is groundwater monitoring data available from Government-owned/monitored bores in the Study area.

Groundwater monitoring locations in the Project area are shown in Figure 4.5 and discussed further in the GIA (Appendix A).

There are numerous groundwater monitoring sites within and near the HVO Complex and good spatial coverage in the alluvium. Annual groundwater monitoring reports prepared by HVO also provide details of groundwater level and quality monitoring data (temporal and spatial).

4.6.3 Hydraulic properties

Extensive hydraulic testing has been undertaken across the Hunter Valley using field packer testing, laboratory core permeability testing and falling/rising head tests.

Further discussion and presentation of measured hydrogeological property data is provided in the GIA in Appendix A.

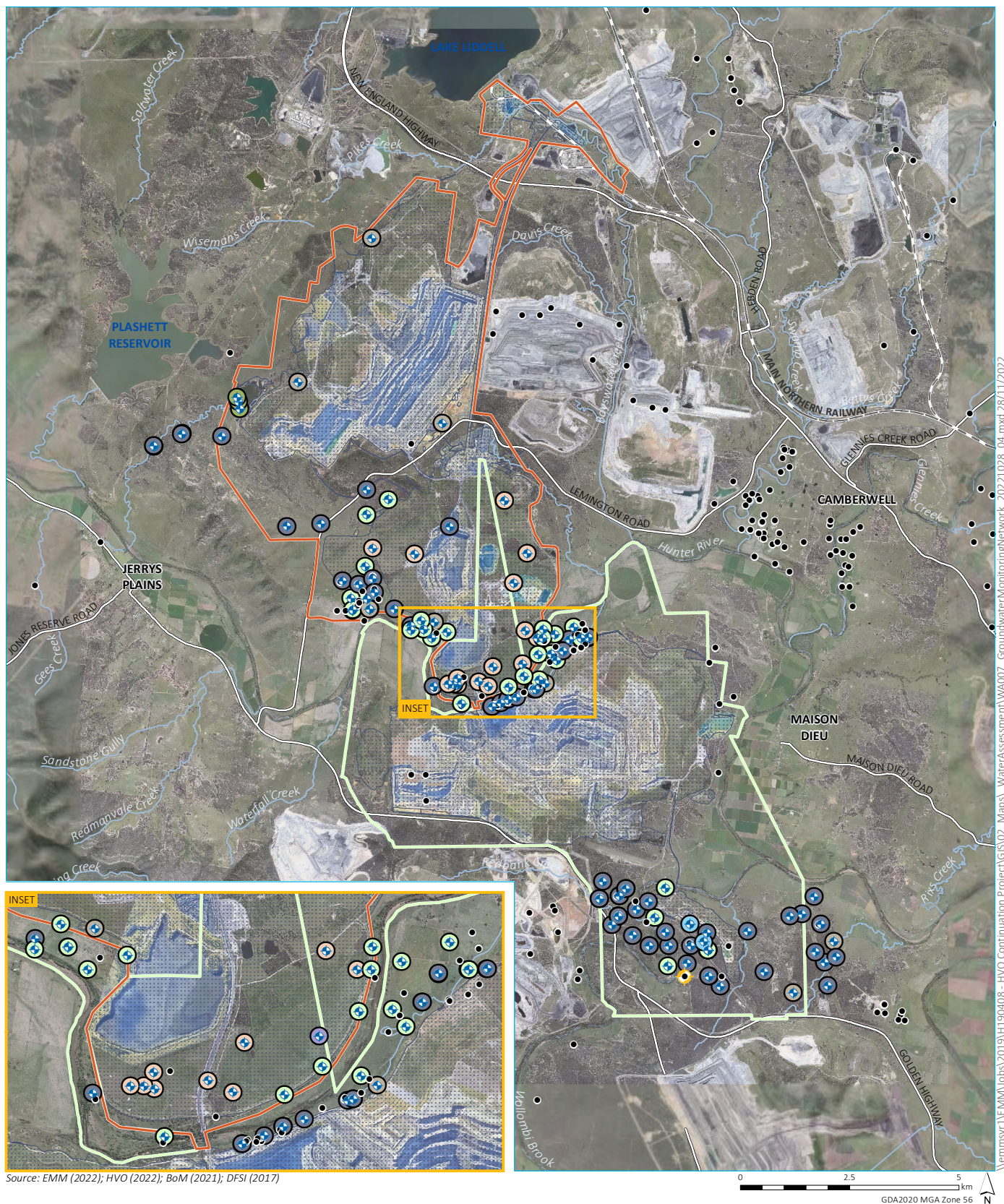
4.6.4 Groundwater levels and flow direction

Groundwater levels and flow direction in the alluvium is largely controlled by surface topography and surface water flows.

The potentiometric surface in the Permian is generally at a lower elevation than the alluvial watertable (downward gradient from the alluvium to the Permian) due to historical mining in the area. As such, there is expected to be downward leakage from the alluvium to the Permian that will be limited by hydraulic properties of the regolith and interburden.

Detailed groundwater level and spatial analysis for bores at HVO has been conducted as part of the GIA (Appendix A). The analysis shows a strong connection between groundwater level trends in the alluvium and Hunter River flows. This observation is supported by observations provided in the Annual Reviews and by groundwater level monitoring at a NSW Government monitoring bore upstream of HVO (GW271031). Figure 4.6 presents a hydrograph of publicly available groundwater level data and stream height data from the WaterNSW Liddell gauge (station 210083), which demonstrates the strong connection between the regulated Hunter River and the alluvium.

GW271031 is located upstream of the HVO Complex and therefore not influenced by mining activities at HVO. Figure 4.6 shows the climatic variation in the alluvial watertable from January 2010 to mid-2021, where the watertable varied by approximately 1.1 m (within the 10th and 90th percentile range of the measurements).



KEY

- | | |
|---|---|
| Existing HVO North development consent boundary (DA 450-10-2003) | Regolith |
| Existing HVO South project approval boundary (PA 06-0261) | Warkworth Sands |
| Previous mining disturbance | Permian |
| GW monitoring bore (BoM) | Coal seam |
| + Groundwater monitoring location (HVO) | Interburden |
| + LUG bore | Existing environment |
| Other | Rail line |
| Lithology | Major road |
| Alluvium | Named watercourse |
| Spoil | Named waterbody |

Groundwater monitoring network

HVO Continuation Project
Water Assessment
Figure 4.5

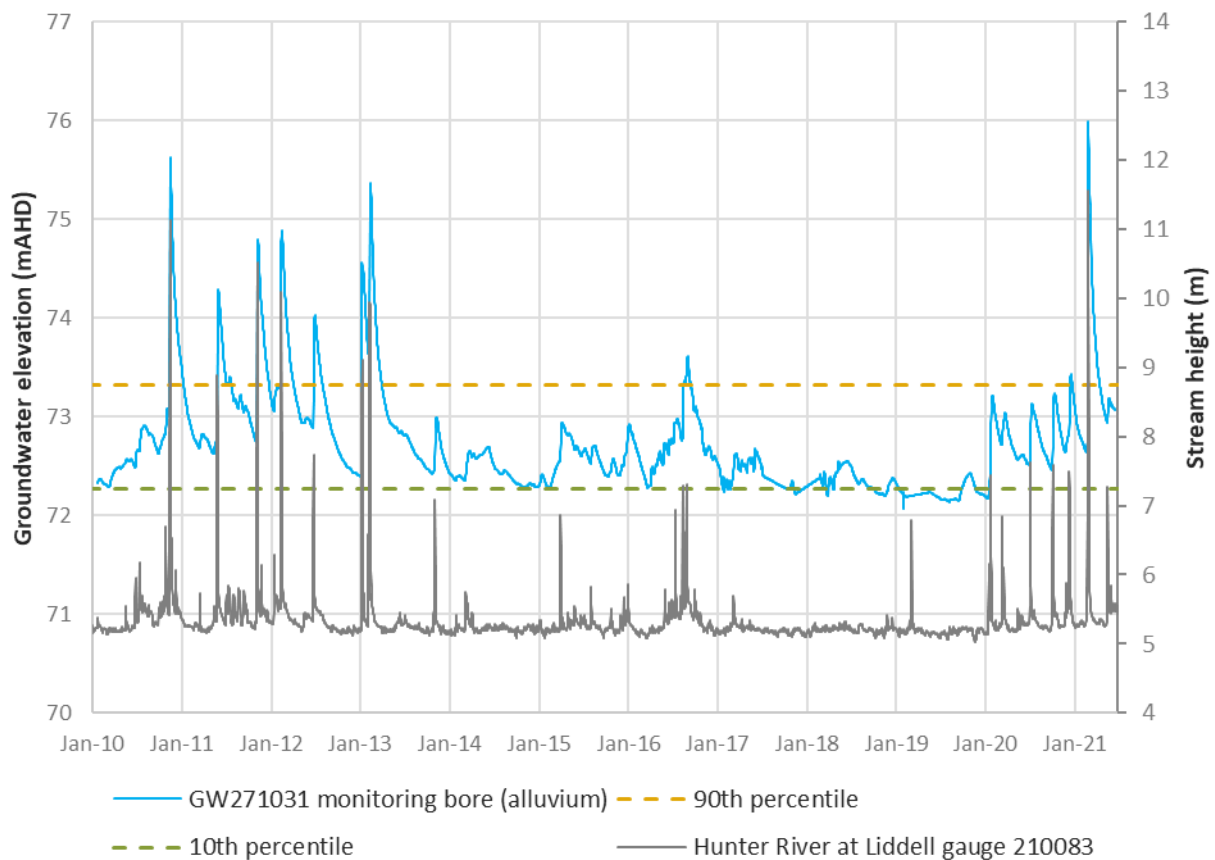


Figure 4.6 GW271031 hydrograph

i Alluvial saturated thickness

The groundwater model used for the GIA (AGE 2022) indicates the predicted 2020 alluvial saturated thickness:

- in the Hunter River alluvium south of Carrington Pit ranges between 1 and 8 m;
- ranges from 1 to 6 m in the western arm of the paleochannel;
- ranges from 2 to 10 m in the area between Alluvial Lands and HVO South;
- increases up to 14 to 24 m in the Hunter River alluvium east of HVO South; and
- ranges from <1 m to 6 m in the Wollombi Brook alluvium in the South Lemington Pit 1 area, increasing with distance downstream towards the confluence with the Hunter River.

4.6.5 Groundwater quality

Groundwater sampling for water quality analysis has been undertaken extensively within the Project area and surroundings (Section 4.6.2).

Monitoring shows the alluvial aquifer in the Hunter River has relatively low salinity (brackish) and variability, thereby meeting the criteria to be classified as “highly productive” groundwater source (defined under the AIP).

The Permian groundwater is characterised by higher salinity (moderately saline).

Historically, the salinity of the paleochannel alluvium has been elevated, freshening in areas close to the river where the effects of recharge and mixing are more evident (MER 2010). In 2021, groundwater salinity ranged

from 889 $\mu\text{S}/\text{cm}$ at a monitoring location closer to the river (4040P) and up to 9,290 $\mu\text{S}/\text{cm}$ at a monitoring bore installed within a remnant area of paleochannel alluvium between the West Pit and Carrington Pit (which has since been backfilled). pH generally ranged from 6.5 to 7.5 in 2021.

4.6.6 Environmental and community values

Beneficial uses of groundwater are limited to the alluvium. Groundwater extracted from the Hunter River alluvium supports irrigation, livestock drinking water and domestic and stock purposes. However, the alluvium groundwater is generally not suitable for long-term irrigation purposes.

Shallow groundwater also supports ecosystems that rely on (eg stygofauna) or opportunistically access water (eg river red gums), and therefore is likely to have cultural and spiritual value to Aboriginal people.

Permian groundwater has limited beneficial use due to the salinity, however it is intercepted through mining activities and used where possible (as a priority over other water sources) within mine water management systems.

Groundwater users, including ecosystems that are potentially dependent on water are discussed further in Section 4.7.2.

4.7 Water receptors

The location of identified water receptors is presented in Figure 4.7 and are described in subsequent sections.

4.7.1 Surface water users

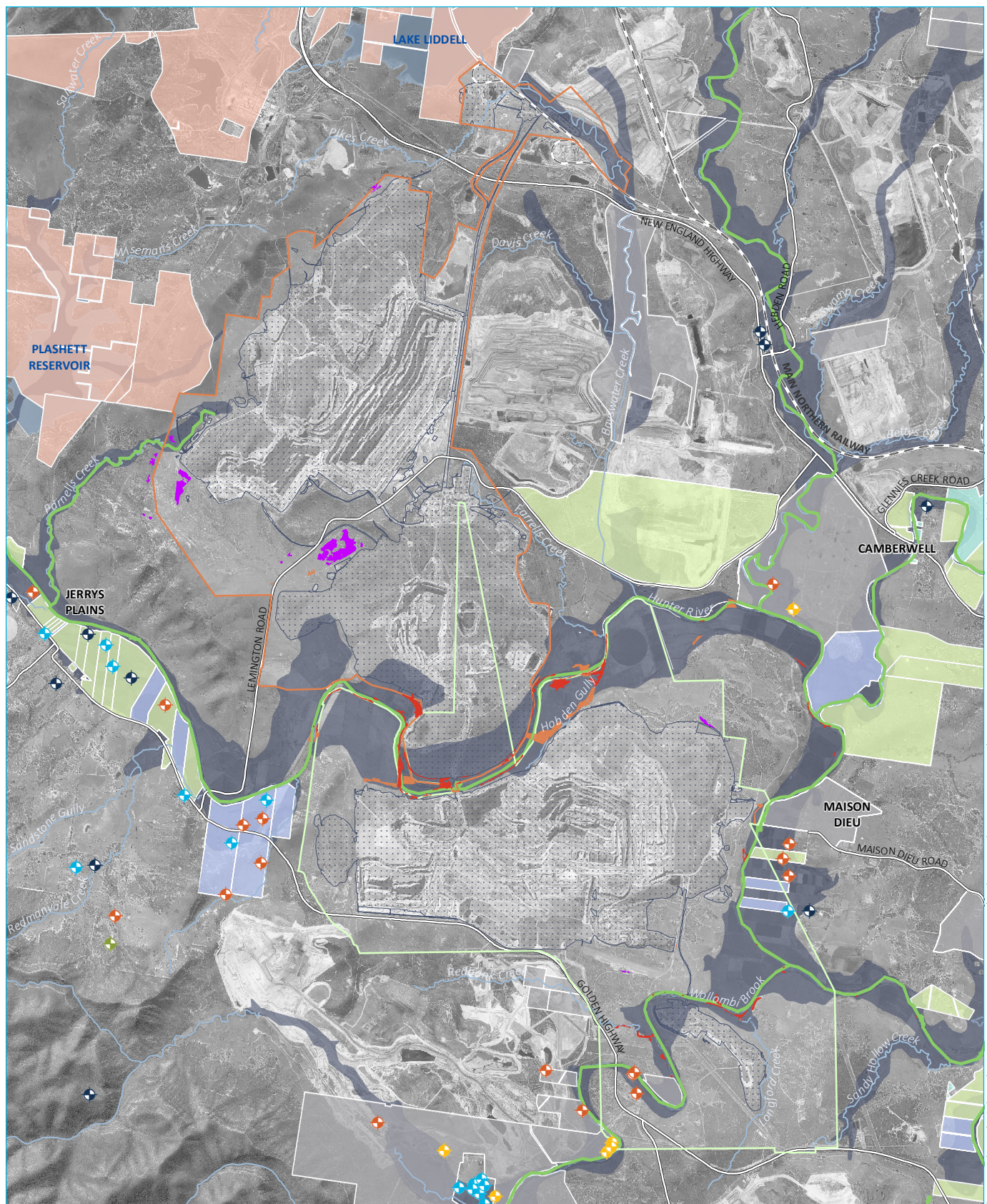
There are non-mining water users downstream of the HVO Complex within the Hunter River catchment (Figure 4.7). Extraction from the Hunter River and tributaries in the Study area is mainly for town water supply, power generation, mining, industrial, agriculture and irrigation purposes.

In NSW, landholders can take water under basic landholder rights without a WAL or approval in certain circumstances. There are three types of basic landholder rights under the WM Act²:

- **Domestic and stock rights:** owners or occupiers of land overlaying an aquifer or with river, estuary or lake frontage can take water without a licence for domestic purposes or for stock watering.
- **Harvestable rights:** landholders can capture and store a proportion of the rainfall runoff from their landholding in one or more harvestable rights dams without requiring a water access licence, water supply work approval, or water use approval.
- **Native title:** anyone who holds native title with respect to water, as determined under the *Commonwealth Native Title Act 1993*, can take and use water for a range of personal, domestic and non-commercial purposes.

It is assumed that water is captured for domestic and stock rights and harvestable rights in the Study area. The specific location of these activities is not known; however, the majority of land adjacent to the HVO Complex is owned by the HVO JV parties or other mining operations.

² <https://www.dpie.nsw.gov.au/water/licensing-and-trade/basic-landholder-rights>



Source: EMM (2022); HVO (2022); BoM (2021); DFSI (2017); GA (2011)

KEY

- | | | |
|--|--|----------------------------------|
| Existing HVO North development consent boundary (DA 450-10-2003) | Supplementary water | Vegetation community (HVO, 2020) |
| Existing HVO South project approval boundary (PA 06-0261) | Unregulated river | PCT 42 River Red Gum |
| Previous mining disturbance | Bore type | Existing environment |
| Aquatic groundwater dependent ecosystem (BoM GDE Atlas) | Water Supply | Rail line |
| Alluvial extent | Commercial and industrial | Major road |
| Other water access user | Irrigation | Named watercourse |
| Domestic and stock | Stock and domestic | Named waterbody |
| Local water utility | Unknown | |
| Major utility | Vegetation community (Umwelt, 2022) | |
| Regulated river | PCT 42 River Red Gum/ River Oak Riparian Woodland | |
| | PCT 1692 Bull Oak Grassy Woodland of the Central Hunter Valley | |

Water receptors

HVO Continuation Project
Water Assessment
Figure 4.7

4.7.2 Groundwater users

Most third-party (non JV) landholder bores are primarily located upstream and downstream of the Project area along the Hunter River and are screened within the Quaternary alluvium.

Figure 4.7 shows the locations of the third-party bores.

4.7.3 Water-dependent ecosystems

Ecosystems that are potentially reliant on surface water include: instream ecosystems that depend on streamflow (including in-stream ecosystems reliant on groundwater baseflow), and riparian ecosystems that depend on surface water and overbank flows.

GDEs are ecosystems that potentially rely on either the surface or subsurface expression of groundwater.

A review of the relevant WSPs, GDE Atlas and other literature has been conducted.

The GDE Atlas was developed as a national dataset of Australian GDEs to inform groundwater planning and management. However, ground-based surveys and hydrogeological information is necessary to confirm the presence of mapped GDEs and/or identify the presence of other potential GDEs.

An aquatic ecology and GDE assessment of the Study area was conducted by ELA (2022) and comprised a desktop assessment to identify potential GDEs in the Study area and follow-up field surveys to identify aquatic habitat, and assess ecological condition of identified potential GDEs and aquatic ecology.

The desktop phase of the aquatic ecology and GDE assessment identified the following potential water dependent ecosystems in the Study area (ELA 2022; Appendix M of the EIS):

- baseflow discharge to the Hunter River;
- aquifer ecosystems of the Hunter River alluvium and associated tributary aquifers;
- River red gum populations at Carrington Billabong, and along the Hunter River and Wollombi Brook;
- Bull Oak Grassy Woodland of the Central Hunter Valley (in the Hunter River riparian zone); and
- Warkworth Sands Woodland community.

ELA conducted field surveys in April 2020, September 2020 and January 2022, that included:

- macroinvertebrate and water quality sampling to assess baseline conditions (pre-Project) along the Hunter River, and at sites on Bayswater Creek, Wollombi Brook, Bowmans Creek, Farrells Creek and Parnells Creek (including locations upstream and downstream of HRSTS discharge locations);
- stygofauna surveys at 30 monitoring bores across the HVO Complex, of which 11 were dry and could not be sampled;
- field surveys to assess the ecological values and conditions of the identified potential GDEs using the protocol outlined in the *Risk Assessments Guidelines for Groundwater Dependent Ecosystems* (Serov et al 2012); and
- condition assessment of four vegetation sites selected from the desktop and remote sensing analyses using the BAM (river red gum stands and stands of Bull Oak Grassy Woodland of the Central Hunter Valley).

The locations of the potential water-dependent ecosystems within the Study area are shown in Figure 4.7.

i Aquatic ecology

The following was observed during the aquatic ecology surveys:

- Large flow events result in erosion and movement of sand and gravel beds along the Hunter River.
- Wollombi Brook (in the Study area) had moderate flow and high turbidity.
- Bowmans Creek had shallow isolated pools in April and September 2020, and was flowing in January 2022.
- Bayswater Creek was dry in April and September 2020, and the channel was full of terrestrial weeds, and was assessed to be poor aquatic habitat.
- Farrells Creek was dry, no macrophytes or other habitat features were present.

ii Potential GDEs

The ecological surveys conducted for the Project observed that all vegetation stands were in low to moderate condition.

The Carrington Billabong is an ephemeral freshwater wetland south of the previously mined Carrington Pit. Ecological health monitoring of the vegetation in the billabong is conducted by HVO. The main vegetation at the billabong is the river red gum ecological community that opportunistically access groundwater stored within the alluvium and rely on river flooding for germination. As discussed above, the alluvium is predominantly recharged by leakage from the river and historical monitoring has shown relatively stable groundwater levels despite the historical mining.

Figure 4.8 presents a conceptual diagram of the river red gums and their reliance on water.

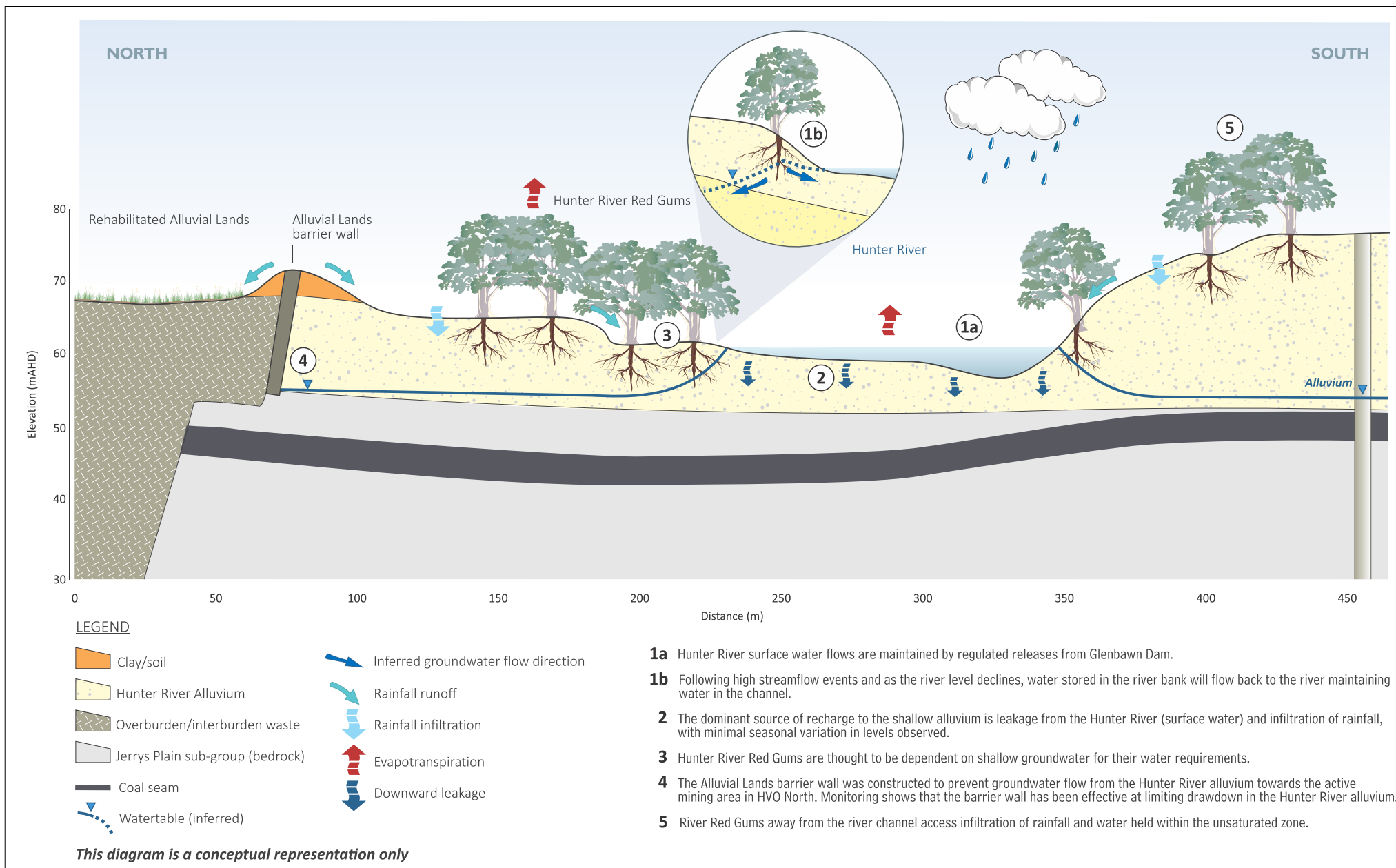
Stygofauna are known to occur in alluvial sediments within the Study area along the Hunter River, Bowmans Creek, Glennies Creek and Wollombi Brook (ELA 2022). They may also occur in the shallow fractured rock up to 60 m depth where they colonise fracture networks of secondary porosity. The presence of stygofauna becomes increasingly uncommon in the deeper, unweathered rock where high groundwater salinity, and low dissolved oxygen levels limit their occurrence.

The Warkworth Sands Woodland communities are largely associated with the unconsolidated aeolian sediments in the area. The saturation in the sands is variable. In October 2020, two dedicated monitoring bores were installed within the sand in the South Lemington Pit 1 area (refer Figure 4.5), with the screened interval installed at the base of the sand. At the time of the installation, the sand was dry. Pressure transducer data loggers were installed in the bores and data shows infiltration of rainfall following large (or continuous) rainfall events results in temporary saturation. Figure 4.9 presents a hydrograph of groundwater level monitoring at these bores and shows temporary saturation occurring following large rainfall events in March 2021 (at the south bore only), November 2021, March 2022 and July 2022, which are separated by dry periods. The aeolian sand in this location is not in hydraulic connection with the Hunter River alluvium and is disconnected from the underlying potentiometric surface in the Permian.

The vegetation associated with the Warkworth Sands Woodland are thought to rely on infiltration of rainfall and a seasonal perched watertable and are not considered further in the water assessment.

A diagram showing the conceptual understanding of the Warkworth Sands Woodland in the South Lemington Pit 1 area and the interaction between terrestrial vegetation with water is presented in Figure 4.10.

More information on the potential water dependent ecosystems is present in the Study area is provided in the aquatic ecology and GDE assessment report (ELA 2022; Appendix M to the EIS).



Receptor conceptual diagram – Hunter River and River Red Gums

HVO Continuation Project

Water Assessment

Figure 4.8

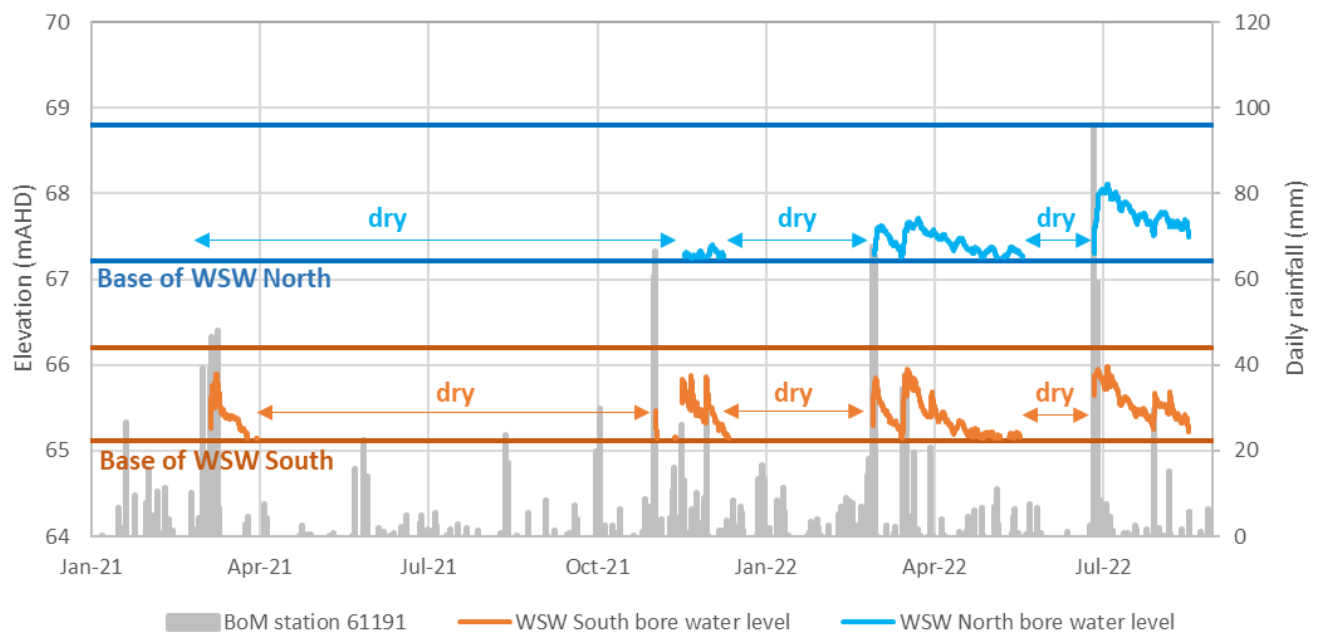
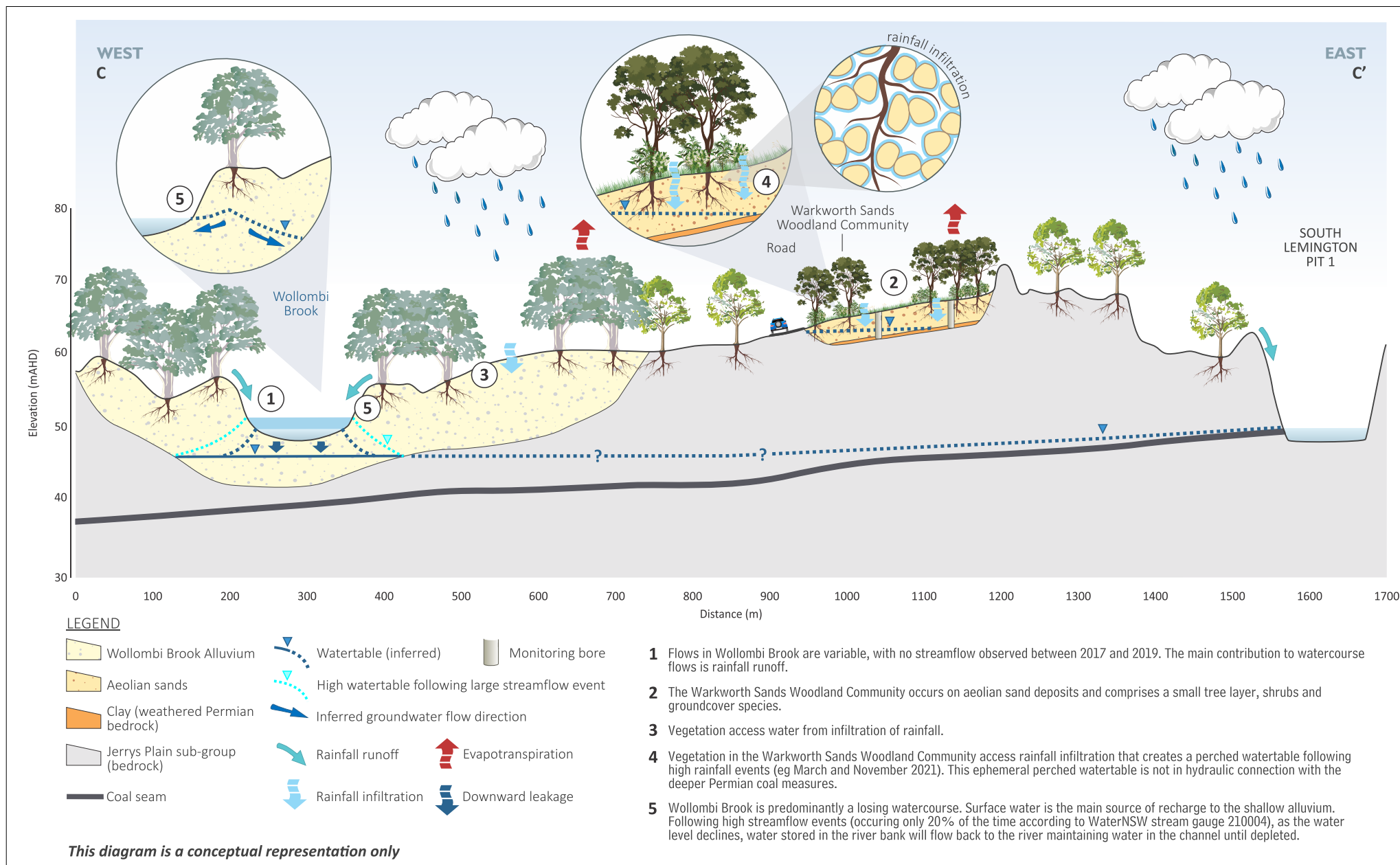


Figure 4.9 Warkworth Sands monitoring bore hydrograph



Receptor Conceptual Diagram – Warkworth Sands and Wollombi Brook

HVO Continuation Project

Water Assessment

Figure 4.10

5 Conceptual model

A conceptual model describes the key processes in the hydrological and hydrogeological environment. It is based on hypotheses and assumptions, some of which will be derived from data sourced from the water environment under investigation and others will be based on general hydrogeological or hydrological principles. The conceptual model forms the basis of assumptions adopted in the numerical models and is the basis for the water-related impact assessments.

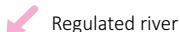
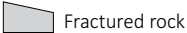
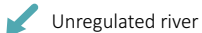
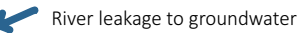
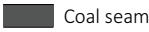
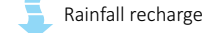
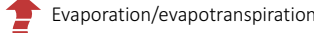
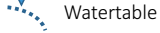
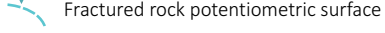
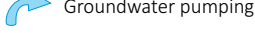
5.1 Existing conditions

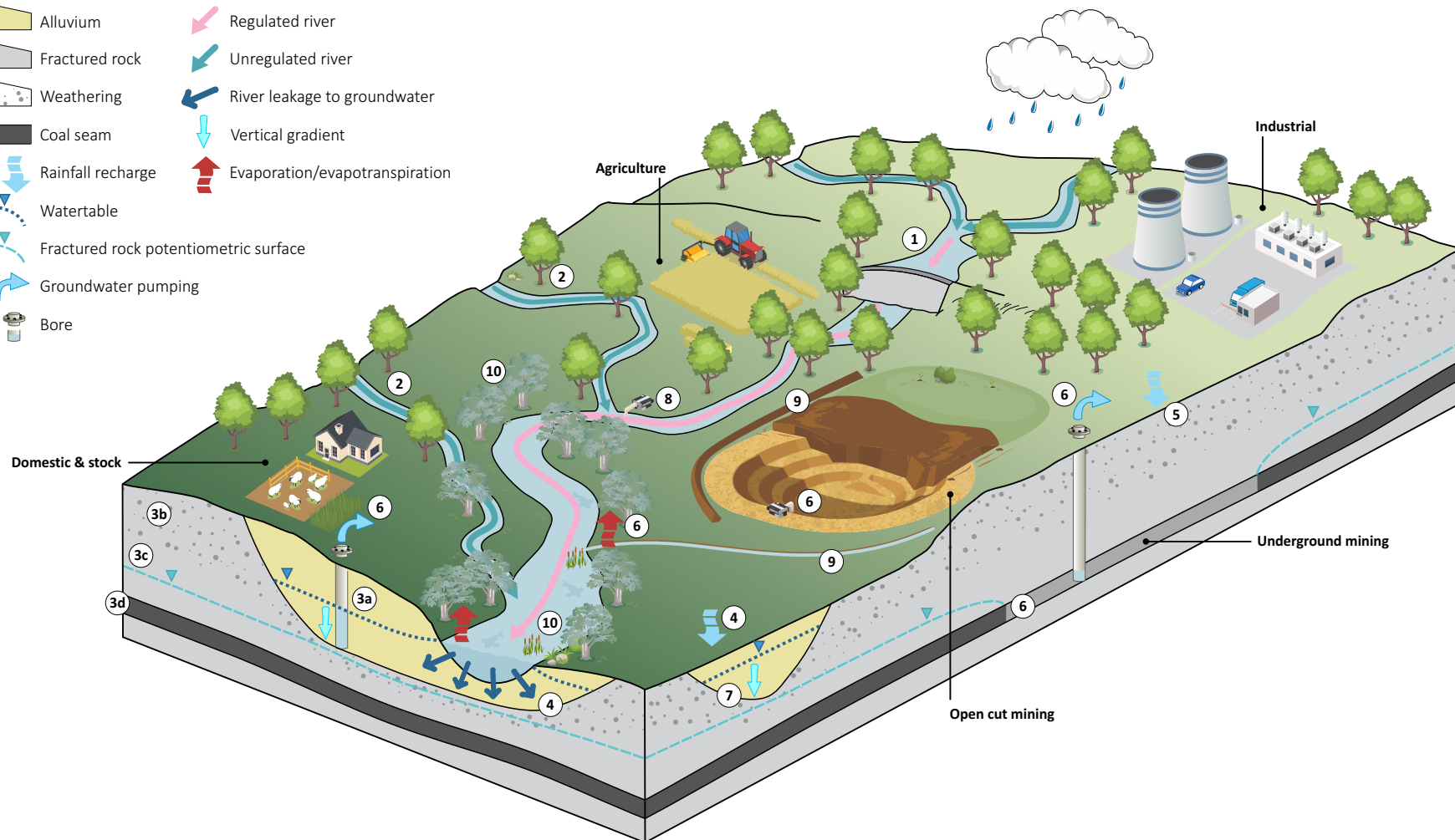
Figure 5.1 provides a generalised illustration of the conceptual model under the existing conditions, which is discussed in Chapter 4 and the GIA (Appendix A). The following points summarise the processes/activities shown with the corresponding numbers on Figure 5.1.

1. The Hunter River is a regulated river controlled by releases from Glenbawn Dam and Glennies Creek Dam, maintaining streamflow and supply to downstream entitlement holders and basic landholder rights.
2. The tributaries to the Hunter River are unregulated and as such are ephemeral. Some of the smaller watercourses (such as Farrells Creek and Parnells Creek) are mostly dry and only flow following high rainfall events. Figure 5.2 illustrates the conceptual understanding of the surface water and groundwater interaction for these minor watercourses.
3. Groundwater systems include:
 - a. Alluvial aquifers (including the paleochannel) form unconfined aquifers, and quality is fresh to brackish. The alluvium is generally more permeable than other lithologies, with recorded hydraulic conductivities ranging from 10^{-2} m/day to 10^2 m/day (AGE 2022).
 - b. The regolith does not form aquifers due to limited saturated thickness.
 - c. Permian interburden layers form aquitards.
 - d. Permian coal seams generally form low to moderately permeable confined aquifers, with poor groundwater quality. Hydraulic conductivity generally decreases with depth due to increased rock mass strength (AGE 2022).
4. Recharge to the alluvium occurs via infiltration of rainfall and leakage from surface water to the watertable. In the Hunter River alluvium, groundwater levels and aquifer saturation is predominantly due to leakage from the Hunter River, which is mostly a losing watercourse in the Project area. River leakage into the alluvium in the region is up to four times greater than direct rainfall recharge (McVicar et al 2015). The saturated thickness of the paleochannel ranges from 1 m to 6 m.
5. Recharge to the Permian groundwater system(s) occurs via downward leakage from the overlying saturated alluvium (with seepage rates limited by the vertical hydraulic conductivity of the regolith, overburden and interburden) and/or gradual infiltration of rainfall where the Permian outcrops.
6. Groundwater discharge occurs via:
 - a. evapotranspiration from vegetation, such as the river red gums, where the watertable is sufficiently shallow;

- b. seepage to active or disused mining areas (where in hydraulic connection);
 - c. as baseflow to watercourses in areas where the watertable is in hydraulic connection with the watercourse and at higher elevation than the height of water in the watercourse (this may occur seasonally);
 - d. from the alluvium to Permian strata via downward leakage where Permian potentiometric surfaces are lower than the base of the alluvium; and
 - e. active pumping from bores.
7. The vertical hydraulic gradient between the alluvium and the Permian is generally downward, due to historical mining depressurising the Permian.
8. Surface water users in the Study area include water extracted from the Hunter River for industrial, mining, domestic and stock or agricultural purposes. Landholders with waterfront land also access have basic landholder rights.
9. The existing HVO WMS includes levees for flood protection and drains to divert clean water from undisturbed or rehabilitated areas.
10. Ecosystems that potentially rely on surface water and/or groundwater:
- river red gum communities (including in the Carrington Billabong area) that opportunistically access shallow groundwater recharged by leakage from the Hunter River and Wollombi Brook, and rely on flooding for germination;
 - stygofauna occurring principally in alluvial sediments along the Hunter River and its tributaries;
 - aquatic ecosystems; and
 - Warkworth Sand Woodland communities which rely principally on rainfall infiltration and a seasonal perched watertable observed to occur after large rainfall events.

LEGEND

-  Alluvium
-  Regulated river
-  Fractured rock
-  Unregulated river
-  Weathering
-  River leakage to groundwater
-  Coal seam
-  Vertical gradient
-  Rainfall recharge
-  Evaporation/evapotranspiration
-  Watertable
-  Fractured rock potentiometric surface
-  Groundwater pumping
-  Bore



NOT TO SCALE

Note: Conceptual representation only.

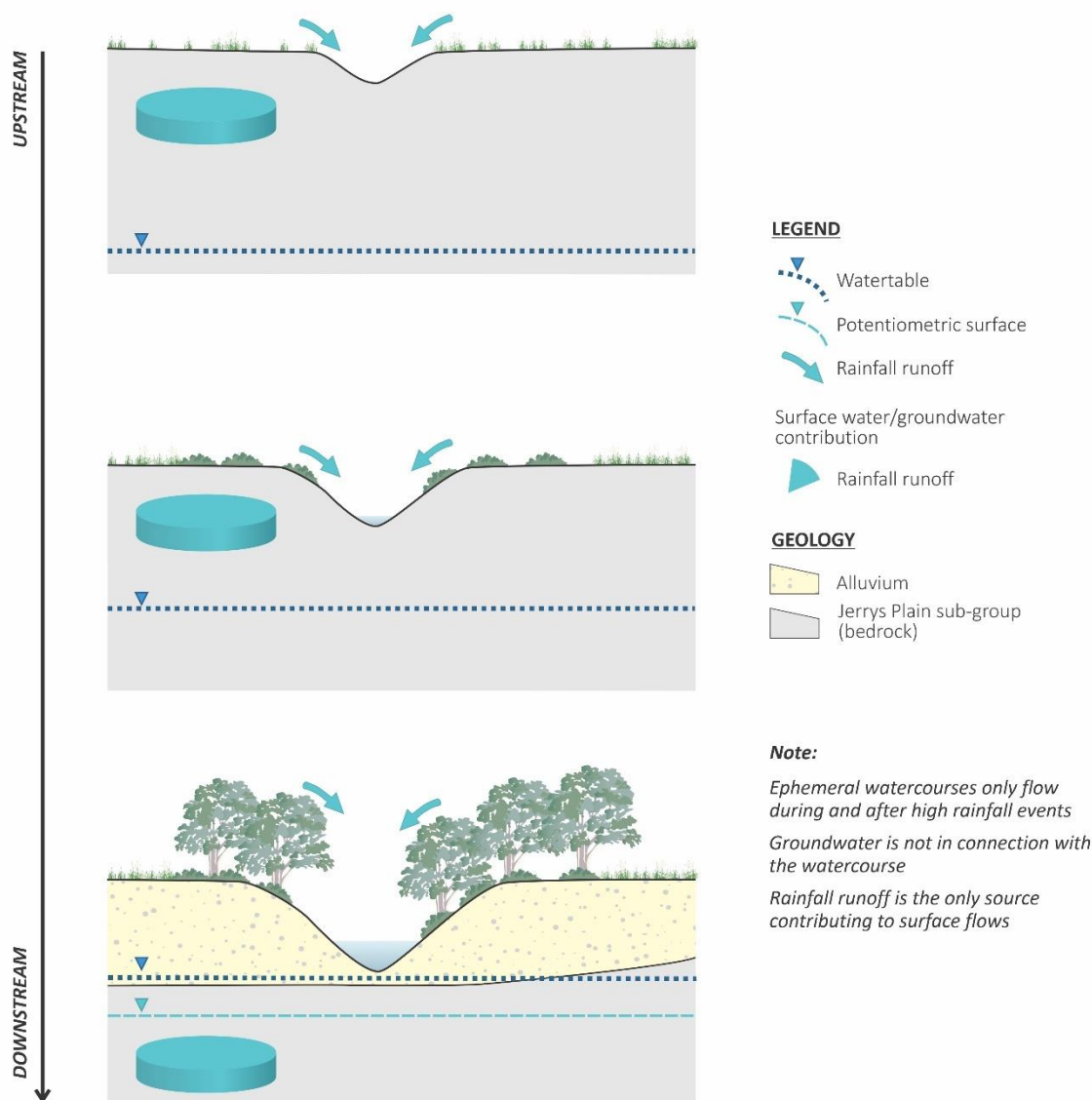


Figure 5.2 Ephemeral creek generic conceptual diagram

5.2 Conditions during mining

The conceptual model will mostly remain the same during mining. The key changes associated with the Project that have the potential to affect water resources and water-dependent assets include:

- Permian depressurisation would increase as mining progresses to the deeper Barrett seam at HVO North. However, the potentiometric surface in the Permian strata is already lower than the alluvial watertable due to approved existing and historical mining.
- In the Carrington West Wing area in HVO North, where mining is approved to the base of the Bayswater seam, mining would extend deeper to the base of the Barrett seam. Differences between the approved operations the Project would relate to the following:
 - Consistent with the approach to the Carrington Pit barrier construction, following mining up to the highwall, a barrier wall of compacted clay would be placed on alluvial benches on the highwall (and keyed into the top of the Permian strata).

- During mining, groundwater in the alluvium would seep into the active mine areas (and would be appropriately managed to achieve safe mining conditions), resulting in localised drawdown of the watertable in the Hunter River alluvium (Figure 5.3). However, only minor seepage into the pit was observed during construction of the Carrington Pit barrier wall on the eastern arm of the paleochannel.
 - The extent of the drawdown in the alluvium would be buffered by continued leakage from the Hunter River, and the alluvium would remain saturated. The drawdown induced leakage from the Hunter Regulated River would be accounted for within HVO's existing entitlements (high security entitlements) and therefore streamflow in the Hunter River will not be affected.
 - Once installed, the barrier wall would limit groundwater inflow from the alluvium to the mine and the alluvial watertable would quickly recover due to leakage from the Hunter River.
 - Ecosystems that rely on groundwater, such as stygofauna and vegetation opportunistically accessing shallow groundwater, would continue to have access to groundwater due to continued recharge from the Hunter River regulated flows. In addition, the short-term change in the watertable would not prevent the long-term viability of the water-dependent assets.
- The main causal pathway for potential impacts from mining on the water dependent ecosystems is depressurisation of the Permian strata resulting in drawdown within the Hunter River and Wollombi Brook alluvium. However, the Permian is already depressurised in this area due to historical and approved mining and there is a downward hydraulic gradient from the shallow alluvial watertable to the Permian. Further depressurisation of the deeper Barrett seam is therefore unlikely to significantly affect the shallow groundwater table within the alluvium based on existing observations and the conceptual understanding. As a result, potential impacts on the Hunter River and associated alluvial aquifers are expected to be minor beyond already approved operations.
 - Upgrades to Lake James and Parnells Dam would be conducted to increase the capacity to store water intercepted during mining. As these upgrades are being undertaken on existing dams with no change in the location of the dam, the upgrades would not result in a change to the contributing catchments.
 - As the Project will not intercept new surface water catchments, the potential impact on streamflow is expected to be negligible.
 - HVO is not seeking to change existing approvals or licences for the discharge of mine water under the HRSTS and the Project is not proposing to obtain any additional HRSTS credits. Therefore, the potential impact of the Project on water quality is expected to be negligible.

5.3 Post mining conditions

The key conceptual considerations post mining are:

- The Project will result in one final void at HVO North, rather than three voids as per the current approved operations.
- Permian potentiometric surface would slowly recover after cessation of mining activities. However, the final voids will remain groundwater sinks due to the depth and size.
- The barrier walls will remain in place post mining. Therefore, groundwater inflows from the alluvium to the final voids and associated watertable drawdown are expected to be minor, due to the continued recharge from the Hunter River.

- The barrier walls would also prevent potential seepage from the emplacement areas to the alluvium, thereby avoiding contamination of the Hunter River alluvium (Figure 5.3).
- Drawdown in the alluvium as a result of the final voids would be limited, therefore ecosystems that rely on alluvial groundwater would not to be significantly impacted.
- Following closure, the drainage systems in the Project area will be established to divert upstream catchment runoff away from the final voids (as much as practical) and to downstream watercourses.
- The Carrington West Wing Levee will be decommissioned, returning floodplain storage capacity for the Hunter River in this area.

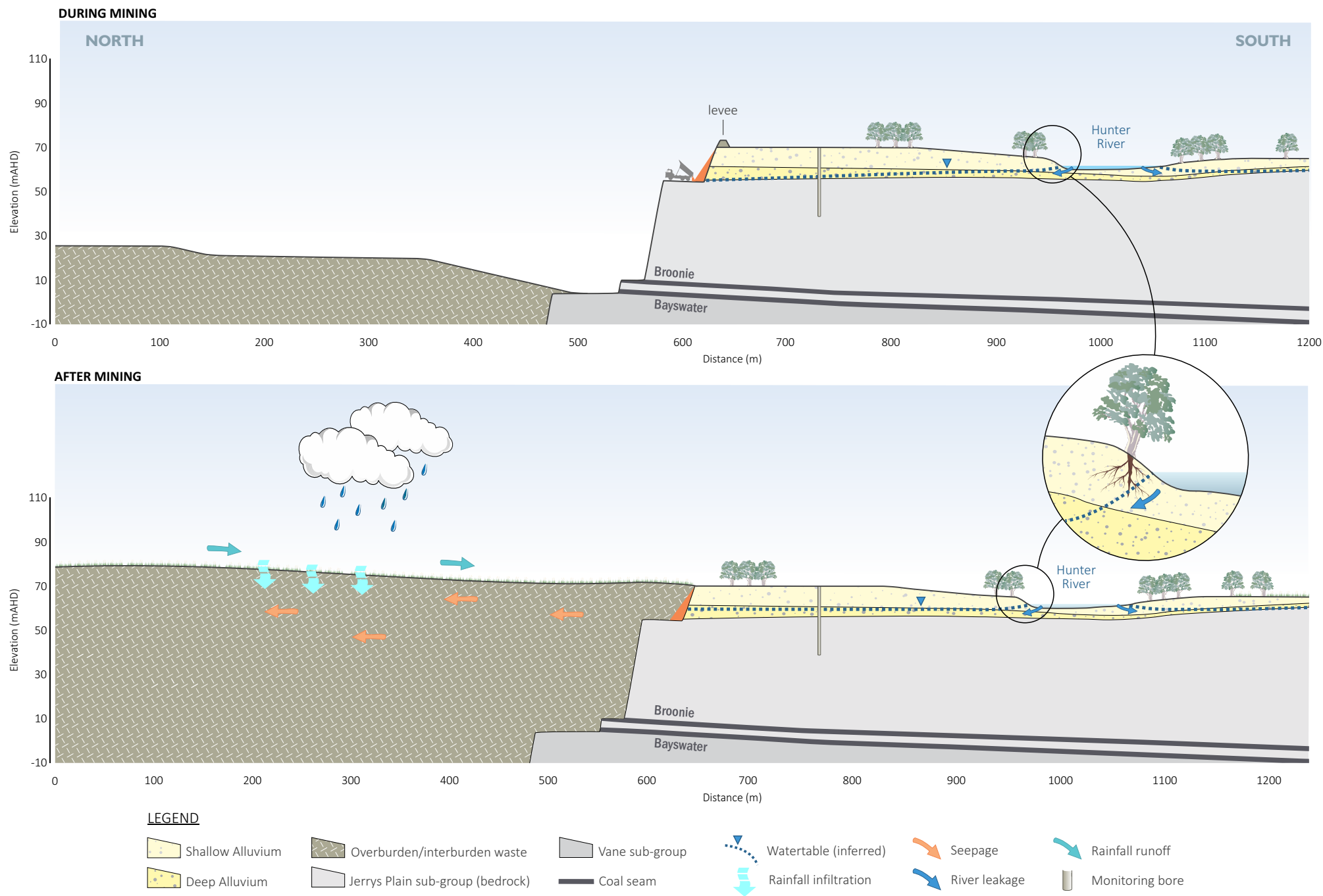


Figure 5.3 Carrington West Wing mining area and western paleochannel conceptual diagram

6 Assessment approach

6.1 Introduction

The Project will include minor additional disturbance area between West Pit and Carrington Pit, and will continue to operate the HVO integrated WMS for the Project.

The Project will intercept groundwater and has the potential to result in changes to the existing groundwater and surface water regime. The Project will result in additional depressurisation of the Permian strata directly intersected by mining. However, because the HVO Complex already comprises active and approved mining, the potential for the Project to result in a significant incremental impact on water resources is reduced due to existing and approved impacts and existing depressurisation.

Activities specific to the Project that have the potential to have an incremental impact on water resources and water users include:

- new or upgrades to WMS infrastructure (including upgrades to approved flood levees) and continued use of the integrated WMS;
- realignment of Lemington Road;
- direct interception of groundwater by mining (including mining deeper in previously disturbed areas);
- capture and storage of different water qualities within the WMS;
- waste management, including tailings and overburden/interburden material; and
- physical disruption of hydrogeological units (mainly mining deeper in previously disturbed areas).

6.2 Avoidance and mitigation measures

The Project considers a design that avoids and minimises impacts to water resources and water dependent assets, including:

- removing the currently approved coal extraction in South Lemington Pit 1 and 2 from the Project mine plan;
- realignment of Lemington Road and improving flood immunity at the new proposed Hunter River crossing;
- mainly limiting disturbance to previously disturbed or approved areas, thereby limiting avoiding disturbing new catchments;
- revised design of the Carrington West Wing barrier wall such that it is constructed on the highwall alluvial benches following mining and prior to backfilling, still meeting the main objectives of the current approved barrier wall;
- continued operation of the existing WMS, including preferential use of sediment-laden and mine water over extraction from the Hunter River; and
- operating in accordance with the requirements of EPL 640 and WALs.

6.3 Assessment criteria

6.3.1 Overview

The adopted assessment criteria are based on the assessment requirements outlined in the relevant legislations, policies and guidelines detailed in Chapter 3. In addition, the licensing requirements of the Project have also been assessed against the WM Act, relevant WSPs and the AIP. The AIP assessment framework checklist is included in Appendix E.

Table 6.1 presents the water affecting activities and potential effects typically associated with, the potential duration of the effect and associated impact on a receptor and a summary of the assessment method(s) used for the impact assessment.

Table 6.1 Water affecting activities, potential effects, impacts on receptors, and assessment methods

Direct effect	Water affecting activity	Potential effect	Potential duration	Potential impact at a receptor	Assessment method
During operations					
Quantity	Groundwater inflows to open cut pits, including mining deeper in previously mined areas.	Additional aquifer depressurisation or drawdown, changed groundwater flow paths, local induced flows, indirect take from overlying or adjacent water sources.	Duration of the development, may take years to observe.	Reduced access to water, reduced or loss of habitat.	Groundwater modelling (Appendix A) Aquatic ecology and GDE assessment (ELA 2022)
	Built infrastructure (new or re-alignment of roads, WMS).	Minor change in watercourse catchment reducing or changing streamflow/flood regime, diversion of/changes to watercourses geomorphology.		Changes to aquatic habitat, change to access during flooding events.	Water balance modelling (Appendix B) Streamflow modelling (Appendix B) Flood modelling (Appendix B) Aquatic ecology and GDE assessment (ELA 2022)
	Tailings storage	Perched watertable, seepage, watertable mounding.	Continuous (depends on management)	Waterlogging, detrimental changes to habitat.	Not applicable – tailings will be stored below the base of weathering and alluvium, if present
	Spoil emplacement	Altered recharge	Duration of the development, may take years to observe	Changes to habitat, reduced access to water.	Groundwater modelling (Appendix A)
Quality	Groundwater inflows to open cut pits	Mobilisation of salt (water quality changes), development of acid sulphate soils or acid mine drainage from pit walls.	Duration of the development.	Change in beneficial use/environmental or cultural value, detrimental change to ecosystem, reduction in or removal of biodiversity or species.	Soil and Land Impact Assessment Report (Minesoils 2022) Geochemistry Assessment (Appendix C)
	Water storage	Leaching of solutes, overflow to watercourses altering surface water quality.			Water balance modelling (Appendix B) Water quality assessment (Appendix B)

Table 6.1 Water affecting activities, potential effects, impacts on receptors, and assessment methods

Direct effect	Water affecting activity	Potential effect	Potential duration	Potential impact at a receptor	Assessment method
	Licensed water discharge	Mixing of water quality			Water quality assessment (Appendix B) Aquatic ecology and GDE assessment (ELA 2022)
	Spoil emplacement/tailings storage	Acid mine drainage, leaching of solutes, seepage from backfilled areas to the alluvium.			Geochemistry assessment (Appendix C) Groundwater modelling (Appendix A)
Surface water-groundwater interactions	Groundwater inflows to open cut pits.	Altered baseflow to watercourse, increased leakage from watercourse to groundwater, induced inflows of different water quality.	Duration of the development, may take years to observe.	Increase in number of no flow days, reduced fish migration passage.	Groundwater modelling (Appendix A) Streamflow modelling (Appendix B) Aquatic ecology and GDE assessment (ELA 2022)
Aquifer disruption	Excavation	Removal of part of whole of an aquifer and/or aquitard, change in groundwater flow paths (noting that the disturbance area for the Project will largely not change, so this included only for cumulative impact assessment purposes).	Permanent, unless backfilled.	Reduction in ecosystem habitat, change in groundwater levels in adjacent water source(s).	Groundwater modelling (Appendix A) Aquatic ecology and GDE assessment (ELA 2022)
	Backfilling	Altered hydraulic properties, change in groundwater flow paths.	May be permanent		Groundwater modelling (Appendix A)
Closure					
Quantity	Groundwater inflows to final voids	Evaporative losses of water from final voids, continued groundwater drawdown, slow groundwater level recovery	Often hundreds of years	Reduced access to water, reduced or loss of habitat (possibly permanent)	Groundwater modelling (Appendix A)

Table 6.1 Water affecting activities, potential effects, impacts on receptors, and assessment methods

Direct effect	Water affecting activity	Potential effect	Potential duration	Potential impact at a receptor	Assessment method
	Tailings storage	Perched watertable, seepage, watertable mounding.	Potentially hundreds of years	Waterlogging, detrimental changes to habitat.	Not applicable – tailings will be stored below the base of weathering and alluvium, if present
Quality	Final pit lakes	Evapoconcentration of salts within the pit lake, potential acid mine drainage (acidification of pit lake).	Continuous	Change in beneficial use/environmental or cultural value, detrimental change to ecosystem, reduction in or removal of biodiversity or species.	Groundwater model (Appendix A) Water balance modelling (Appendix B) Geochemistry assessment (Appendix C)
	Spoil emplacement	Seepage from backfilled areas to the alluvium.	Potentially many years		Groundwater model (Appendix A) Geochemical assessment (Appendix C)
Surface water-groundwater interactions	Groundwater inflows to final voids	Altered baseflow to watercourse, increased leakage from watercourse to groundwater.	Often hundreds of years	Increase in number of no flow days, reduced fish migration passage (possible permanent).	Groundwater model (Appendix A) Streamflow modelling (Appendix B) Aquatic ecology and GDE assessment (ELA 2022)
	Rehabilitation	Altered flow regimes	Potentially hundreds of years, dependent on rehabilitation.		Streamflow modelling (Appendix B)

6.3.2 Groundwater

The potential impacts of the Project on groundwater resources and associated assets have been assessed against the minimal harm thresholds defined in the AIP. The AIP assessment framework has been completed and is included in Appendix E.

The Project area has the potential to impact both ‘highly productive’ alluvial aquifers (associated with the Hunter River and its tributaries) and a ‘less productive’ porous and fractured rock source (the Permian groundwater system). The applicable minimal impact considerations are shown respectively in Table 6.2 and Table 6.3. Impacts to groundwater are assessed via the consideration of water receptors discussed in Section 4.7. The AIP minimal impact considerations process is presented in Figure 6.1.

Cumulative variation in the watertable and/or pressure head decline criteria in the AIP are for ‘post-WSP’ variations only. EMM understands the reference to ‘post-WSP’ (in regards to minimal impact considerations) to mean that projects /activities should be assessed against environmental conditions at the time of a WSP being enacted (or soon after), allowing for climate variation. For the Hunter River alluvium (managed under the Hunter Unregulated River and Alluvial WSP), this is late 2009. It is an acknowledgement of activities prior to commencement of the WSP. The cumulative assessment has been conducted and results are also included in the GIA (Appendix A).

Table 6.2 Minimal impact considerations for ‘highly productive’ alluvial aquifer

Watertable	Water pressure	Water quality
1. Less than or equal to a 10% cumulative variation in the watertable, allowing for typical climatic ‘post-WSP’ variations, 40 m from any: a) high priority GDE; or b) high priority culturally significant site; listed in the schedule of the relevant WSP. A maximum of a 2 m decline cumulatively at any water supply work.	1. A cumulative pressure head decline of not more than 40% of the post-WSP pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work.	1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. 2. No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. 3. No mining activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100 m vertically beneath (or the 3D extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a reliable water supply. 4. Not more than 10% cumulatively of the 3D extent of the alluvial material in this water source to be excavated by mining activities beyond 200 m laterally from the top of high bank and 100 m vertically beneath a highly connected surface water source that is defined as a reliable water supply.

Table 6.2 Minimal impact considerations for ‘highly productive’ alluvial aquifer

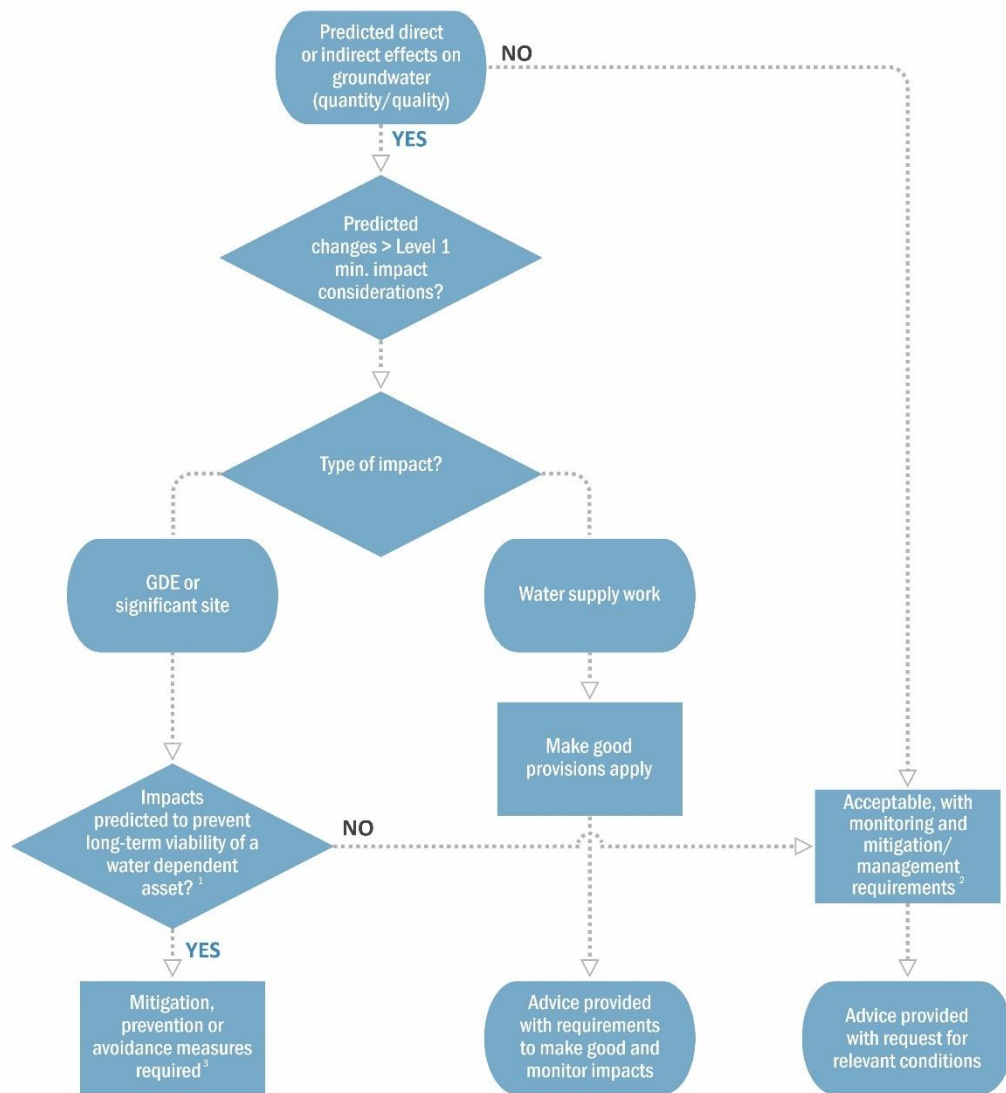
Watertable	Water pressure	Water quality
2. If more than 10% cumulative variation in the watertable, allowing for typical climatic ‘post-WSP’ variations, 40 m from any: a) high priority GDE; or b) high priority culturally significant site; listed in the schedule of the relevant WSP then appropriate studies (including the hydrogeology, ecological condition and cultural function) will need to demonstrate to the Minister’s satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than a 2 m decline cumulatively at any water supply work then make good provisions should apply.	2. If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister’s satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	3. If conditions 1 to 4 is not met then appropriate studies will need to demonstrate to the Minister’s satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.

Source: NOW (2012).

Table 6.3 Minimal impact considerations for ‘less productive’ porous rock water source

Watertable	Water pressure	Water quality
1. Less than or equal to 10% cumulative variation in the watertable, allowing for typical climatic ‘post-WSP’ variations, 40 m from any: a) high priority GDE; or b) high priority culturally significant site; listed in the schedule of the relevant WSP. A maximum of a 2 m decline cumulatively at any water supply work.	1. A cumulative pressure head decline of not more than a 2 m decline, at any water supply work.	1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.
2. If more than 10% cumulative variation in the watertable, allowing for typical climatic ‘post-WSP’ variations, 40 m from any: a) high priority GDE; or b) high priority culturally significant site; listed in the schedule of the relevant WSP then appropriate studies (including the hydrogeology, ecological condition and cultural function) will need to demonstrate to the Minister’s satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than a 2 m decline cumulatively at any water supply work then make good provisions should apply.	2. If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister’s satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	2. If condition 1 is not met then appropriate studies will need to demonstrate to the Minister’s satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.

Source: NOW (2012).



- 1 Assessment as per Serov et al 2012, with consideration of uniqueness, ecological/cultural value and timeframe of the impact.
- 2 Conditions of approval may include requirements for adaptive management to monitor and mitigate or remediate impacts that exceed level 1 thresholds.
- 3 Where there are no suitable or practical mitigation or prevention options, the proponent may be asked to avoid impacts by modifying the proposed activity.

Figure 6.1 AIP minimal impact considerations process (adapted from DPI Water 2012a)

6.3.3 Surface water

Criteria for assessing potential impacts on surface water quantity, quality and the flooding regime is summarised in Table 6.4.

Table 6.4 **Surface water assessment criteria**

Water quantity (flow, level and availability)	Water quality	Flooding
WSP rules	Water quality objectives.	Improved flood immunity to public infrastructure.
River flow objectives	Site-specific trigger values and ANZG (2018).	Minimal change to existing maximum flood depth on third-party properties, based on the 1:100 AEP event (consistent with the Singleton Local Environmental Plan 2013 flood planning level).
Minimal change in number of no flow days.	Operating within the requirements of EPL 640 and the HRSTS.	Minimal increase in flood velocity (<2 m/sec).
No change in access to water for downstream users.		No change to the flood hazard category for primary transport corridors.
		No impact to land use during flood events.

6.3.4 Aquatic ecology and GDEs

Criteria for assessing potential impacts on aquatic ecology and GDEs identified in Section 4.7 included:

- number of no flow days;
- water quality objectives and ANZG (2018); and
- risk assessment guidelines for GDEs (Serov et al 2012).

6.4 Assessment methods

Details of the assessment approach and methods is discussed in the technical assessment reports in Appendix A, Appendix B, Appendix C and Appendix M of the EIS.

6.5 Cumulative impacts

As previously discussed, HVO is located in an area where the surface water and groundwater environment has been highly modified by historical mining, industrial and agricultural activities over the past 70 years or so. Due to the dynamic nature of the regional hydrogeology, ongoing impacts associated with approved and historic mining will continue to affect groundwater levels and pressures, and connected surface water resources, irrespective of whether the Project occurs. Due to the minor change to the approved disturbance area, removal of coal extraction from South Lemington Pit 1 and 2 from the mine plan, and mainly restricting continued mining to deeper seams in previously mined areas, the potential incremental impact of the Project on water resources and water-dependent assets is expected to be minor.

Cumulative impacts are more relevant for groundwater resources and water-dependent assets, including the predicted cumulative change in groundwater levels in the alluvium due to historical approved and proposed mining, which has the potential to affect receptors identified in Section 4.7.

As discussed above, the AIP requires assessment of cumulative impacts from the commencement of a WSP, which for the Hunter River alluvium is 2009.

6.6 Peer review

6.6.1 Surface water

The flooding assessment was peer reviewed by Barry Rodgers (BMT). During the development of the HVO flood model and assessment of Project impacts, a separate flood study of the Hunter River is being undertaken by BMT on behalf of Singleton Council (Council). Barry Rodgers has been engaged throughout the development of the HVO flood model to provide a peer review and to align methodologies and broad outcomes of this study with the Council study. The flooding peer review is attached in Appendix F.

A peer review of the remaining aspects of the SWIA was conducted by Ian Rowbottom (EMM). The SWIA peer review is attached in Appendix F. Ian Rowbottom has been involved throughout the development of the SWIA. The review comprised inputs and involvement over the following aspects of the SWIA:

- WMS and water balance modelling;
- streamflow impact assessment;
- water quality assessment and cumulative impact assessment; and
- final void hydrology and climate change assessment.

6.6.2 Groundwater modelling

A peer review of the groundwater model was conducted by Associate Hydrogeologist Dr Doug Weatherill (EMM). The review was undertaken in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al 2012) and included input and involvement over the three main stages of groundwater modelling as follows:

- conceptualisation and model updates;
- model calibration; and
- model predictions/uncertainty.

The peer reviewer deemed that the model objectives were satisfied and that the model is fit for purpose where the purpose is indicative mine inflows and potential impacts on groundwater resources and receptors. The peer review report is attached in Appendix F.

7 Surface water impact assessment

7.1 Introduction

Due to the integrated nature of the WMS, some aspects of the SWIA have been considered together (for the HVO North and HVO South). In general, impacts are presented for the HVO Complex with discussion provided on the two approvals where appropriate.

The Project will mine areas within existing approved disturbance boundaries, including mining previously disturbed areas. Consequently, the incremental impact of the Project on adjacent surface water systems is generally expected to be minor or negligible.

The following sections are a summary of the SWIA; further discussion is available in Appendix B (Engeny 2022).

7.2 WMS performance

Model results indicate that average inflows are dominated by rainfall runoff (47% of the total inflow) while groundwater is only a small contributor (4% of the total inflow). Hunter River extraction via existing high security WALs represents the main water source (19% of the total inflow on average) while use of general security WALs is minor (1% or less through the Project) and therefore the Project has low reliance on this entitlement category.

The majority of water used on site is for coal processing (38% on average) and dust suppression (25% on average). Discharge via the HRSTS represents approximately 12% of the average outflows over the life of the Project.

The proposed WMS for the Project is predicted to maintain a sufficient water supply for the operation and discharge capacity to preventing flooding of operational areas of the mine, operating in accordance with existing EPL and HRSTS release conditions (the Project does not require changes to the existing HRSTS credits even under very wet conditions).

7.3 Streamflow impacts

As described above, the WMS for the Project will be consistent with the requirements of the approved operations, with the exception of mining through new areas (between Mitchell Pit and Carrington Pit) and re-disturbance of some rehabilitated areas. As outlined in Chapter 6, lowering of the watertable due the Project has the potential to result in changes in surface water-groundwater interaction. Engeny (2022) has used the groundwater model predicted changes in surface water-groundwater interaction to inform the streamflow impact assessment.

The streamflow assessment indicates there will be minimal to no changes to the annual flow and average duration of dry periods for Hunter River and most of its tributaries. Only three ephemeral watercourses were found to have changes of 1% or more due to the Project:

- Parnells Creek: average duration of dry periods within the representative “dry” year increased from 152 days to 154 days (1% increase) during Project operations;
- Unnamed Tributary 1 at HVO North: Average duration of dry periods within the representative “dry” year increased from 157 days to 164 days (4% increase) during Project operations, due to extending mining between the Mitchell Pit and Carrington Pit; and
- Farrells Creek: Average duration of dry periods within the representative “dry” year increased from 158 days to 161 days (2% increase) during operations.

The predicted change in streamflow is negligible for the Hunter River and Wollombi Brook and minor for the ephemeral tributaries. Potential impacts on surface water downstream users, including basic landholder users will be negligible.

7.4 Surface water quality

Under the HRSTS, releases can occur during high flow periods. The water balance model (Engeny 2022) predicts that 50% of the time, the median discharge volume will be 100 times less than flows in the Hunter River. On 5% of release days, flow in the Hunter River is predicted to be 80 times greater than the discharge volume. Engeny (2022) calculated the potential change to water quality in the Hunter River due to discharge via the HRSTS, using the more conservative dilution ratio of 80:1 (Hunter River flow 80 times larger than discharge volume).

Following mixing, water quality concentrations in the Hunter River are generally predicted to remain below the 80th percentile background concentrations. The exceptions are listed in Table 7.1.

All mixed concentrations were found to remain below the 95th percentile background concentrations indicating that the expected water quality is within the existing natural range of the Hunter River (detailed results are provided in Appendix B).

Therefore, discharge under the HRSTS is not expected to have an adverse effect on surface water quality or change the beneficial use.

Table 7.1 Estimated change in water quality concentrations due to HRSTS discharge following mixing (Engeny 2022)

Analyte	Mixed concentration (mg/L)	Hunter River upstream 80 th percentile concentration (mg/L)	Percent change relative to Hunter River upstream 80 th percentile
Carbonate alkalinity	1.7	0.7	65%
Sulphate (SO ₄)	42.6	2.6	6.6%
Sodium (Na)	84.2	3.8	4.7%
TDS	509.5	11.7	2.3%
Chloride (Cl)	142.3	2.3	1.7%
Potassium (K)	6.0	0	0.8%
Total alkalinity	257.3	1.5	0.6%
Magnesium (Mg)	33.6	2.2	0.6%
Bicarbonate alkalinity	250.3	0.3	0.1%

7.5 Flooding assessment

The flood model development and detailed results are provided in the SWIA report (Engeny 2022). The following sections provide a summary of the key outcomes.

The modelled scenarios are detailed in Appendix B and summarised below:

- Project Baseline: Baseline conditions utilising the available topographic data (2016 and 2020) with adjustments for operational changes planned for completion prior to the Project, including haul road approach to Cheshunt Pit at Hunter River crossing, construction of the North Void TSF Levee 1 (north-west Levee) and construction of the South Lemington Pit 1 flood protection upgrade at the haul road ramp.

- Project Operation: Construction of Project infrastructure including Carrington West Wing Levee, North Void TSF Levee 2 (south-east levee), Riverview Levee, Cheshunt Levee and Lake James upgrades, as well as construction of the Lemington Road realignment. This scenario also includes incorporation of the planned mine progression as per the Year 22 stage plan (approximately 2044) as the worst case for potential impact on the floodplain during operations.
- Project Closure: Consistent with Project Operations with the incorporation of the final landform design and decommissioning of the Carrington West Wing Levee (some incorporated into the final landform), except for the Riverview Levee and Alluvial Lands Levee.

7.5.1 Impacts to mine infrastructure

The results of the flood modelling in regards to immunity of key mine infrastructure show:

- All active open cut pits are shown to meet the minimum 0.1% AEP flood immunity (plus freeboard) standard adopted by HVO during the operational phase of the Project. During the later years of operations, North Pit will be exposed to a risk of flood ingress during Extreme Events (defined as four times the 1% AEP) via overtopping of the Carrington West Wing Levee.
- The final voids will have flood immunity up to and including the Extreme Event.

7.5.2 Impacts to public infrastructure

The main public infrastructure in the vicinity of HVO prone to flooding impacts is Lemington Road. Currently, Lemington Road at Moses Crossing becomes inundated during events smaller than 10% AEP, and has been closed for an average of 60 days per year since 2010. The proposed realignment and new Hunter River bridge crossing of Lemington Road will significantly improve the flood immunity of this road adjacent to the Hunter River. The new Hunter River crossing will exceed 10% AEP flood immunity during the Project and post closure.

7.5.3 Impacts to third-party properties

The flood modelling for the Project indicates minor flooding impacts to properties not owned by the JV partners. The Project is predicted to result in minor additional flood level changes ranging between 20–50 mm, but generally less than 30 mm, at 15 properties (being contiguous landholdings) not owned by the HVO JV. The impact is predicted to be minor, as the properties are already subject to flooding, and the maximum modelled change in flood affected area is estimated to be 0.15% of the total property for any individual property. In addition, the predicted change in flooding will not have an impact on the use of the land (agricultural (grazing and cropping) or crown land).

7.5.4 Flood hazard and emergency management

There are no broad scale changes to flood hazard categories forecast due to the Project. Small changes in road inundation durations were forecast; however, the small changes are not expected to have an impact on use of the land or public safety or emergency management. Overall, there is a significant benefit to the local community through improved immunity and access of the realigned Lemington Road.

Detailed results are provided in the SWIA (Appendix B).

7.5.5 Channel stability

Predicted velocity impacts are generally localised around Project infrastructure (eg levees, Lemington Road, South Lemington Pit 1). The magnitude of velocities in areas of impact generally remain within the existing ranges experienced and remain a low likelihood of causing scour (<2 m/sec). No significant change to flood velocities was observed on properties not owned by the JV partners.

Detailed results and maps of the change in maximum modelled flood velocity due to the Project are provided in the SWIA (Appendix B).

7.5.6 Carrington West Wing Levee

During consultation with DPE Water on the Project, the NSW Government queried the potential for geomorphic changes due to constriction caused by construction of the proposed Carrington West Wing Levee. This levee (previously called the Mitchell Levee) is already approved under the existing development consent at HVO North (designed up to 1% AEP).

As the most frequent event causing flood flows in this area, Engeny (2022) adopted the 5% AEP event to assess potential geomorphic impacts of the reduced flood storage associated with the approved levee.

The peak velocity distribution in the vicinity of the Carrington West Wing Levee indicate that changes are concentrated between the river channel and the downstream (eastern) half of the levee and are generally of small magnitude (<0.5 m/sec increase). A maximum velocity increase of approximately 1 m/sec is predicted to occur at the toe of the levee.

The predicted velocities generally remain less than 1 m/sec on the alluvial lands of the floodplain. This is consistent with the velocities in the area under existing conditions. This area is agricultural land with good vegetation cover and there is no sign of geomorphic instability under current conditions. The predicted velocity changes are unlikely to change the existing geomorphic regime, and would occur under the current approved design of the levee (that is, these changes are not specific to the Project).

Adjacent to the levee the maximum velocity is approximately 1.5 m/sec, which can be readily managed through incorporation of scour protection in the detailed design of the levee.

The combination of appropriate design, scour protection on the levee and monitoring following large flood events (5% AEP or larger) is adequate to mitigate the risk of erosion due to construction of the already approved levee.

8 Groundwater impact assessment

8.1 Introduction

The potential impact of the Project on the groundwater regime has been assessed from an incremental (comparison between approved and proposed) and cumulative perspective (estimating the effects of historic approved, the Project and other planned mining activities).

The proposed change to mining at HVO South will result in less groundwater drawdown in the Wollombi Brook alluvium in comparison to the approved operations, through the removal of mining in the South Lemington Pit 1 and 2 area from the mine plan. As such, the incremental drawdown in the Wollombi Brook alluvium due to proposed changes to mining at HVO South is not presented.

At HVO North, as mining will be progressing deeper through previously disturbed or currently approved mining areas, the incremental effects of the Project at HVO North are expected to be minor.

The predicted incremental and cumulative drawdown is focused on the alluvium, as it provides habitat for and access to water for water-dependent assets.

This section is focused on the potential impacts during operations. Assessment of potential post mining impacts is provided in Chapter 10, as this is inter-related with the final void water balance modelling completed by Engeny (2022).

The following sections provide a summary of the GIA attached in Appendix A (AGE 2022).

8.2 Watertable drawdown

8.2.1 Incremental drawdown

The maximum drawdown is predicted to occur during mining prior to the installation of the Carrington West Wing barrier wall. Figure 8.1 shows the maximum incremental drawdown predicted to occur within the Hunter River alluvium. This represents a short-term peak drawdown that is predicted to occur prior to installation of the barrier wall.

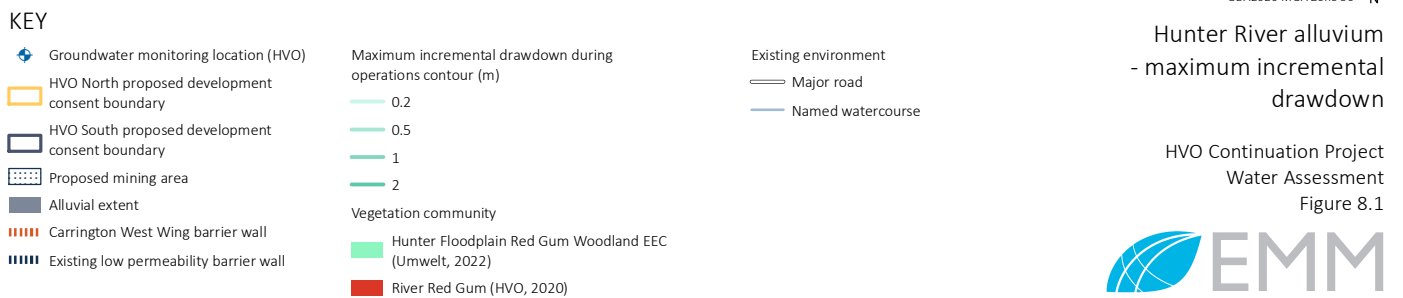
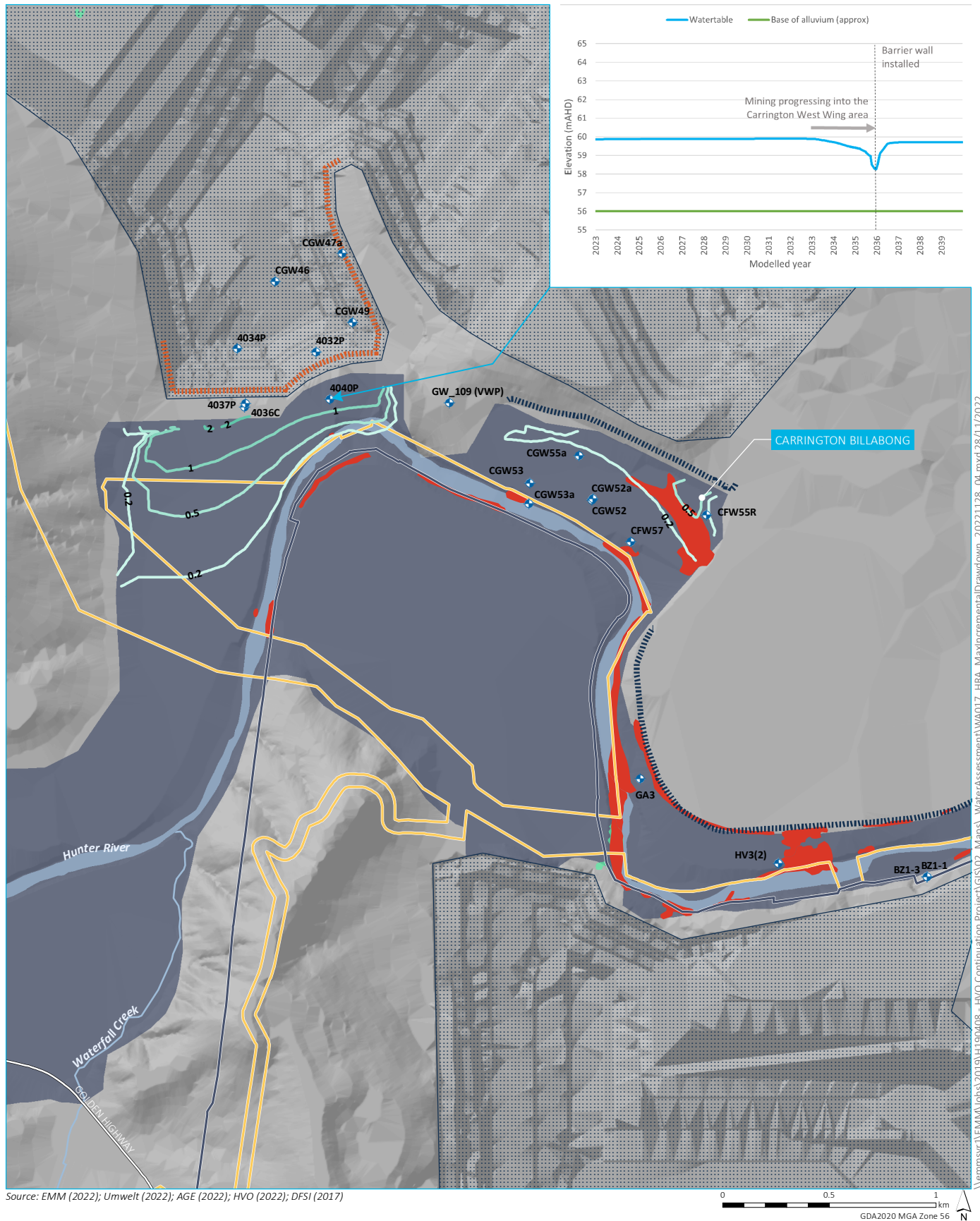
A hydrograph of the predicted alluvial groundwater level at existing monitoring bore 4040P is also presented on Figure 8.1. This figure shows the gradual decline in the watertable as mining progresses south-east into the Carrington West Wing area, followed by recovery after installation of the barrier wall. The hydrograph on Figure 8.1 also shows the alluvium is predicted to remain saturated during the period of peak drawdown, due to the strong connection between the Hunter Regulated River and the alluvium.

Low permeability barrier walls in the Alluvial Lands and Carrington Pit highwall (across the eastern arm of the paleochannel) were constructed to reduce the extent of drawdown in the alluvium. Depressurisation of the interburden and coal strata and associated vertical gradient between the Permian and the alluvium induces minor drawdown in the alluvium. The Carrington West Wing barrier wall is predicted to similarly limit drawdown in the alluvium following installation.

These results show the proposed timing of the barrier wall installation is not predicted to result in significant impacts on water receptors. This is discussed further in Chapter 9.

The groundwater model predicts minor additional drawdown in the Carrington Billabong area (between 0.2 and 0.5 m; Figure 8.1) due to mining to the deeper Permian seams in this area.

There are no third-party water supply bores within the predicted extent of drawdown. Therefore, no third-party bores will be impacted by the Project.



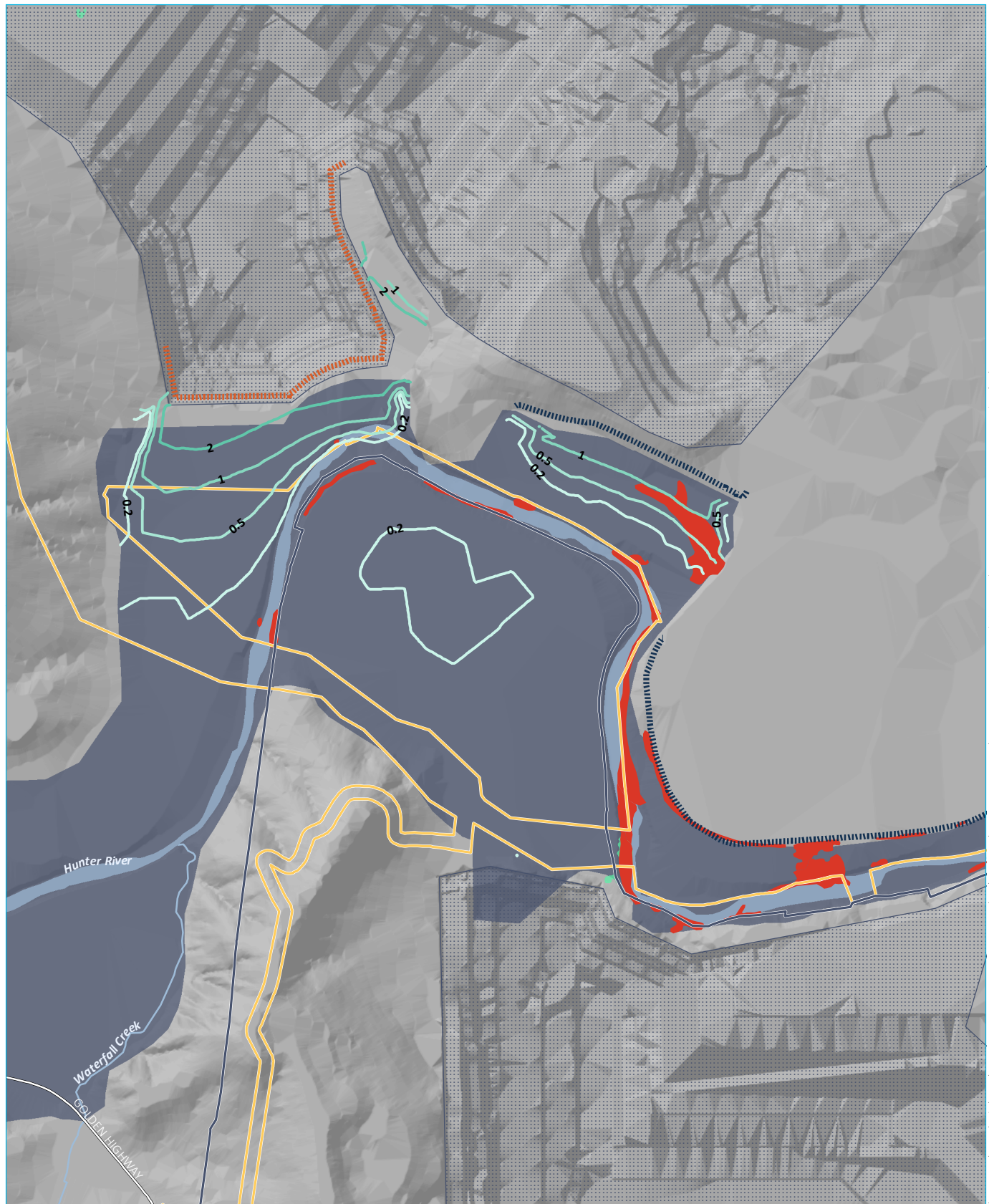
8.2.2 Cumulative drawdown

The predicted cumulative drawdown was calculated by comparing the results of a model scenario of the proposed mine plan (ie the Project) to a baseline scenario where simulated mining ceases after 2009 (which is when the Hunter Unregulated and Alluvial WSP commenced), effectively allowing groundwater levels to recover in this baseline 2009 scenario. Climate stresses in the model domain were simulated. This scenario is therefore conservative and results in exaggerated predictions of groundwater drawdown and changes in surface water-groundwater interaction due to the approved and proposed mining. This represents a limitation in the groundwater modelling and the requirements of the AIP to estimate cumulative drawdown effects “post-WSP”.

Figure 8.2 and Figure 8.3 show the maximum cumulative drawdown predicted to occur within the Hunter River alluvium and the Wollombi Brook alluvium over the operational life of the Project (ie until 2050). The figures show the maximum drawdown predicted to occur due to the cumulative effect of historical approved and proposed mining at the HVO Complex and at other mining operations in the Study area.

The cumulative maximum drawdown predicted in the Hunter River alluvium (during operations) is similar to the predicted incremental drawdown, indicating the majority of the drawdown is attributable to the short-term drawdown prior to installation of the Carrington West Wing barrier wall.

In the Wollombi Brook alluvium, a peak cumulative drawdown of up to 5 m is predicted in the area above the historical Lemington underground mine (Figure 8.3). Drawdown is predicted due to the simulated continued extraction of groundwater from the Lemington Underground bore for operational water use, continuing the downward vertical gradient between the Permian groundwater systems and the Wollombi Brook alluvium. The coal seams intersected by Lemington Underground subcrop under parts of the Wollombi Brook creating minor cumulative drawdown slightly further downstream towards the confluence with the Hunter River. The drawdown is a cumulative impact and not due to the Project.



Source: EMM (2022); Umwelt (2022); AGE (2022); HVO (2022); DFSI (2017)

KEY

- HVO North proposed development consent boundary
- HVO South proposed development consent boundary
- Proposed mining area
- Alluvial extent
- Carrington West Wing barrier wall
- Existing low permeability barrier wall

Maximum cumulative drawdown during operations contour (m)

- 0.2
- 0.5
- 1
- 2

Vegetation community

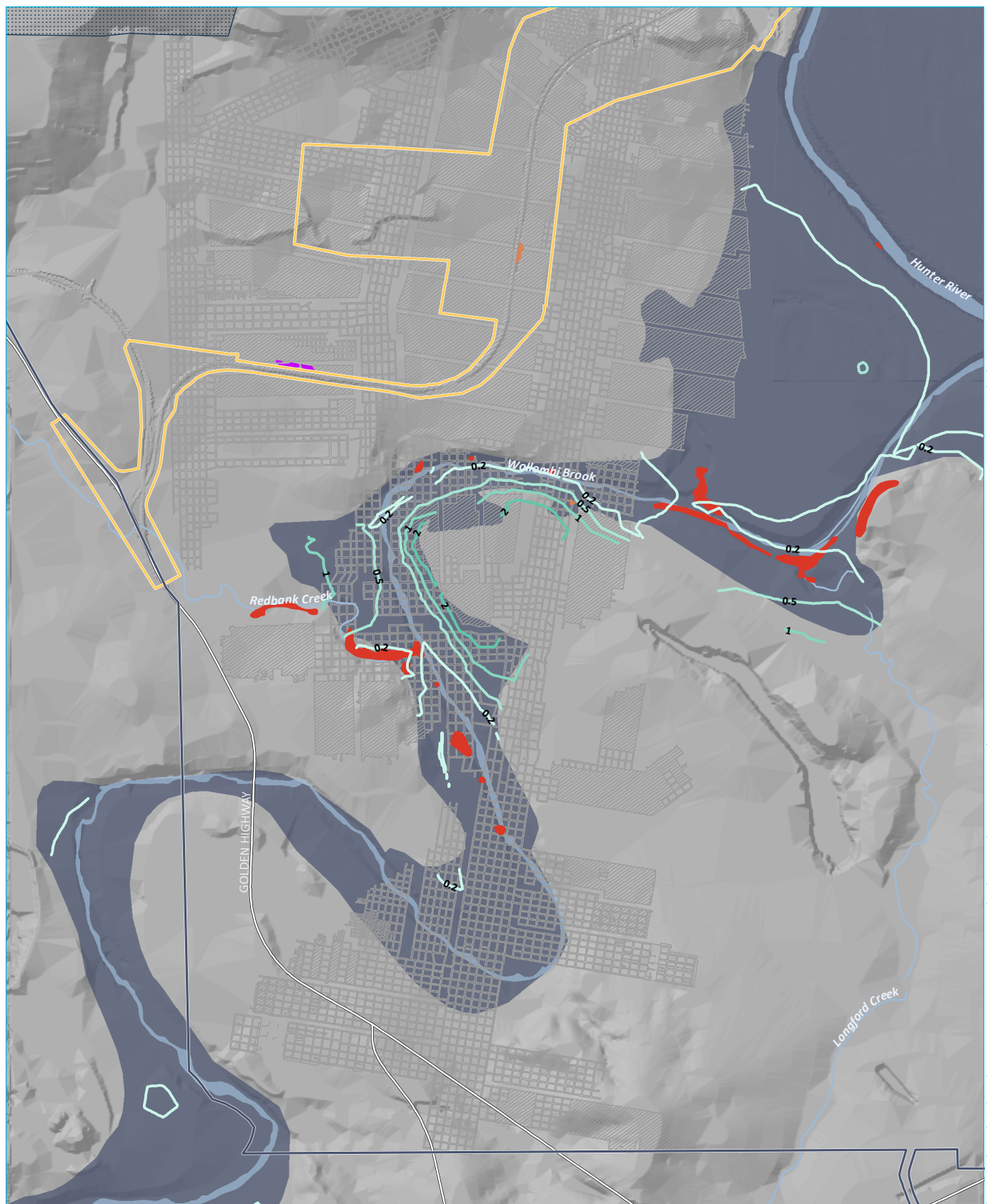
- Hunter Floodplain Red Gum Woodland EEC (Umwelt, 2022)
- River Red Gum (HVO, 2020)

Existing environment

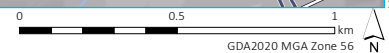
- Major road
- Named watercourse
- Named waterbody

Hunter River alluvium
- maximum cumulative
drawdown during operations

HVO Continuation Project
Water Assessment
Figure 8.2



Source: EMM (2022); Umwelt (2022); AGE (2022); HVO (2022); DFSI (2017)



KEY

- HVO North proposed development consent boundary
- HVO South proposed development consent boundary
- Proposed mining area
- Alluvial extent
- Lemington Underground mine plan
- Existing environment
- Major road
- Named watercourse

- PCT 42 | River Red Gum (HVO, 2020)
- Vegetation community (Umwelt, 2022)
- PCT 42 | River Red Gum/ River Oak Riparian Woodland
- PCT 1692 | Bull Oak Grassy Woodland of the Central Hunter Valley
- Maximum cumulative drawdown during operations contour (m)
- 0.2
- 0.5
- 1
- 2

**Wollombi Brook alluvium
- maximum cumulative
drawdown during operations**

HVO Continuation Project
Water Assessment
Figure 8.3

8.2.3 Predictive uncertainty analysis results

AGE (2022) processed the outputs from the predictive uncertainty analysis in accordance with the risk-based language proposed in Middlemis & Peeters (2018). The ranges adopted are shown in Table 8.1.

The ranges include outputs from all model runs that are deemed to be within an acceptable calibration. There may be one outlier model run within the dataset that produces the extremities of the ranges on the figures.

Figure 8.4 show the likelihood of the maximum cumulative drawdown at any time during mining exceeding 2 m within the Hunter River alluvium. In the figure, the language used for the description of uncertainty detailed in Table 8.1 is used.

Table 8.1 Predictive uncertainty analysis results discussion terminology

Narrative descriptor	Probability class	Description	Colour code
Very likely	90–100 %	Likely to occur even in extreme conditions	
Likely	67–90 %	Expected to occur in normal conditions	
About as likely as not	33–67 %	About an equal chance of occurring as not	
Unlikely	10–33 %	Not expected to occur in normal conditions	
Very unlikely	0–10 %	Not likely to occur even in extreme conditions	

Source: AGE (2022)

Figure 8.4 shows that in the Hunter River alluvium, the area where the cumulative drawdown is likely to exceed 2 m is limited to the immediate vicinity of the HVO North Carrington West Wing mining area in the western arm of the paleochannel, with an extension of up to 150 m from the pit. The area classified ‘about as likely as not’ extends up to 200 m from the pit shell, and beyond that the likelihood of more than 2 m of drawdown is ‘unlikely’ to ‘very unlikely’. This is because the loss of alluvial groundwater to the pit and depressurised underlying Permian units is less than the recharge rate from the Hunter River and rainfall infiltration to the alluvial groundwater system across the majority of the model runs. Figure 8.4 also shows it is very unlikely that there will be more than 2 m cumulative drawdown in the Carrington Billabong area.

The results of the uncertainty analysis provide confidence in the base model predictions presented in Section 8.2.1 and 8.2.2.

Further discussion on the uncertainty analysis is provided in Appendix A.

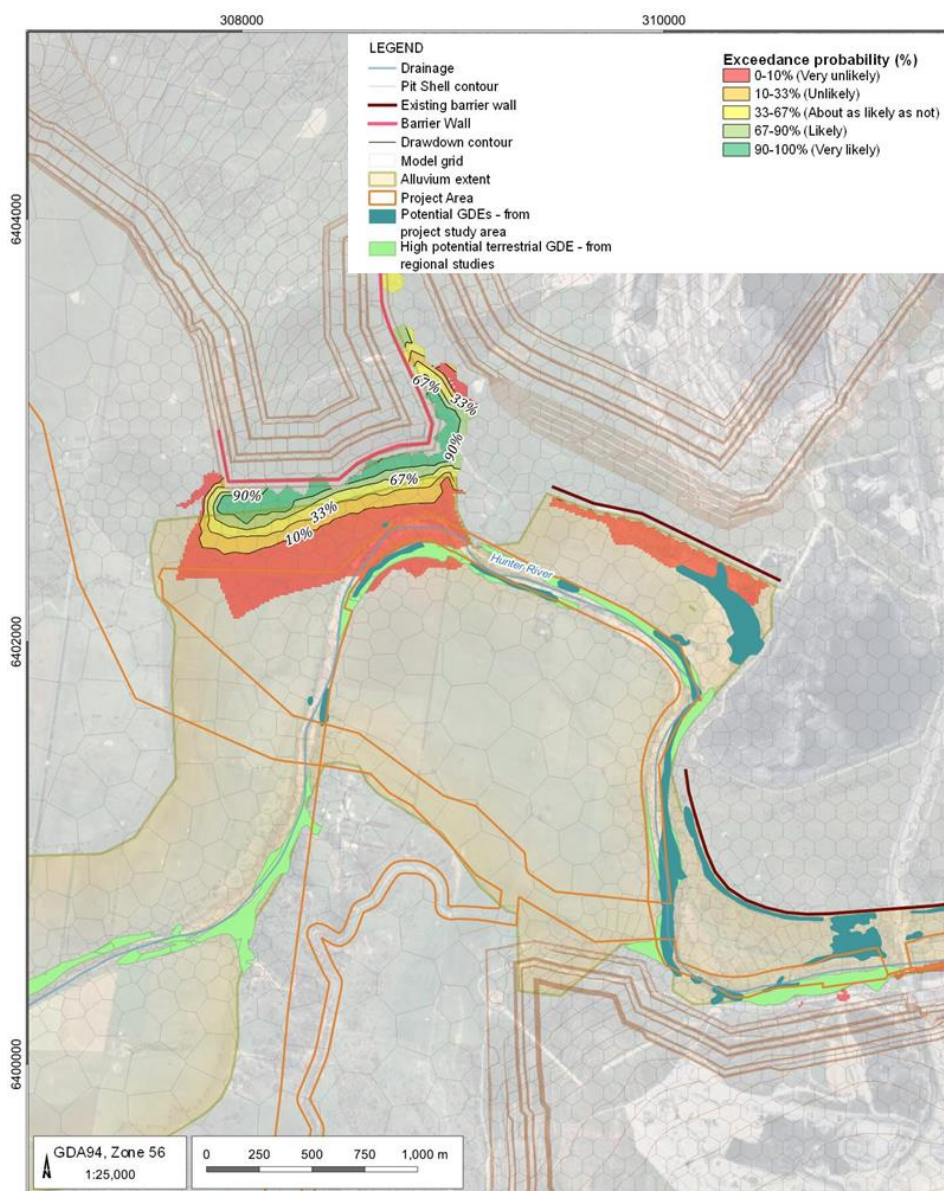


Figure 8.4 Cumulative Hunter River alluvial drawdown – likelihood of 2 m drawdown extent (AGE 2022)

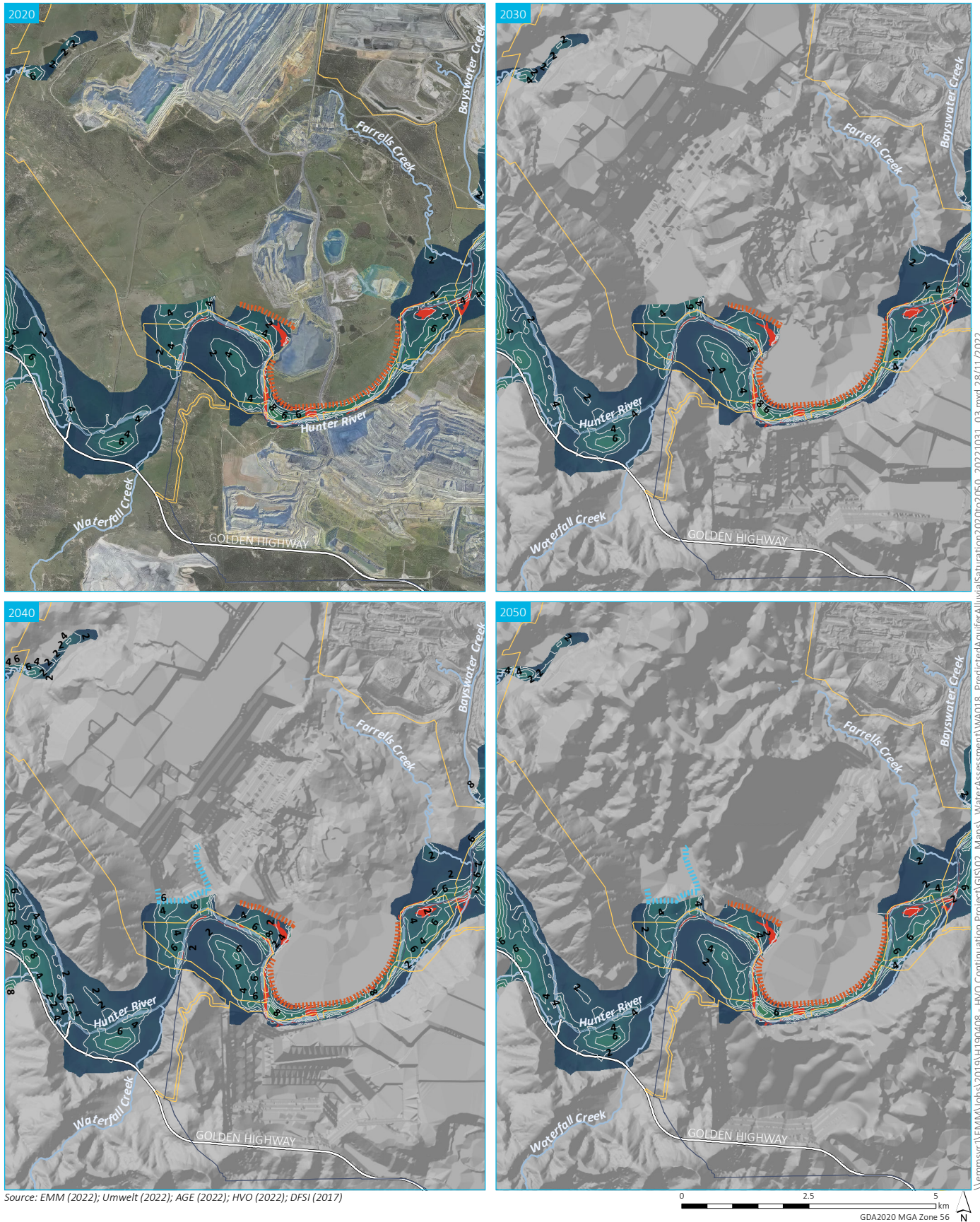
8.3 Saturated thickness changes

Despite the minor drawdown predicted in the Hunter River alluvium as a result of the Project, the alluvium will remain saturated due to leakage of surface water through the bed of the Hunter River.

The predicted saturated thickness within the alluvial aquifer over the operating life of the Project is presented on Figure 8.5 for years 2020 (ie saturated thickness at the end of the calibration), 2030, 2040 and 2050 (ie at the planned end of mining). The figure shows:

- minimal change to the saturated thickness during operations;
- the extent of saturation remains unchanged;
- the aquifer is not dewatered during the Project; and
- the change in saturated thickness at identified receptors is minor.

The potential impact of the Project on water dependent assets is discussed in Section 9.



KEY

- HVO North proposed development consent boundary
- HVO South proposed development consent boundary
- Existing low permeability barrier wall
- Carrington West Wing barrier wall
- Predicted aquifer alluvial saturation contour (m)
- Existing environment
- Major road
- Named watercourse

Vegetation community

- Hunter Floodplain Red Gum Woodland EEC (Umwelt, 2022)
- River Red Gum (HVO, 2020)

Predicted aquifer alluvial saturation (m)

- 38 m
- 0 m

Predicted aquifer alluvial saturation – 2020 to 2050

HVO Continuation Project
Water Assessment
Figure 8.5

8.4 Groundwater inflows

The groundwater model has been used to predict annual volumes of groundwater intercepted by mining and extracted from the Lemington Underground during operations.

The volume is predicted to peak at approximately 2,100 ML/year in Year 18 (approximately 2040). The volume reduces following the installation of the barrier wall and when mining ceases at HVO South in Year 23.

Further discussion is provided in the GIA in Appendix A.

8.5 Groundwater quality

The Project has the potential for groundwater quality changes as a result of:

- exposure of acid sulphate soils;
- seepage from backfilled emplacement areas to the alluvial watertable and Hunter River; and
- production of acid rock drainage.

The Soil and Land Resources Assessment Report (Appendix P to the EIS; Minesoils 2022) assessed the potential risk associated with acid sulphate soils. The Project area does not contain any of the five acid sulphate classes listed on the NSW Acid Sulphate Soil Planning Map. Based on the land elevation and distance from the coast, in conjunction with existing mapping for NSW, the potential for acid sulphate soils is considered a very low risk. Further, there is no evidence of acid sulphate soils indicators such as soil gleying, odour, marine sediments and organic materials recorded as part of the soils survey. As such, acid sulphate soils are not considered further in this report.

The potential for seepage from mining areas backfilled with dry overburden and interburden material to the alluvial watertable and Hunter River has been considered as part of the GIA and in this report using outcomes from the groundwater model, site observations and geochemical characteristics reported by EGi (2022).

The potential for production of acid rock drainage and metalloid leachate during operations has been considered as part of the geochemistry assessment (Appendix C).

i Acid rock drainage

The potential for acid rock drainage or metal leachate is low as the geochemical assessment for the Project (Appendix C) indicates the majority of rejects generated by the Project are likely to be NAF. Although 15% of the rejects samples tested were PAF, the thorough intermingling of rejects and overburden, and the excess acid neutralising capacity in the overburden, suggests that these bulk fill zones are unlikely to result in any significant acid rock drainage issues or effects on rehabilitation.

Waste material (overburden and interburden) will continue to be managed in accordance with current site management practices, including:

- isolation of acid rock drainage potential and saline waste through:
 - placement of PAF and saline material far from the Hunter River;
 - encapsulation of PAF waste within low permeability NAF cell; and
 - blending of NAF and PAF overburden;
- avoiding placement of PAF close to the surface to prevent leachate runoff; and

- seepage collection drainage and diversion drains.

These practices are effective, as observed in the surface water quality monitoring data, where water quality within the mine water system is generally neutral to alkaline, and salinity up to 5,170 mg/L TDS.

8.5.2 HVO South

There is no proposed change to waste management at HVO South from the existing approved operation. Therefore, the proposed operations at HVO South will have negligible impact on groundwater quality, including the beneficial use of groundwater.

The final pit floors for the Cheshunt and Riverview Pits are expected to terminate at the base of the Bayswater Seam, which will potentially expose pyritic Archerfield Sandstone. The implications of this on pit water quality was assessed in more detail with water quality modelling (EGi 2022b), and overall is expected to have no significant impact on water quality. Water quality monitoring of water pumped from active mine areas will be conducted during operations if this mine water is pumped out as part of the WMS.

8.5.3 HVO North

The residual activity that has the potential to impact groundwater quality in the alluvium or water quality in the Hunter River is the potential for seepage from mining areas backfilled with overburden and interburden material.

i Backfilling in the Carrington West Wing area

In contrast to the existing approved operation at HVO North, mining for the Project will occur as one main pit, advancing in a south-east direction towards the ultimate final void location in the current Carrington Pit area.

As discussed in the EIS and consistent with the current approved operations, the mine plan involves progressively backfilling of mined areas with overburden and interburden waste material, followed by progressive rehabilitation.

During mining, the floor of the main pit will be deep and intercepted groundwater will be actively managed as part of the mine water system. This will result in depressurisation of the Permian strata and development of a steep hydraulic gradient towards the pit area. Therefore, the active mining area will be a groundwater sink.

Prior to backfilling the mined area in the Carrington West Wing area, the barrier wall would be constructed on the highwall across the alluvium (and keyed into the Permian). As discussed in Section 2.2.3ii, this approach is consistent with the Carrington Pit barrier wall on the eastern arm of the paleochannel. In addition, constructing the barrier wall prior to backfilling would have the same outcomes, in regards to potential for seepage from backfilled areas, as the current approved operations (where condition 23 of the HVO North development consent states the barrier wall should be constructed prior to mining resuming within 100 m of the remnant paleochannel alluvium).

Groundwater monitoring shows that groundwater levels in the rehabilitated Alluvial Lands area are lower than the Hunter River alluvium (refer to Appendix A), supporting the conceptual understanding and modelling results that the potential for the watertable in the backfilled Carrington West Wing area to rise to a similar or higher elevation than the alluvium is unlikely. Therefore the potential for seepage to migrate towards the Hunter River alluvium is negligible.

Therefore, the Project, through the proposed mitigation measures, is predicted to have a negligible impact on groundwater quality in the HVO North area, including potential to alter the beneficial use of groundwater.

9 Potential impacts on water dependent ecosystems

9.1 Groundwater dependent vegetation

River red gum communities and Bull Oak Grassy Woodland of the Central Hunter Valley mapped by Umwelt (2022) are considered opportunistic users of alluvial groundwater. In addition, river red gums rely on river flooding for germination.

Groundwater modelling predicts minor incremental drawdown in the Hunter River alluvium near the riparian river red gum sites, however, drawdown will be less than 0.5 m and no widespread dewatering will occur. Potential drawdown of the alluvial watertable is buffered by the leakage from the Hunter River, which has controlled flow through releases from Glenbawn Dam.

During periods of drawdown, river red gums and Bull Oak Grassy Woodland of the Central Hunter Valley vegetation will continue to have access to shallow alluvial groundwater. In addition, the Project is predicted to have a negligible impact on Hunter River flow and flooding regime. Therefore, river red gum communities will continue to rely on flooding for germination.

The river red gum community of the Hunter Valley is considered a threatened population under the BC Act, but at HVO it is highly disturbed so is classified as having a moderate ecological value (using the GDE Assessment Guidelines). Under the GDE Risk Matrix, the ecosystem is classified as D (moderate ecological value, low risk; ELA (2022)).

The predicted conservative cumulative alluvial drawdown exceeds the AIP level 1 minimal impact considerations in a small area (refer Table 6.2). However, the aquatic ecology and GDE assessment demonstrates that the variation will not prevent the long-term viability of the ecosystem.

Therefore, no significant impact on groundwater dependent vegetation is expected due to the Project.

9.2 Aquifer ecological communities

There is a good understanding of the stygofauna presence in the Hunter River (and tributary) alluvium due to many years of research and surveys. The Hunter River alluvium in the Project area is a stygofauna habitat and hosts diverse stygofauna communities. As such, it is considered High Ecological Value. However, the stygofauna taxa within the Project area are known to be widespread throughout the Hunter Valley (ELA 2022).

As discussed in Section 8.2.1 and shown on Figure 8.1, the predicted maximum incremental drawdown is predicted for small sections of the Hunter River alluvial aquifer and reaches a maximum of 2 m in the Carrington West Wing area prior to the installation of the barrier wall. This represents a short duration peak drawdown and groundwater levels are predicted to recover following installation of the barrier wall. In addition, the alluvial aquifer is predicted to remain saturated as downward leakage of water through the bed of the Hunter River will maintain aquifer saturation. Therefore, impacts from the Project on stygofauna communities are predicted to be minor.

The western arm of the paleochannel will be mined during the excavation of Carrington West Wing as part of approved operations. This will have an impact on the local stygofauna community in the paleochannel, as they will not be able to migrate out of the impact area prior to excavation. However, this impact is already approved as part of Carrington West Wing extension (HVO North Mod 3, MER 2010).

The risk to the stygofauna community associated with the Project is low because there will be no additional excavation in the alluvium beyond what has already been approved. The cumulative impact to the stygofauna community from already-approved mining in the paleochannel is high and is categorised in the GDE Risk Matrix as C (High Ecological Value, High Risk; ELA (2022)).

The predicted conservative cumulative drawdown impact exceeds the AIP level 1 minimal impact considerations (refer Table 6.2), however, the aquatic ecology and GDE assessment demonstrates that the variation will not prevent the long-term viability of the ecosystem in the Hunter River alluvium in the Project area, outside of the paleochannel area.

9.3 Aquatic ecology

Some species of fish living in the Hunter River require access to estuarine reaches to spawn. Such species of fish could be impacted if river levels reduce to an extent where this migration is impaired for long periods of time. Flow in the Hunter Regulated River is maintained by releases from Glenbawn Dam and inflow from tributaries, rather than from contribution from groundwater. The results of the streamflow analysis (summarised in Section 7.3 and discussed in detail in Appendix B), show minor to negligible change in streamflow and duration of dry days due to the Project.

The findings of the aquatic ecology and GDE assessment (ELA 2022; Appendix M of the EIS) is that there will be no additional impact to aquatic ecology in the Hunter River, and only minor impacts to the aquatic ecology in the Hunter River tributaries due to the Project.

10 Final void assessment

10.1 Introduction

When the final landform is achieved, all operations will be complete, and the disturbance areas will be rehabilitated. As discussed in Section 2.2.4, the final landform will result in a single void at HVO North and a single void at HVO South.

In comparison to the approved operation, the HVO South void will remain largely unchanged; however, the HVO North void is a reduction from three final voids (at West Pit, Mitchell Pit and Carrington Pit) to a single void.

The voids have been designed to remain long-term sinks. As described in the SWIA (Appendix B), drainage systems will be established on rehabilitated overburden emplacement areas, as well as around the perimeter of the final voids to divert upstream catchment runoff away from the final voids and to downstream watercourses. As such, the final landform design minimises capture of surface water and thereby limits long-term impacts on streamflow.

Table 10.1 provides a comparison of the catchment areas of the approved final voids at the HVO Complex and the catchment areas of the proposed (indicative) final voids. It shows the proposed final landform will result in a reduction in catchment area reporting to the final voids, in comparison to the current approved final landform.

Closure options and strategies including the final land use are described in the Mine Closure and Rehabilitation Strategy (Appendix T of the EIS).

Table 10.1 Comparison of approved and proposed (indicative) final void catchment areas

Proposed void	Approved void	Catchment area of approved void (ha)	Catchment area of proposed void (ha)	Change in catchment area (ha)
HVO South	Riverview Pit	1,145 ¹	704	-431
HVO North	West Pit	497 ²	720	-51
	Mitchell Pit	154 ³		
	Carrington Pit	120 ⁴		
	Combined total	771		

Notes:

1. HVO South Mod 5 assessment
2. HVO North West Pit EIS (MER 2003)
3. Calculated (refer Chapter 3 of the EIS)
4. HVO North Mod 3 (Carrington West Wing) (MER 2010)

10.2 Final pit lake recovery

The results of the final void hydrology and salinity modelling base case (ie most likely scenario) are presented for HVO North and HVO South proposed final voids in Figure 10.1 and Figure 10.2, respectively.

The HVO North pit lake level is predicted to reach an equilibrium level of approximately -80 mAHD after 1,000 years, which is approximately 155 m below natural ground surface. At this elevation, the pit lake surface area is approximately 210 ha.

The predicted long-term pit lake level of the proposed HVO North void is approximately 120 m deeper than the predicted pit lake level for the approved Carrington void at HVO North. MER (2010) predicted a long-term pit lake level of around 40 mAHD, which is approximately 20 m below the average Hunter River level (58–60 mAHD). As such, the single proposed void at HVO North will act as a stronger sink than the current approved voids at HVO North.

The HVO South pit lake level is predicted to reach an equilibrium level of approximately -84 mAHD after 900 years, which leaves a freeboard of approximately 160 m. At this elevation, the pit lake surface area is 172 ha. The assessment for HVO South Mod 5 estimated a long-term lake elevation of 30 mAHD and lake surface area of 337 ha. The modelling completed for the Project indicates the HVO South pit lake will be considerably deeper than previously predicted, with the HVO South void predicted to act as a regional sink. The difference in predicted long-term lake levels is likely be due to interaction with the proposed deep HVO North void, reduced catchment area reporting to the HVO South void (in comparison to the current approved landform) and greater evaporative losses from the proposed HVO North void (in comparison to the current approved voids).

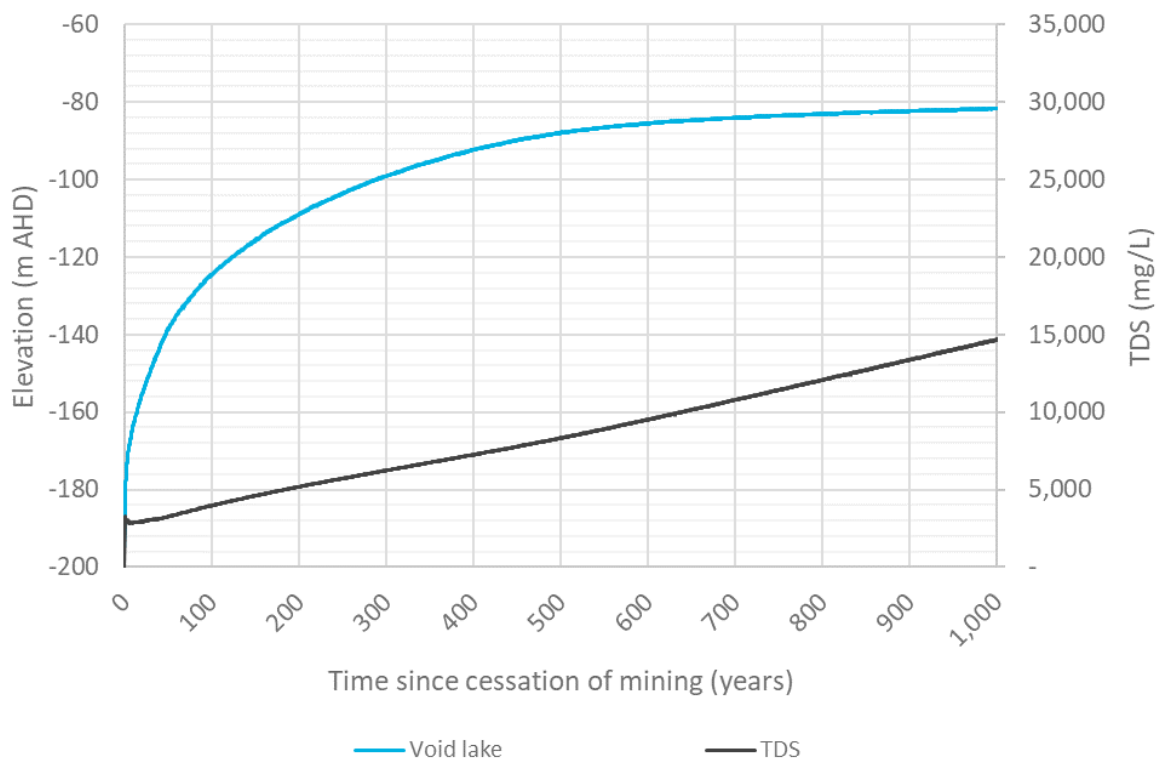


Figure 10.1 HVO North pit lake recovery and salinity (Engeny 2022)

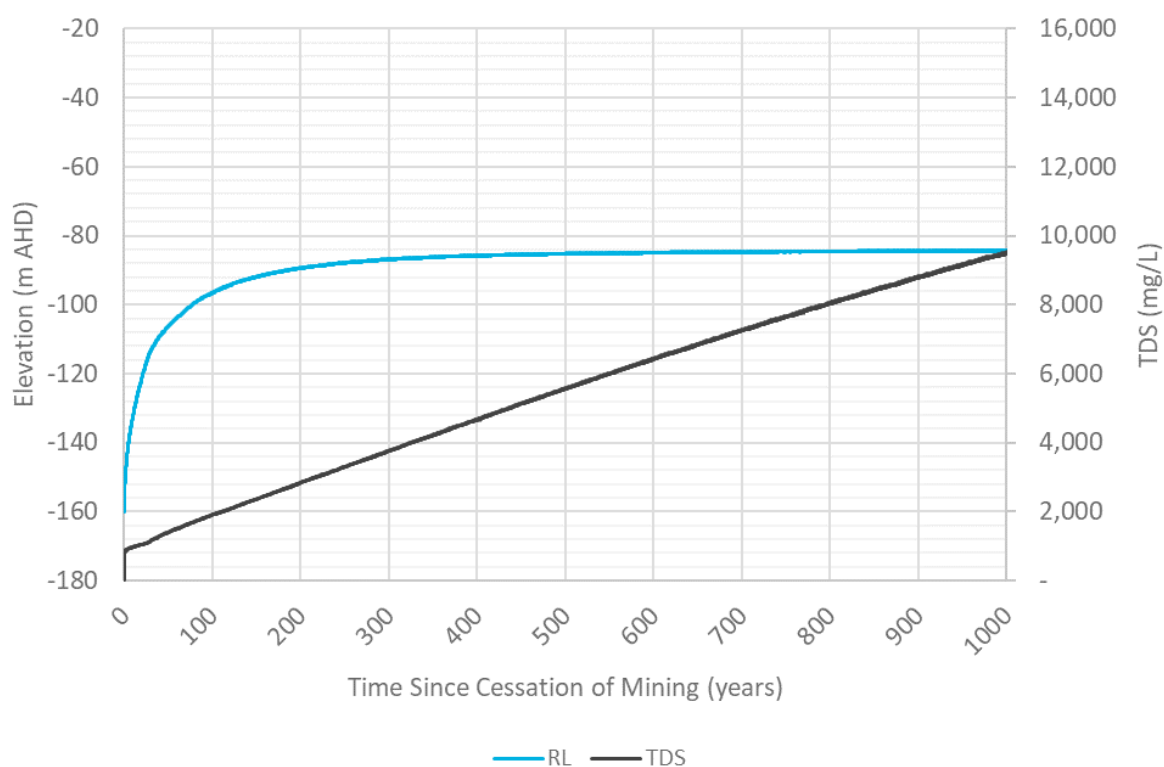


Figure 10.2 HVO South pit lake recovery and salinity (Engeny 2022)

10.3 Post closure groundwater levels and flow direction

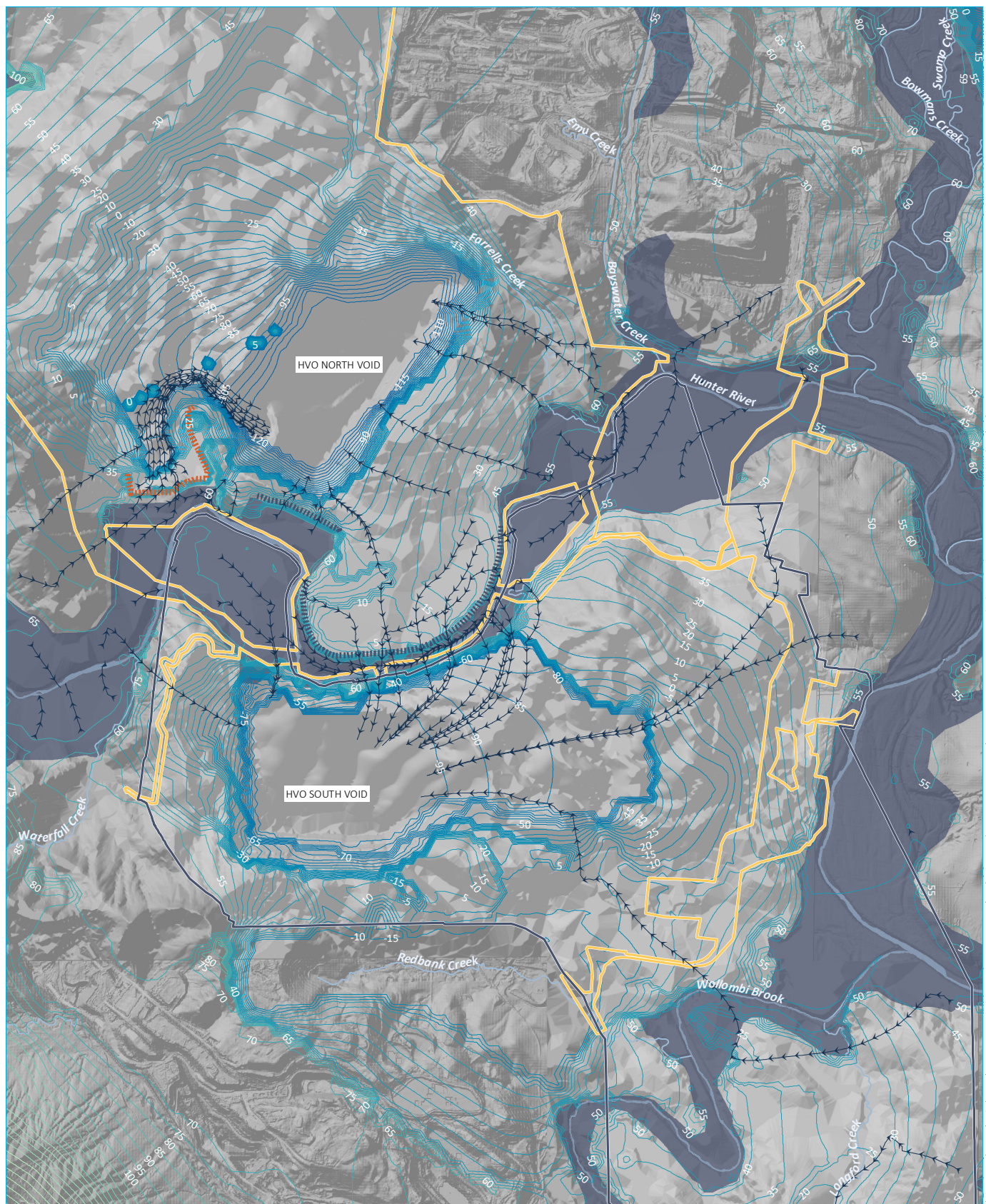
The groundwater model predicted recovery within the groundwater flow regime over a period of 1,000 years, simulating the predicted pit lake recovery predicted by the final void hydrology model (Engeny 2022).

The groundwater model was used to predict groundwater flow movement over time (particle tracking), focusing on:

- watertable recovery and groundwater flow direction in backfilled emplacement areas to evaluate the potential for groundwater to seep from these backfilled areas towards the alluvium and Hunter River; and
- the watertable in the Hunter River alluvium to evaluate groundwater flow direction and interaction with the voids long-term.

The simulated watertable at 100 years after closure and tracking of groundwater flow is presented in Figure 10.3 (noting that the groundwater movement is lateral and vertical).

The groundwater modelling results confirm the conceptual understanding that both final voids will act as regional groundwater sinks, with groundwater flow directions towards the pit lakes. Figure 10.3 shows the HVO South void is predicted to act as a regional groundwater sink.



Source: AGE (2022); EMM (2022); HVO (2022); BoM (2021); DFSI (2017); GA (2011)

KEY

- HVO North proposed development consent boundary
- HVO South proposed development consent boundary
- Alluvial extent
- Carrington West Wing barrier wall
- Existing low permeability barrier wall
- Particle tracking result
- Named watercourse

- Named waterbody
- 2150 predicted watertable (mAHD)
 - < -100
 - -100 to -50
 - -50 to 0
 - 0 to 50

- 50 to 75
- 75 to 100
- 100 to 125
- 125 to 150
- 150 to 200

Post-mining groundwater levels and flow direction (particle tracking)

HVO Continuation Project
Water Assessment
Figure 10.3

10.3.1 Incremental drawdown

The maximum incremental post mining drawdown in the Hunter River alluvium is presented in Appendix A. Post mining maximum incremental drawdown in the Hunter River alluvium is predicted to be less than the incremental drawdown predicted during operations. The cause of the long-term drawdown in the alluvium is due to groundwater pressures in the Permian remaining depressed due to the final voids acting as regional sinks.

10.3.2 Cumulative drawdown

Figure 10.4 shows the conservative maximum cumulative drawdown predicted to occur within the alluvium after closure of the Project.

Cumulative drawdown is predicted to remain in the same areas as during operations but will spread slightly. This is due to the influence of the continuing evaporative pumping effect from the final voids post mining whilst the groundwater regime reaches a new equilibrium.

Post mining, the cumulative drawdown in the Wollombi Brook alluvium is predicted to be the same as during operations (Figure 8.3).

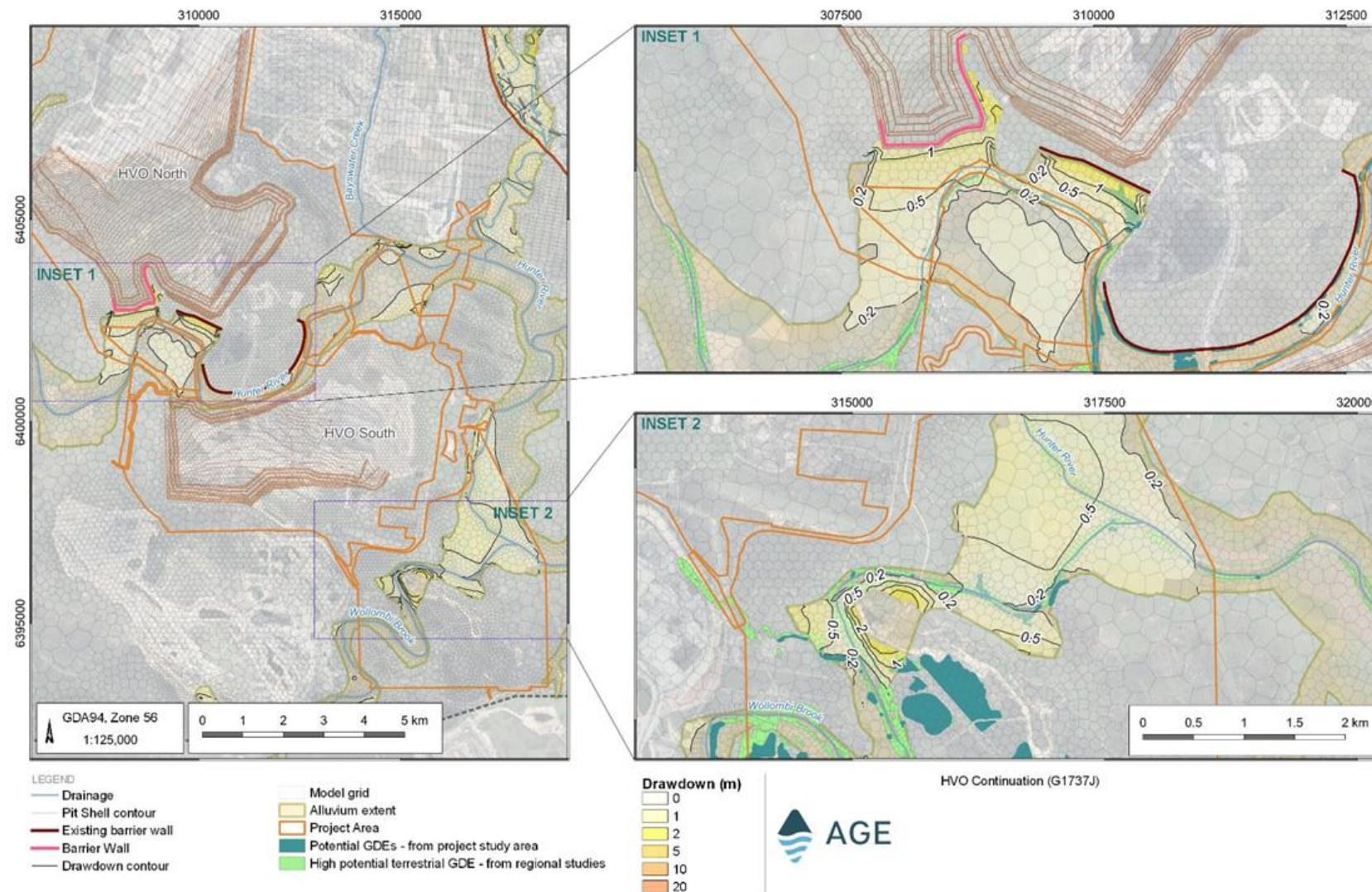


Figure 10.4 Maximum cumulative alluvial drawdown post mining (AGE)

10.4 Potential impacts on water-dependent assets

Due to the significant depth of the final voids, the groundwater flux is predicted to remain into the voids and the lakes will act as a groundwater sink with no risk of overflows to the surface environment.

Given the depth and change from three voids to one void, the HVO North void for the Project will act as a stronger sink than the currently approved Carrington void evaporative sink. In addition, the surface water and groundwater modelling indicate the HVO South void will also act as a stronger evaporative sink than the currently approved HVO South void.

A conceptual cross section (approximately north to south) through the HVO North and South voids is presented in Figure 10.5. It illustrates the outcomes and conceptual understanding discussed in Section 10.2 to 10.4:

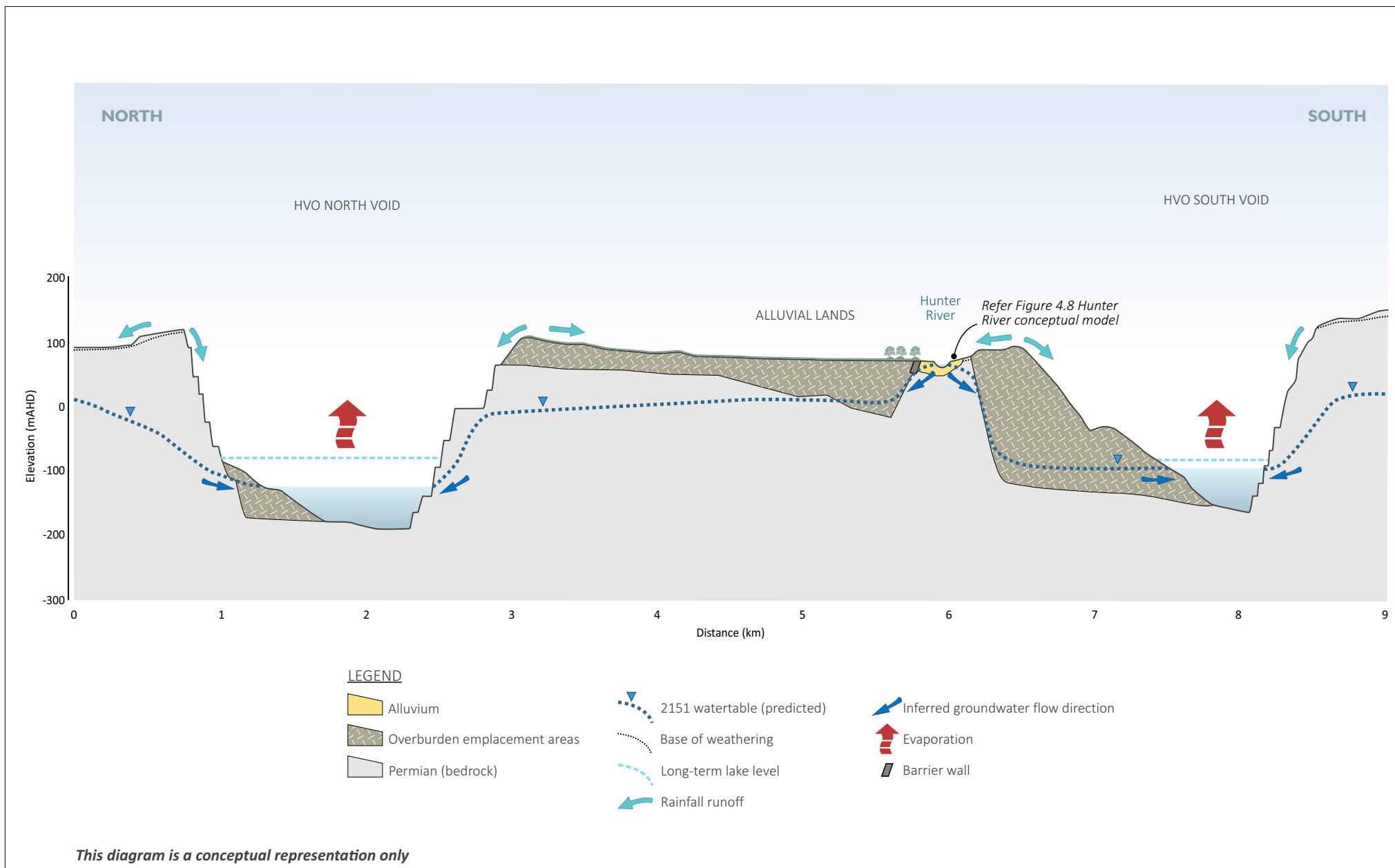
- 100 years after mining ceases, the predicted watertable and pit lake level are depressed, with groundwater flow directions towards the voids;
- the Hunter River alluvium remains saturated due to the strong hydraulic connection with the Hunter River;
- surface water drainage towards from the voids is minimal, to limit the potential long-term impact on streamflow;
- evaporation is the dominant loss from the voids and the voids are predicted to remain groundwater sinks;
- the long-term pit lake level is considerably deeper than the base of the alluvium and the base of weathering, therefore the risk of seepage from the pit lakes to shallow groundwater is negligible; and
- the risk of spill from the pit lakes is negligible.

Consistent with the predicted drawdown during operations, the post mining incremental alluvial drawdown is not predicted to have a significant impact on GDEs or surface water.

River red gums and other riparian vegetation that opportunistically use shallow groundwater will continue to have access to shallow alluvial groundwater. In addition, the Project is predicted to have a negligible impact on Hunter River flow and flooding regime post mining. Therefore, river red gum communities will continue to rely on flooding for germination.

In addition, there are no third-party bores located within the zone of influence and there is negligible risk that groundwater levels at privately-owned bores will be affected by the Project or the proposed final voids.

The surface water, groundwater, aquatic ecology and GDE assessments demonstrate the proposed final voids are not predicted to have a significant impact on water resources and water-dependent assets.



Final voids conceptual diagram
HVO Continuation Project
Water Assessment
Figure 10.5

10.5 Water quality

To meet the Project objectives to balance economic, environmental and social benefits, the landform has been designed to minimise the catchment reporting to the proposed voids. The runoff area contributing to the voids is sufficiently small so that evaporation dominates, and the voids remain as strong long-term groundwater sinks.

Post mining, the pit lake water will concentrate salts and become more saline over time due to evaporative losses. The following summarises the outcomes of the predicted lake chemistry at 1,000 years post closure from the hydrogeochemical pit lake modelling (EGi 2022b):

- the pit lake will be alkaline and brackish;
- at 1,000 years, the salinity (TDS) of the HVO North pit lake is predicted to be approximately 11,000 mg/L, whilst the HVO South pit lake is predicted to be slightly less saline at approximately 6,600 mg/L TDS;
- the dominant soluble salts will be sulphate, chloride and sodium; and
- there could also be slightly elevated concentrations (ie 0.1 to 1 mg/L) of some elements, including aluminium, boron, barium, manganese, nickel, selenium, and zinc, but other environmentally important metals and metalloids are predicted to occur at trace concentrations only.

For comparison purposes, the tolerance level for sheep to salinity in drinking water is up to 10,000 mg/L TDS without loss of production. Sheep can tolerate drinking water salinity up to 13,000 mg/L TDS for short periods or for extended periods if feeding on lush green feed (ANZECC & ARMCANZ 2000).

10.5.1 Potential water quality impacts

The predicted increasing salinity will not pose a risk to highly connected surface water sources, shallow groundwater or associated receptors, as:

- there is negligible risk of spilling from the pit lakes to the surface water environment;
- the pit lake level will remain below the base of the alluvium and base of weathering (Figure 10.5); and
- the voids will remain permanent sinks, creating a hydraulic gradient from the backfilled mine areas towards the void.

The potential for seepage to migrate from backfilled mine areas (such as in the Carrington West Wing area) has been assessed using the groundwater model for the Project (AGE 2022; Appendix A). As described in the EIS and the Mine Closure and Rehabilitation Strategy (Appendix T of the EIS), the conceptual post mining land use for the area will be agriculture (grazing), transitioning to native woodland.

Figure 10.3 shows infiltration of rainfall in the backfilled mine areas will gradually flow towards the pit lakes, as evidenced by the groundwater flow particle tracking completed as part of the GIA (Appendix A). Following consultation with DPE Water, AGE (2022) conducted an additional sensitivity scenario where the hydraulic conductivity and storage properties of the overburden/interburden emplacement material was reduced (within the range of conceptual understanding), and the recharge was increased (in comparison to the base case model). This was conducted to assess the worst-case potential for seepage in the backfilled mine areas to migrate towards the Hunter River and associated alluvium. The modelling is discussed further in Appendix A, however the predicted long-term watertable elevation and groundwater flow direction (shown as particle tracking) is presented on Figure 10.6 (note the particle tracking from the base case model, as presented on Figure 10.3, is also presented for comparison purposes).

The particle tracking included releasing particles within the backfilled areas, north of the existing and proposed barrier walls at HVO North. Figure 10.6 shows the voids remain strong sinks and dominate the groundwater flow direction. Changing the hydraulic properties of the emplacement material results in less of a contrast with the host Permian and the scenario predicts groundwater in the backfilled Carrington West Wing area would move slowly through the unmined Permian material in the CM-CD1 area towards the HVO North void.

Therefore, the risk of seepage from the backfilled mine areas migrating through the existing and proposed barrier walls towards the Hunter River alluvium is negligible. This is the same outcome for the approved Carrington West Wing barrier wall.

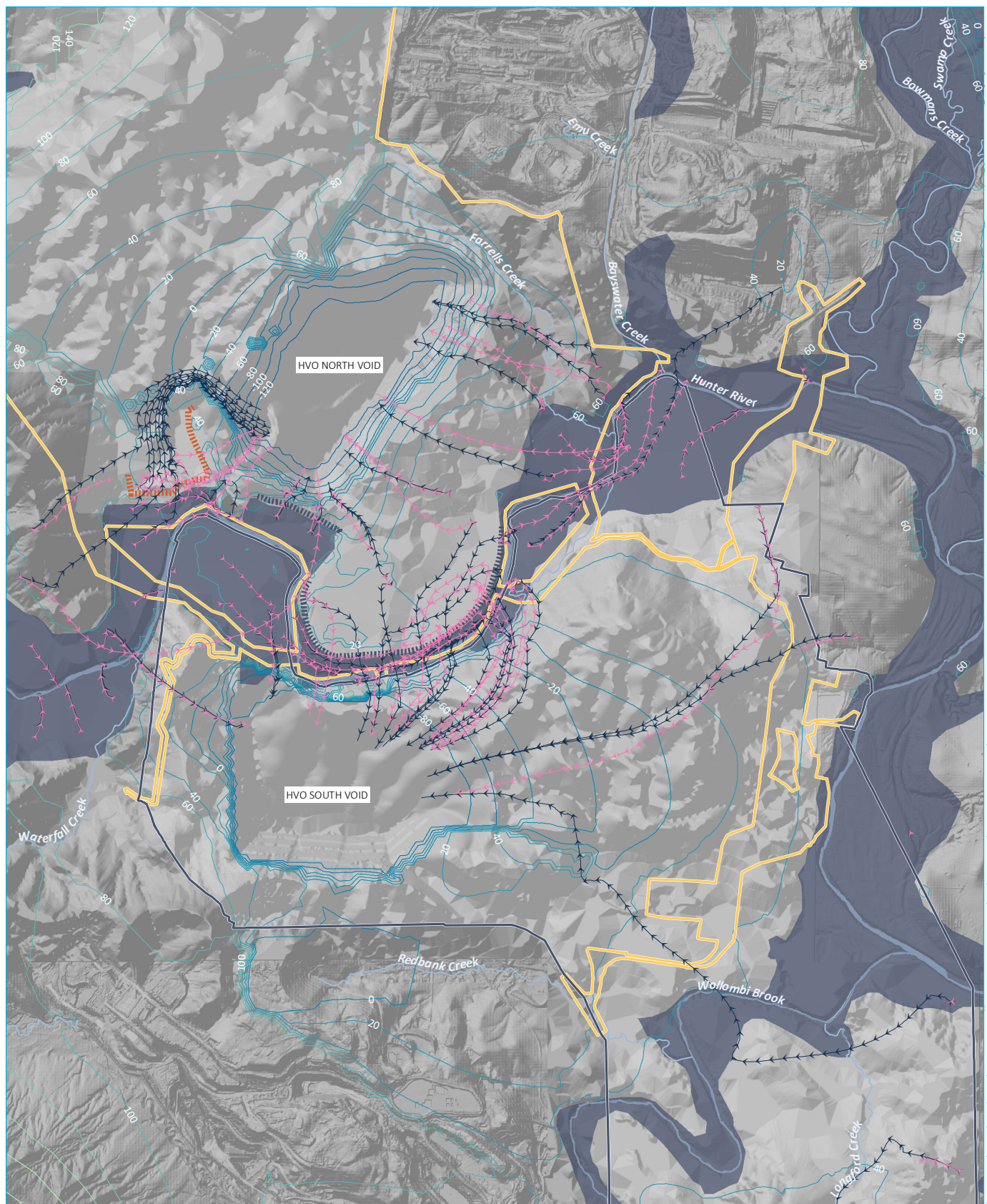
The findings of the surface water and groundwater assessments demonstrate the potential impact of the Project on water quality is insignificant and the Project is not predicted to change to the beneficial use category, or environmental, social and cultural value of the alluvial groundwater or connected surface water sources.

10.6 Climate change

The results of the final void hydrology model climate change scenarios suggest that in all but one of the climate change scenarios, the pit lake levels are predicted to be lower than in the base case and the salinity (TDS) is higher. The exception is the “RCP8.5 Higher” scenario that predicts higher pit lake levels and lower salinity in both final voids. Even in this scenario, the final voids are predicted to remain groundwater sinks and the calculated pit lake level is approximately 70 m below the Hunter River.

A climate change groundwater model scenario was also conducted as part of the GIA (Appendix A), simulating a 15% reduction in recharge. The outcomes of the modelling show little difference in the alluvial drawdown along the Hunter River and Wollombi Brook. Recharge (as leakage) from surface water buffers most of the effects of reduced recharge/enhanced evapotranspiration simulated in the climate change scenario.

Detailed results are provided in the SWIA in Appendix B (Engeny 2022) and the GIA in Appendix A (AGE 2022).



Source: AGE (2022); EMM (2022); HVO (2022); BoM (2021); DFSI (2017); GA (2011)

KEY

- | | |
|--|--|
| HVO North proposed development consent boundary | 2150 predicted watertable (mAHd) - sensitivity model |
| HVO South proposed development consent boundary | — < -100 |
| Alluvial extent | — -100 to -50 |
| Carrington West Wing barrier wall | — -50 to 0 |
| Existing low permeability barrier wall | — 0 to 50 |
| ➔ Particle flow path (base case) | — 50 to 75 |
| ➔ Particle flow path (sensitivity) | — 75 to 100 |
| — Named watercourse | — 100 to 125 |
| Named waterbody | — 125 to 150 |
| | — 150 to 200 |

Groundwater model sensitivity - post-mining watertable and groundwater flow direction

HVO Continuation Project
Water Assessment
Figure 10.6

11 Water licensing

11.1 NSW water legislation and policies for licensing water take

11.1.1 Overview

HVO is required to license surface water and groundwater take in accordance with the WM Act, AIP and the relevant statutory WSPs. This includes water taken for use as well as water intercepted and managed as a result of mining activities (including runoff and groundwater inflows to pits), unless exempt under the *Water Management (General) Regulation 2018* (WM Regulation) or the EP&A Act. Sufficient entitlement must be held to account for the peak water take from each water source (directly or indirectly), prior to the take occurring.

The WM Act requires water users or landholders to hold:

- a WAL to take water from a river, lake, dam or groundwater for irrigation, industrial, or commercial purposes;
- a water supply work approval to construct and use a water supply work, such as a pump, dam, channel or bore;
- a water use approval for a specific purpose at a particular location;
- a flood work approval for works on floodplain that divert floodwaters; and
- a controlled activity approval to carry out work in a watercourse or within 40 m of the bank of a river, lake or estuary, such as extracting material from a river bed, constructing a creek crossing or residential developments.

Under Clause 4.41(1)(g) of the EP&A Act, SSD projects are exempt from requiring:

- a water use approval under Section 89 of the WM Act;
- a water management work approval under Section 90 of the WM Act; or
- an activity approval (other than an aquifer interference approval) under Section 91 of the WM Act.

As the Project is an SSD, there is no requirement to obtain approvals under the WM Act.

In accordance with the AIP, HVO is required to hold licences both the direct and indirect take from adjacent and overlying water sources. Water can be taken indirectly when an aquifer interference activity causes water to flow from another connected groundwater or surface water source. Flows induced from other water sources also constitute take of water.

11.1.2 Harvestable rights

Owners or occupiers of a landholding are entitled to collect a proportion of the runoff from their property in one or more dams located on a minor or unmapped stream and use the water without the need for a licence or approval under the WM Act. Landholders may capture, store and use up to 10% of the average regional runoff for their property. The total capacity of all dams on a property allowed under the harvestable right is called the maximum harvestable right dam capacity (MHRDC). An MHRDC calculator is available on the WaterNSW website, which considers location, rainfall and variations in rainfall patterns.

Using the MHRDC calculator, the HVO JV harvestable right dam capacity for its contiguous landholdings³ of 13,343 hectares (ha) is 935 ML.

11.2 Approach to licensing

HVO is required to hold licences for the following water take under the WM Act (and in accordance with the AIP):

- groundwater inflows to mining areas (this volume may be sourced from a combination of groundwater sources and surface water sources);
- reduction in baseflow to watercourses due to watertable drawdown (as the source is groundwater, this is a groundwater take);
- increase in surface water leakage to groundwater due to watertable drawdown (as the source is surface water, this is surface water take);
- catchment runoff captured by the WMS, unless exempt under the WM Regulation (surface water take); and
- water supply for operational requirements (pumping from the Hunter Regulated River Water Source).

Table 11.1 lists the water requirements relevant to the Project by water source and the approach used to estimate the take. For example, groundwater inflow to mining areas is calculated using the groundwater model (AGE 2022) and water supply requirements from the Hunter Regulated River is calculated by the water balance model developed by Engeny (2022).

Due to the integrated nature of the WMS for the HVO Complex, it is not practically possible to separate out licensing requirement for HVO North and HVO South individually. As such, the water licensing requirements for the Project overall (HVO North and South) are presented in the following sections.

HVO holds multiple work approvals and WALs for the HVO Complex. To reduce the administrative demand on the JV and NSW Government, and following approval of the Project, HVO proposes to consolidate WALs and consolidate works into a Miscellaneous Work approval each for HVO South and HVO North.

³ Contiguous landholdings is defined in WM Act, where *two or more parcels that together form a single area of land (ignoring any division that arises merely because the land is transected by a road or river)*

Table 11.1 Summary of HVO water licensing requirements by water source and method used to estimate take

Water sharing plan	Relevant water source	Relevant management zone	Groundwater inflows to pit(s)	Reductions in baseflow due to watertable drawdown	Increase in river leakage due to watertable drawdown	Captured catchment runoff	Additional water supply
Hunter Regulated River Water Source 2016	Hunter Regulated River Water Source	Zone 1B (from Glenbawn Dam to Goulburn River Junction)	Groundwater model (AGE 2022)	Groundwater model (AGE 2022)	Groundwater model (AGE 2022)	Not applicable	Water balance model (Engeny 2022)
		Zone 2A (from Glennies Creek junction to Wollombi Brook junction)	Groundwater model (AGE 2022)	Groundwater model (AGE 2022)	Groundwater model (AGE 2022)	Not applicable	Water balance model (Engeny 2022)
		Zone 2B (from Wollombi Brook junction to Oakhampton rail bridge)	Groundwater model (AGE 2022)	Groundwater model (AGE 2022)	Groundwater model (AGE 2022)	Not applicable	Not applicable
Hunter Unregulated and Alluvial Water Sources 2022	Hunter Regulated River Alluvial Water Source	Upstream Glennies Creek	Groundwater model (AGE 2022)	Not applicable	Not applicable	Not applicable	Not applicable
		Downstream Glennies Creek	Groundwater model (AGE 2022)	Not applicable	Not applicable	Not applicable	Not applicable
		Glennies Creek	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
	Jerrys Water Source	Jerrys	Groundwater model (AGE 2022)	Groundwater model (AGE 2022)	Groundwater model (AGE 2022)	Water balance model (Engeny 2022)	Not applicable
	Lower Wollombi Brook Water Source		Groundwater model (AGE 2022)	Groundwater model (AGE 2022)	Groundwater model (AGE 2022)	Not applicable	Not applicable
	Singleton Water Source		Groundwater model (AGE 2022)	Groundwater model (AGE 2022)	Groundwater model (AGE 2022)	Water balance model (Engeny 2022)	Not applicable

Table 11.1 **Summary of HVO water licensing requirements by water source and method used to estimate take**

Water sharing plan	Relevant water source	Relevant management zone	Groundwater inflows to pit(s)	Reductions in baseflow due to watertable drawdown	Increase in river leakage due to watertable drawdown	Captured catchment runoff	Additional water supply
North Coast Fractured and Porous Rock Groundwater Sources 2016	Sydney Basin-North Coast Groundwater Source		Groundwater model (AGE 2022)	Not applicable	Not applicable	Not applicable	Not applicable

11.3 Water licensing strategy

11.3.1 During operations

i Surface water take

a Hunter Regulated River Water Source

Figure 11.1 presents the Project's predicted surface water licensing requirements from the Hunter Regulated River Water Source (Zones 1B and 2A). Licensing of water take from this source is required to meet Project water demands, and to account for an increase in leakage from the Hunter River resulting from groundwater drawdown.

As discussed in Section 7.2, the water balance model assumes extraction from the Hunter River using high security entitlements held for the HVO Complex. The results presented in Figure 11.1 represent the predicted demand in a median rainfall year. The licensing requirement for the Hunter Regulated River peaks in Year 21 (approximately 2043) at 4,424 ML/year, which is below the current high security entitlement held by HVO (4,689 high security entitlement shares). In very dry years, where the Project will have greater demand from the Hunter Regulated River, additional water will be extracted under the remaining high security entitlement or existing general security entitlement (HVO holds 6,637 general security entitlement shares in Zone 1B and 2A).

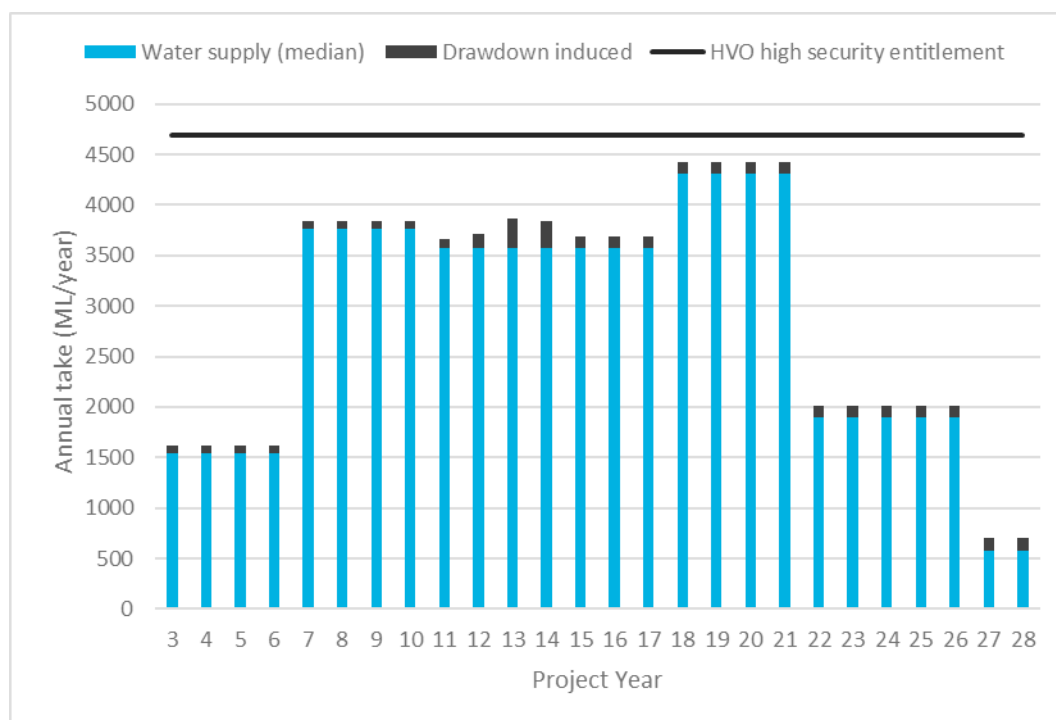


Figure 11.1 Surface water take from Hunter Regulated River Water Source (high security)

b Hunter Unregulated River Water Sources

The integrated WMS includes storages located on non-minor and minor streams, and storages located off stream. Where storages are located on minor streams (as defined by the WM Regulation spatial data) and capture water to prevent contamination of a water source, they are considered excluded works under Schedule 1, item 3 of the WM Regulation and so the take is exempt. Other storages located on minor streams in the Project WMS can be accounted for within HVO's available harvestable right volume.

The WM Act requires all water take from non-minor streams to be licensed. Therefore, the catchment runoff captured by storages (existing and proposed) in the Project WMS has been calculated.

Table 11.2 lists the storages that are (or will be) located on streams classified as non-minor streams under the current WM Regulation hydroline dataset. However, many storages have been in place prior to the commencement of the WM Act provisions, for example Lake James (Dam 15S) was in place prior to 1984 and Parnells Dam (Dam 9W) was constructed in approximately 1993.

To meet the objectives of the WMP, which includes minimising impacts to the environment, the WMS includes clean water diversions around storages (where practical) limiting the collection of catchment runoff in these structures. Existing (and some proposed) diversions have been approved under previous modifications to development consents and the WMP.

Consistent with DPE Water's advice to the NSW Mineral's Council, HVO is of the view the WM Regulation hydroline dataset should be updated to reflect these authorised diversions. If this is the case, then many of the storages listed in Table 11.2 would be located on minor streams or not on a river at all. Notwithstanding this, EMM has estimated the surface water licensing requirements in the various water sources, based on the current WM Regulation hydroline dataset.

Table 11.2 **Project WMS – storages on non-minor streams**

Dam name	Existing or future	Water source
Lake James (Dam 15S)	Existing	Singleton Water Source
Dam 14W	Existing	Jerrys Water Source and Management Zone
Parnells Dam (Dam 9W)	Existing	
Dam 18W	Existing	
Dam 21W	Existing	
Dam 16W	Existing	
Dam 35S	Existing	
Dam 28W	Existing	
DP3N	Future	
DP10N	Future	
DP11N	Future	
DP14N	Future	

Figure 11.2 presents the predicted surface water licensing requirements for the Jerrys Water Source (Jerrys Management Zone), as managed under the Hunter Unregulated River and Alluvial WSP. Water take from this source includes capture of runoff by storages located on non-minor watercourses within the Project WMS.

The peak licensing requirement is 558 ML/year (median rainfall year) between Year 22 to 28 (approximately 2044 to 2050), which is below the existing entitlement held by HVO (705 unregulated river entitlement shares). During wetter periods, HVO would use the remainder of the entitlement and/or access additional entitlement on the open market (eg temporary trade). As shown in Table 3.4, the total unregulated river entitlements held in the Jerrys management zone is 2,044, leaving 1,339 entitlements available for trade.

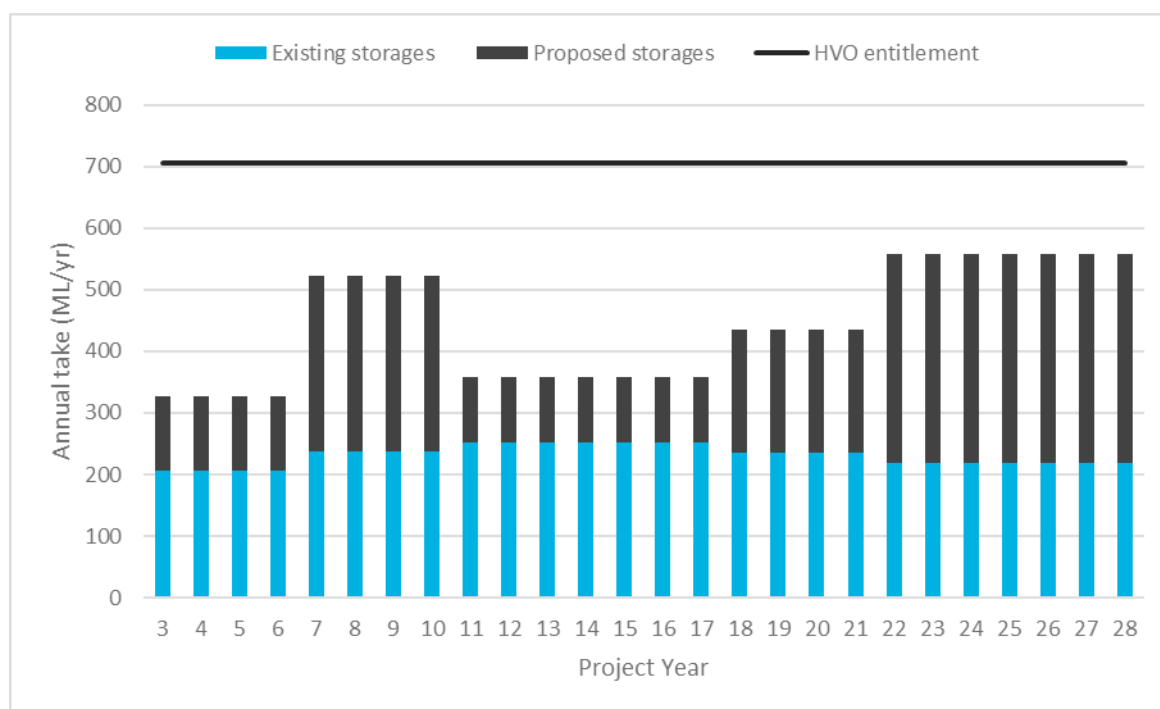


Figure 11.2 Surface water take (median) from the Jerrys Water Source (Hunter Unregulated River) associated with the WMS

Figure 11.3 presents the predicted surface water licensing requirements for the Singleton Water Source, managed under the Hunter Unregulated River and Alluvial WSP. Water take from this source includes capture of minor clean water runoff to Lake James (Dam 15S), which is located on a small non-minor watercourse. Lake James has been in place at HVO South since 1984 (possibly earlier). The purpose of Lake James (Dam 15S) is to store water intercepted during mining and/or provide storage of excess water collected in the WMS during wet conditions that can be discharged to the Hunter River under EPL 640 as part of the HRSTS. The storage has been designed to the practical minimum and the purpose is not to capture and use catchment runoff.

The peak licensing requirement is 9 ML/year (median rainfall year) from Year 11 to 28. HVO does not hold entitlement in this water source. This water storage was legally in place prior to the commencement of the Hunter Unregulated River and Alluvial WSP in 2009 and therefore the application of the WM Act. Its associated take should have been licensed by Government on transition to the WM Act. In addition, as mentioned above, HVO is of the view the hydroline spatial dataset should be updated to reflect the authorised diversion(s). On this basis, HVO will either seek an exemption from the requirement to hold entitlement for this take, or seek a licence from Government for this legitimate legacy take.

There is no predicted surface water take from the Lower Wollombi Brook Water Source due to the Project.

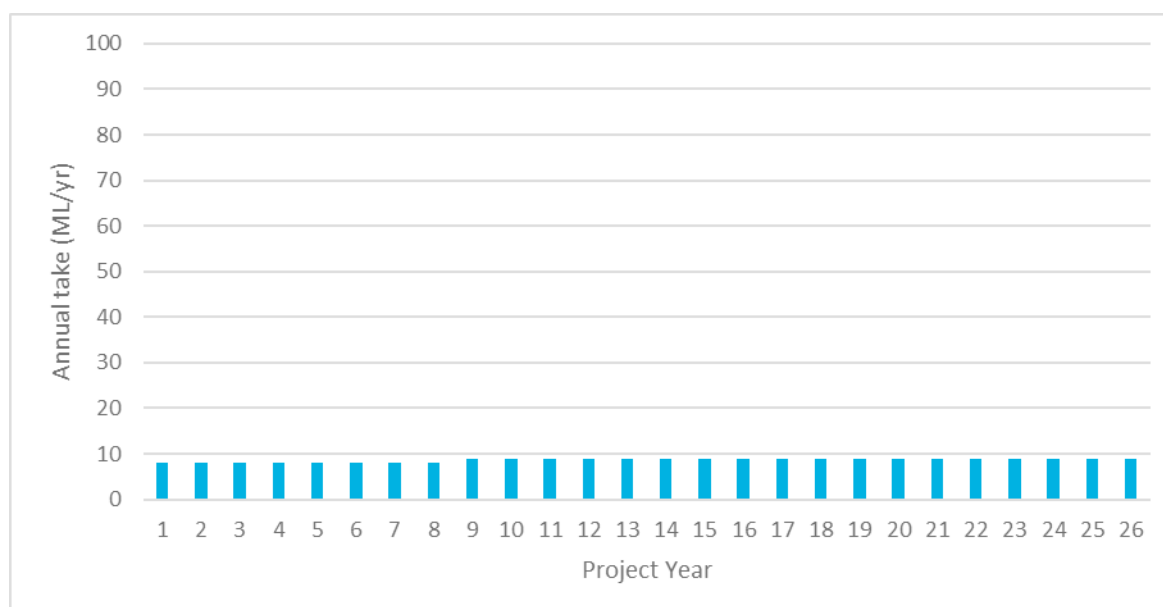


Figure 11.3 Surface water take (median) from the Singleton Water Source (Hunter Unregulated River) associated with the WMS

ii Groundwater take

a Hunter Regulated River Alluvial Water Source

Figure 11.4 presents the predicted groundwater licensing requirements for the Hunter Regulated River Alluvial Water Source (upstream Glennies Creek and downstream Glennies Creek management zones). Water take from these sources includes reduction in groundwater discharge (as baseflow) to the Hunter River. In accordance with the AIP, the source of this change is groundwater and is due to drawdown within the alluvium (or leakage from the alluvium to the Permian), and as such, this change is a groundwater take.

The predicted peak take from the upstream Glennies Creek Management Zone is 280 ML/year (in Year 14), which is below the existing entitlement of 448 aquifer access licence shares held by HVO. The predicted peak take from the downstream Glennies Creek Management Zone is 15 ML/year (in Year 28) and is well below the aquifer access licence entitlement held by HVO of 289 shares.

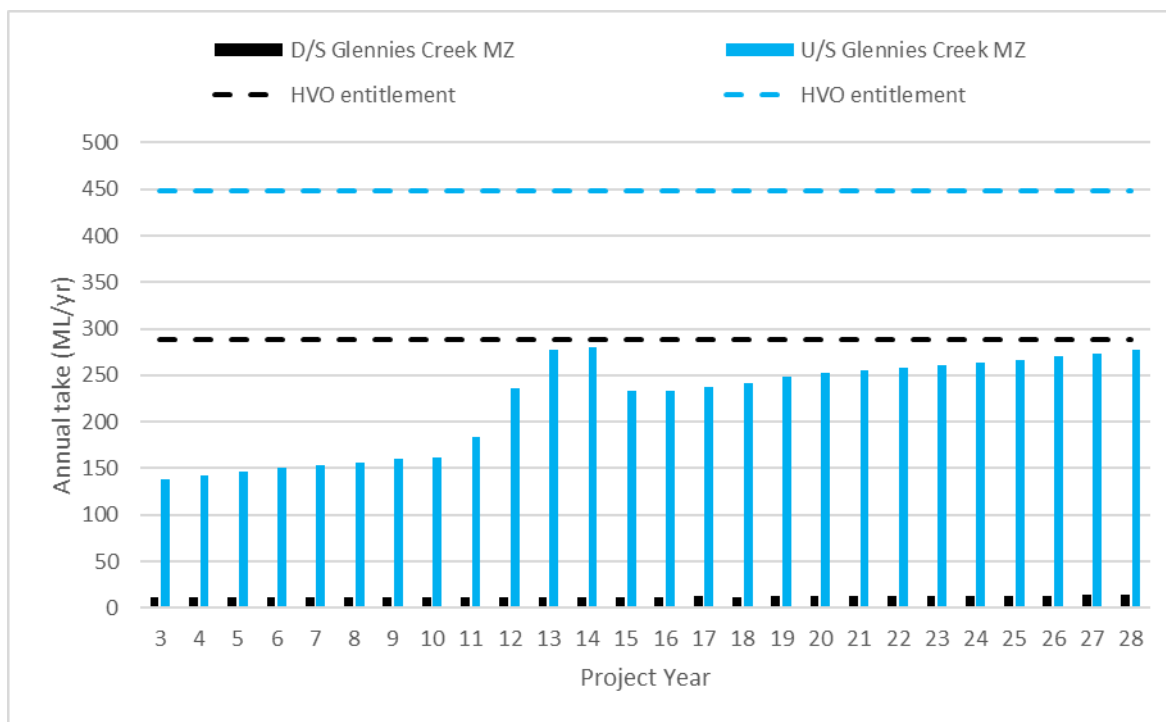


Figure 11.4 Groundwater take from the Hunter Regulated River Alluvial Water Source (downstream and upstream management zones)

b Hunter Unregulated River (alluvial) Water Sources

Figure 11.5 presents the predicted groundwater licensing requirements for the Lower Wollombi Brook and Singleton Water Sources. Water take from these sources includes reduction in groundwater discharge (as baseflow) to Wollombi Brook. In accordance with the AIP, the source of this change is groundwater and is due to drawdown within the alluvium (or leakage from the alluvium to the Permian), and as such, this change is a groundwater take.

The predicted peak take from the Lower Wollombi Brook Water Source is 26 ML/year (in Year 3 and 14), which is below the existing entitlement of 144 aquifer access licence shares held by HVO. The predicted peak take from the Singleton Water Source is only 4 ML/year (in Year 21 to 28) and is well below the aquifer access licence entitlement held by HVO of 225 shares.

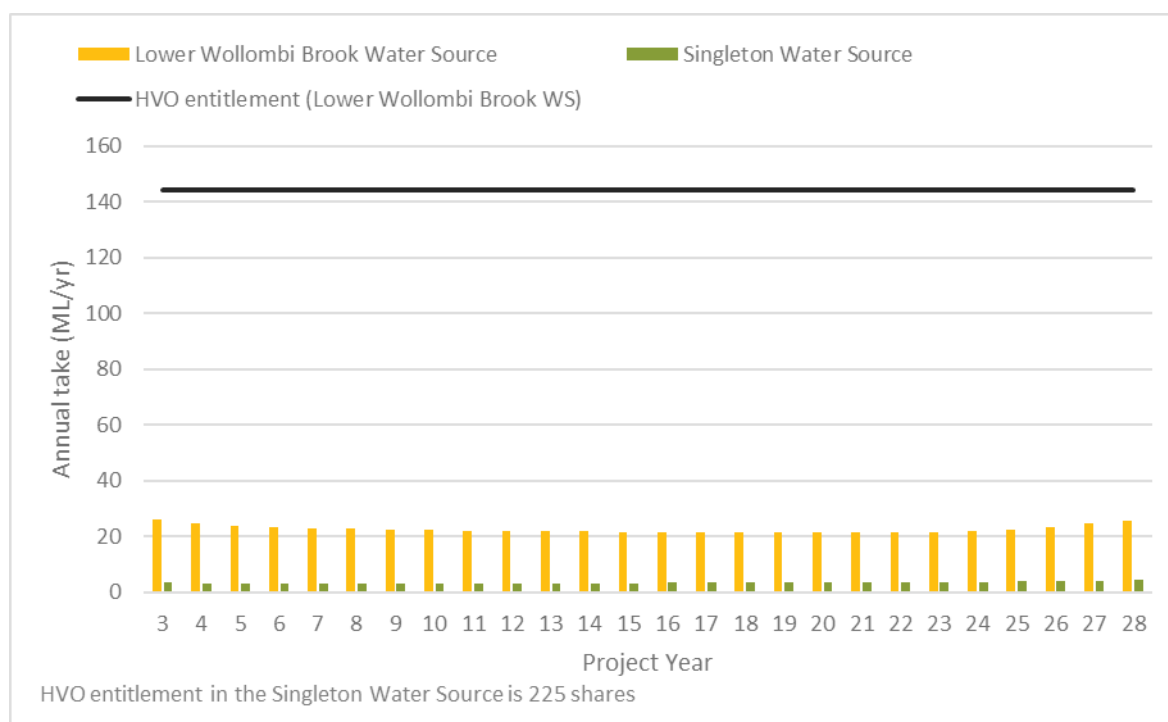


Figure 11.5 Groundwater take from the alluvium associated with the Lower Wollombi Brook and Singleton Water Sources (Hunter Unregulated River)

c Sydney Basin-North Coast Groundwater Source

Figure 11.6 presents the predicted groundwater licensing requirements for the Sydney Basin-North Coast Groundwater Source. Water take from these sources is due to groundwater inflow to mined areas.

The predicted peak take from this groundwater source is 2,133 ML/year (in Year 18, approximately 2040), which is below the existing entitlement of 5,560 aquifer access licence shares held by HVO.

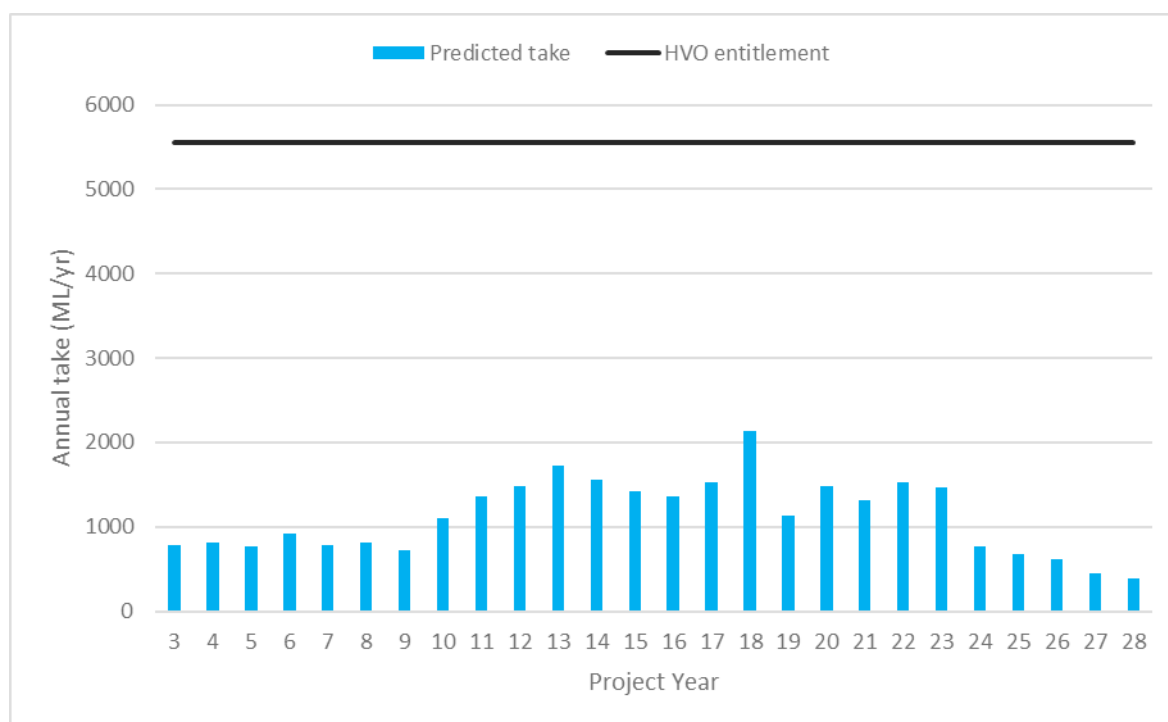


Figure 11.6 Groundwater take from the Sydney Basin-North Coast Groundwater Source

No additional entitlement is required within these groundwater sources as a result of the Project.

11.3.2 Post mining

i Surface water take

a Catchment runoff (to the voids)

As discussed earlier in this report, the final landform includes a single final void at HVO North and at HVO South. Both voids will be located in the Jerrys Water Source, managed under the Hunter Unregulated River and Alluvial WSP.

As described in the SWIA (Appendix B), drainage systems will be established on the final sections of the rehabilitated overburden emplacement areas, as well as around the perimeter of the final voids to divert upstream catchment runoff away from the final voids and to downstream drainage systems/watercourses. At closure, the HVO North void and HVO South void catchment areas are 720 ha and 714 ha, respectively.

The final detail of any remaining dam configuration, design of the drainage systems and associated licensing will be further investigated and resolved during preparation of the relevant stages of the Rehabilitation Management Plan and in the detailed closure planning process.

The final void water balance model (Engeny 2022) predicted a median annual runoff volume of 561 ML/year for HVO North Void and 534 ML/year for HVO South Void.

Catchment runoff into the final voids will be accounted for against harvestable rights (935 ML/year) and HVO's existing entitlement held in the Jerrys Water Source (705 unregulated river entitlement shares).

b Indirect take

The indirect surface water take due to river leakage to groundwater has been predicted by the groundwater model for the Project (AGE 2022). At 100 years after mining, the following peak surface water licensing entitlement is estimated:

- Hunter Regulated River Zone 1B (Goulburn River junction to Glennies Creek junction): 63 ML/year.
- Hunter Regulated River Zone 2A (Glennies Creek junction to Wollombi Brook): 3 ML/year.
- Hunter Regulated River Zone 2B (downstream of Wollombi Brook junction): 5 ML/year.
- Jerrys Water Source (Jerrys management zone) (unregulated river entitlement): 18 ML/year.

The predicted peak surface water take from the Hunter Regulated River post mining will be accounted for within HVO's high security entitlement.

The predicted peak take from the Jerrys Water Source will be accounted for within HVO's existing unregulated river entitlements in that water source.

ii Groundwater take

Following completion of mining, the voids will slowly fill with water from rainfall, runoff and groundwater inflow. As the watertable rises locally at the voids, water will be sourced from further afield to fill the void space. As such, there will be changes in groundwater flow from the overlying alluvium and connected surface water due to the evaporative pumping effect created by the pit lakes. The groundwater model predicts the evaporative pumping effect of the pit lakes will stabilise at between about 1,200 ML/year and 1,300 ML/year (AGE 2022). This is the long-term predicted take from the Sydney Basin-North Coast Groundwater Source and is within the entitlement held by HVO.

The indirect groundwater take from alluvium has also been predicted using the groundwater model developed for the Project (AGE 2022). At 100 years after mining, the following peak alluvial groundwater licensing entitlement is estimated:

- Hunter Regulated River Alluvial Water Source (upstream of Glennies Creek): 468 ML/year.
- Hunter Regulated River Alluvial Water Source (downstream of Glennies Creek): 33 ML/year.
- Jerrys Water Source: 18 ML/year.

The predicted peak post mining groundwater take from the Hunter Regulated River Alluvial Water Source (downstream of Glennies Creek) and Jerrys Water Source will be accounted for within HVO's existing entitlement. The majority of the predicted peak post mining groundwater take from the Hunter Regulated River Alluvial Water Source (upstream of Glennies Creek) can be accounted for within HVO's existing entitlement (448 shares), however an additional 20 shares may be required to be purchased from the open water market.

The post mining predicted take will be reviewed as part of groundwater model validation during operations and as part of closure planning.

12 Risk assessment

12.1 Risk assessment and management framework

An evaluation of Project activities and potential incremental impacts on water resources and water-dependent assets, with consideration of the avoidance and mitigation measures listed in Section 6.2, has been completed.

The Glencore risk assessment matrix has been used to quantify the potential risks of the Project on water receptors and is presented in Table 12.1.

Table 12.1 Glencore risk assessment matrix

Basis of rating	Likelihood				
Consequence	E - rare	D - unlikely	C - possible	B - likely	A - almost certain
5 – catastrophic	15 (M)	19 (H)	22 (H)	24 (H)	25 (H)
4 – major	10 (M)	14 (M)	18 (H)	21 (H)	23 (H)
3 – moderate	6 (L)	9 (M)	13 (M)	17 (H)	20 (H)
2 – minor	3 (L)	5 (L)	8 (M)	12 (M)	16 (M)
1 – negligible	1 (L)	2 (L)	4 (L)	7 (M)	11 (M)

Note: L: low | M: medium | H: high

The classification of likelihood and risk factors used for the risk assessment are defined in Table 12.2 and Table 12.3.

Table 12.2 Classification of likelihood

Likelihood factor	Description
A – almost certain	- May occur several times a year; - expected to occur; or - has occurred several times within Glencore’s operations.
B – likely	- May occur about once a year; - more likely to occur than not to occur; or - has occurred at least once within Glencore’s operations.
C – possible	- Could occur more than once during a lifetime; - as likely to occur as not to occur; or - has occurred at least once in the mining/commodities trading industries.
D – unlikely	- Could occur about once during a lifetime; - more likely not to occur than to occur; or - has occurred at least once in broader worldwide industry.
E – rare	- Unlikely to occur during a lifetime; - very unlikely to occur; or - no known occurrences in broader worldwide industry.

Table 12.3 **Classification of consequence**

Risk factor	Environmental impact	Compliance impact
5 – catastrophic	• Unconfined and widespread; • environmental damage or long-term effect (permanent; >10 years); and • requires major remediation.	• Major litigation/prosecution at Glencore corporate level; • loss of licence to operate
4 - major	• Long-term (2 to 10 years) impact; and • requires significant remediation.	• Major litigation/prosecution at Department level.
3 - moderate	• Medium-term (<2 years) impact (typically within a year); and • requires moderate remediation.	• Major litigation/prosecution at Operation level.
2 - minor	• Near source; • short-term impact (typically weeks); and • requires minor remediation.	• Regulation breaches resulting in fine or litigation.
1 - negligible	• Near source and confined; • no lasting environmental damage or effect (typically <day); and • requires minor or no remediation.	• Regulation breaches without fine or litigation

12.2 Risk evaluation

The risks of potential impacts caused by the Project are summarised in Table 12.4. The risk evaluation assumes no additional controls (beyond those included as part of the Project design) are in place.

Table 12.4 **Assessment of unmitigated potential impacts or events**

Potential impact mechanism	Potential impact/event	Rating reasoning	Risk analysis	
			Environment	Compliance
Groundwater quantity: actual alluvial groundwater drawdown exceeds model predictions.	Exceedance of AIP minimal impact criteria at third-party bores.	Landholder bores well outside the 2 m predicted drawdown (including uncertainty results); past studies and substantial available data increase model reliability/confidence.	1 (L)	1 (L)
	Potential long-term loss of water-dependent ecosystem viability (and thereby impacts on the tangible and intangible cultural values) beyond already approved impact.	Past studies and substantial available data increase model reliability/confidence.	6 (L)	3 (L)
Groundwater quantity: predicted groundwater take exceeds licensed allocation.	Unlicensed water take.	Groundwater modelling shows groundwater takes well within existing entitlement; low uncertainty on results given substantial data available for the Project and surroundings.		5 (L)
Groundwater quality: enhanced mixing between aquifer units with different groundwater quality.	Groundwater quality changes in alluvial aquifers and/or watercourses affect water users.	Historically, upward leakage from the Permian to the alluvium occurred (and currently occurs in some areas). Minimal upward leakage from Permian brackish aquifers to the alluvium/watercourses is currently occurring within the Project area. All model scenarios predict lowering of Permian heads as a result of the Project. Upward leakage from the Permian to the alluvium in the Project area is unlikely.	3 (L)	
Groundwater quality: seepage of contaminated water from emplacement areas to alluvium and/or watercourses.	Groundwater quality changes in alluvial aquifers and/or watercourses, adversely affecting water users, aquatic ecosystems and social and cultural values.	Groundwater levels in the backfilled emplacement areas predicted to be well below the base of the alluvium – no seepage is predicted. Groundwater flow direction is predicted to be towards the pits/final voids (during and post mining); no seepage from backfilled emplacement areas to the alluvium predicted. Barrier walls exist and will be installed (as approved) in areas where overburden/interburden is adjacent to the alluvium; limiting seepage potential.	5 (L)	
Groundwater quality: seepage of saline void water to alluvium and/or watercourses.	Groundwater quality changes in alluvial aquifers and/or watercourses.	Final voids predicted to act as groundwater sinks in all model scenarios; seepage to the alluvium extremely unlikely.	6 (L)	

Table 12.4 **Assessment of unmitigated potential impacts or events**

Potential impact mechanism	Potential impact/event	Rating reasoning	Risk analysis	
			Environment	Compliance
Surface water and groundwater interaction: actual groundwater drawdown exceeds model predictions.	Increased reduction in baseflow that affects streamflow and aquatic ecosystems, and having an indirect impact on social and cultural values.	Minimal predicted reductions in streamflow in main watercourses (Hunter River and Wollombi Brook); model considered reliable. The Hunter River is a regulated system and HVO holds considerable entitlement for the predicted take. Therefore any surface water take due to changes in groundwater interaction will be offset through existing high security entitlement. Some ephemeral minor tributaries are predicted to experience an increased duration of dry periods, however the impact will be negligible as these watercourses are typically dry for more than half the year.	5 (L)	
Surface water quantity: reduction in streamflow within watercourses.	Streamflow impacted greater than predicted.	The Project will not impact new catchments. Mining activities are mainly within the existing approved disturbance area / mining tenement. Modelling is based on considerable data and therefore has low uncertainty.	3 (L)	
Surface water quality: enhanced erosion and sediment runoff.	Increased loads of suspended solids in site runoff.	Continued operation of the HVO WMS in accordance with the WMP. Sediment and erosion controls will be implemented prior to disturbance; Sediment and erosion controls will be designed and constructed in accordance with Blue Book and existing management measures.	5 (L)	
Surface water quantity: predicted surface water take exceeds licensed allocation.	Unlicensed water take.	Predicted takes are based on robust modelling informed by substantial data available for the Project. Water balance modelling assessed water requirements under a range of climate scenarios. HVO holds considerable water entitlement in the water sources and water entitlements are available for trade, if needed.		5 (L)

Table 12.4 **Assessment of unmitigated potential impacts or events**

Potential impact mechanism	Potential impact/event	Rating reasoning	Risk analysis	
			Environment	Compliance
Aquatic ecology: Restriction to fish passage within the Hunter River due to construction of the Hunter River Bridge resulting in changes to Hunter River flow regimes, and the potential for damming.	Fish unable to migrate through Hunter River system; construction activities scheduled during native fish migratory season.	Detailed engineering design and construction plan so that no change to flow regimes or damming occurs; construction works to avoid being scheduled during native fish migratory season.	5 (L)	
Less than adequate assessment of geological faults and structures in groundwater impact assessment and model.	Groundwater inflows greater than predicted due to high hydraulic conductivity of geological structures; instability of pits.	Geological structures in the Project area are well known due to extensive investigations for historical mining and substantial dataset. At HVO North, mining will mainly involve mining deeper in previously excavated areas; uncertainty considered low.	3 (L)	
Cumulative impacts: multiple mining operations in proximity to Hunter River.	Unacceptable increase of cumulative mining impacts on the Hunter River and Wollombi Brook systems. Regulator and community concern.	The additional impact (contributing to the cumulative impact) due to the Project is minor, as predicted by robust modelling informed by substantial data available for the Project.	3 (L)	
Changes in flow velocity in the Project area due to levee construction or upgrades.	Channel stability adversely affected in the Project area.	The existing approved operations includes construction of levees, including the Carrington West Wing levee (designed for 1% AEP as per condition 26 of the HVO North consent), so the additional incremental change due to the Project is minor. Flood modelling (comparison between existing/baseline and the Project) shows low risk to channel stability.	5 (L)	

13 Monitoring, mitigation and management

13.1 Water management strategy

During operations, water will continue to be managed in accordance with the existing water management objectives to minimise fresh water usage, impacts on the environment and neighbours to the HVO Complex, and interference to mining production.

The above will be achieved through the Project design features, including:

- the Mitchell clean water diversion;
- extension of existing WMS including the construction of flood levees to provide flood protection to mine workings during operations and immunity up to and including the Extreme Event for the residual pit lakes at closure, including Cheshunt Levee, Riverview Levee and the North Void TSF Levee 2 (southern levee); and
- Lemington Road realignment.

Post mining, a key objective of the closure WMS is to limit runoff to the voids. Drainage lines will be compatible with the surrounding drainage network and will direct upstream catchment runoff towards downstream watercourses, including the Hunter River. As part of closure and rehabilitation planning, the final landform design would consider including drainage channel(s) so that potential daylighting of seepage from the backfilled mining areas (eg in the Carrington area) would be directed to the void.

In addition, the Carrington West Wing Levee will be decommissioned at closure to reinstate floodplain storage in this area.

13.2 Mine material management

The following provides a summary of the water-related recommendations in the geochemical assessment (Appendix C):

- Operational blending of NAF and PAF overburden/interburden together with the excess alkaline leachate from NAF materials prevent acid rock drainage and water quality impacts from PAF materials for the bulk of the waste rock dumps.
- Continued monitoring of the mine water system for indicators of acid mine drainage.
- Tailings to be deposited below the base of weathering in accordance with Glencore's standard to limit seepage risks and potential upward movement of salts. In addition, tailings areas will be capped and designed to be free draining, limiting the potential for water ponding.

Overall, with the above management strategies implemented, the Project is expected to present a low risk with respect to acid rock drainage and metal leaching. The key focus of materials management will be to exclude any potentially problematic materials from the near surface region of overburden/interburden dumps and TSF capping layers, and control upward migration of salts to prevent impacts on rehabilitation. This will be readily achievable given the overall low proportion of problematic materials.

13.3 Erosion and sediment control measures

All sediment dams are sized based on the Glencore Erosion and Sediment Control Protocol and Landcom *Managing Urban Stormwater: Soils and Construction* (Blue Book) (Landcom 2004).

Consistent with existing management and mitigation measures, HVO will implement erosion and sediment control measures:

- during construction, and design of scour protection measures during detailed design phase; and
- where works are within the areas defined as waterfront land (ie the bed of a watercourse and the land on each side within 40 metres of the bank), to minimise the impact of the works on the watercourse and adjoining land.

During operations, erosion and sediment control will continue to be undertaken in accordance with the Erosion and Sediment Control Plan which forms part of the WMP. This is discussed further in Appendix B.

13.4 Monitoring program

13.4.1 Water take

HVO is committed to comply with the rules of the applicable WSPs, the WM Act, WM Regulation and all associated policies, including the *NSW Non-Urban Water Metering Policy*. Methods for measuring and metering water take will be included in the updated WMP for the Project. This will include for example, commitment to continue to meter pumped transfer between storages and pumped volumes from the open cut pit. Where interception of water cannot be practically metered, HVO will use monitoring data and modelling to predict and report take. Examples interception of water cannot be practically metered include:

- runoff volumes;
- rainfall on a dam surface;
- leakage from watercourses to groundwater; and
- evaporation from surfaces of dams.

HVO will conduct the following to assist with calculating and reporting water intercepted by the Project:

- continue to monitor rainfall at the site;
- continue to measure and record pumping between storages;
- measure and record pumped volumes from the open cut pit;
- continue groundwater level monitoring at existing monitoring locations and new locations that will be agreed with DPE Water;
- continue surface water level monitoring in the Hunter River;
- use of monitoring data to calibrate the water balance model; and
- use of monitoring data to review and verify groundwater model predictions, including estimates of river leakage to groundwater (an indirect take).

13.4.2 Surface water quality

HVO has a comprehensive existing water quality monitoring program in accordance with the approved WMP (refer Section 4.3.2). This program is suitable for ongoing use to monitor the performance of the WMS and initiate investigations and corrective actions if required.

The surface water monitoring program covers all three water category areas within the HVO Complex (ie clean, sediment and mine water systems). The surface water monitoring program will continue in accordance with the approved WMP. Following approval of the Project, HVO will implement increased frequency of comprehensive analysis from annually to six monthly for all sites.

As documented in the WMP, HVO uses the following performance indicators to initiate site specific investigations regarding surface water quality:

- professional judgement to determine that the single deviation or a developing trend could result in environmental harm;
- three consecutive measurements of EC or pH exceed trigger values; and
- one measurement of TSS exceeds the trigger value.

A summary of the surface water monitoring results will continue to be provided in the HVO Annual Review. In addition, any significant findings regarding the implementation of the WMP will be reported in the Annual Review and will document reviews and feedback relating to the maintenance and performance of the WMS.

13.4.3 Groundwater

HVO has an established substantial groundwater monitoring network to monitor groundwater levels / pressures and quality at the HVO Complex, as shown on Figure 4.5 and detailed in the WMP and the GIA (Appendix A). The WMP describes groundwater monitoring requirements for determining:

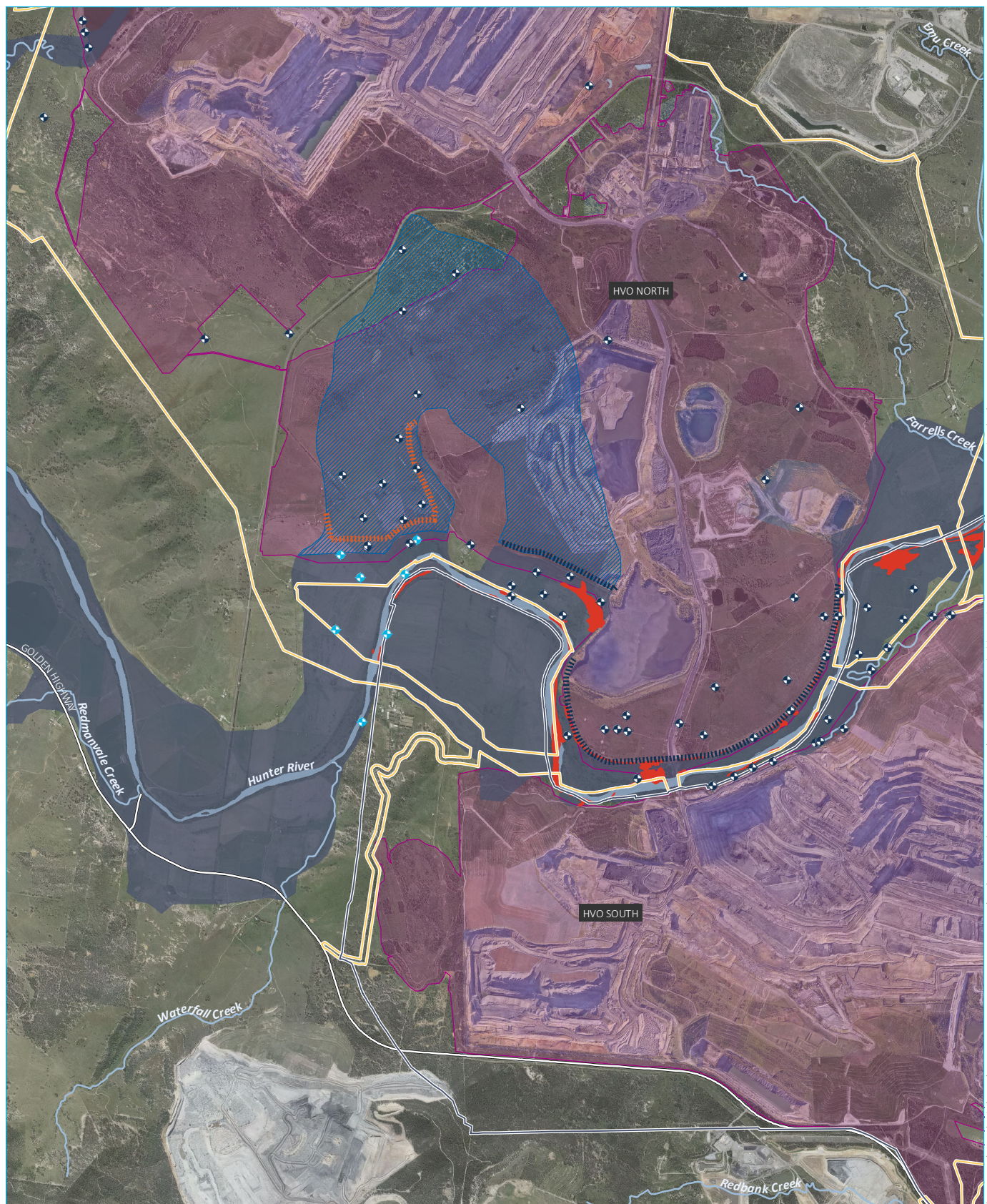
- water take from water sources;
- effectiveness of the low permeability barrier walls;
- impacts on privately-owned bores;
- impacts on water-dependent assets;
- seepage/leachate from water storages;
- Alluvial Lands area management; and
- validation of the groundwater model.

The main alluvial drawdown impacts from the Project are predicted to occur in the Hunter River alluvium south of the Carrington West Wing barrier wall where the existing groundwater monitoring network is currently limited to four monitoring bores (two installed in the alluvium and two installed in interburden). Additional monitoring bores will be installed within the zone of predicted short-term incremental drawdown to monitor impacts in this area (Figure 13.1).

A network of eight nested monitoring bores will be installed in this area, with separate bores screened with the alluvium and Permian strata. The bores will be equipped with pressure transducer data loggers to record changes in groundwater pressure, the records of which will be calibrated with regular (eg quarterly) manual measurements of depth to groundwater level. The bores will be installed approximately one year prior to mining commences in the remnant paleochannel to allow collection of background groundwater level trends prior to the effects of mining.

In addition, piezometers will be installed downstream of the Carrington West Wing barrier wall, consistent with the approach used for the Carrington Pit barrier wall. The purpose of the piezometers would be to monitor for changes in salinity (as EC) and pressure.

In addition to groundwater monitoring in the Carrington West Wing alluvial area, a review of the groundwater monitoring network and monitoring equipment will be conducted as part of updates to the WMP (discussed further in Section 13.6). This would consider installation of additional pressure transducer data loggers at other monitoring bores to increase the monitoring frequency without affecting personnel time and associated cost.



KEY

- | | |
|---|---|
| HVO North proposed development consent boundary | Carrington West Wing barrier wall |
| HVO South proposed development consent boundary | Existing low permeability barrier wall |
| Existing and approved disturbance area | + Existing HVO groundwater monitoring location |
| Former extent of paleochannel | + Proposed monitoring bore |
| Alluvial extent | Existing environment |
| River Red Gum (HVO, 2020) | Major road |
| | — Named watercourse |

Proposed additional groundwater monitoring - Carrington West Wing area

HVO Continuation Project
Water Assessment
Figure 13.1

13.5 River red gum health monitoring and management

Mitigation measures for the river red gum communities of Carrington Billabong and the Hunter River are given in detail in the *River Red Gum Rehabilitation and Restoration Strategy* (HVO 2022). Restoration and rehabilitation strategies will be continued and adapted as required over the life of the Project. Current controls focus on terrestrial aspects of the river red gum communities, rather than on groundwater, and include:

- fencing and stock access control;
- weed management;
- support of naturally recruited natives to boost natural regeneration; and
- erosion control and bank stabilisation.

Additional recommendations are given in *River Red Gum Monitoring Report* (Ecoplaning 2021) and include:

- active weed management to reduce cover and diversity of weeds; and
- investigation of potential to artificially inundate (via pumping) the Carrington Billabong to promote the germination and recruitment of river red gums.

13.6 Management plans

Following approval of the Project, the WMP will be updated in consultation with DPE Water and the EPA. The updated WMP will address any specific development consent or licence conditions and will include:

- proposed mitigation and management measures for the Project;
- objectives and performance criteria including trigger levels for investigating any potentially adverse impacts associated with the Project, including groundwater level and quality trigger levels for the Carrington Billabong area and Hunter River alluvium south of the Carrington West Wing barrier wall (discussed further below);
- details of monitoring, inspection and maintenance programs;
- reporting procedures for the results of the monitoring program; and
- plans to respond to any exceedances of the performance criteria and indicators.

TARPs, which define contingency plans and remedial measures, will be reviewed as part of the update to the approved WMP.

Performance criteria is detailed in the approved WMP, and HVO has developed the following performance indicators to initiate site specific investigations regarding groundwater levels and quality:

- professional judgement determines that the single deviation or a developing trend could result in environmental harm; and
- three consecutive measurements of EC, pH or groundwater level exceed trigger values.

The primary objective of trigger levels is to provide an early indication of potential impacts to receptors and initiate a management response. They are not intended to be an instrument to assess 'compliance' and should not be used in this capacity (ANZG 2018).

The outcomes of the investigation are reported in the Annual Review.

13.6.1 Low permeability barrier monitoring and management plan

In accordance with condition 25 of the HVO North development consent (DA 450-10-2003), HVO will develop a low permeability barrier monitoring and management plan (LPB MMP) following Project approval and in consultation with DPE Water.

The LPB MMP would include the following:

- Identification and design of dedicated groundwater monitoring bores in the area shown on Figure 13.1 that will be installed approximately one year prior to mining in the remnant paleochannel.
- Monitoring requirements and methodologies, including monitoring of groundwater levels/pressures and salinity at a suitable frequency (such as daily records at alluvial monitoring bores using level temperature conductivity (LTC) data loggers), and sampling for comprehensive laboratory water quality analysis at a suitable frequency, to evaluate the efficacy of the Carrington West Wing barrier wall.
- Identification and design of piezometers to be installed downstream of the Carrington West Wing barrier wall during construction.
- Summary of the Carrington West Wing barrier wall construction methodology and design requirements.
- Identification of other monitoring requirements or adjustments, such as at the Hunter River and/or river red gum stands.
- Selection of trigger levels, and appropriate action response plan(s), for groundwater level and salinity in the Hunter River alluvium south of the Carrington West Wing barrier wall so that groundwater level and quality is adequately managed.
- Summarising reporting commitments that will evaluate multiple lines of evidence for assessing potential impacts at receptors, including groundwater quality, groundwater levels/pressures, mining activity, climate (rainfall and temperature), streamflow, surface water quality and riparian vegetation health monitoring. This is because changes to groundwater (quantity or quality) are likely to precede any impacts to the biological indicators associated with GDEs (termed secondary impacts by Serov et al (2012)) and should be used as early indicators of possible receptor impact.

Groundwater quality performance triggers for the Carrington West Wing barrier wall area will be reviewed as baseline data is collected (ahead of mining in the remnant paleochannel). The performance triggers will be based on statistical analysis of the recorded ranges in baseline concentrations of selected leading indicators (eg salinity and sulphate concentrations). Groundwater level (as elevation or trends) performance triggers will be based on a combination of baseline data for selected monitoring bores as well as comparison of measured and model predicted levels/heads for different stages of the Project.

13.7 Groundwater model validation

Continuous improvements to the numerical groundwater flow model will be undertaken as and when new data become available, particularly where there is a divergence of observed groundwater system response from that predicted by the model. Groundwater monitoring data will be used to validate and verify the groundwater model predictions. New data may require a revision and update of the conceptual hydrogeological model prior to updating and recalibrating the numerical model and re-running of predictive scenarios. Where this is deemed necessary, the WMP may also require updating depending on any changes to the conceptualisation and model predictions.

As mining progresses, a need for further model updates will be assessed every three years based on evaluation of groundwater monitoring data and findings of impact verification.

13.8 Residual risk assessment

Risk evaluation in Section 12.2 were re-assessed considering the recommended controls and management measures outlined above. A revised risk assessment is provided in Table 13.1.

Table 13.1 Assessment of residual risk of potential impacts or events

Potential impact mechanism	Potential impact/event	Management or mitigation	Residual risk	
			Environment	Compliance
Groundwater quantity: actual alluvial groundwater drawdown exceeds model predictions.	Potential long-term loss of water-dependent ecosystem viability beyond already approved impact.	Additional groundwater monitoring bores to be installed in the alluvium south of the Carrington West Wing barrier wall and LPB MMP to be developed in consultation with DPE Water, including development of early warning trigger levels and response plan. Ecohealth monitoring at Carrington Billabong to continue.	3 (L)	
Groundwater quantity: predicted groundwater take exceeds licensed allocation.	Unlicensed water take.	Monitoring and measurement of take. Model review and validation to be conducted every three years to re-evaluate model predictions (including predicted take).		3 (L)
Groundwater quality: seepage of contaminated water from emplacement areas to alluvium and/or watercourses.	Groundwater quality changes in alluvial aquifers and/or watercourses.	Additional groundwater monitoring bores to be installed in the alluvium south of the Carrington West Wing barrier wall and LPB MMP to be developed in consultation with DPE Water, including development of early warning trigger levels and response plan.	3 (L)	
Surface water and groundwater interaction: actual groundwater drawdown exceeds model predictions.	Increased reduction in baseflow that affects streamflow and aquatic ecosystems.	Additional groundwater monitoring bores to be installed in the alluvium south of the Carrington West Wing barrier wall and LPB MMP to be developed in consultation with DPE Water, including development of early warning trigger levels and response plan.	3 (L)	
Surface water quantity: reduction in streamflow within watercourses.	Streamflow impacted greater than predicted.	Continued operation of the WMS in accordance with the WMP.	3 (L)	
Surface water quantity: predicted surface water take exceeds licensed allocation.	Unlicensed water take.	Monitoring and measurement of take.		3 (L)

14 Conclusions

The water impact assessments for the Project, including groundwater, surface water, aquatic ecology and GDE studies, considered potential impacts on water resources and water-dependent assets that could result from the Project during operations and after closure.

The assessments show the Project can operate within and meet the requirements of the water regulatory framework. Key results are summarised below.

14.1 Surface water impacts

Key outcomes of the SWIA and aquatic ecology assessment are summarised as follows:

- Impacts on Hunter River and Wollombi Brook streamflow will be negligible:
 - In addition, a decrease in the duration of dry periods is predicted at Wollombi Brook due to the removal of previously approved mining in the South Lemington Pit 1 and 2 areas from the Project.
- Minor changes in streamflow is predicted for three ephemeral watercourses during operations. The minor changes to streamflow due to the Project mainly relates to small reductions in catchment areas associated with mining extending between the existing West and Mitchell Pits to Carrington Pit, and changes in surface water-groundwater interaction. The predicted change in streamflow will have a minor impact on the number of dry days, as many of these ephemeral watercourses are dry (on average) for more than half of the year under current conditions. Post mining, potential streamflow impacts are expected to be negligible.
- Potential impacts on surface water downstream users will be negligible as no changes in streamflow regimes are predicted in the Hunter River, given it is a regulated system and HVO hold sufficient entitlement for the predicted reduction in streamflow due to the Project.
- No impacts are predicted on the aquatic ecology of the Hunter River, particularly as flow will be mitigated through regulated releases from Glenbawn Dam, and only minor impacts to the aquatic ecology in the tributaries to the Hunter River are expected.
- The proposed WMS for the Project is predicted to maintain a sufficient water supply for the operation and discharge capacity to preventing flooding of operational areas of the mine.
- Potential impacts on surface water quality are expected to be minimal and will continue to be mitigated through an appropriately sized, designed and operated WMS, including release from sediment dams in accordance with their design and discharge of mine water in accordance with approved environment protection licence limits and HRSTS credits. Modelling indicates that the impact of approved HRSTS discharges will have a negligible impact on water quality. Concentrations of key analytes are predicted to remain within the existing ranges observed in the Hunter River.
- The flood modelling for the Project indicates no impact on the use of the land (grazing and cropping or crown land).
- The proposed realignment of Lemington Road will significantly improve flood immunity of this road adjacent to the Hunter River.
- The Project is not predicted to change the flood hazard categories, or have an impact on use of the land, public safety or emergency management.

- Changes in velocity are presented to be localised around Project infrastructure and will remain within the existing ranges experienced, with a low likelihood of causing scour.

14.2 Groundwater impacts

Key outcomes of the GIA and GDE assessment are summarised as follows:

- No impact is predicted at third-party groundwater bores.
- Construction of the approved Carrington West Wing barrier wall will limit the long-term drawdown in the Hunter River alluvium and the potential for seepage from the backfilled mine areas to the alluvium. The potential impact on water quality is minor. In addition, a LPB MMP will be developed, including development of early warning trigger levels and response plan, identifying mitigation measures to manage potential unexpected effects.
- Groundwater modelling predicts a short-term increase in groundwater drawdown in the alluvium in the Carrington West Wing area prior to construction of the barrier wall (noting this area is already approved for coal extraction under the existing development consent at HVO North). Following installation of the barrier wall, groundwater levels are predicted to recover. During the short-term peak drawdown period, saturation in the alluvium will remain due to leakage from the Hunter River.
- Minimal drawdown (less than 0.5 m) is predicted in the Hunter River alluvium near mapped river red gum communities and widespread dewatering will not occur. This predicted drawdown will be buffered by leakage through the riverbed. Therefore, no significant impact in ecological receptors is predicted.
- No additional drawdown in the Wollombi Brook alluvium is predicted. In contrast, the avoidance measure of removing mining in the South Lemington Pit 1 and 2 area from the mine plan is predicted to result in a reduction in potential drawdown in the Wollombi Brook alluvium (in comparison to the approved operations).
- No changes to the environmental, community and cultural values referenced in Sections 4.3.4 and 4.6.6 are predicted due to the Project.

14.3 Final void

Key outcomes of the final void assessment are:

- the predicted long-term watertable and pit lake level will be depressed, with groundwater flow directions towards the voids;
- the Hunter River alluvium is predicted to remain saturated due to the strong hydraulic connection with the Hunter River;
- evaporation will be the dominant loss from the voids and the voids are predicted to remain groundwater sinks;
- the long-term pit lake level is considerably deeper than the base of the alluvium and the base of weathering, therefore the risk of seepage from the pit lakes to shallow groundwater is negligible;
- the risk of spill from the pit lakes is negligible;

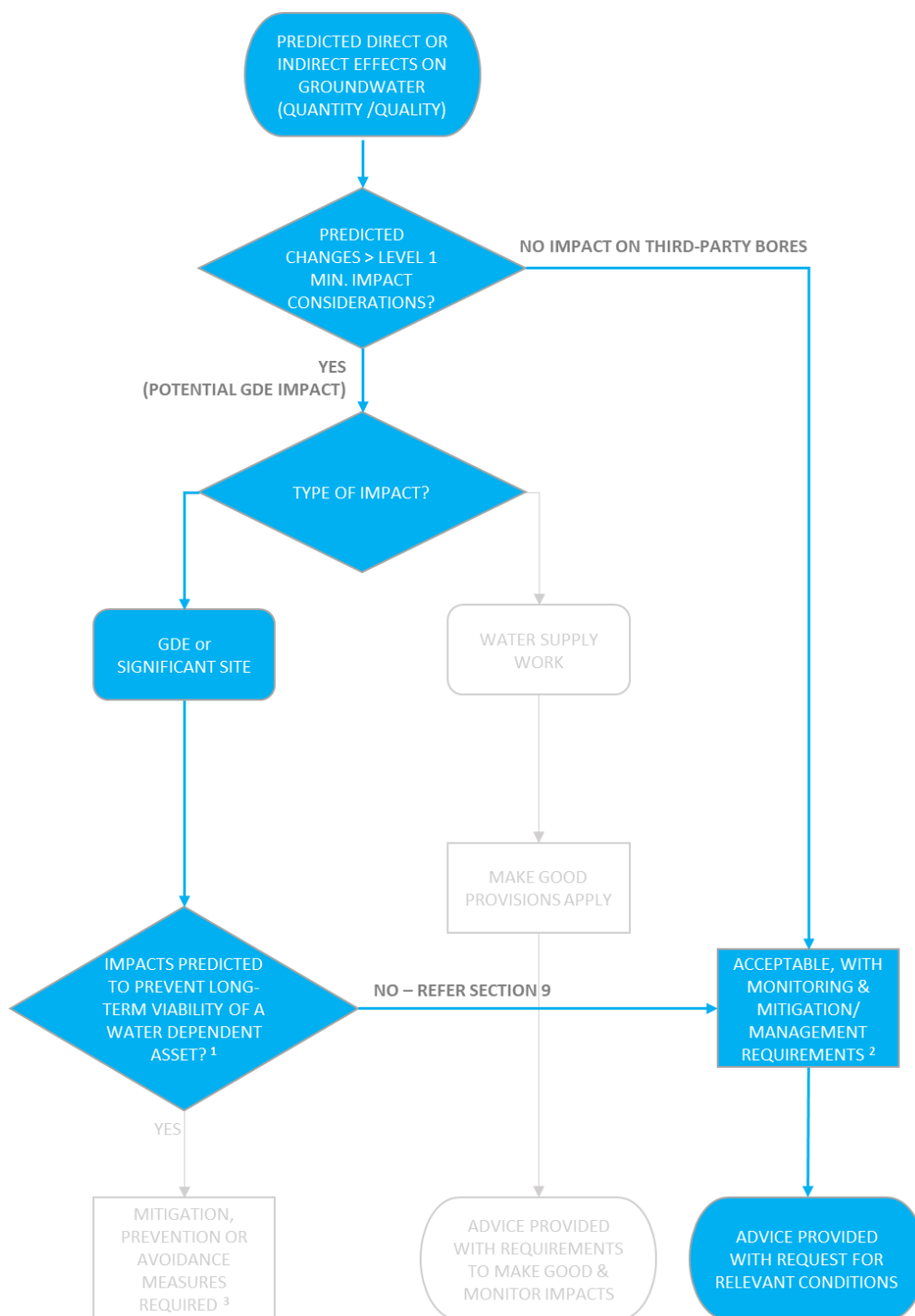
- the runoff area contributing to the voids is sufficiently small so that evaporation dominates, and the voids remain as strong long-term groundwater sinks thereby attracting seepage from the surrounding strata (at a very low rate); and
- infiltration of rainfall in the backfilled mine areas will gradually flow towards the pit lakes, as evidenced by the groundwater particle tracking completed as part of the GIA (Appendix A), and the risk of seepage from the backfilled mine areas migrating through the existing and proposed barrier walls to the Hunter River alluvium is negligible.

Given the depth and change from three voids to one void, the HVO North void for the Project will act as a stronger sink than the currently approved Carrington void evaporative sink. In addition, the surface water and groundwater modelling indicate the HVO South void will also act as a stronger evaporative sink than the currently approved HVO South void.

Consistent with the predicted drawdown during operations, the post mining incremental alluvial drawdown is not predicted to have a significant impact on GDEs or surface water resources.

The predicted cumulative drawdown is very conservative as the long-term predicted watertable is compared to a model where mining effects cease in 2009, effectively allowing groundwater levels to recover. The predicted cumulative alluvial drawdown (post mining) exceeds the NSW aquifer interference policy level 1 minimal impact considerations; however, the aquatic ecology and GDE assessment (ELA 2022) demonstrates that the predicted change in watertable will not prevent the long-term viability of the ecosystem. This is illustrated in Figure 14.1.

River red gums and riparian vegetation that opportunistically use shallow groundwater will continue to have access to shallow alluvial groundwater. In addition, the Project is predicted to have a negligible impact on Hunter River flow and flooding regime post mining. Therefore, river red gum communities will continue to rely on flooding for germination.



1. Assessment as per Serov et al 2012, with consideration of uniqueness, ecological/cultural value and timeframe of the impact.
2. Conditions of approval may include requirements for adaptive management to monitor and mitigate or remediate impacts that exceed level 1 thresholds.
3. Where there are no suitable or practical mitigation or prevention options, the proponent may be asked to avoid impacts by modifying the proposed activity.

Figure 14.1 Overview of Project assessment against the AIP minimal impact considerations process

14.4 Water licensing

HVO holds considerable water entitlement in the relevant surface water and groundwater sources in the Project area, which is sufficient to account for the predicted takes.

The integrated WMS includes storages located on non-minor and minor streams, and storages located off stream that are required for the future approved operation and Project operation. Where storages are located on minor streams (as defined by the WM Regulation spatial data set) and capture water to prevent contamination of a water source, they are considered excluded works under Schedule 1, item 3 of the WM Regulation and so the take is exempt. Other storages located on minor streams in the Project WMS can be accounted for within HVO's available harvestable right volume. The WM Act requires all water take from non-minor streams to be licensed. Therefore, the catchment runoff captured by storages (existing and proposed) in the Project WMS has been calculated.

References

Australasian Groundwater and Environmental Consultants (AGE) 2017, *HVO South Modification 5 Groundwater Study*, prepared for EMM Consulting Pty Ltd.

2019, *Glendell Continued Operations Project EIS - Groundwater Impact Assessment* prepared for Umwelt (Australia) Pty Limited.

2022, *HVO Continuation Project EIS - Groundwater Impact Assessment*, prepared for EMM Consulting Pty Limited.

ANZECC and ARMCANZ 2000, *Australian and New Zealand guidelines for fresh and marine water quality*. Agriculture and Resource Management Council of Australia and New Zealand and the Australian and New Zealand Environment and Conservation Council.

ANZG 2018, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia.

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

Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A 2012, *Australian Groundwater Modelling Guidelines*, Waterlines report, National Water Commission, Canberra, June 2012.

Colquhoun, GP, Hughes KS, Deyssing L, Ballard JC, Phillips G, Troedson AL, Folkes CB, and Fitzherbert JA 2018, *New South Wales Seamless Geology geodatabase, version 1* [Digital Dataset]. Geological Survey of New South Wales, NSW Department of Planning and Environment, Maitland.

Department of Planning and Environment (DPE) 2022a, *Groundwater assessment toolbox for major projects in NSW, overview document*, technical guidelines prepared for the water group.

2022b, *Guidelines for Groundwater Documentation for SSD/SSI Projects*, technical guideline.

2022d, *Minimum Requirements for Groundwater Modelling*, technical guideline.

2022e, *Cumulative Groundwater Impact Assessment Approaches*, technical guideline.

Department of Primary Industries – Water (DPI – Water) 2017, *Water Sharing Plan for the Hunter Regulated River Water Source Background Document*. First published March 2017.

Department of Planning, Industry and Environment 2022, eSPADE soil profile and soil mapping.

DECC 2007, *Floodplain Risk Management Guideline: Practical Consideration of Climate Change*. NSW Department of Environment and Climate Change.

DIPNR 2005, *Floodplain Development Manual*. NSW Department of Infrastructure, Planning and Natural Resources.

DoE 2013, *Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources*, Commonwealth DoE.

2018, *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals*, Commonwealth Department of the Environment (DoE).

Ecoplanning 2021, *River Red Gum Monitoring Report - 2020 Annual monitoring report*, prepared for HV Operations.

EGi 2022a, *HVO Continuation Project EIS - Geochemical Assessment*, prepared for HV Operations Ltd.

2022b, *Hunter Valley Operations – Continuation Project, Water quality predictions for final pit voids*, prepared for HV Operations Pty Ltd.

Eco Logical Australia (ELA) 2022, *Hunter Valley Operations Continuation Project - aquatic ecology and groundwater dependent ecosystems assessment*, prepared for EMM Consulting Pty Ltd on behalf of HV Operations Ltd.

EMM Consulting Pty Ltd (EMM) 2022a, *Hunter Valley Operations Continuation Project Environmental Impact Statement*, prepared for HV Operations. Reference H190408

2022b, *HVO Continuation Project - Mine Closure and Rehabilitation Strategy*, prepared for HV Operations Pty Ltd.

Engeny Water Management (Engeny) 2018a, *HVO Environmental Constraints Surface Water Management and Water Balance*, prepared for HV Operations Pty Ltd.

2018b, *Mount Owen Continued Operations Modification 2 Surface Water Impact Assessment*.

2022, *HVO Continuation Project - Surface Water Impact Assessment*, prepared for EMM Consulting Pty Ltd on behalf of HV Operations Pty Ltd.

Gardner WB 1854, *Volume 02: Production and Resources of the Northern and Western Districts of New South Wales*, 1854 [ca. 1842-1858].

Glencore Coal Assets Australia (GCAA) 2019, *HVO Continuation Project – Prefeasibility Study Report*, dated March 2019. Not published.

Hunter Valley Operations (HVO) 2018, *Hunter Valley Operations Water Management Plan*, Hunter Valley Operations.

2022, *River Red Gum Rehabilitation and Restoration Strategy*.

Landcom 2004, *Managing Urban Stormwater: Soils and Construction*, the 'Blue Book'. Volume 1, 4th edition

McVicar TR, Pinetown KL, Hodgkinson JH, Barron OV, Rachakonda PK, Zhang YQ, Dawes WR, Macfarlane C, Holland KL, Marvanek SP, Wilkes PG, Li LT and Van Niel TG 2015, *Context statement for the Hunter subregion. Product 1.1 for the Hunter subregion from the Northern Sydney Basin Bioregional Assessment*. Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia.

Mackie Environmental Research (MER) 2009, *Groundwater management studies – Ravensworth Operations Project*, prepared for Umwelt.

2010, *Carrington West Wing modification groundwater assessment*, prepared for EMM Consulting Pty Ltd.

Minesoils Pty Ltd (Minesoils) 2022, *Hunter Valley Operations Continuation Project - Soils and Land Impact Assessment Report*, prepared for EMM Consulting Pty Ltd. Reference MS-029.

Moran C, Vink S, Straughton G and Howe P 2010, *Framework for assessing potential local and cumulative effects of mining on groundwater resources - Report 3 Framework for risk-based assessment of cumulative effects to groundwater from mining*, Australian National Water Commission.

Murray TA and Power WL 2021, *Information Guidelines Explanatory Note: Characterisation and modelling of geological fault zones*. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Agriculture, Water and the Environment, Commonwealth of Australia 2021.

NOW 2012, *NSW Aquifer Interference Policy, NSW Government Policy for the licensing and assessment of aquifer interference activities*, NSW Department of Primary Industries - Office of Water.

Serov P, Kuginis L, Williams JP 2012, *Risk assessment guidelines for groundwater dependent ecosystems, Volume 1 – The conceptual framework*, NSW Department of Primary Industries, Office of Water, Sydney.

SKM 2013, *Liddell Coal Operations Modification 5 to Development Consent DA305-11-01*, dated April 2013.

SLR Consulting Pty Ltd (SLR) 2019, *HVO North Void Seepage Study – Remedial Options Assessment*, prepared for Hunter Valley Operations, November 2019. Reference 620.12182-R12.

Umwelt 2022, *Hunter Valley Operations Continuation Project Biodiversity Development Assessment Report*, prepared for HV Operations Pty Ltd.

Wafer J 2014 “Placenames as a Guide to Language Distribution in the Upper Hunter, and the Landnám Problem in Australian Toponomastics.” In *Indigenous and Minority Placenames: Australian and International Perspectives*, eds. Ian D. Clark, Luise Hercus, and Laura Kostanski. Canberra, ACT: ANU Press, 57–82.