

Permit

Environmental Protection Act 1994

Environmental authority EPML03337715

This environmental authority is issued by the administering authority under Chapter 5 of the Environmental Protection Act 1994.

Environmental authority number: EPML03337715

Environmental authority takes effect on 14 April 2021

Environmental authority holder(s)

Name(s)	Registered address
Umal Consolidated Pty Ltd	Level 14, 480 Queen Street BRISBANE CITY QLD 4000
BHP COAL PTY LTD	Level 14, 480 Queen Street BRISBANE CITY QLD 4000 Australia
QCT INVESTMENT PTY. LTD.	Level 16 480 Queen Street BRISBANE CITY QLD 4000 Australia
MITSUBISHI DEVELOPMENT PTY LTD	Level 16, 480 Queen Street BRISBANE CITY QLD 4000
QCT MINING PTY. LTD.	Level 16 480 Queen Street BRISBANE CITY QLD 4000 Australia
QCT RESOURCES PTY LIMITED	Level 16, 480 Queen Street BRISBANE CITY QLD 4000
BHP Queensland Coal Investments Pty Ltd	Level 14, 480 Queen Street BRISBANE CITY QLD 4000

Environmentally relevant activity and location details

Environmentally relevant activity/activities	Location(s)
Ancillary 08 - Chemical Storage 1: Storing a total of 50t or more of chemicals of dangerous goods class 1 or class 2, division 2.3 under subsection (1)(a)	ML1763
Schedule 3 13: Mining black coal	ML1763
Ancillary 08 - Chemical Storage 1: Storing a total of 50t or more of chemicals of dangerous goods class 1 or class 2, division 2.3 under subsection (1)(a)	ML70421
Schedule 3 13: Mining black coal	ML70421

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Environmentally relevant activity/activities	Location(s)
Ancillary 63 - Sewage Treatment 1: Operating sewage treatment works, other than no-release works, with a total daily peak design capacity of (c) more than 1500 but not more than 4000EP	ML1763
Ancillary 62 - Resource recovery and transfer facility operation 1: Operating a facility for receiving and sorting, dismantling, baling or temporarily storing- (c) category 2 regulated waste	ML1763
Ancillary 62 - Resource recovery and transfer facility operation 1: Operating a facility for receiving and sorting, dismantling, baling or temporarily storing- (c) category 2 regulated waste	ML70421
Ancillary 63 - Sewage Treatment 1: Operating sewage treatment works, other than no-release works, with a total daily peak design capacity of (c) more than 1500 but not more than 4000EP	ML70421

Additional information for applicantsEnvironmentally relevant activities

The description of any environmentally relevant activity (ERA) for which an environmental authority (EA) is issued is a restatement of the ERA as defined by legislation at the time the EA is issued. Where there is any inconsistency between that description of an ERA and the conditions stated by an EA as to the scale, intensity or manner of carrying out an ERA, the conditions prevail to the extent of the inconsistency.

An EA authorises the carrying out of an ERA and does not authorise any environmental harm unless a condition stated by the EA specifically authorises environmental harm.

A person carrying out an ERA must also be a registered suitable operator under the *Environmental Protection Act 1994* (EP Act).

Contaminated land

It is a requirement of the EP Act that an owner or occupier of contaminated land give written notice to the administering authority if they become aware of the following:

- the happening of an event involving a hazardous contaminant on the contaminated land (notice must be given within 24 hours); or
- a change in the condition of the contaminated land (notice must be given within 24 hours); or
- a notifiable activity (as defined in Schedule 3) having been carried out, or is being carried out, on the contaminated land (notice must be given within 20 business days);

that is causing, or is reasonably likely to cause, serious or material environmental harm.

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For further information, including the form for giving written notice, refer to the Queensland Government website www.qld.gov.au, using the search term 'duty to notify'.

Take effect

Please note that, in accordance with section 200 of the EP Act, an EA has effect:

- a) if the authority is for a prescribed ERA and it states that it takes effect on the day nominated by the holder of the authority in a written notice given to the administering authority-on the nominated day; or
- b) if the authority states a day or an event for it to take effect-on the stated day or when the stated event happens; or
- c) otherwise-on the day the authority is issued.

However, if the EA is authorising an activity that requires an additional authorisation (a relevant tenure for a resource activity, a development permit under the *Sustainable Planning Act 2009* or an SDA Approval under the *State Development and Public Works Organisation Act 1971*), this EA will not take effect until the additional authorisation has taken effect.

If this EA takes effect when the additional authorisation takes effect, you must provide the administering authority written notice within 5 business days of receiving notification of the related additional authorisation taking effect.

If you have incorrectly claimed that an additional authorisation is not required, carrying out the ERA without the additional authorisation is not legal and could result in your prosecution for providing false or misleading information or operating without a valid environmental authority.

Alison Sinclair
Department of Environment and Science
Delegate of the administering authority
Environmental Protection Act 1994

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Date issued: 14 April 2021

Obligations under the *Environmental Protection Act 1994*

In addition to the requirements found in the conditions of this environmental authority, the holder must also meet their obligations under the EP Act, and the regulations made under the EP Act. For example, the holder must comply with the following provisions of the Act:

- general environmental duty (section 319)
- duty to notify environmental harm (section 320-320G)
- offence of causing serious or material environmental harm (sections 437-439)
- offence of causing environmental nuisance (section 440)
- offence of depositing prescribed water contaminants in waters and related matters (section 440ZG)
- offence to place contaminant where environmental harm or nuisance may be caused (section 443)

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Conditions of environmental authority

Schedule A: General	
Condition number	Condition
A1	This environmental authority authorises environmental harm referred to in the conditions. Where there is no condition or this environmental authority is silent on a matter, the lack of a condition or silence does not authorise environmental harm.
A2	In carrying out the mining activity authorised by this environmental authority, disturbance of land may occur in the areas marked as green on the map that is shown in Annexure 1 of this environmental authority.
A3	The holder of this environmental authority must: a) install all measures, plant and equipment necessary to ensure compliance with the conditions of this environmental authority b) maintain such measures, plant and equipment in a proper and efficient condition c) operate such measures, plant and equipment in a proper and efficient manner d) ensure all instruments and devices used for the measurement or monitoring of any parameter under any condition of this environmental authority are properly calibrated.
A4	Monitoring Except where specified otherwise in another condition of this environmental authority, all monitoring records or reports required by this environmental authority must be kept for a period of not less than 5 years.
A5	Financial assurance The activity must not be carried out until the environmental authority holder has given financial assurance to the administering authority as security for compliance with this environmental authority and any costs or expenses, or likely costs or expenses, mentioned in section 298 of the Act.
A6	The amount of financial assurance must be reviewed by the holder of this environmental authority when a plan of operations is amended or replaced or the authority is amended.
A7	Notification of emergencies, incidents and exceptions The holder of this environmental authority must notify the administering authority by written notification within 24 hours, after becoming aware of any emergency or incident which results in the release of contaminants not in accordance, or reasonably expected to be not in accordance with, the conditions of this environmental authority.

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A8	Within 10 business days following the initial notification of an emergency or incident, or receipt of monitoring results, whichever is the latter, further written advice must be provided to the administering authority, including the following: a) results and interpretation of any samples taken and analysed b) outcomes of actions taken at the time to prevent or minimise unlawful environmental harm c) proposed actions to prevent a recurrence of the emergency or incident.
A9	Complaints The holder of this environmental authority must record all environmental complaints received about the mining activities including: a) name, address and contact number for of the complainant b) time and date of complaint c) reasons for the complaint d) investigations undertaken e) conclusions formed f) actions taken to resolve the complaint g) any abatement measures implemented h) person responsible for resolving the complaint.
A10	The holder of this environmental authority must, when requested by the administering authority, undertake relevant specified monitoring within a reasonable timeframe nominated or agreed to by the administering authority to investigate any complaint of environmental harm. The results of the investigation (including an analysis and interpretation of the monitoring results) and abatement measures, where implemented, must be provided to the administering authority within 10 business days of completion of the investigation, or no later than 10 business days after the end of the timeframe nominated by the administering authority to undertake the investigation.
A11	Third party reporting The holder of this environmental authority must: a) within 1 year of the commencement of this environmental authority, obtain from an appropriately qualified person a report on compliance with the conditions of this environmental authority b) obtain further such reports at regular intervals, not exceeding 3 yearly intervals, from the completion of the report referred to above c) provide each report to the administering authority within 90 days of its completion.

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A12	Where a condition of this environmental authority requires compliance with a standard, policy or guideline published externally to this environmental authority and the standard is amended or changed subsequent to the issue of this environmental authority, the holder of this environmental authority must: a) comply with the amended or changed standard, policy or guideline within 2 years of the amendment or change being made, unless a different period is specified in the amended standard or relevant legislation, or where the amendment or change relates specifically to regulated structures conditions in this environmental authority b) until compliance with the amended or changed standard, policy or guideline is achieved, continue to remain in compliance with the corresponding provision that was current immediately prior to the relevant amendment or change.
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Schedule B: Air	
Condition number	Condition
B1	When requested by the administering authority or as a result of a complaint (which is neither frivolous nor vexatious nor based on mistaken belief in the opinion of the authorised officer), dust and particulate monitoring must be undertaken, and the results thereof notified to the administering authority within 14 days following completion of monitoring. Monitoring must be carried out at a place(s) relevant to the potentially affected dust sensitive place.
B2	The holder of the environmental authority shall ensure that all reasonable and feasible avoidance and mitigation measures are employed so that the dust and particulate matter generated by the mining activities do not exceed the following levels when measured at any sensitive or commercial place: a) Dust deposition of 120 milligrams per square metre per day, averaged over 1 month, when monitored in accordance with the most recent version of Australian Standard AS3580.10.1 Methods for sampling and analysis of ambient air—Determination of particulate matter—Deposited matter – Gravimetric method. b) A concentration of particulate matter with an aerodynamic diameter of less than 10 micrometres (PM10) suspended in the atmosphere of 50 micrograms per cubic metre over a 24-hour averaging time, for no more than 5 exceedances recorded each year, when monitored in accordance with the most recent version of either: i. Australian Standard AS3580.9.6 Methods for sampling and analysis of ambient air—Determination of suspended particulate matter—PM10 high volume sampler with size-selective inlet – Gravimetric method; or ii. Australian Standard AS3580.9.9 Methods for sampling and analysis of ambient air—Determination of suspended particulate matter—PM10 low volume sampler—Gravimetric method; or iii. Australian Standard AS3580.9.8 Methods for sampling and analysis of ambient air—Determination of suspended of suspended particulate matter—PM10 continuous direct mass method using a tapered element oscillating microbalance analyser; or iv. Australian Standard AS3580.9.11 Methods for sampling and analysis of ambient air—Determination of suspended particulate matter—PM10 beta attenuation monitors.

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Schedule C: Water	
Condition number	Condition
C1	Contaminant release Contaminants that will, or have the potential to cause environmental harm must not be released directly or indirectly to any waters as a result of the authorised mining activities, except as permitted under the conditions of this environmental authority.
C2	The release of mine affected water to internal water management infrastructure installed and operated in accordance with a Water Management Plan that complies with condition C6 is permitted.
C3	Water reuse Mine affected water may be piped or trucked or transferred by some other means that does not contravene the conditions of this environmental authority and deposited into artificial water storage structures, such as farm dams or tanks, or used directly at properties owned by the environmental authority holder or a third party (with the consent of the third party).
C4	Annual water monitoring reporting The following information must be recorded in relation to all water monitoring required under the conditions of this environmental authority and submitted to the administering authority in the specified format: a) the date on which the sample was taken b) the time at which the sample was taken c) the monitoring point at which the sample was taken d) the measured or estimated daily quantity of mine affected water released from all release points e) the release flow rate at the time of sampling for each release point f) the results of all monitoring and details of any exceedances of the conditions of this environmental authority g) water quality monitoring data must be provided to the administering authority in the specified electronic format upon request.
C5	Temporary interference with waterways Destroying native vegetation, excavating, or placing fill in a watercourse, lake or spring necessary for and associated with mining operations must be undertaken in accordance with Department of Natural Resources and Mines (or its successor) <i>Riverine protection permit exemption requirements, WSS/2013/726 Version 1.01</i>.

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C6	Water management plan A Water Management Plan must be developed by an appropriately qualified person and implemented.
C7	Stormwater and water sediment controls An Erosion and Sediment Control Plan must be developed by an appropriately qualified person and implemented for all stages of the mining activities on the site to minimise erosion and the release of sediment to receiving waters and contamination of stormwater.
C8	Stormwater, other than mine affected water, is permitted to be released to waters from: a) erosion and sediment control structures that are installed and operated in accordance with the Erosion and Sediment Control Plan required by condition C7 b) water management infrastructure that is installed and operated, in accordance with a Water Management Plan that complies with condition C6, for the purpose of ensuring water does not become mine affected water.

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Schedule D: Noise	
Condition number	Condition
D1	The holder of this environmental authority must ensure that noise generated by the mining activities does not cause the criteria in Table D1 (Noise Limits) to be exceeded at a sensitive place or commercial place.
D2	The holder of this environmental authority must ensure that blasting does not cause the limits for peak particle velocity and air blast overpressure in Table D2 (Blasting Noise Limits) to be exceeded at a sensitive place or commercial place.
D3	In the event of periodic and/or complaint/s, noise monitoring and recording must include the following descriptor characteristics and matters: a) LAN,T (where N equals the statistical levels of 1, 10 and 90 and T = 15 mins) b) background noise LA90 c) the level and frequency of occurrence of impulsive or tonal noise and any adjustment and penalties to statistical levels d) atmospheric conditions including temperature, relative humidity and wind speed and directions e) effects due to any extraneous factors such as traffic noise f) location, date and time of monitoring g) if the complaint concerns low frequency noise, Max LpLIN,T and one third octave band measurements in dB(LIN) for centre frequencies in the 10 – 200 Hz range. h) if the complaint concerns sleep disturbance, attended LAMax 1 minute logging during a continuous two night period.
D4	The holder of this environmental authority must develop and implement a blast monitoring program to monitor compliance with Table D2 – Blasting noise limits for: a) all blasts undertaken on this site at the nearest sensitive place or commercial place; and b) all blasts conducted during any time period specified by the administering authority at the nearest sensitive place or commercial place.

Table D1 (Noise Limits)

Sensitive Place						
Noise level dB(A) measured as:	Monday to Saturday			Sundays and Public Holidays		
	7am to 6pm	6pm to 10pm	10pm to 7am	9am to 6pm	6pm to 10pm	10pm to 9am
L _{Aeq} , adj, 15mins	CV = 50 AV = 5	CV = 45 AV = 5	CV = 40 AV = 0	CV = 45 AV = 5	CV = 40 AV = 5	CV = 35 AV = 0
L _{A1} , adj, 15mins	CV = 55 AV = 10	CV = 50 AV = 10	CV = 45 AV = 5	CV = 50 AV = 10	CV = 45 AV = 10	CV = 40 AV = 5
Commercial Place						
Noise level dB(A) measured as:	Monday to Saturday			Sundays and Public Holidays		
	7am to 6pm	6pm to 10pm	10pm to 7am	7am to 6pm	6pm to 10pm	10pm to 7am
L _{Aeq} , adj, 15mins	CV = 55 AV = 10	CV = 50 AV = 10	CV = 45 AV = 5	CV = 50 AV = 10	CV = 45 AV = 10	CV = 40 AV = 5

Table D1 – Noise limits notes:

1. CV = Critical Value
2. AV = Adjustment Value
3. To calculate noise limits in Table D1:
 If $bg \leq (CV - AV)$: Noise limit = $bg + AV$
 If $(CV - AV) < bg \leq CV$: Noise limit = CV
 If $bg > CV$: Noise limit = $bg + 0$
4. In the event that measured bg (LA90, adj, 15 mins) is less than 30 dB(A), then 30 dB(A) can be substituted for the measured background level
5. bg = background noise level (LA90, adj, 15 mins) measured over 3-5 days at the nearest sensitive receptor
6. If the project is unable to meet the noise limits as calculated above alternative limits may be calculated using the processes outlined in the Planning for Noise Control guideline.

Table D2 (Blasting Noise Limits)

Parameter	Sensitive or commercial place blasting noise limits	
	7am to 6pm	6pm to 7am
Airblast overpressure	115 dB (Linear) Peak for 9 out of 10 consecutive blasts initiated and not greater than 120 dB (Linear) Peak at any time	No blasting
Ground vibration peak particle velocity	5mm/second peak particle velocity for 9 out of 10 consecutive blasts and not greater than 10 mm/second peak particle velocity at any time	

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Schedule E: Groundwater	
Condition number	Condition
E1	The holder of this environmental authority must not release contaminants to groundwater.
E2	All determinations of groundwater quality and biological monitoring must be performed by a suitably qualified person. Groundwater monitoring should be conducted in accordance with the <i>Queensland Water Quality Guidelines, Version 3</i> (DEHP, 2013b).
E3	The holder of the environmental authority must implement a groundwater monitoring program which has been developed by a suitably qualified person. The program must be able to detect a significant change to groundwater quality values and standing water levels (consistent with the current suitability of the groundwater for domestic and agricultural use) due to activities that are part of this mining project.
E4	The holder of the environmental authority must report the results and analysis of groundwater monitoring to the administering authority on request.
E5	Groundwater affected by the mining activities must be monitored at compliance bores within the nominated geologies and minimum frequencies defined in Table E1 (Groundwater Monitoring Locations and Frequency) .
E6	If the groundwater investigation trigger levels defined in Table E2 (Groundwater Quality Triggers and Limits) are exceeded, the environmental authority holder must complete an investigation into the potential for environmental harm and notify the administering authority within twenty-eight (28) days of receiving the analysis results.
E7	The environmental authority holder must not cause an exceedance of any contaminant limits in Table E2 (Groundwater Quality Triggers and Limits) and must notify the administering authority within twenty-eight (28) days of receiving the analysis results.
E8	Where it is identified that there is potential for environmental harm under condition E6 or condition E7 , an action plan to mitigate potential environmental harm must be developed by a suitably qualified person and implemented within 3 months of the completion of the investigation under condition E6 or condition E7 .
E9	Determining contaminant trigger level and limit type The background groundwater quality for each aquifer must be determined from hydraulically isolated background bore(s) that have not been affected by any mining activities. The groundwater contaminant trigger levels and limit type as per Table E2 (Groundwater Quality Triggers and Limits) must be determined and submitted to the administering authority within 24 months from the date of commencement of mining activities.

E10	Bore construction and maintenance and decommissioning The construction, maintenance and management of groundwater bores (including background and compliance groundwater monitoring bores) must be undertaken in a manner that prevents or minimises impacts to the environment and ensures the integrity of the bores to obtain accurate monitoring. Construction and decommissioning must be in accordance with the <i>Minimum Construction Standard for Water Bores in Australia</i>.
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Table E1 (Groundwater Monitoring Locations and Frequency)

Monitoring Point ^{1, 2}	Easting (GDA94)	Northing (GDA94)	Location	Aquifer	Parameters and Monitoring Frequency ^{1,2}
Reference Bores					
TBA	TBA	TBA	TBA	TBA	TBA
Compliance Bores					
TBA	TBA	TBA	TBA	TBA	TBA

Note:

- 1 To be completed three months prior to the commencement of mining activities authorised by this Environmental Authority
- 2 Relevant geology/ies, number of bores and monitoring frequencies to be determined by a suitably qualified person.

Table E2 (Groundwater Quality Triggers and Limits)

Parameter	Unit	Trigger Level	Contaminant Limit
Groundwater Level	RL	Greater than 2 metre drawdown from the background level	
pH	pH units	6.5 to 8.5	
Electrical Conductivity	µS/cm	80th percentile of baseline results per unit to be provided as per condition E9	90th percentile background to be provided as per condition E9
Total Dissolved Solids	mg/L		
Calcium	mg/L		
Magnesium	mg/L		
Sodium	mg/L		
Potassium	mg/L		
Chloride	mg/L		
Sulphate	mg/L		
Carbonate	mg/L		
Bicarbonate	mg/L		
Total Nitrogen	mg/L		
Nitrogen Oxides	mg/L		
Ammonia	mg/L		
Phosphate	mg/L		
Aluminium	mg/L		
Arsenic	mg/L		
Iron	mg/L		
Mercury	mg/L		
Antimony	mg/L		
Total Petroleum Hydrocarbons (C6-C40)	mg/L		

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Schedule F: Land	
Condition number	Condition
F1	Rehabilitation landform criteria Unless otherwise permitted under the conditions of this environmental authority, all areas significantly disturbed by mining activities must be rehabilitated in accordance with Table F1 (Rehabilitation Requirements) .
F2	The environmental authority holder must rehabilitate in accordance with this environmental authority, any disturbance from mining activities which were undertaken under: a) this environmental authority; or b) any other environmental authority held by this environmental authority holder that applied to the land that is the subject of this environmental authority.

Table F1 (Rehabilitation Requirements)

Post Mining Land Use	Goal	Objective	Indicator	Acceptance Criteria
Cattle grazing	Safe to humans and wildlife	Safety hazards in rehabilitation are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is geotechnically stable	Factor of safety	≥1.5
		Rehabilitation is erosionally stable	Extent, slope gradient and groundcover	1. Groundcover >50% 2. 70% of slopes ≤20%
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
		Deep drainage from rehabilitation achieves relevant water quality objectives for groundwater	EC	Not significantly different to: (a) the EPP (Water) schedule documents water quality objectives for relevant groundwater chemistry zones; or, (b) local water quality objectives developed in accordance with the Queensland Water Quality Guidelines.
	Able to sustain the agreed post-mining land use	Rehabilitation is suitable for sustainable cattle grazing	Land suitability assessment for cattle grazing	Land suitability class ≤3 or not different from pre-mining class if ≥4. Assessment completed in accordance with <i>LSA Framework for Open-Cut Coal Mine Rehabilitation 2018 (A rule-set for land suitability assessment of sustainable beef cattle grazing on land rehabilitated after open-cut coal mining in the Bowen Basin Queensland)</i> unless otherwise agreed in writing between the administering authority and the environmental authority holder.
			Leucaena stem density	<250 stems >2m height per ha (1 per 40m ²), mean total area

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Dryland cropping	Safe to humans and wildlife	Safety hazards in rehabilitation are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is geotechnically stable	Factor of safety	≥1.5
		Rehabilitation is erosionally stable	Percentage of cultivation at >1% slope gradient with functional contour banks	100% of rehabilitated areas
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
		Deep drainage from rehabilitation achieves relevant water quality objectives for groundwater	EC	Not significantly different to: (a) the EPP (Water) schedule documents water quality objectives for relevant groundwater chemistry zones; or, (b) local water quality objectives developed in accordance with the Queensland Water Quality Guidelines.
	Able to sustain the agreed post-mining land use	Rehabilitation is suitable for sustainable dryland cropping	Land suitability assessment for dryland cropping	Land suitability class ≤3 or not different from pre-mining class if ≥4. Assessment completed in accordance with the <i>Regional Land Suitability Frameworks for Queensland 2013</i> unless otherwise agreed in writing between the administering authority and the environmental authority holder.
Woodland habitat	Safe to humans and wildlife	Safety hazards in rehabilitation are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is geotechnically stable	Factor of safety	≥1.5 unless an alternative is justified by an appropriately qualified person
		Rehabilitation is erosionally stable	Groundcover (steep slopes, >15%)	80%
			Groundcover (lesser slopes, ≤15%)	50%
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
		Deep drainage from rehabilitation achieves relevant water quality objectives for groundwater	EC	Not significantly different to: (a) the EPP (Water) schedule documents water quality objectives for relevant groundwater chemistry zones; or, (b) local water quality objectives developed in accordance with the Queensland Water Quality Guidelines.
	Able to sustain the agreed post-mining land use	Native bushland characteristics	Species richness Trees Shrubs Grasses	≥2 ≥3 ≥4
			Tree canopy cover	≥16%

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Water Storage	Safe to humans and wildlife	Safety hazards in rehabilitation are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is geotechnically stable	Factor of Safety	≥1.5
		Rehabilitation is erosionally stable (banks and immediate surrounds)	Groundcover	>50%
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
		Deep drainage from rehabilitation achieves relevant water quality objectives for groundwater	EC	Not significantly different to: (a) the EPP (Water) schedule documents water quality objectives for relevant groundwater chemistry zones; or, (b) local water quality objectives developed in accordance with the Queensland Water Quality Guidelines.
	Able to sustain the agreed post-mining land use	Rehabilitation retains water that is a potential resource for cattle grazing, with quality according to ANZECC guidelines version October 2000	TDS Calcium Magnesium Nitrate Nitrite Sulphate	≤5,000mg/L ≤1,000mg/L ≤2,000mg/L ≤400mg/L ≤30mg/L ≤1,000mg/L
Watercourse	Safe to humans and wildlife	Safety hazards are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
	Stable	Rehabilitation is erosionally stable	Geomorphic index (IDC method)	Greater or equal to upstream or downstream values.
	Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to upstream values
	Able to sustain the agreed post-mining land use	Riparian vegetation	Riparian vegetation index (IDC method)	Greater or equal to upstream or downstream values.

F3	Rehabilitation must commence progressively in accordance with the plan of operations.
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F4	Before applying for surrender of a mining lease, the holder must (if applicable) provide to the administering authority a site investigation report under the Act, in relation to any part of the mining lease which has been used for notifiable activities or which the holder is aware is likely to be contaminated land, and also carry out any further work that is required as a result of that report to ensure that the land is suitable for its final land use.
F5	Before applying for progressive rehabilitation certification for an area, the holder must (if applicable) provide to the administering authority a site investigation report under the Act, in relation to any part of the area the subject of the application which has been used for notifiable activities or which the holder is aware is likely to be contaminated land, and also carry out any further work that is required as a result of that report to ensure that the land is suitable for its final land use under condition F1 .
F6	The holder of the environmental authority must minimise the potential for contamination of land by hazardous contaminants.
F7	Matters of State Environmental Significance Despite condition A2, activities are only authorised to occur within Matters of State Environmental Significance as shown in Annexure 2 if: a) the activities are carried out in the location; and b) the activities are no greater than the estimated maximum extent of impact for each Matter of State Environmental Significance as in Table F2 (Matters of State Environmental Significance (for Broadmeadow underground mine extension)) and Table F3 (Matters of State Environmental Significance (for Redhill project)); and c) if the activity is deemed a significant impact in Table F2 (Matters of State Environmental Significance (for Broadmeadow underground mine extension)), an offset must be delivered subject to conditions F7 to F9, inclusive.
F8	Agreed delivery arrangement A suitably qualified person/appropriately qualified person must prepare any offset delivery plan and determine any proposed financial settlement offset.
F9	Post-stage analysis A suitably qualified person must prepare a report for each annual return period which includes: a) the actual extent of all completed impacts on Matters of State Environmental Significance referred to in condition F7; and b) a notice of election to address outstanding offset debits for the authorised activity.

Table F2 (Matters of State Environmental Significance (for Broadmeadow underground extension))

Prescribed matters of state environmental significance with significant residual impacts			Maximum authorised residual impact area (ha)
Regulated vegetation	Regional Ecosystem	VM Act ¹ Status	TOTAL
Connectivity Areas			71.9
Protected Wildlife Habitat	Regional Ecosystem	NC Act ² Status	TOTAL

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Ornamental snake habitat*	11.4.2	Vulnerable	25.76
Koala habitat*	11.4.2	Special Least Concern	25.76
	11.5.3		7.89
	11.5.9		38.78

*Notes:*** These MSES overlap with Matters of National Environmental Significance and will be conditioned for Offsets by the Commonwealth.**1 Vegetation Management Act 1999**2 Nature Conservation Act 1992*

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Table F3 (Matters of State Environmental Significance (for Red Hill Project))

Prescribed matters of state environmental significance with significant residual impacts			Maximum authorised residual impact area (ha)
Regulated vegetation	Regional Ecosystem	VM Act ¹ Status	TOTAL
	11.3.1	Endangered	63.55
	11.3.2	Of Concern	174.5
	11.3.4	Of Concern	135.08
	11.4.2	Of Concern	366.25
	11.4.7	Endangered	57.63
	11.4.8	Endangered	55.80
	11.4.9	Endangered	125.53
	11.5.16	Endangered	28.09
	11.9.1	Endangered	0.64
Connectivity Areas			853.01
Protected Wildlife Habitat	Regional Ecosystem	NC Act ² Status	TOTAL
Koala habitat*	11.3.2	Special Least Concern	174.5
	11.3.3		7.01
	11.3.4		135.08
	11.3.25		135.12
	11.4.2		366.25
	11.4.7		57.63
	11.4.8		55.80
	11.5.3		512.55
	11.5.9		0.07
Ornamental Snake habitat*	11.3.1	Vulnerable	63.55
	11.3.2		174.50
	11.3.3		7.01
	11.3.4		135.08
	11.4.2		366.25
	11.4.7		57.63
	11.4.8		55.80
	11.4.9		125.53
	11.3.25		135.12
	500m buffer around known locations		43.07
Squatter Pigeon habitat*	11.5.3	Vulnerable	252 (within 1km of permanent water)
	11.5.9		
	11.5.16		
Wetlands and Watercourses			Maximum authorised residual impact area (ha)
Stream order 1			25.52
Stream order 2			22.24
Stream order 3			80.20
Stream order 5			316.44

Notes:

* These MSES overlap with Matters of National Environmental Significance and will be conditioned for Offsets by the Commonwealth.

1 Vegetation Management Act 1999

2 Nature Conservation Act 1992

Deemed conditions in Sections 18, 22, 24 and 25 of the Environmental Offsets Act 2014 are taken to be conditions of this environmental authority.

The holder of the environmental authority must provide an environmental offset for significant residual impacts on Matters of State Environmental Significance in accordance with the requirements of the Environmental Offsets Act 2014 (including deemed conditions), the Environmental Offsets Regulation 2014 and the Queensland Environmental Offsets Policy 2014.

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F10	Subsidence management plan A Subsidence Management Plan must be developed and implemented by the holder of this environmental authority prior to the commencement of activities that result in subsidence.
F11	The Subsidence Management Plan must be developed to the satisfaction of the administering authority in accordance with the departmental guideline <i>Watercourse subsidence – Central Queensland Mining Industry</i> or any subsequent versions, and must include the following components: a) Provide for proper and effective management of the actual and potential environmental impacts resulting from the mining activity and ensure compliance with the conditions of the environmental authority b) The condition of the existing watercourse (including baseline assessment) c) The proposed impacts of subsidence on land, watercourses and floodplains within the area of disturbance, including, but not limited to: i. Physical condition of surface drainages: - Erosion - Areas susceptible to higher levels of erosion such as watercourse confluences - Incision processes - Stream widening - Tension cracking - Lowering of beds and banks - Creation of in stream waterholes - Changes to local drainage patterns ii. Overland Flow: - Capture of overland flow by subsided long-wall panels - Increased overbank flows due to lowering of high bank of watercourses - The portion of local and large scale catchment likely to be captured by subsided longwall panels and the associated impacts on downstream users iii. Water Quality: - Surface water - Groundwater - Overland flow water detained in subsided longwall panels iv. Land condition: Current land condition to be impacted by subsidence v. Infrastructure: - Detail of existing infrastructure (pipelines, railway, power lines and haul roads) should be identified where there is a potential impact from the effects of land subsidence d) Proposed options for mitigating any impacts associated with subsidence and how these mitigation methods will be implemented e) A risk assessment f) A monitoring, evaluation and maintenance program g) Cumulative impacts on watercourses or catchments h) Impacts on groundwater.

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F12	The holder of this environmental authority must not commence subsidence of a longwall panel unless the holder has submitted two copies of the Subsidence Management Plan with certification by a suitably qualified and experienced person, that the plan is compliant in all respects with the environmental authority, to the administering authority.
F13	Annual inspection The holder of this environmental authority must arrange for each subsided longwall panel to be inspected annually by a suitably qualified and experienced person, in accordance with conditions F14 to F17 .
F14	The annual inspection required by condition F13 must be conducted prior to 1 November of each year.
F15	At each annual inspection, the condition of each subsided longwall panel must be assessed, including the structural, geotechnical and hydraulic adequacy of the subsided longwall panel and the adequacy of the works with respect to the Subsidence Management Plan.
F16	For each inspection, two copies of the report must be certified by a suitably qualified and experienced person and be provided to the administering authority within 28 days of the inspection.
F17	The report must detail any remedial works that have been undertaken and the outcomes of these works.
F18	Remedial works The holder of the environmental authority, if directed by the administering authority, shall carry out any remedial works that are deemed necessary to minimise impacts on the physical integrity of the watercourse from subsidence.

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Schedule H: Sewage Treatment	
Condition number	Condition
H1	The only contaminant permitted to be released to land is treated sewage effluent in compliance with the release limits stated in Table H1 (Contaminant release limits to land) .
H2	The holder of this environmental authority must, 3 months prior to the start of mining activities, submit a plan of the nominated area(s) where effluent will be disposed. Treated sewage effluent may only be released to land in accordance with the conditions of this approval at the following locations: a) within the nominated area(s) b) other land for the purpose of dust suppression and/or fire-fighting.
H3	The application of treated effluent to land must be carried out in a manner such that: a) vegetation is not damaged b) there is no surface ponding of effluent c) there is no run-off of effluent.
H4	If areas irrigated with effluent are accessible to employees or the general public, prominent signage must be provided advising that effluent is present and care should be taken to avoid consuming or otherwise coming into unprotected contact with the effluent.
H5	All sewage effluent released to land must be monitored at the frequency and for the parameters specified in Table H1 (Contaminant release limits to land) .
H6	The daily volume of effluent release to land must be measured and records kept of the volumes of effluent released.
H7	When circumstances prevent the irrigation or beneficial reuse of treated sewage effluent such as during or following rain events, waters must be directed to wet weather storage or alternative measures must be taken to store/lawfully dispose of effluent.
H8	The holder of this environmental authority must provide to the administering authority prior to the start of construction, a description of the minimum area of land, excluding any necessary buffer zones, to be utilised for the irrigation and/or beneficial reuse of treated sewage effluent.
H9	Treated sewage effluent must only be supplied to another person or organisation that has a written plan detailing how the user of the treated sewage effluent will comply with their general environmental duty under section 319 of the Act whilst using the treated sewage effluent.

Table H1 (Contaminant release limits to land)

Contaminant	Unit	Release Limit	Limit Type	Frequency
5 day Biochemical oxygen demand (BOD)	mg/L	20	Maximum	Monthly
Total suspended solids	mg/L	30	Maximum	Monthly
Nitrogen	mg/L	30	Maximum	Monthly
Phosphorous	mg/L	15	Maximum	Monthly
E. coli	Organisms / 100mL	1000	Maximum	Monthly
pH	pH units	6.0 to 9.0	Range	Monthly

Schedule J: Regulated Structures	
Condition number	Condition
J1	Assessment of consequence category The consequence category of any structure must be assessed by a suitably qualified and experienced person in accordance with the <i>Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)</i> at the following times: a) prior to the design and construction of the structure, if it is not an existing structure; or b) prior to any change in its purpose or nature of its stored contents; or c) following any change in surroundings or in the conditions downstream
J2	A consequence assessment report and certification must be prepared for each structure assessed and the report may include a consequence assessment for more than one structure.
J3	Certification must be provided by the suitably qualified and experienced person who undertook the assessment, in the form set out in the <i>Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)</i> .
J4	All regulated structures must be designed by, and constructed* under the supervision of a suitably qualified and experienced person in accordance with the requirements of the <i>Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)</i>. <i>*Certification of design and construction may be undertaken by different persons.</i>
J5	Construction of a regulated structure is prohibited unless: a) the holder has submitted a consequence category assessment report and certification to the administering authority; and b) certification for the associated operating procedures has been certified by a suitably qualified and experienced person in compliance with the relevant condition of this authority.
J6	Certification must be provided by the suitably qualified and experienced person who oversees the preparation of the design plan in the form set out in the <i>Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)</i> , and must be recorded in the Regulated Dams/Levees register.

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J7	Regulated structures must: a) be designed and constructed in accordance with and conform to the requirements of the <i>Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)</i>; b) be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of: i. floodwaters from entering the regulated dam from any watercourse or drainage line; and ii. wall failure due to erosion by floodwaters arising from any watercourse or drainage line.
J8	Certification by the suitably qualified and experienced person who supervises the construction must be submitted to the administering authority on the completion of construction of the regulated structure, and state that: a) the 'as constructed' drawings and specifications meet the original intent of the design plan for that regulated structure; b) construction of the regulated structure is in accordance with the design plan.
J9	Operation of a regulated structure Operation of a regulated structure, except for an existing structure, is prohibited unless: a) the holder has submitted to the administering authority: i. one paper copy and one electronic copy of the design plan and certification of the 'design plan' in accordance with condition J6; ii. a set of 'as constructed' drawings and specifications; iii. certification of those 'as constructed drawings and specifications' in accordance with condition J8; iv. where the regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the Design Storage Allowance (DSA) volume across the system, a copy of the certified system design plan; b) the requirements of this authority relating to the construction of the regulated structure have been met; c) the holder has entered the details required under this authority, into a Register of Regulated Dams; and d) there is a current operational plan for the regulated structures.
J10	Each regulated structure must be maintained and operated, for the duration of its operational life until decommissioned and rehabilitated, in a manner that is consistent with the current operational plan and, if applicable, the current design plan and associated certified 'as constructed' drawings.
J11	Mandatory reporting level Conditions J12 to J15 inclusive only apply to Regulated Structures which have not been certified as low consequence category for 'failure to contain – overtopping'.

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J12	The Mandatory Reporting Level (the MRL) must be marked on a regulated dam in such a way that during routine inspections of that dam, it is clearly observable.
J13	The holder must, as soon as practical and within 48 hours of becoming aware, notify the administering authority when the level of the contents of a regulated dam reaches the MRL.
J14	The holder must, immediately on becoming aware that the MRL has been reached, act to prevent the occurrence of any unauthorised discharge from the regulated dam.
J15	The holder must record any changes to the MRL in the Register of Regulated Structures.
J16	Design storage allowance The holder must assess the performance of each regulated structure or linked containment system over the preceding November to May period based on actual observations of the available storage in each regulated dam or linked containment system taken prior to 1 July of each year.
J17	By 1 November of each year, storage capacity must be available in each regulated structure (or network of linked containment systems with a shared DSA volume), to meet the DSA volume for the dam (or network of linked containment systems).
J18	The holder must, as soon as possible and within 48 hours of becoming aware that the regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on 1 November of any year, notify the administering authority.
J19	The holder must, immediately on becoming aware that a regulated structure (or network of linked containment systems) will not have the available storage to meet the DSA volume on 1 November of any year, act to prevent the occurrence of any unauthorised discharge from the regulated dam or linked containment systems.
J20	Annual inspection report Each regulated structure must be inspected each calendar year by a suitably qualified and experienced person.
J21	At each annual inspection, the condition and adequacy of all components of the regulated structure must be assessed and a suitably qualified and experienced person must prepare an annual inspection report containing details of the assessment and include recommended actions to ensure the integrity of the regulated structure.
J22	The suitably qualified and experienced person who prepared the annual inspection report must certify the report in accordance with the <i>Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)</i> .

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J23	The holder must: a) Within 20 business days of receipt of the annual inspection report, provide to the administering authority: i. The recommendations section of the annual inspection report; and ii. If applicable, any actions being taken in response to those recommendations; and b) If, following receipt of the recommendations and (if applicable) actions, the administering authority requests a full copy of the annual inspection report from the holder, provide this to the administering authority within 10 business days* of receipt of the request. <i>*Please note that for some model conditions, such as model conditions for dams associated with a resource activity - non mining activity, the notification requirements may be located in a separate part of the conditions of an environmental authority (e.g. under notification requirement conditions).</i>
J24	Transfer arrangements The holder must provide a copy of any reports, documentation and certifications prepared under this authority, including but not limited to any Register of Regulated Structures, consequence assessment, design plan and other supporting documentation, to a new holder on transfer of this authority.
J25	Decommissioning and rehabilitation Regulated structures must not be abandoned but be either: a) decommissioned and rehabilitated to achieve compliance with condition J26; or b) be left in-situ for a beneficial use(s) provided that: i. it no longer contains contaminants that will migrate into the environment; and ii. it contains water of a quality that is demonstrated to be suitable for its intended beneficial use(s); and iii. the administering authority, the holder of the environmental authority and the landholder agree in writing that the regulated structure will be used by the landholder following the cessation of the environmentally relevant activity(ies).

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J26	After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria: a) the landform is safe for humans and fauna; b) the landform is stable with no subsidence or erosion gullies for at least 3 years; c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated; d) not allowing for acid mine drainage; or e) there is no ongoing contamination to waters (including groundwater); f) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the <i>Instructions for the treatment and management of acid sulfate soils (2001)</i>; g) all significantly disturbed land is reinstated to the pre-disturbed land suitability class; h) for land that is not being cultivated by the landholder: i. groundcover, that is not a declared pest species is established and self-sustaining ii. vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining, and iii. the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the resource activity(ies). i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within 3 months of mining activities being completed.
J27	Register of regulated structures A Register of Regulated Structures must be established and maintained by the holder for each regulated structure.
J28	The holder must provisionally enter the required information in the Register of Regulated Structures when a design plan for a regulated structure submitted to the administering authority.
J29	The holder must make a final entry of the required information in the Register of Regulated Structures once compliance with condition J9 has been achieved.
J30	The holder must ensure that the information contained in the Register of Regulated Structures is current and complete on any given day.
J31	All entries in the Register of Regulated Structures must be approved by the chief executive officer for the holder of this authority, or their delegate, as being accurate and correct.
J32	The holder must, at the same time as providing the annual return, supply to the administering authority a copy of the records contained in the Register of Regulated Structures, in the electronic format required by the administering authority.

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Schedule H: Waste	
Condition number	Condition
K1	Unless otherwise permitted by the conditions of this environmental authority or with prior approval from the administering authority and in accordance with a relevant standard operating procedure, waste must not be burnt.
K2	The holder of this environmental authority may burn vegetation cleared in the course of carrying out extraction activities provided the activity does not cause environmental harm at any sensitive place or commercial place.
K3	Disposal of tyres Disposing of scrap tyres resulting from the authorised activities in spoil emplacements is acceptable, provided tyres are placed as deep in the spoil as reasonably practicable. A record must be kept of the number and location for tyres disposed.
K4	Acid sulfate soils The holder of this environmental authority must treat and manage acid sulfate soils in accordance with the latest edition of the <i>Queensland Acid Sulfate Soil Technical Manual</i> .
K5	Tailings disposal The holder of this environmental authority must not dispose of any tailings at this site.

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Schedule H: Exploration Activities	
Condition number	Condition
L1	Exploration activities must be undertaken in accordance with the most recent version of the document <i>Eligibility criteria and standard conditions for exploration and mineral development projects</i> .
L2	If the only ERA carried out under this environmental authority is Exploration activities (ERA9), the requirements under the following conditions of this environmental authority do not apply: a) Condition C6 – Water Management Plan b) Condition C7 – Erosion and Sediment Control Plan c) Condition E5 and E9 – Groundwater Monitoring d) Condition F10 – Subsidence Management Plan e) Condition H2 – Effluent Disposal Plan.

END OF CONDITIONS

Definitions

Key terms and/or phrases used in this document are defined in this section. Environmental authority holders should note that where a term is not defined, the definition in the *Environmental Protection Act 1994*, its regulations or environmental protection policies must be used. If a word remains undefined it has its ordinary meaning.

Airblast overpressure means energy transmitted from the blast site within the atmosphere in the form of pressure waves. The maximum excess pressure in this wave, above ambient pressure is the peak airblast overpressure measured in decibels linear (dBL).

Annual exceedance probability or AEP means the probability that at least one event in excess of a particular magnitude will occur in any given year.

Annual inspection report means an assessment prepared by a suitably qualified and experienced person containing details of the assessment against the most recent consequence assessment report and design plan (or system design plan);

- a) against recommendations contained in previous annual inspections reports;
- b) against recognised dam safety deficiency indicators;
- c) for changes in circumstances potentially leading to a change in consequence category;
- d) for conformance with the conditions of this authority;
- e) for conformance with the 'as constructed' drawings;
- f) for the adequacy of the available storage in each regulated dam, based on an actual observation or observations taken after 31 May each year but prior to 1 November of that year, of accumulated sediment, state of the containment barrier and the level of liquids in the dam (or network of linked containment systems);
- g) for evidence of conformance with the current operational plan.

Appropriately qualified person means a person who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relative to the subject matter using the relevant protocols, standards, methods or literature.

Assessed or assessment by a suitably qualified and experienced person in relation to a consequence assessment of a dam, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit of the assessment:

- a) exactly what has been assessed and the precise nature of that determination;
- b) the relevant legislative, regulatory and technical criteria on which the assessment has been based;
- c) the relevant data and facts on which the assessment has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and
- d) the reasoning on which the assessment has been based using the relevant data and facts, and the relevant criteria.

Associated works in relation to a dam, means:

- a) operations of any kind and all things constructed, erected or installed for that dam; and
- b) any land used for those operations.

Authority means an environmental authority or a development approval.

Bed and banks for a waters, river, creek, stream, lake, lagoon, pond, swamp, wetland or dam means land over which the water of the waters, lake, lagoon, pond, swamp, wetland or dam normally flows or that is normally covered by the water, whether permanently or intermittently; but does not include land adjoining or adjacent to the bed and banks that is from time to time covered by floodwater.

Beneficial use in respect of dams means that the current or proposed owner of the land on which a dam stands, has found a use for that dam that is:

- a) of benefit to that owner in that it adds real value to their business or to the general community,
- b) in accordance with relevant provisions of the Environmental Protection Act 1994,
- c) sustainable by virtue of written undertakings given by that owner to maintain that dam, and
- d) the transfer and use have been approved or authorised under any relevant legislation.

Blasting means the use of explosive materials to fracture:

- a) rock, coal and other minerals for later recovery; or
- b) structural components or other items to facilitate removal from a site or for reuse.

Bunded means within bunding consistent with Australian Standard 1940.

Certification means assessment and approval must be undertaken by a suitably qualified and experienced person in relation to any assessment or documentation required by this authority, including design plans, 'as constructed' drawings and specifications, construction, operation or an annual report regarding regulated structures, undertaken in accordance with the Board of Professional Engineers of Queensland Policy Certification by RPEQs (ID: 1.4 (2A)).

Chemical means:

- a) an agricultural chemical product or veterinary chemical product within the meaning of the *Agricultural and Veterinary Chemicals Code Act 1994 (Commonwealth)*; or
- b) a dangerous good under the dangerous goods code; or
- c) a lead hazardous substance within the meaning of the *Workplace Health and Safety Regulation 1997*; or
- d) a drug or poison in the Standard for the Uniform Scheduling of Drugs and Poisons prepared by the Australian Health Ministers' Advisory Council and published by the Commonwealth; or
- e) any substance used as, or intended for use as:
 - i. a pesticide, insecticide, fungicide, herbicide, rodenticide, nematocide, miticide, fumigant or related product; or
 - ii. a surface active agent, including, for example, soap or related detergent; or
 - iii. a paint solvent, pigment, dye, printing ink, industrial polish, adhesive, sealant, food additive, bleach, sanitiser, disinfectant, or biocide; or
 - iv. a fertiliser for agricultural, horticultural or garden use; or
- f) a substance used for, or intended for use for:
 - i. mineral processing or treatment of metal, pulp and paper, textile, timber, water or wastewater; or
 - ii. manufacture of plastic or synthetic rubber.

Commercial place means a work place used as an office or for business or commercial purposes, which is not part of the mining activity and does not include employees accommodation or public roads.

Construction or constructed in relation to a dam includes building a new dam and modifying or lifting an existing dam, but does not include investigations and testing necessary for the purpose of preparing a design plan.

Consequence in relation to a structure as defined, means the potential for environmental harm resulting from the collapse or failure of the structure to perform its primary purpose of containing, diverting or controlling flowable substances.

Consequence category means a category, either low, significant or high, into which a dam is assessed as a result of the application of tables and other criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

Dam means a land-based structure or a void that contains, diverts or controls flowable substances, and includes any substances that are thereby contained, diverted or controlled by that land-based structure or void and associated works.

Dam crest volume means the volume of material (liquids and/or solids) that could be within the walls of a dam at any time when the upper level of that material is at the crest level of that dam. That is, the instantaneous maximum volume within the walls, without regard to flows entering or leaving (for example, via spillway).

Design plan is a document setting out how all identified consequence scenarios are addressed in the planned design and operation of a regulated structure.

Design storage allowance or DSA means an available volume, estimated in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority, must be provided in a dam as at 1 November each year in order to prevent a discharge from that dam to an annual exceedance probability (AEP) specified in that Manual.

Designer for the purposes of a regulated dam, means the certifier of the design plan for the regulated dam.

Disturbance of land includes:

- a) compacting, removing, covering, exposing or stockpiling of earth;
- b) removal or destruction of vegetation or topsoil or both to an extent where the land has been made susceptible to erosion;
- c) carrying out mining within a watercourse, waterway, wetland or lake;
- d) the submersion of areas by tailings or hazardous contaminant storage and dam/structure walls;
- e) temporary infrastructure, including any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc.) which is to be removed after the mining activity has ceased; or
- f) releasing of contaminants into the soil, or underlying geological strata.

However, the following areas are not included when calculating areas of disturbance:

- a) areas off lease (e.g. roads or tracks which provide access to the mining lease);
- b) areas previously disturbed which have achieved the rehabilitation outcomes;
- c) by agreement with the administering authority, areas previously disturbed which have not achieved the rehabilitation objective(s) due to circumstances beyond the control of the mine operator (such as climatic conditions);
- d) areas under permanent infrastructure. Permanent infrastructure includes any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc.) which is to be left by agreement with the landowner; or
- e) disturbance that pre-existed the grant of the tenure.

Effluent means treated waste water released from sewage treatment plants.

Emergency action plan means documentation forming part of the operational plan held by the holder or a nominated responsible officer, that identifies emergency conditions that sets out procedures and actions that will be followed and taken by the dam owner and operating personnel in the event of an emergency. The actions are to minimise the risk and consequences of failure, and ensure timely warning to downstream communities and the implementation of protection measures. The plan must require dam owners to annually update contact.

Environmental authority means an environmental authority granted in relation to an environmentally relevant activity under the *Environmental Protection Act 1994*.

Environmental authority holder means the holder of this environmental authority.

Environmentally relevant activity means an environmentally relevant activity as defined under section 18 of the *Environmental Protection Act 1994*.

Existing structure means a structure that was in existence prior to the adoption of this schedule of conditions under the authority.

Exploration activity has the same meaning as explore.

Explore means take action to determine the existence, quality and quantity of minerals on, in or under land or in the waters or sea above land by—

- a) prospecting;
- b) using instruments, equipment and techniques appropriate to determine the existence of any mineral;
- c) extracting and removing from land for sampling and testing an amount of material, mineral or other substance in each case reasonably necessary to determine its mineral bearing capacity or its properties as an indication of mineralisation;

Extreme Storm Storage means a storm storage allowance determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority

Flowable substance means matter or a mixture of materials that can flow under any conditions potentially affecting that substance. Constituents of a flowable substance can include water, other liquids fluids or solids, or a mixture that includes water and any other liquids fluids or solids either in solution or suspension.

Hydraulic performance means the capacity of a regulated dam to contain or safely pass flowable substances based on the probability (AEP) of performance failure specified for the relevant hazard category in the *Site Water Management Technical Guideline for Environmental Management of Exploration and Mining in Queensland* (DME 1995).

Infrastructure means water storage dams, roads and tracks, buildings and other structures built for the purpose of mining activities but does not include other facilities required for the long-term management of mining impacts or the protection of potential resources. Such other facilities include dams, waste rock dumps, voids, or ore stockpiles and buildings as well as other structures whose ownership can be transferred and which have a residual beneficial use for the next owner of the mining leases or the background land owner.

Land in the “land schedule” of this document means land excluding waters and the atmosphere.

Land use means the selected post mining use of the land, which is planned to occur after the cessation of mining operations.

Leachate means a liquid that has passed through or emerged from, or is likely to have passed through or emerged from, a material stored, processed or disposed of at the operational land which contains soluble, suspended or miscible contaminants likely to have been derived from the said material.

Levee means an embankment that only provides for the containment and diversion of stormwater or flood flows from a contributing catchment, or containment and diversion of flowable materials resulting from releases from other works, during the progress of those stormwater or flood flows or those releases; and does not store any significant volume of water or flowable substances at any other times.

Low consequence dam means any dam that is not a high or significant consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.

m means metres.

Mandatory reporting level or MRL means a warning and reporting level determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

Manual means the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

Mine affected water

- a) means the following types of water:
 - i. pit water, tailings dam water, processing plant water;
 - ii. water contaminated by a mining activity which would have been an environmentally relevant activity under Schedule 2 of the Environmental Protection Regulation 2008 if it had not formed part of the mining activity;
 - iii. rainfall runoff which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated, excluding rainfall runoff discharging through release points associated with erosion and sediment control structures that have been installed in accordance with the standards and requirements of an Erosion and Sediment Control Plan to manage such runoff, provided that this water has not been mixed with pit water, tailings dam water, processing plant water or workshop water;
 - iv. groundwater which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated;
 - v. groundwater from the mine's dewatering activities;
 - vi. a mix of mine affected water (under any of paragraphs i)-v) and other water.
- b) does not include surface water runoff which, to the extent that it has been in contact with areas disturbed by mining activities that have not yet been completely rehabilitated, has only been in contact with:
 - i. land that has been rehabilitated to a stable landform and either capped or revegetated in accordance with the acceptance criteria set out in the environmental authority but only still awaiting maintenance and monitoring of the rehabilitation over a specified period of time to demonstrate rehabilitation success; or
 - ii. land that has partially been rehabilitated and monitoring demonstrates the relevant part of the landform with which the water has been in contact does not cause environmental harm to waters or groundwater, for example:
 - a. areas that are been capped and have monitoring data demonstrating hazardous material adequately contained with the site;
 - b. evidence provided through monitoring that the relevant surface water would have met the water quality parameters for mine affected water release limits in this environmental authority, if those parameters had been applicable to the surface water runoff; or
 - iii. both.

Measures include any measures to prevent or minimise environmental impacts of the mining activity such as bunds, silt fences, diversion drains, capping, and containment systems.

Modification or modifying (see definition of 'construction')

NATA means National Association of Testing Authorities, Australia.

Operational plan includes:

- a) normal operating procedures and rules (including clear documentation and definition of process inputs in the DSA allowance);
- b) contingency and emergency action plans including operating procedures designed to avoid and/or minimise environmental impacts including threats to human life resulting from any overtopping or loss of structural integrity of the regulated structure.

Peak particle velocity or ppv means a measure of ground vibration magnitude which is the maximum rate of change of ground displacement with time, usually measured in millimetres/second (mm/s).

Receiving environment, in relation to an activity that causes or may cause environmental harm, means the part of the environment to which the harm is, or may be, caused. The receiving environment includes (but is not limited to):

- a) a watercourse;
- b) groundwater;
- c) land; and
- d) sediments.

Receiving waters means the waters into which this environmental authority authorises releases of mine affected water.

Register of Regulated Structures includes:

- a) Date of entry in the register;
- b) Name of the dam, its purpose and intended/actual contents;
- c) The consequence category of the dam as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*;
- d) Dates, names, and reference for the design plan plus dates, names, and reference numbers of all document(s) lodged as part of a design plan for the dam;
- e) Name and qualifications of the suitably qualified and experienced person who certified the design plan and 'as constructed' drawings;
- f) For the regulated dam, other than in relation to any levees –
 - i. The dimensions (metres) and surface area (hectares) of the dam measured at the footprint of the dam;
 - ii. Coordinates (latitude and longitude in GDA94) within five metres at any point from the outside of the dam including its storage area
 - iii. Dam crest volume (megalitres);
 - iv. Spillway crest level (metres AHD).
 - v. Maximum operating level (metres AHD);
 - vi. Storage rating table of stored volume versus level (metres AHD);
 - vii. Design storage allowance (megalitres) and associated level of the dam (metres AHD);
 - viii. Mandatory reporting level (metres AHD);
- g) The design plan title and reference relevant to the dam;
- h) The date construction was certified as compliant with the design plan;
- i) The name and details of the suitably qualified and experienced person who certified that the constructed dam was compliant with the design plan;
- j) Details of the composition and construction of any liner;
- k) The system for the detection of any leakage through the floor and sides of the dam;
- l) Dates when the regulated dam underwent an annual inspection for structural and operational adequacy, and to ascertain the available storage volume for 1 November of any year;
- m) Dates when recommendations and actions arising from the annual inspection were provided to the administering authority;
- n) Dam water quality as obtained from any monitoring required under this authority as at 1 November of each year.

Regulated dam means any dam in the significant or high consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* published by the administering authority.

Regulated structure includes land-based containment structures, levees, bunds and voids, but not a tank or container designed and constructed to an Australian Standard that deals with strength and structural integrity.

Rehabilitation means the process of reshaping and revegetating land to restore it to a stable landform and in accordance with the acceptance criteria set out in this environmental authority and, where relevant, includes remediation of contaminated land.

Release event means a surface water discharge from mine affected water storages or contaminated areas.

Representative means a sample set that covers the variance in monitoring or other data due to either natural changes or operational phases of the mining activities.

RL means reduced level, relative to mean sea level as distinct from depths to water.

Sensitive place means:

- a) a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises; or
- b) a motel, hotel or hostel; or
- c) an educational institution; or
- d) a medical centre or hospital; or
- e) a protected area; or
- f) a public park or gardens.

* NOTE: A mining camp (i.e., accommodation and ancillary facilities for mine employees or contractors or both, associated with the mine the subject of the environmental authority) is not a sensitive place for that mine or mining project, whether or not the mining camp is located within a mining tenement that is part of the mining project the subject of the environmental authority.

Structure means dam or levee.

Spillway means a weir, channel, conduit, tunnel, gate or other structure designed to permit discharges from the dam, normally under flood conditions or in anticipation of flood conditions.

Suitably qualified and experienced person in relation to regulated structures means a person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the *Professional Engineers Act 2002*, and has demonstrated competency and relevant experience:

- a) for regulated dams, an RPEQ who is a civil engineer with the required qualifications in dam safety and dam design.
- b) for regulated levees, an RPEQ who is a civil engineer with the required qualifications in the design of flood protection embankments.

Note: It is permissible that a suitably qualified and experienced person obtain subsidiary certification from an RPEQ who has demonstrated competence and relevant experience in either geomechanics, hydraulic design or engineering hydrology.

Suitably qualified and experienced person in relation to watercourse subsidence means one who holds relevant professional qualifications to the satisfaction of the administering authority; AND the administering authority is satisfied that person has knowledge, suitable experience and demonstrated expertise in relevant fields, as set out below:

- a) knowledge of engineering principles related to the structures, hydrology, hydraulics and environmental impact of watercourse subsidence; and
- b) a total of five years of suitable experience and demonstrated expertise in the following categories:
 - i. hydrology with particular reference to flooding, estimation of extreme storms or water management.
 - ii. hydraulics with particular reference to sediment transport and deposition and erosion control.
 - iii. hydrogeology with particular reference to seepage, groundwater.

System design plan means a plan that manages an integrated containment system that shares the required DSA and/or ESS volume across the integrated containment system.

The Act means the *Environmental Protection Act 1994*.

Void means any constructed, open excavation in the ground.

Watercourse has the meaning in Schedule 4 of the Environmental Protection Act 1994 and means a river, creek or stream in which water flows permanently or intermittently—

- a) in a natural channel, whether artificially improved or not; or
- b) in an artificial channel that has changed the course of the watercourse.

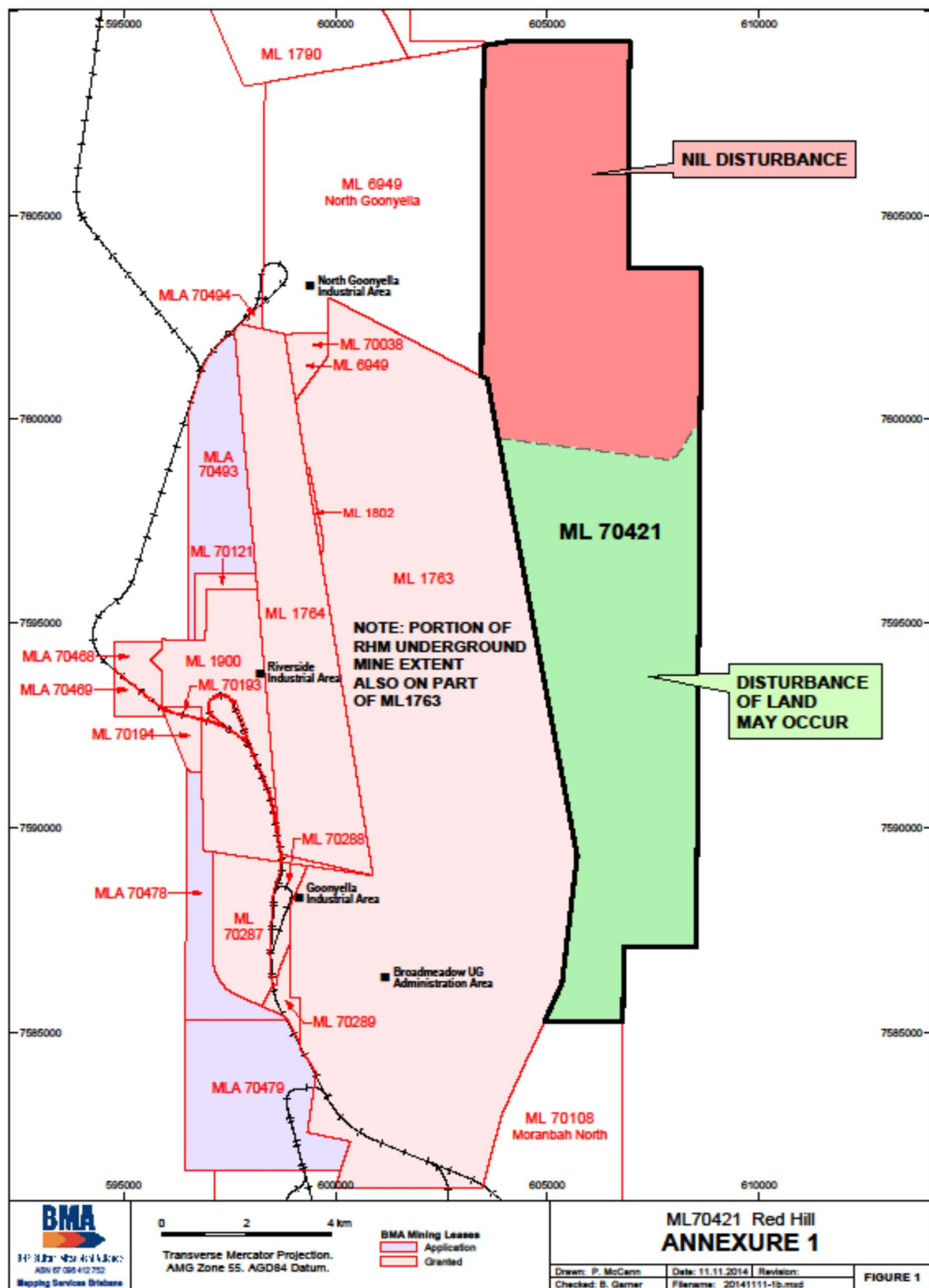
Watercourse includes the bed and banks and any other element of a river, creek or stream confining or containing water.

Waters includes all or any part of a river, stream, lake, lagoon, pond, swamp, wetland, unconfined surface water, unconfined water in natural or artificial watercourses, bed and banks of a watercourse, dams, non-tidal or tidal waters (including the sea), stormwater channel, stormwater drain, roadside gutter, stormwater run-off, and groundwater.

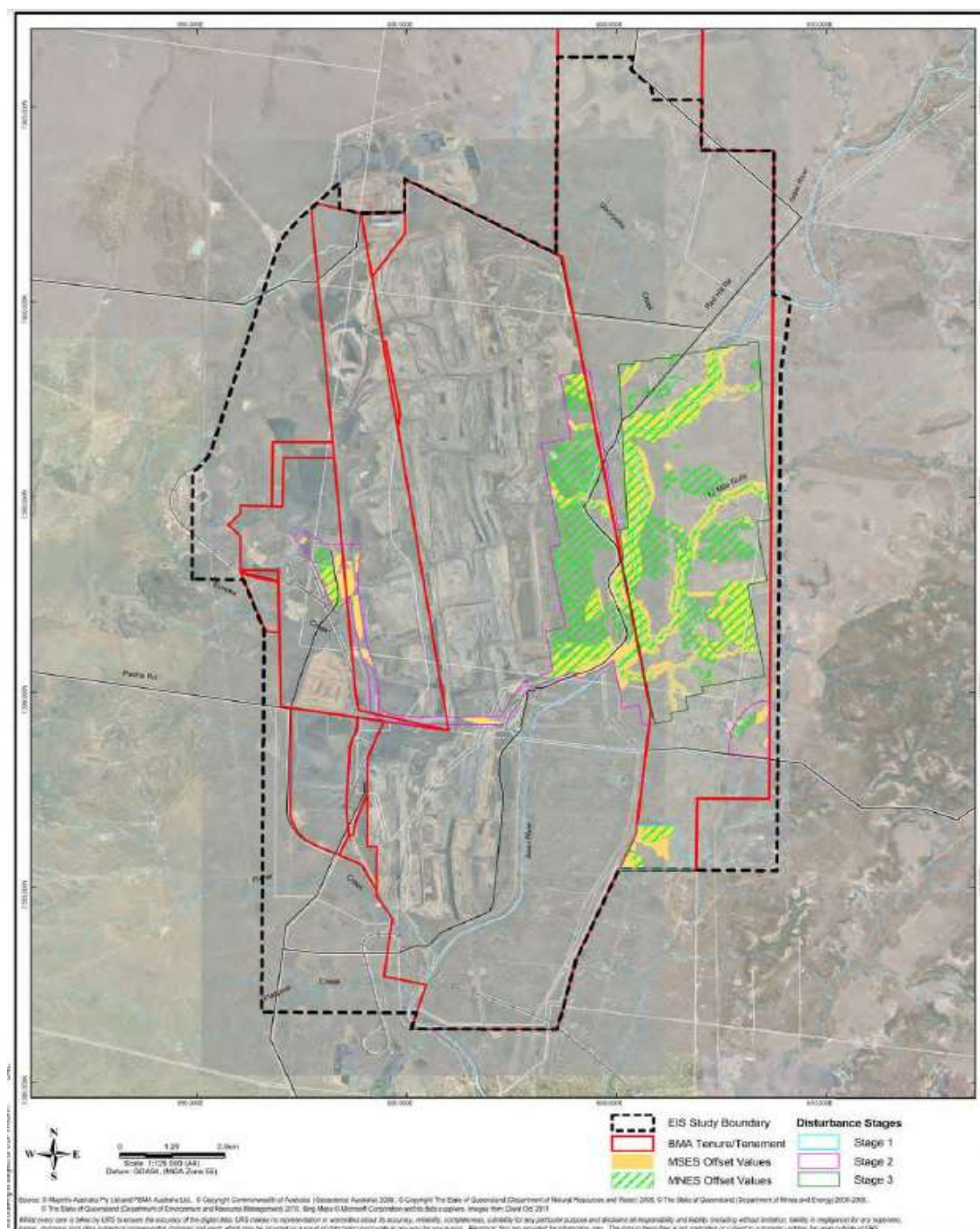
µS/cm means microsiemens per centimetre.

END OF DEFINITIONS

Annexure 1: Red Hill Mine Area of Disturbance



Annexure 2: Matters of State Environmental Significance



RED HILL MINING LEASE PROJECT

MNES AND MSES OVERLAP



URS

COORDINATOR-GENERAL'S EVALUATION REPORT

Figure: 5.2

File No: 42627373-p-2296.wor Drawn: VH Approved: CT Date: 13-03-2016

Rev. A A4

END OF ENVIRONMENTAL AUTHORITY

Notice

Environmental Protection Act 1994

Progressive rehabilitation and closure plan transition notice

This statutory notice is issued by the administering authority¹ under section 754 of the Environmental Protection Act 1994 to advise you that you must submit a proposed Progressive rehabilitation and closure plan (PRC plan).

BHP Coal Pty Ltd
Level 14, 480 Queen Street,
Brisbane City, QLD 4000

Craig.lockhart@bhp.com; Trudy.mazucco@bhp.com

Attention: Craig Lockhart & Trudy Mazucco

Our reference: EPML03337715

Transition Notice for a PRC plan

1 Environmental authority details

Environmental authority EPML03337715 dated 14 April 2021 issued to BHP Coal Pty Ltd, Mitsubishi Development Pty Ltd, QCT MINING PTY. LTD., Umal Consolidated Pty Ltd, QCT INVESTMENT PTY. LTD., BHP Queensland Coal Investment Pty Ltd and QCT Resources Pty Limited.

Land description: ML1763 and ML70421

2 Required action

The holder(s) of environmental authority EPML03337715 must submit a proposed PRC plan that meets the requirements in sections 126C and 126D of the *Environmental Protection Act 1994*, pursuant to section 754 of the *Environmental Protection Act 1994*. The holder(s) must submit the proposed PRC plan to the administering authority, by **13 December 2024**.

3 Transitional provisions

Pursuant to the transitional provisions in section 754(3) of the *Environmental Protection Act 1994*, the holder(s) of the environmental authority are not required to comply with the requirements under section 126C(1)(g) or (h), or 126D(2) or (3) of the *Environmental Protection Act 1994* if –

- (a) an outcome for the land has been identified under a land outcome document; and

¹ The Department of Environment and Science is the administering authority under the *Environmental Protection Act 1994*.

Progressive rehabilitation and closure plan transition notice

- (b) the outcome for the land is the same as, or substantially similar to, the outcome for the land if it were a non-use management area under a PRCP schedule.

A land outcome document is defined under section 750 of the *Environmental Protection Act 1994*.

Section 126C(1)(g) or (h), or 126D(2) of the *Environmental Protection Act 1994* require reasons and evidence to be provided to support a proposed non-use management area.

Section 126D(3) of the *Environmental Protection Act 1994* provides for any void that is contained wholly or partly in a flood plain to be rehabilitated to a stable condition.

In accordance with section 754(4) of the *Environmental Protection Act 1994*, if a land outcome document does not state sufficient detail to identify either the location or area of the land to which the outcome relates, the proposed PRC plan must state—

- (a) if the area is not identified — how the total area of the land to which the outcome relates will be minimised; and
- (b) if the location is not identified — how the mining environmental authority holder will ensure the location of the land to which the outcome relates minimises risks to the environment.

4 Supporting information

As detailed in section 2 of this notice, your PRC plan and associated PRCP schedule is required to address the relevant legislative requirements.

Please refer to the guideline Progressive Rehabilitation and Closure Plans (ESR/2019/4964) for more information about the requirements of the PRC plan and associated PRCP schedule, and the assessment process.

5 Consultation

The administering authority recommends that you request a pre-lodgement meeting to discuss the requirements of the proposed PRC plan in more detail. To request a pre-lodgement meeting, please complete and lodge the form 'Application for pre-lodgement services' (ESR/2015/1664) to arrange a meeting.

Should you have any questions in relation to this notice, contact Business Centre Coal via the below details.



Signature

13/12/2021

Date

Chris Wake
Department of Environment and Science
Delegate of the administering authority
Environmental Protection Act 1994

Enquiries:
Coal Business Centre
Department of Environment and Science
PO Box 3028, Emerald QLD 4720
Phone: (07) 4987 9320
Email: CRMining@des.qld.gov.au



Memorandum

Date 29 November 2021
To Chris Wake, Manager Environmental Services, Department of Environment and Science
From Trudy Mazucco, Principal Closure Planning Minerals Australia
CC Craig Lockhart, Manager Closure Planning Minerals Australia
Subject Progressive Rehabilitation and Closure Plan – Red Hill Mine

Purpose

The purpose of this memo is to provide context and background information for the purpose of completing a Progressive Rehabilitation and Closure Plan (PRC Plan) and associated PRCP Schedule for the Environmental Authority (EA) noted below (Red Hill Mine). This information is intended to facilitate the issuing of a notification for the PRC Plan and associated PRCP Schedule for this EA.

Environmental Authority Number: EPML03337715 (14 April 2021)

Environmental Authority Holders: BHP Billiton Mitsubishi Alliance (BMA) equity holding, comprising:

- QCT Mining Pty Ltd
- QCT Resources Pty Ltd
- QCT Investments Pty Ltd
- BHP Coal Pty Ltd
- BHP Queensland Coal Investments Pty Ltd
- Mitsubishi Development Pty Ltd
- Umal Consolidated Pty Ltd

PRCP Requirement	BHP information submission for review
Introduction	Red Hill Mine (RHM) is a planned underground expansion located directly east of the existing Goonyella Riverside Broadmeadow Mine (GRBM) Complex. The underground expansion was approved under EA (EPML03337715) in 2016, but construction and operation has not yet commenced. Environmentally relevant activities are authorised on mining leases (MLs) ML1763 and ML70421. It is important to note that RHM's portal entry will be accessed via the GRBM pits and waste from coal processing will be disposed at GRBM. Therefore, the development of the RHM and GRBM PRC Plans and PRCP schedules will be aligned as required.
Project Planning	
Project description	RHM is planned as a longwall mining operation. A new mine industrial area (MIA) is proposed, including a new coal handling and preparation plant (CHPP), run-of-mine (ROM) and coal stockpiles, site offices, laydown areas, power and water supply support, workshops, vehicle wash-down area, and fuel storage and/re-fuelling area. Infrastructure and services will be shared with GRBM where feasible. The PRC Plan will be aligned to the operational footprint approved at the point of PRCP submission; understanding that PRCP amendments may be required over time.
Mining activities	The larger eastern portion of the RHM underground expansion footprint is located on ML70421 and the smaller western portion located on ML1763. (Shared infrastructure with the GRBM complex is located on ML1763, ML1764 and ML1900). The underground operation is planned to include longwall panels, with a potential production capacity of 14Mtpa of high quality hard coking coal. The total underground mining footprint will be approximately 3,600ha.
Existing rehabilitation	Not applicable as mining has not yet commenced.
PMLUs	The predominant pre-mining land uses at RHM are cattle grazing and woodland habitat. As per the <i>BHP PRCP Landform and Rehabilitation DES memo Final 28082020</i>, BHP has transitional arrangements for RHM for the post-mining land uses (PMLUs) listed in Table F1 of the EA, which include: • Cattle grazing; • Dryland cropping; • Woodland habitat; • Water storage; and • Watercourse. The completion criteria in Table F1 will also be transitioned to milestone criteria in the PRC Plan. The location, extent and viability of these PMLUs will be detailed in the PRC Plan.
NUMAs	Not applicable – no voids at RHM.
Voids in floodplains	Not applicable – no voids at RHM.

PRCP Requirement	BHP information submission for review
Community consultation	As a transition site, there is no requirement for community consultation prior to submission of PRC Plan. However, BHP will follow an engagement plan over the life of the operation, in line with current internal stakeholder engagement frameworks.
Rehabilitation and Management Measures	
Hydrogeology	Groundwater ingress will vary over the life of the RHM underground expansion depending on the characteristics of the particular part of the coal seam being mined, the number of panels targeted, and the rate of mining. EIS-related groundwater modelling indicated that groundwater ingress could reach a peak of around two gegalitres per year during the last five years of operation for the RHM. However, the volume of ingress will be impacted by the rate and timing for development. Some groundwater will be removed prior to interception by mining through pre-drainage of incidental mine gas, which has the potential to reduce inflows to the underground. It is estimated that a peak of up to 800 ML per annum of groundwater may be derived from IMG pre-drainage. Groundwater inflow will be pumped from the RHM extension to the GRBM complex water management network. <i>Importantly, development of the Red Hill PRCP is proposed to be tied to the development of the GRBM groundwater model and assessment (due to the operational interlinkages between these workings). After the submission of the PRC Plan and PRCP schedule, ongoing groundwater data collection will be required to refine the models to provide greater confidence and to confirm rehabilitation methods, milestones and schedule pertaining to groundwater.</i>
Flooding	Parts of the site are within the Isaac River floodplain. As per the <i>BHP PRCP Flood Modelling Position – 23072020 memo</i>, BHP will use a risk-based approach to flood modelling. Where the risk-based approach identifies a flood modelling requirement, the modelling will be completed using criteria identified as appropriate for the location.
Soil and capping material	As per the <i>BHP PRCP Landform and Rehabilitation DES memo Final 28082020</i>, the soil and capping assessment at RHM will include: • Topsoil quality, quantity, treatments and management; • Availability, quality and quantity of any other capping material required; and • Strategies to address any deficits including development of alternative growth media to support appropriate PMLUs.
Waste characterisation	The rejects materials from the proposed RHM CHPP will consist of the following: • Dense medium coarse reject material; • Fine reject material; and • Flotation tailings material. The dewatered tailings and rejects will be placed in the existing waste storage facilities serving the GRBM complex. New tailings or rejects storage facilities are not required for the expansion. As detailed in <i>BHP PRCP Geochem DES Update 26082020</i>, site-specific data collected from GRBM Complex, in addition to those collected for other Moranbah Coal Measure sites, (<i>PRCP memos – comments and feedback 25092020</i>) will be used to assist with defining the environmental geochemical properties of key material domains at RHM.

PRCP Requirement	BHP information submission for review
	A classification system will be developed from the geochemical and physical characterisation that will confidently identify beneficial and problematic waste from a chemical and physical stability perspective.
Landform design	The main landform consideration will be subsidence caused by the underground operations. The PRC Plan will include the detail for landform design as per the <i>BHP PRCP Landform and Rehabilitation DES memo Final</i> .
Cover design	A risk-based approach will be used to determine areas that may require a cover design.
Water management	Closure water management planning will integrate the results of other technical studies such as waste characterisation, subsidence models, groundwater assessments and landform design, to provide an understanding of the post mining water management requirements and potential risks. Water management planning will identify requirements for any ongoing dewatering or treatment and how this is to be achieved.
Revegetation	The PRC Plan will include the detail for revegetation as per the <i>BHP PRCP Landform and Rehabilitation DES memo Final 28082020</i>. The Revegetation Plan will be consistent with the revegetation planning requirements of the PRCP guideline and existing BHP rehabilitation management plans. The Revegetation Plan will describe the works for establishing and managing the revegetation as it relates to the intended PMLUs as listed in Table F1 of the EA (e.g. cattle grazing, woodland habitat, watercourses, water storage and dryland cropping).
TSFs	Not applicable – no tailings to be disposed at RHM.
Voids	No applicable – no open pit mining at RHM.
Underground mining	The requirements of the PRCP Guideline will be compiled for the planned RHM underground workings.
Infrastructure	As per the <i>BHP PRCP Landform and Rehabilitation DES memo Final 28082020</i> , all required information on decommissioning or retainment of infrastructure will be included as part of the PRC Plan.
Risk assessment	
Risk assessment	To be completed as part of the PRC Plan.
Rehabilitation trials and monitoring and maintenance	Rehabilitation trials may be conducted throughout the life of mine, where needed, but will not be included in the PRC Plan. Monitoring and maintenance will be based on current BHP processes. As per the <i>BHP PRCP Landform and Rehabilitation DES memo Final 28082020</i>, all required information will be included.
PRCP Schedule	
Rehabilitation milestones, and milestone criteria	To be completed based on the content of the PRC Plan.

Recommendations

Review and consider the above information as a basis for PRCP compilation for RHM.

Yours sincerely

Trudy Mazucco
Principal Closure Planning
Trudy.mazucco@bhp.com

Appendix 1: Goonyella Riverside / Broadmeadow Mine Complex: Supporting Maps

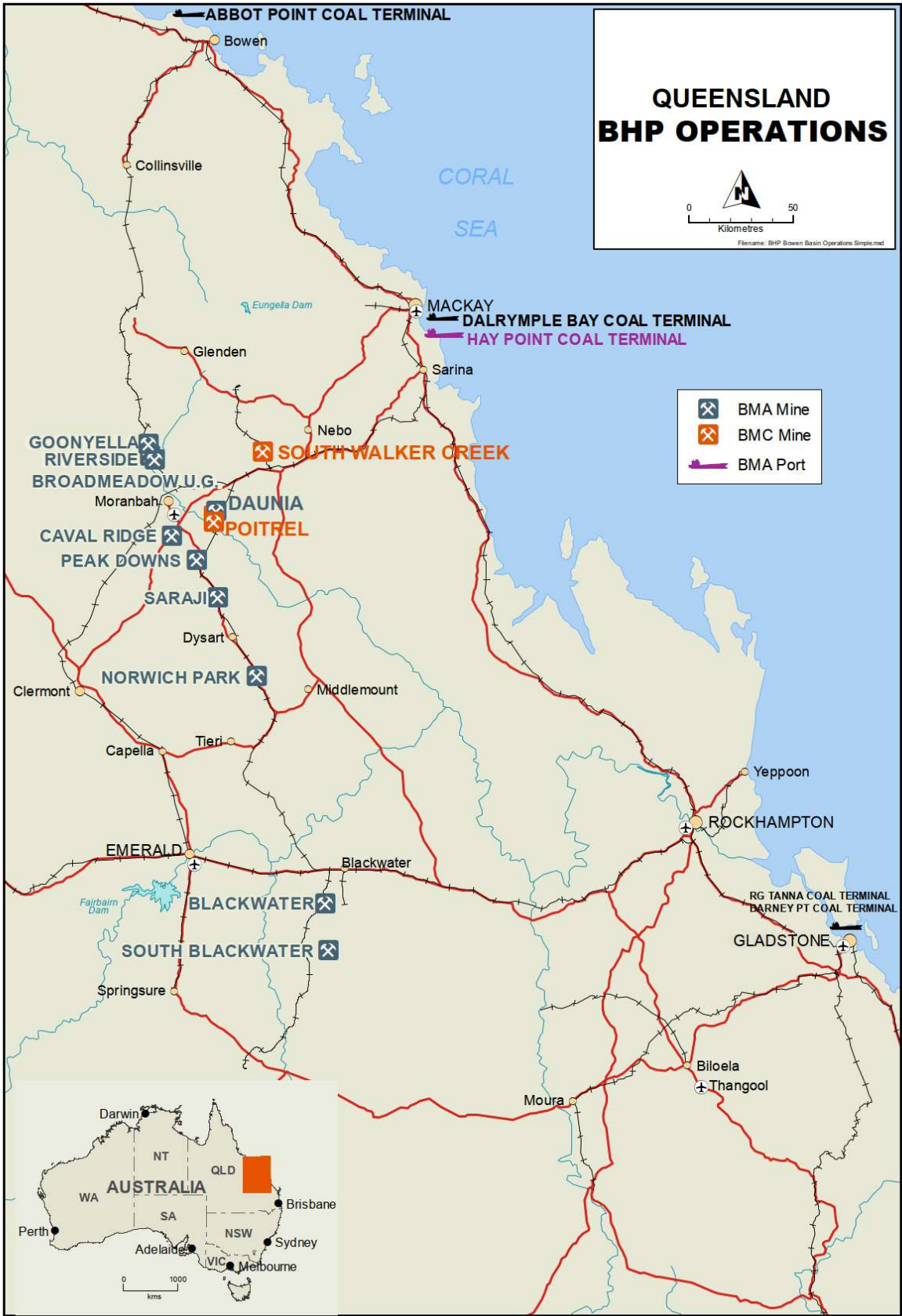


Figure 1: BHP Operations in Queensland

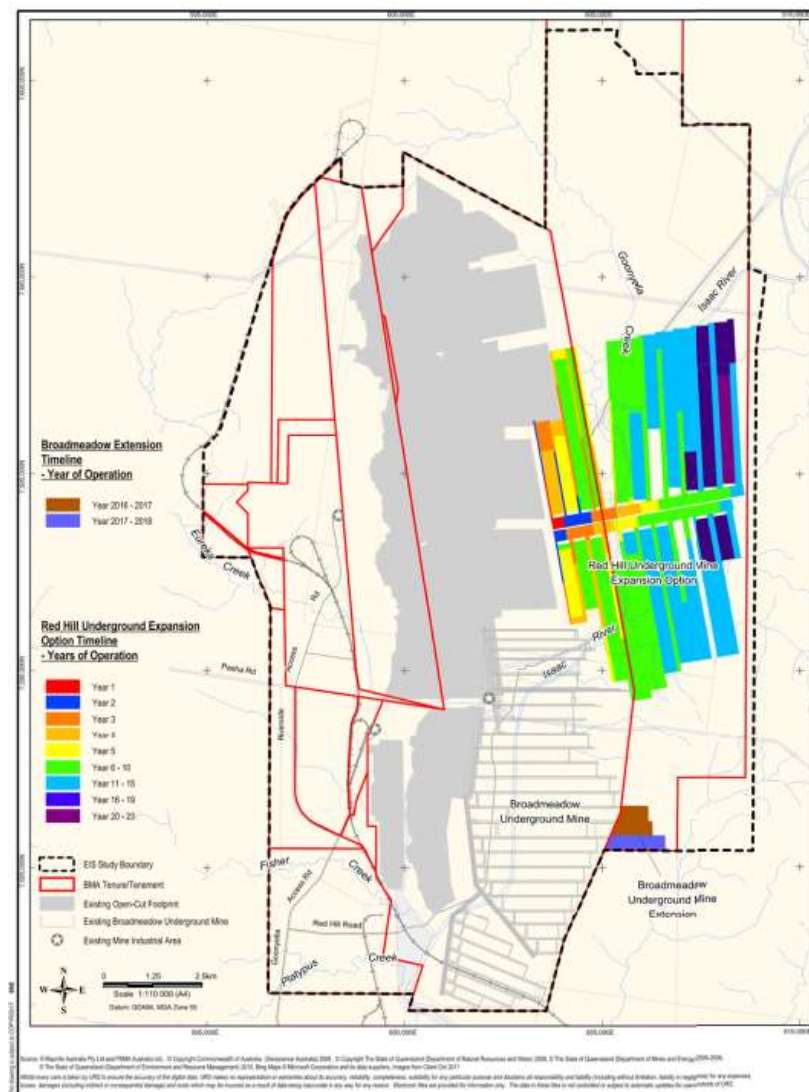
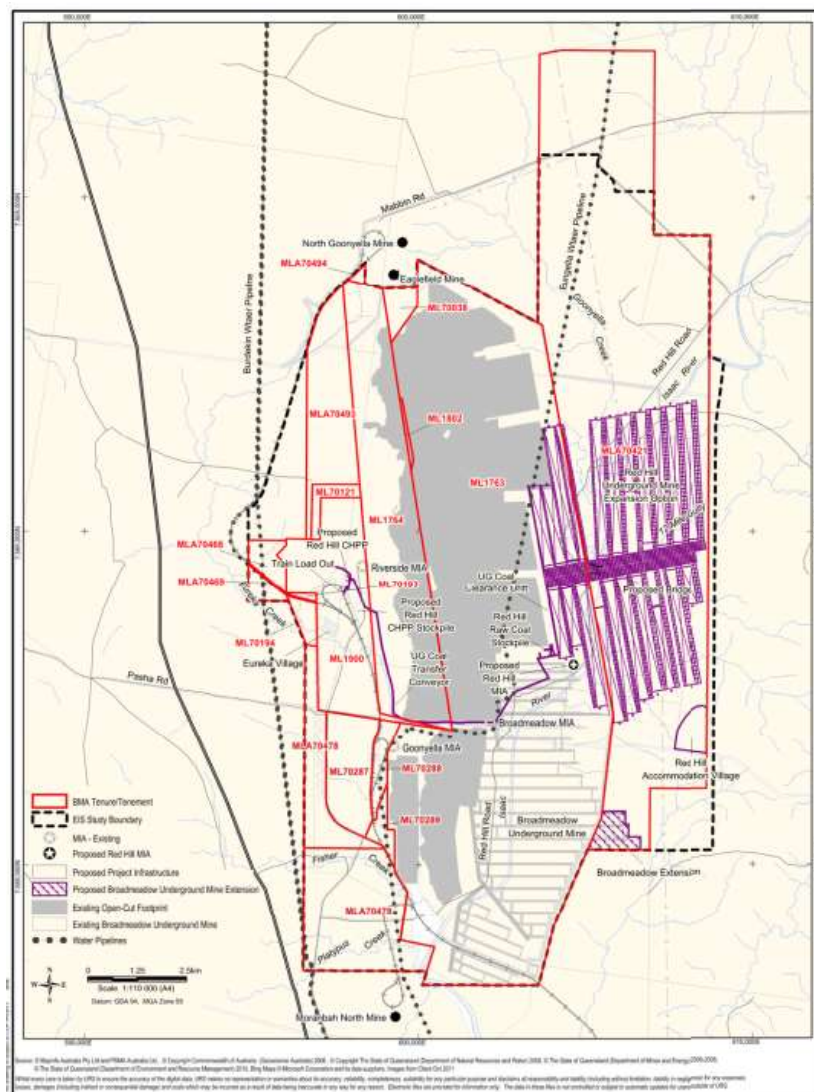


Figure 2: Indicative Red Hill Mine underground mining layout

Transitional Progressive Rehabilitation and Closure Plan - Red Hill Mine

Hydrogeology assessment

25-Nov-2024

BMA Hydrogeology Assessment for Closure Plans

Commercial-in-Confidence

Transitional Progressive Rehabilitation and Closure Plan - Red Hill Mine

Hydrogeology assessment

Client: BHP Mitsubishi Alliance

ABN: 67096412752

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1.0 Introduction

BHP Mitsubishi Alliance Pty Ltd (BMA) appointed AECOM Australia Pty Ltd (AECOM) to undertake a hydrogeological assessment to support the transitional Progressive Rehabilitation and Closure Plan (PRC Plan) for the Red Hill Mine (RHM). The RHM is an approved underground mine, located immediately down dip of the existing Goonyella, Riverside, and Broadmeadow mines (herein referred to as the GRB), located about 30 kilometres (km) north of Moranbah, Queensland (see Figure 1).

This hydrogeological assessment was undertaken in accordance with the relevant requirements of the Queensland Department of Environment and Science (DES) Guideline – Progressive Rehabilitation and Closure Plans (PRC Plans), reference ESR/2019/4964, Version 3.1 (16 September 2024), 'the Guideline'. The groundwater assessment will be utilised to assist in the development of rehabilitation strategies and selection of post-mining land uses (PMLUs) and non-use Management Areas (NUMAs) within the RHM PRC Plan.

The BMA RHM, is an undeveloped hard coking coal underground mine, located immediate adjacent and down dip of the GRB. The mine will be accessed through the open cut pit highwall of the GRB and utilise existing disturbance areas and infrastructure. The RHM is designed to be an extension of the GRB operational life and capacity of operations at the GRB. RHM is operated under Environmental Authority (EA) EPML03337715, which is separate from the GRB.

The GRB metallurgical coal mining complex includes both open cut (Goonyella Riverside Mine) and underground (Broadmeadow Mine) operations, across eighteen (18) Mining Lease (ML) tenures within the geological Bowen Basin (Figure 1). Existing operations at GRB are executed under the conditions of Environmental Authority (EA) EPML00853413, for the extraction of coal via open cut strip mining from the Goonyella Riverside Mine and underground extraction of coal from the Broadmeadow Mine.

RHM is located within ML 70421. Mine workings of relevance for the GRB are located primarily on ML 1763 and ML 1764, which include existing open cut pits: Thiess Pit, Airstrip Pit, Isaac Pit, Broadmeadow Pit, Red Hill Pit, Denham Pit, Cleanskin Pit, Riverside Pit, and Eureka Pit. These MLs and mine workings are included in Figure 2.

It is noted that due to the interconnectivity of the geology and hydrogeology, the PRC Plan groundwater input incorporates both the GRB and RHM.

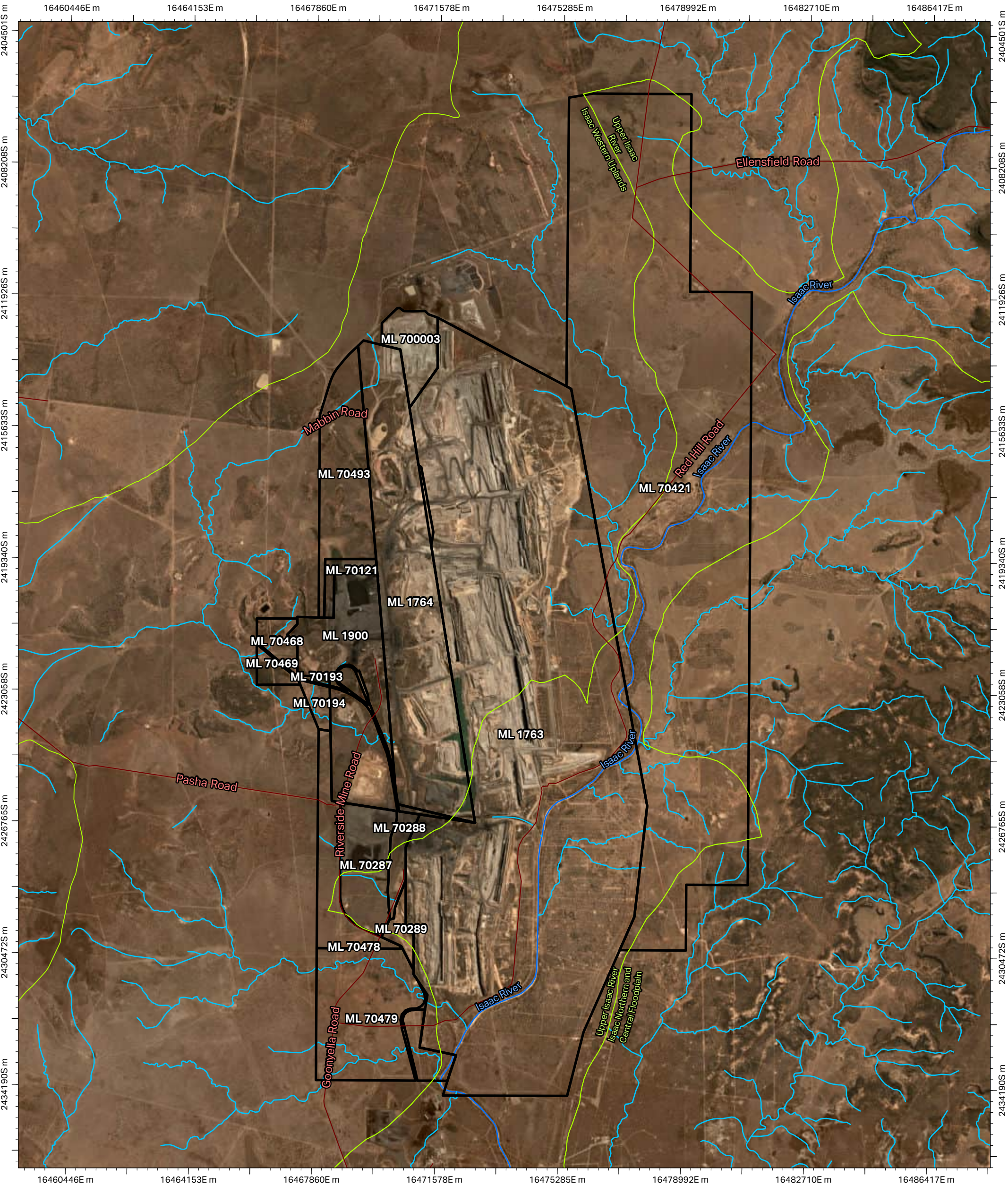
The terms 'Project area' and 'Project' throughout this report includes:

- The GRB (or Goonyella Complex or Goonyella Riverside and Broadmeadow mines and the terms are interchangeable)
- The RHM.

Thus, the Project area is defined as the regional area surrounding the RHM and GRB and is considered in detail within this hydrogeological assessment. This allowed for an informed understanding of the local and more regional scale groundwater system/s plus the existing mining activities and their influence on groundwater resources.

Figure 1 Project locality plan

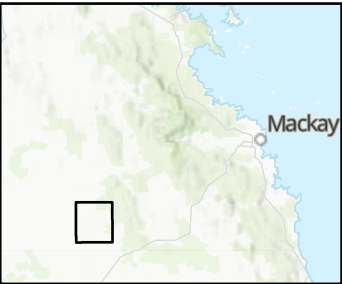
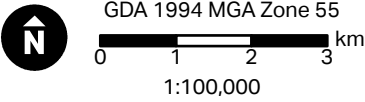
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Basemap image taken 2017

Goonyella, Riverside and Broadmeadow Mines
Locality Plan

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)



1.1 Project Background

The Goonyella open cut coal mine commenced operations in 1971, while the adjacent Riverside underground longwall mine was brought into production in 1982. The mines were merged into a single operation in 1989.

The open pit mine targets three coal seams of the late Permian-aged Moranbah Coal Measures (MCM):

- The Goonyella Upper (GUS) seam.
- The Goonyella Middle (GMS) seam.
- The Goonyella Lower (GLS) seam.

The average thicknesses of these target coal seams are 3.9 m, 7.5 m, and 8.5 m, respectively. Comprising sandstones, siltstones, mudstones, claystone, and coal, the MCM at GRB extends more than 300 m below ground surface.

Operations began at Broadmeadow Mine as an underground longwall mine, which now includes top coal caving mining (TCC) methods, in 2005 under the ownership of BHP Billiton Mitsubishi Alliance. The TCC mining method is defined as “a special type of longwall mining applicable to very thick seams”. This method reduces the amount of good quality coal that can be left using ‘conventional’ longwall equipment. Implementing this method at Broadmeadow increased productivity and offers safety advantages.

The introduction of the longwall top coal caving method, alongside an expansion of the Broadmeadow Mine eastwards, increased the productive capacity at the mine from 0.4 million tonnes per annum (Mtpa) to a new total capacity of 4.8 Mtpa and extended the life of the mine by 21 years. This expansion began producing coal in 2013 as part of the Goonyella Riverside Mine Expansion Project.

The neighbouring Goonyella Riverside mine has two coal handling and processing plants (CHPPs) where mined coal is sorted and washed. Coal from Broadmeadow mine utilises these CHPPs. After being processed, the coal is transported by rail to the BMA-owned Hay Point Terminal.

RHM, an approved but yet to start underground mine, is planned as an extension of the GRB operational life. The mine plan for RHM indicates a start date of 2063 (Section 10.1). The RHM targets the GMS coal seam and will utilise ancillary mining facilities, including CHPPs and mine waste storage facilities at GRB.

Figure 2 Mine leases and current mine areas (source: BMA)

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BHP Mitsubishi Alliance

GOONYELLA RIVERSIDE & BROADMEADOW MINES



0 1 2 km
Projection: ASD68 AMG Zone 55
Scale 1:25000

Filename: GRM_PhotoMap_Monthly.mxd



Mining Leases

Mineral Development Licence

Exploration Permit - Coal

Surface Areas

ML 1763

Goonyella Mine

102,74ha

ML 1764

Riverside Mine

2162.63ha

ML 1802

Riverside Extended

19.22ha

ML 1900

Riverside West

1163ha

ML 70121

Riverside Tailings

90.24ha

ML 70183

Williams Dam North

14.04ha

ML 70194

Williams Dam South

79.73ha

ML 70287

Goonyella Tailings

458.80ha

ML 70288

Goonyella Industrial Area

99.69ha

ML 70289

West Arrip Pit

80.00ha

ML 70421

Red Hill

8841.20ha

ML 70468

Riverside West Ext. 1

120.3ha

ML 70469

Riverside West Ext. 2

74.1ha

ML 70478

Goonyella West 1

426.52ha

ML 70479

Goonyella West 2

1136.5ha

ML 70493

Riverside Northwest

746.15ha

ML 70494

Riverside North

15.60ha

ML 70003

Mabon

281.4ha

EPC 528

Wards Well Infrastructure 8 sub-blocks

Product generated by Mine2Map at 11:19:26 AEST

2.0 Final Landform #2.3

Due to the continuous nature of the geology and hydrogeology at GRB and RHM, plus RHM utilising mining facilities at GRB, the GRB final landform includes for the RHM and was used for the RHM PRC Plan hydrogeological assessment.

The post-mining final GRB landform, which includes for RHM, was provided by BMA and is denoted Landform #2.3, and is shown as Figure 3.

The final landform comprises six planned residual final voids: Goonyella Pit (comprising Redhill Void, Denham Void, Cleanskin Void, Riverside Void), Thiess / Ramp 21 Pit, Ramp 32 East, Ramp 32 South, Broadmeadow Pit, and Isaac Pit (Plate 1).

Ramp 32 East and Ramp 32 South are residual voids derived from the airstrip pit (Figure 2), where airstrip pit will be backfilled and rehabilitated for cattle grazing.

It is noted that Landform #2.3 was utilised in the predictive modelling included in the groundwater study, as reflected in Figure 21.

The final landform provided by BMA, used to assess the suitability of BMA's intended post mining land use (PMLU) at the Project, includes 'Cattle grazing', 'Woodland habitat', 'Water storage' and 'Watercourse' as defined within Table E1 of the EA.

Plate 1 Project final landform and residual voids

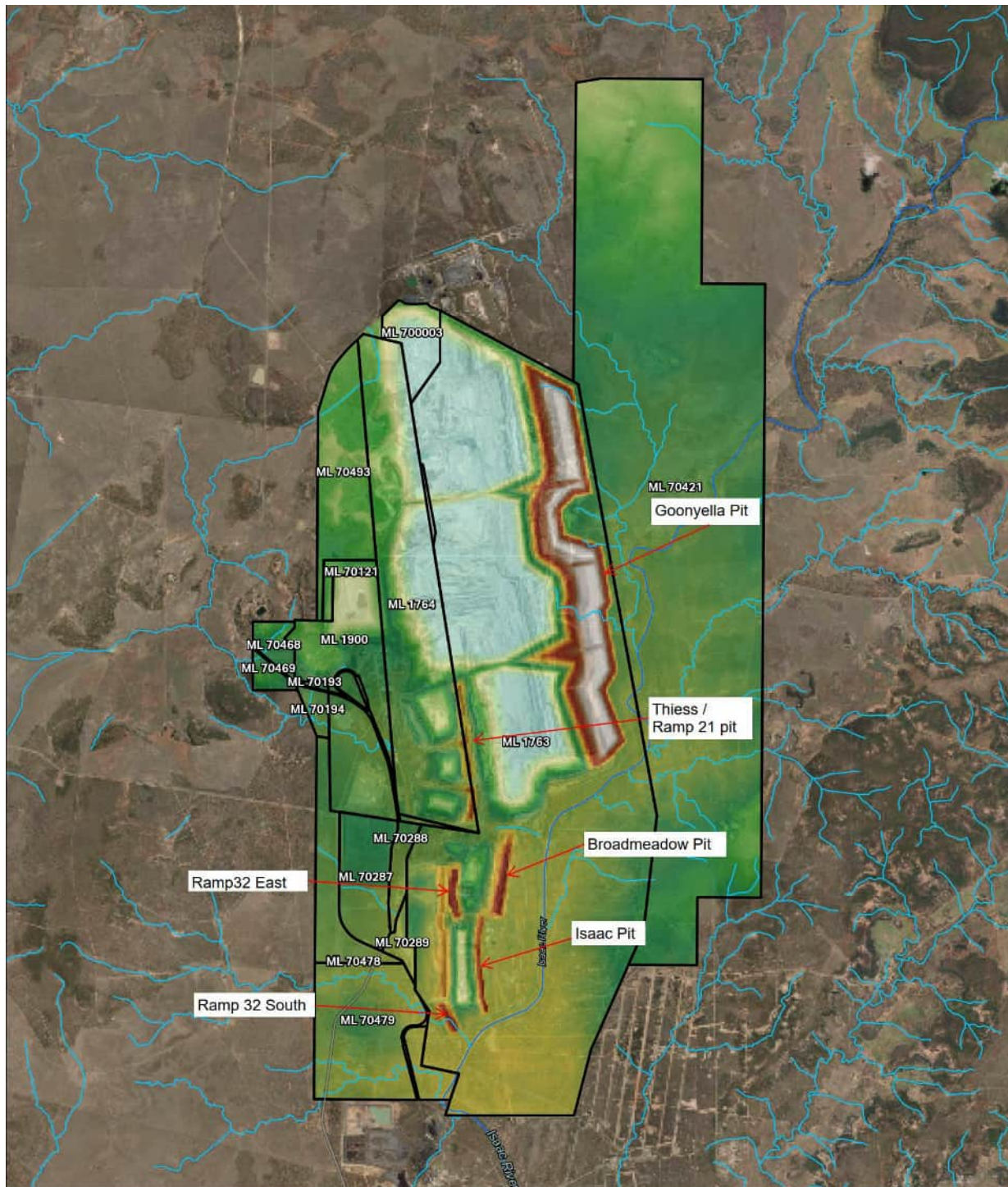
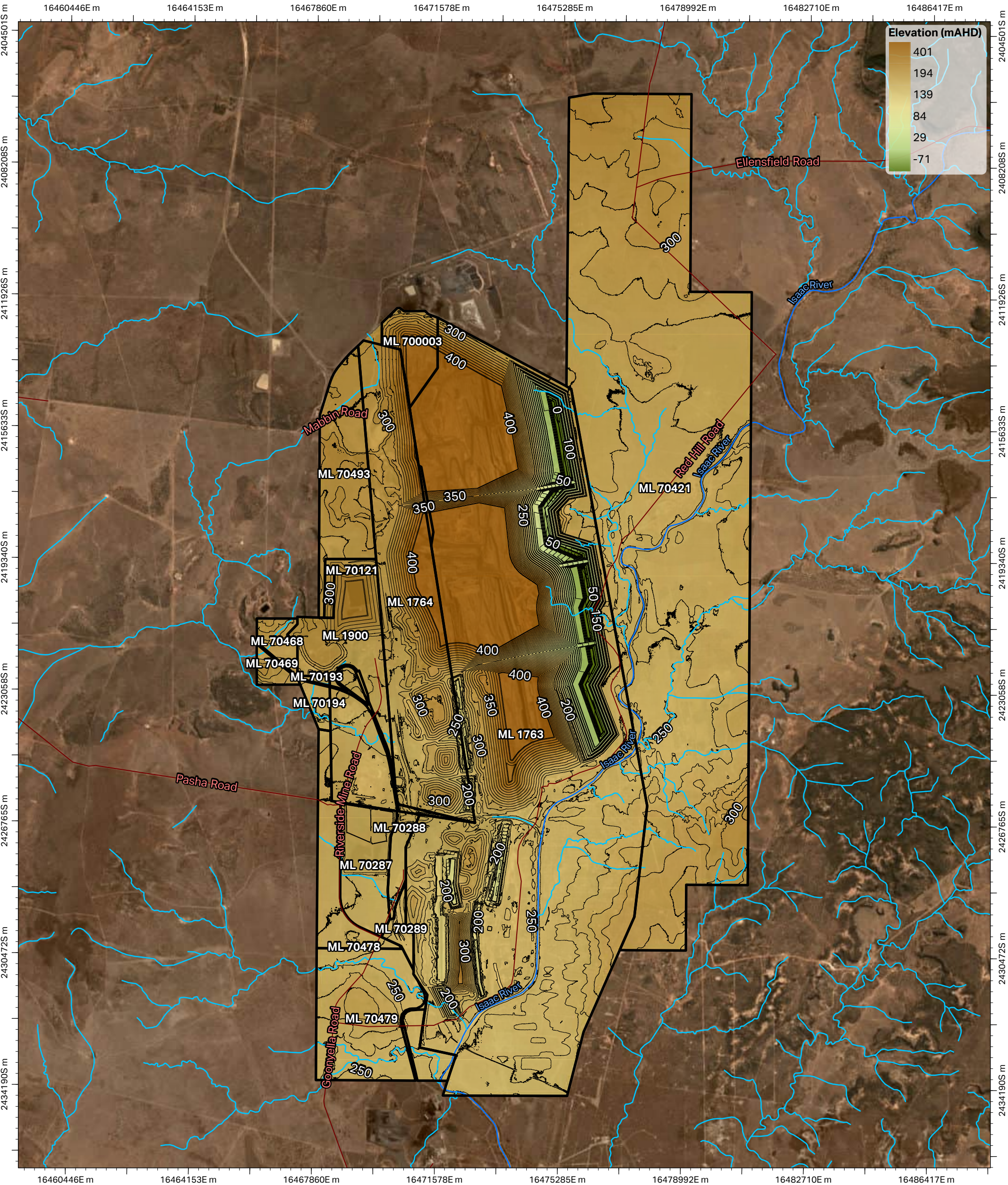


Figure 3 Landform #2.3

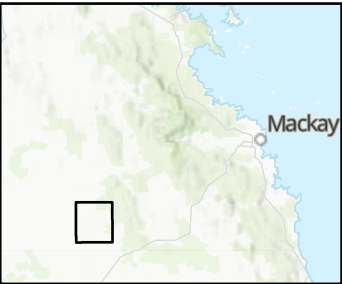
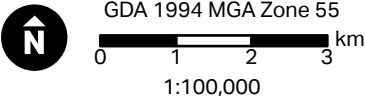
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Basemap image taken 2017

Goonyella, Riverside and Broadmeadow Mines
Post Mining Landform (Landform #2)

-  Mine Lease
-  Watercourse (Major)
-  Watercourse (Minor)



3.0 Objectives

The main objective of the hydrogeological assessment is to assess the potential groundwater related impacts at completion of all mining at GRB and RHM and until conditions stabilise post rehabilitation (i.e. groundwater equilibrium).

A focus of the hydrogeological assessment is demonstrating suitability of the final landform for the intended PMLUs with respect of the Project area groundwater system. As such, the key specific objectives adopted in this assessment to demonstrate this suitability include:

- That the final landform is non-polluting with respect to groundwater:
 - The Goonyella Pit (residual void) is recognised, through predictive groundwater and water balance modelling (Section 15.0), to act as sink for groundwater, including groundwater contained within spoil and underground mine workings.
 - The residual void pit water level/s within the Goonyella Pit remain below groundwater bearing units, (i.e. there is sufficient freeboard to negate risk of void water discharge off site within a groundwater system).
 - The Goonyella residual void water level/s are sufficiently deep to alter local groundwater flow, including the mine footprint area of RHM, such that flow is towards the residual void.
- That there are minimal (little or no) additional impacts to groundwater receptors post-closure caused by the final landform that have not already occurred as a result of approved mining:
 - Little to no additional groundwater drawdown at potential groundwater dependant ecosystem (GDE) locations (Section 15.8.2).
 - Little to no additional groundwater drawdown at anthropogenic bore users (Section 15.8.1).

3.1 Guideline Criteria

A Progressive Rehabilitation and Closure Plan (PRC Plan) is a crucial component of ensuring that an Environmental Authority (EA) holder plans progressive rehabilitation of the land properly and provides conditions to which the land will be rehabilitated before surrendering the EA.

This hydrogeological assessment is undertaken in accordance with the relevant requirements of the Queensland Government Department of Environment and Science (DES) Guideline: Progressive Rehabilitation and Closure Plans (DES Reference: ESR/2019/4964, version 3.01, 16 September 2024).

Note: Guideline section 3.6.4 requires an assessment of groundwater interactions and potential lowering of groundwater levels that includes consideration of the potential exposure of previously saturated geological formations to air, which can lead to AMD generation. Potential AMD generation and migration potential is not discussed in the hydrogeological assessment report, as a geochemical assessment has been compiled separately.

Table 1 Statutory guidelines requirements addressed in the PRC Plan groundwater study

Guideline Section 3.6.1 Hydrogeology Requirements	Report Sections
Determining the groundwater occurrence including the existence of, and depth to, aquifers and aquitards	Section 7.0
Locating groundwater recharge and discharge locations locally and regionally	Sections 7.3, 11.0, 13.0, and 17.0
Groundwater quality within each of the aquifers and from surface expressions (i.e. seeps and springs)	Section 8.0
Current and potential future uses of groundwater including existing groundwater extraction bores	Section 9.1
Groundwater flow direction and velocity, including field tests to determine hydraulic conductivity	Section 7.2 and Section 13.0
The development of potentiometric mapping and hydro stratigraphic cross sections	Sections 7.3, 6.0, 11.0, and 17.0
Groundwater modelling to determine contaminant transport and potential changes to groundwater level from dewatering or waste storage	Section 13.0, 14.0, 15.0, and 16.0
Guideline Section 3.6.3 Voids Requirements	Report Sections
Groundwater modelling to determine whether the void is acting as a sink or a source for groundwater	Section 15.0
A water balance study including an assessment of void surface and groundwater interactions such as:	
• groundwater lowering/reduction in hydraulic head	Section 15.4.3
• cones of depression and associated impacts	Sections 15.4.3, 15.6, and 15.7
• a conceptual model that incorporates all projected inflows, outflows, and recharge rates	Section 11.0, Section 15.4
• each of the major water fluxes into and out of the void	Section 16.3.1
Guideline Section 3.6.4 Underground Mining Requirements	Report Sections
• the development of a hydrogeological conceptual model	Section 11.0 and Section 17.1
• changes to the hydrogeological regime as a result of new cracks in the rock mass which can provide new flow paths in what could have previously been impermeable rock	Section 7.3.4
• potential for vertical connections between previously separated aquifers	Section 7.3.4

4.0 Project area description

The Project area is located within the Isaac River sub-basin of the Fitzroy Basin. The Isaac River sub-basin spans an area of about 22,000 square kilometres (km²). Several tributaries join the Isaac River around the Project.

Eureka and Goonyella creeks are located in proximity to RHM, and drain into the Isaac River. The Eureka Creek was modified with a man-made diversion drain and weir just upstream of where it joins the Isaac River. Eureka Creek is a partially regulated system for runoff from mining activities and is authorised as a discharge point to the Isaac River.

The Isaac River diversion is detailed in Section 5.2.

4.1 Climate

The climate around the Project area is sub-tropical, characterised by high variability in rainfall, temperature, and evaporation. Summer is between December and February and Winter is between June and August. The maximum daily temperature averages between 29.8 and 30.7 °C.

Climate data has been collected from two Bureau of Meteorology (BoM) weather stations around the project site. The weather stations used are:

- Moranbah Airport, QLD (Station 034035) – this station is situated about 36 km south of the project site. The station has been in operation since February 2012 to present day.
- Wentworth, QLD (Station 034015) – this station is situated approximately 43 km southwest of the project site. The station has been in operation since January 1963 to present day.

Average annual rainfall around the Project area is between 500 mm and 560 mm. High rainfall and evaporation occur in the summer months (December to February). Monthly evaporation rates are higher than monthly rainfall amounts throughout the year, indicating a net loss due to evaporation (i.e., a negative climate balance which has implications for final void water levels).

Summary of the average temperature and rainfall from the Moranbah Airport and Wentworth weather stations are presented in Table 2 and Table 3, respectively.

Evaporation data was only available from the Wentworth weather station.

Table 2 Moranbah Airport (Station 034035) Temperature and Rainfall Averages

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Min Temp (°C)	21.5	21.4	20.3	16.9	12.8	10	8.8	8.9	12.7	16.3	18.9	20.6	15.9
Mean Max Temp (°C)	34.5	33.7	32.8	30.3	26.9	24.4	24.3	26.8	30.1	33.2	34.5	34.9	30.7
Mean Rainfall (mm)	103.1	82.6	76.8	25.7	30.6	23.1	38.7	12.2	14.5	22.8	66.3	64.3	560.8

Table 3 Wentworth (Station 034015) Temperature and Rainfall Averages

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Min Temp (°C)	21.7	21.5	20.0	16.7	12.8	9.4	8.1	9.5	12.9	16.7	19.3	21.0	15.8
Mean Max Temp (°C)	33.8	33.0	32.0	29.7	26.4	23.8	23.6	25.8	29.2	32.1	33.6	34.3	29.8
Mean Rainfall (mm)	88.6	77.0	50.2	28.8	28.6	18.4	19.6	18.3	9.9	25.9	54.8	82	499.3
Mean Evaporation (mm)	226.6	185.1	189.1	150.7	119.3	95.7	104.7	138.5	181.3	226.5	235.7	246.9	2,085.2

Rainfall data for the Project area were examined for rainfall patterns. Rainfall data was collected for the period from 2014 to 2024. The coordinates for the weather station rain gauges are provided in Table 4.

Table 4 Rainfall Stations Provided by BMA

Gauge Name	Commenced	Easting (GDA94)	Northing (GDA94)
GRM North AWS 2014 - 2024	2014	599688	7601004
BRM AWS 2014 - 2024	2014	602574	7588265
Eureka Village TEOM 2015 - 2024	2015	596976	7591840
GRM South AWS 2016 - 2024	2016	601182	7583820

The rainfall data indicates an average annual rainfall ranging from 510 to 560 mm, similar to the more regional weather stations.

Table 5 Average Rainfall Data

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
GRM North AWS 2014 - 2024	108.5	66.9	62.9	16.6	36.1	18.9	35.3	11.3	19.	21.7	45.8	73.9	517.2
BRM AWS 2014 - 2024	100.0	63.9	64.3	21.1	30.7	19.5	40.8	12.6	40.9	19.4	60.1	82.4	555.9
Eureka Village TEOM 2015 - 2024	85.6	86.6	90.9	21.4	38.1	25.1	44.6	9.78	17.5	28.8	54.5	73.0	575.8
GRM South AWS 2016 - 2024	94.2	64.7	75.3	19.1	42.0	13.1	39.6	6.7	14.7	15.2	41.9	87.6	514.0

4.2 Topography

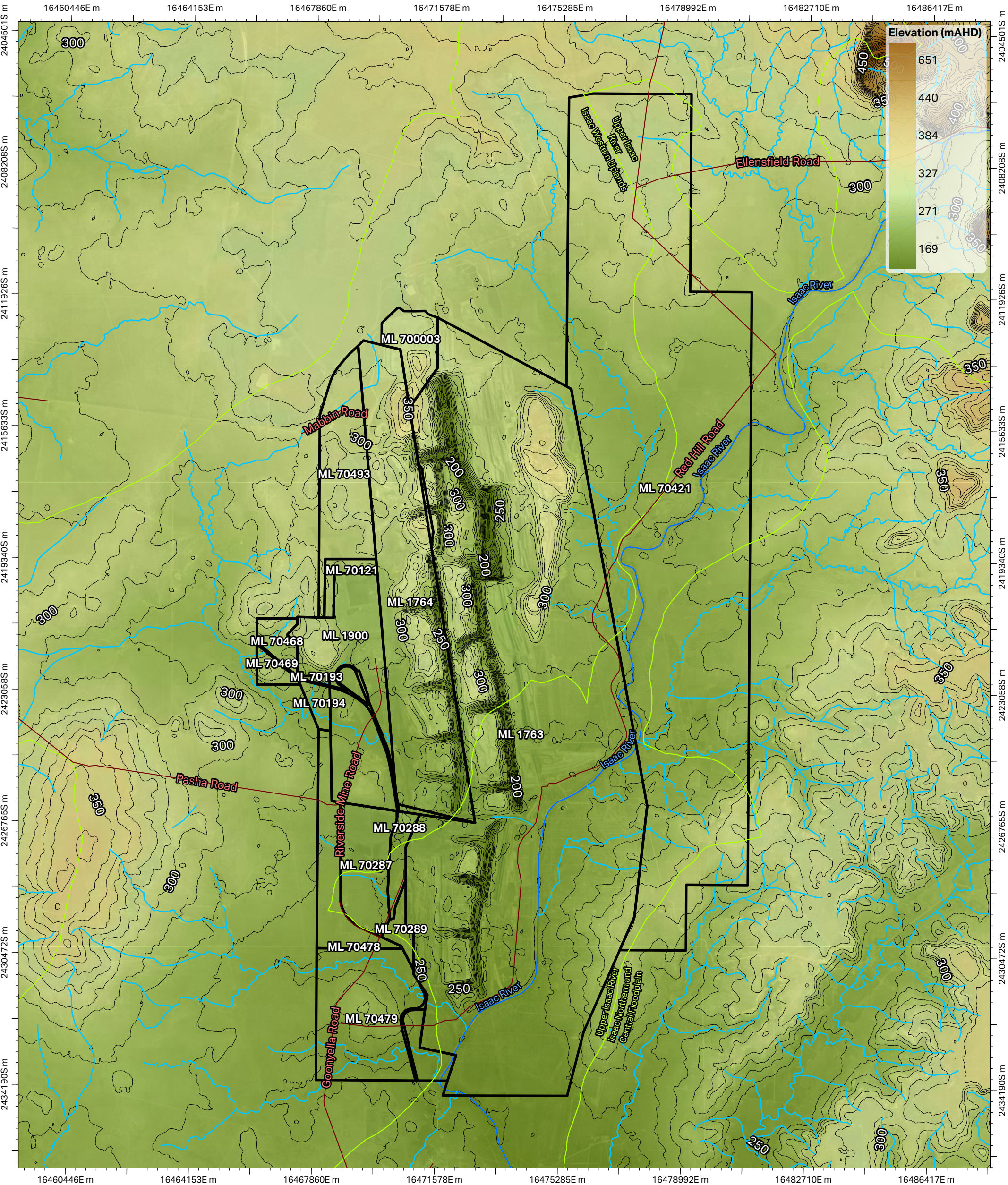
The Project area comprises undulating with gently sloping valleys influenced by three main topographic controls. These include the sloping terrain in the northeast which is controlled by the Burton Range, the low-lying Isaac River floodplains in southwest, and the subtle hills and ridgelines in the west.

Elevation across the Project area ranges from approximately 520 mAHD around the Burton Range to approximately 230 mAHD south of the mines.

Figure 4 provides the topography and drainages across the Project area.

Figure 4 Topography and drainage

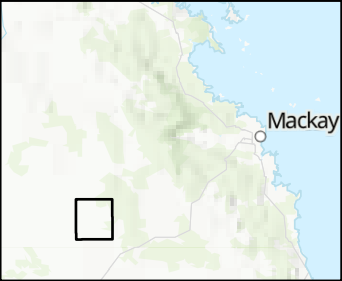
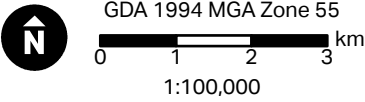
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Basemap image taken 2017

Goonyella, Riverside and Broadmeadow Mines
Topography and Drainage

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)



4.3 Cumulative Rainfall Departure

Cumulative rainfall departure (CRD) from long-term monthly rainfall records from the Moranbah and Wentworth weather stations are presented in Figure 5. The trends in this plot may provide an indication of water level response to rainfall recharge. A positive trend indicates periods of above average rainfall where increased groundwater recharge can occur. A negative slope indicates periods of below average rainfall where decreased groundwater recharge may occur.

Historic rainfall data from Wentworth, from 1964 to 1972, indicates a period of decreased rainfall. This was followed by a period of above-average rainfall (wet cycle) that lasted until 1991. After that, a period of below-average rainfall occurred until 1998, marking a dry cycle. There was an above the average level from 1998 to 2000, indicating an increase in rainfall. Rainfall levels fell below the average from 2000 to 2006 and then increased to above average from 2006 to 2012. A period of low rainfall was observed from 2012 to 2020. Since 2020, rainfall levels have remained above average rainfall.

Both CRD curves, for Moranbah and Wentworth, from 2016 to 2020, indicate a decrease in monthly rainfall in the Project area, leading to a reduction in groundwater recharge. The period from 2020 to 2024 saw a resurgence of wet weather, with rainfall levels surpassing the average and leading to an increase in groundwater recharge (Figure 5).

The CRD data during the period from 2016 to 2024 indicates similar rainfall patterns recorded for both Wentworth and Moranbah weather stations (Figure 5).

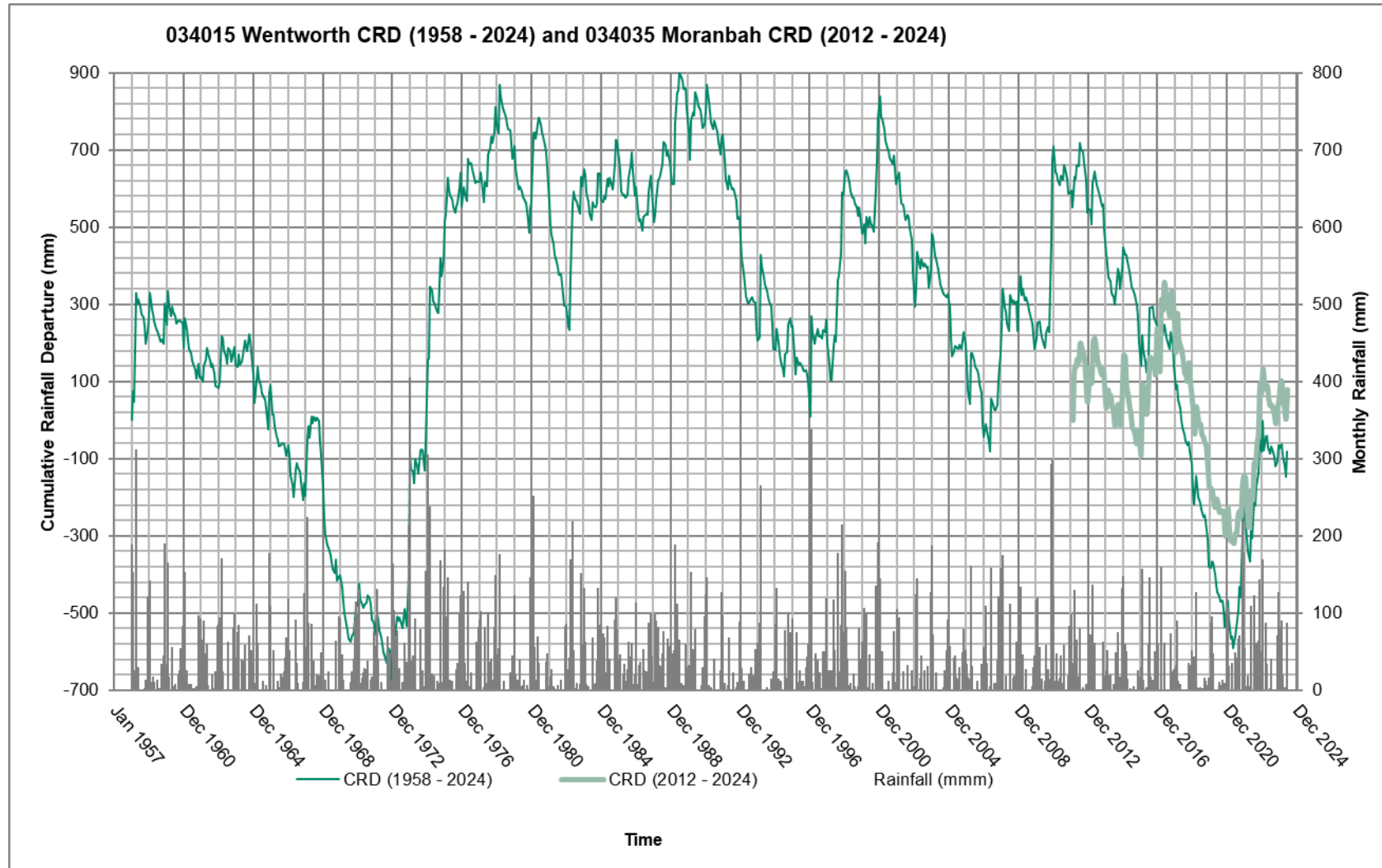


Figure 5 Wentworth (Station 034015) 1958 to 2024 and Moranbah Airport (Station 034035) 2012 to 2024 Cumulative Rainfall Departure curves

5.0 Surface Water and drainage

5.1 Overview

The Project area includes the headwaters of the Isaac-Connors sub-basin of the Fitzroy Basin. The mining activities span from near Eureka Creek to just west of Goonyella Creek and Isaac River. The Isaac River bisects the southwestern Project area, across the Goonyella and Broadmeadow mines, in a north-south direction (Figure 4). Other tributaries located south of the Project site include the Fisher Creek and the Eureka Creek. All these tributaries are considered to be ephemeral and drain into the Isaac River (Plate 2).

Plate 2 Tributaries across the Project area (QGlobe)



Drainage and surface water runoff mimic topography and flow from northeast to southwest across the project area, flowing into the Isaac River and tributaries, within and around the project. Baseflow originates from water stored in bedrock, valley soils, and riparian zones rather than distinct groundwater as water levels recede rapidly after rain events. Baseflow is typically limited to a few days up to approximately one or two weeks after surface runoff (quick flow) has drained from contributing sub-catchments (URS, 2013).

The Isaac River is an ephemeral sand bed stream that is largely alluvial downstream of the Burton Gorge. Geomorphologically, the Isaac River has a channel that is moderately winding and is primarily composed of sand and sediment, with minimal bedrock. Flooding has created a narrow alluvial terrace next to the channel, followed by a larger floodplain that is often flooded during major events.

Goonyella Creek is an ephemeral, slightly-to-moderately winding channel located largely at the Isaac River terrace-valley margin. The channel is relatively narrow and deep and features some bedrock upstream of Red Hill Road. Downstream, the channel merges with the Isaac River

Eureka Creek is also ephemeral and moderately winding (Plate 2).

A number of drainage lines feed into the waterways. Drainage lines consist of narrow channels and broader overland flow, and a series of ponds that remain as flows recede. These water bodies are temporal for short periods after flow.

5.2 Isaac River Diversion

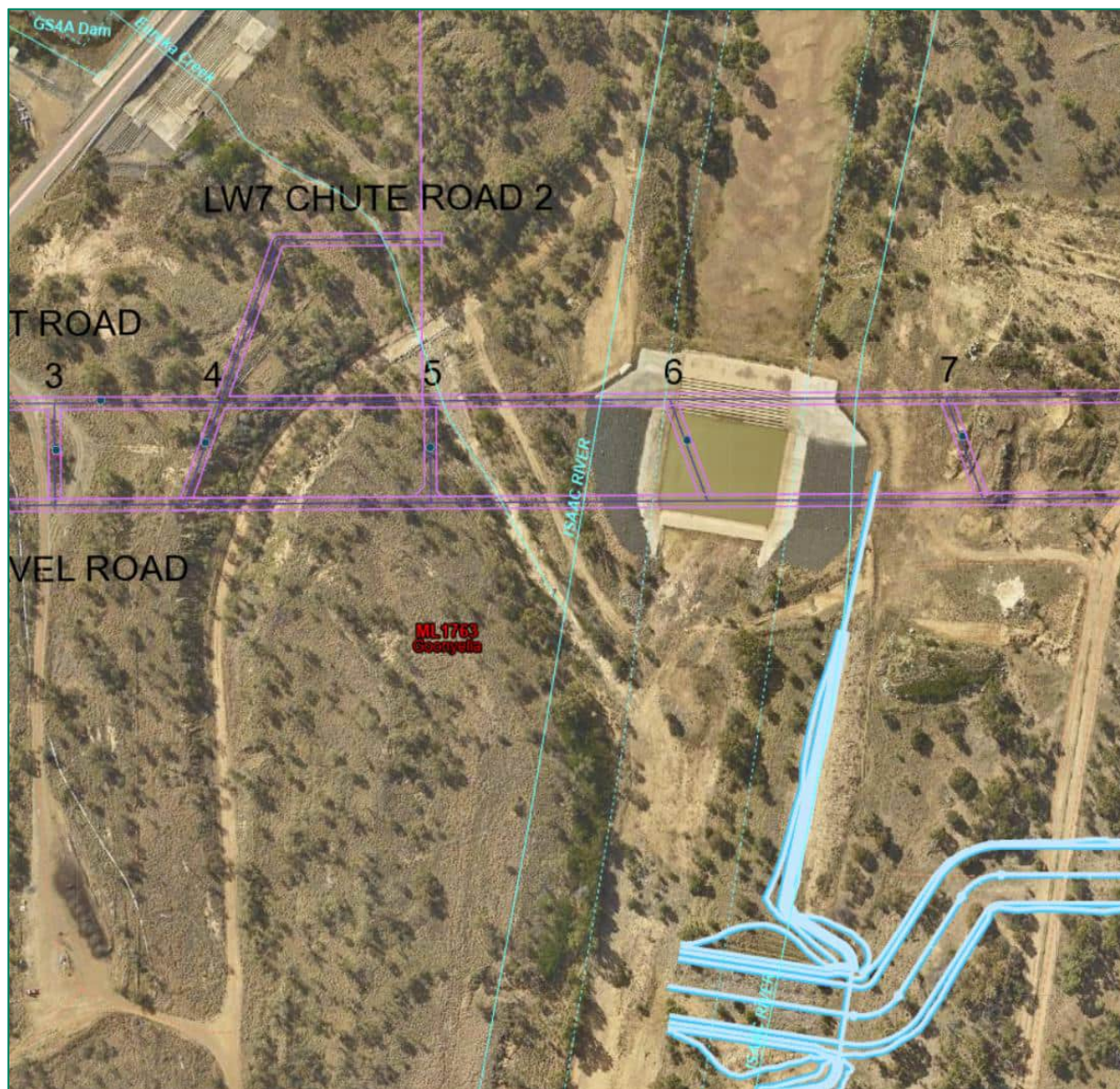
The Isaac River was diverted between 1985 and 1987 to allow access to coal deposits by open cut mining in the Project area. The diversion begins at the same location as Broadmeadow long wall panel, LW105, and replaces approximately 11 km of river channel with 7.8 km of diversion channel including two drop structures of around 2 m in height each, which were designed to manage the bed grade due to shortening of the channel. One drop structure is located immediately upstream of Eureka Creek confluence (Plate 3).

The diversion has bends at its upstream and downstream ends, however, the majority of the diversion is a near linear north-south channel. The diversion is largely cut through the Isaac River terrace, it is presently typically 8 to 12 m deep with a top width of 80 to 100 m.

The Isaac River channel is incised into its floodplain by four to eight metres; the floodplain is inset within the broader terrace by a further two to four metres. The terrace, which is essentially a paleo-floodplain, is the dominant feature within the Project area. It has low relief with a gentle slope often away from the channel and in a downstream direction. The Isaac River diversion has been constructed within the Isaac River terrace and has no contemporary floodplain around the channel.

The excavated sediment from the diversion channel forms an embankment up to six metres above the surrounding terrace along the western bank of the diversion channel. To the east of the terrace, smooth hill slopes of reasonably low gradient rise up to a local catchment boundary near the eastern extent of the GRB mining area. There are only a few incised gully systems toward the upper limit of the local catchment. Two minor tributaries from beyond the mine plan area toward the upstream end of the mine plan, only the southern of these two will be over the mine footprint of GRB.

Plate 3 Drop structure



6.0 Geology

6.1 Regional Geology

6.1.1 Introduction

The Project area is located on the western flank of the northern part of the Bowen Basin, a sedimentary basin that covers an area of approximately 60,000 km². The Bowen Basin is a north-northwest to south-southeast orientated basin which extends from Collinsville in the north to beyond the New South Wales border in the south. It is overlapped by the Surat Basin in the southern region. The Bowen Basin a sedimentary sequence of Permian to Triassic age clastics, which attain a maximum thickness of 9,000 m in the depocentre of the Taroom Trough.

The Bowen Basin is divided into a number of tectonic units that comprise of platforms or shelves trending in the NNW to SSE direction, and are separated by sedimentary troughs. The main geologic feature of the project site is the Collinsville Shelf, which is a stable tectonic environment with sediment accumulation that gently dips and thickens towards the east.

Folding in the basin tends to be gentle and was largely a result of compression by thrust faults along the eastern margin. The area where the Collinsville Shelf meets the Nebo Synclinorium, an extension of the Taroom Trough, is defined by the Jellinbah Thrust Fault Zone. The lack of significant structures distinguishes the Collinsville Shelf sediments from the more disturbed formations of the Nebo Synclinorium.

The regional stratigraphic sequence of the geology can be summarised as Permian to Triassic sedimentary rocks that are overlain by Tertiary age deposits of the Duaringa and Suttor Formations that are separated by olivine-rich basalt remnants. The thin unconsolidated Quaternary alluvium and colluvium overlie the tertiary deposits.

The Permian age Back Creek Group, which generally comprise of fine-grained clastic sedimentary rocks deposited in a fluvial to shallow marine environment. The Back Creek Group is unconformably overlain by the Blackwater Group, which include the Rangal Coal Measures (RCM), the Fort Cooper Coal Measures (FCCM), and the Moranbah Coal Measures (MCM). The Permian deposits outcrop in the eastern and western margins and are unconformably overlain by the Triassic age sedimentary rocks of the Rewan Group. The RCM are the shallowest seams; they have been extensively mined along the eastern and western flanks.

The regional stratigraphy is summarised in Table 6 and presented in Figure 6, which depicts the solid geology as compiled in 1:100,000 scale geological maps as downloaded from QSpatial. Figure 7 presents the surface geology mapped across the Project area (Queensland Government, 2024).

6.1.2 Crustal Extension

Development of the Bowen Basin initiated during the early-Permian as East-West extension generated a series of half graben sub-basins. Subsequent partial filling of the sub-basins occurred in the form of volcanic and sedimentary (lacustrine and fluvial) deposits (i.e. the Reid's Dome Beds (Esterle et al 2002).

6.1.3 Thermal Subsidence

Rapid subsidence due to continued thermal sag and continental erosion led to a marine transgression. From this point onwards, deposition within the basin became dominated by coastal and shallow marine sedimentation (e.g. the Back Creek Group).

6.1.4 Foreland Loading

Evolution of the Bowen Basin continued into the Late Permian, as further basin opening occurred with uplift and renewed volcanism in the east of the basin. During this period the half graben sub-basins became interconnected with continuing burial by a series of transgressive and regressive events.

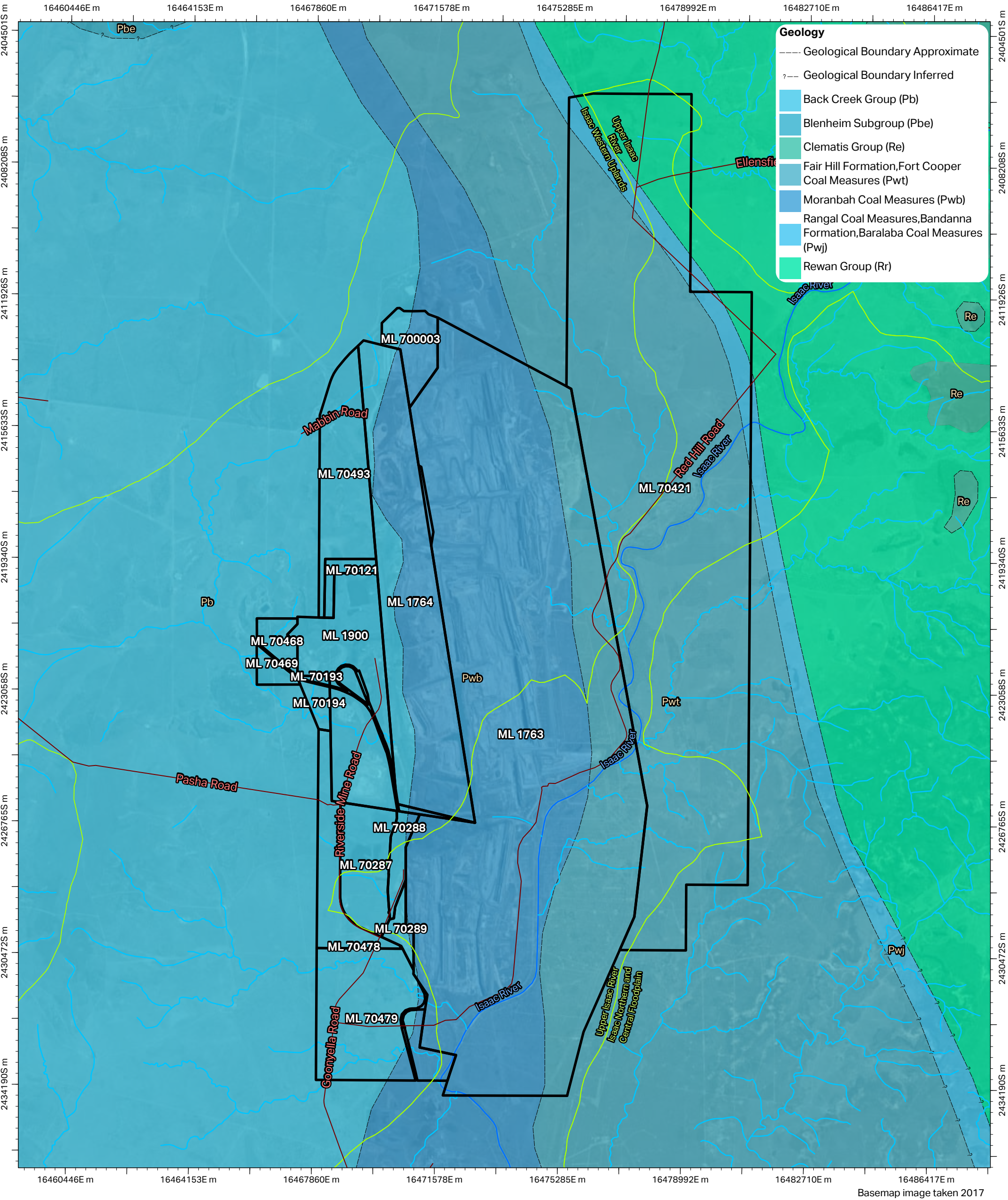
Table 6 Regional Lithostratigraphy

Age	Stratigraphic Unit	Lithology	Typical Thickness (m)	Occurrence
Quaternary	Alluvium	Clay, silts, sand, gravel, and floodplain alluvium	15 - 35	Confined to present day stream alignments, floodplains, alluvial fans, high terraces and paleochannels. Localised along the Isaac River, Eureka and Goonyella Creeks, and floodplains
Tertiary	Undifferentiated Tertiary sediments	Clay, silt, sand, gravel, colluvium, fluvial, and lacustrine deposits including cross-bedded.	15 m	Underlying alluvium or as surficial cover
	Suttor Formation	Quartz sandstone, clayey sandstone, mudstone and conglomerate; fluvial and lacustrine sediments; minor interbedded basalt.	0 - 120	Most extensive in the mine areas and to the east. Sparsely distributed around the Project area
	Basalt	Olivine-rich weathered basalt remnants, moderately weathered and fresh basalts	0 - 80	Isolated outcrop and subcrop/s, inferred dykes, and flow remnants in the norther regions of the Project site
	Duaringa Formation	Mudstone, sandstone, conglomerate, siltstone, some oil shale, lignite, and basalt	0 - 50	The formation does not outcrop in the area of the Project site
Triassic	Moolayember Formation	Mudstone, lithic sandstone, interbedded siltstone, mudstone, sandstone, and thin coal seams	0 - 200	Outcrop farther east of the Project site
	Clematis Sandstone	Quartz sandstone, some quartz conglomerate, minor reddish brown mudstone	0 - 300	Isolated outcrops/subcrop/s in the east and north
	Rewan Formation	Lithic sandstone, pebbly sandstone, conglomerate, red and green mudstone, siltstone, quartz sandstone, and shale	200 - 800	Outcrops east of the Project site; increasing in thickness as it proceeds east
Late Permian*	Rangal Coal Measures	Coal seams, carbonaceous shale and mudstone, tuff, siltstone, and mudstone	25 - 200	Isolated outcrops in the east and north
	Fort Cooper Coal Measures	Coal, brown and green sandstone, labile sandstone, quartzose sublabile sandstone, calcareous and tuffaceous sandstone, mudstone, siltstone, conglomerate, carbonaceous shale, tuff, volcanic conglomerate	100 - 600	Isolated outcrops in the east and north
	Moranbah Coal Measures	Coal, quartzose to sublabile, locally argillaceous sandstone, siltstone, mudstone, carbonaceous mudstone	100 - 700	Underlies the Project site
Middle Permian	Back Creek Group	Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal, and sandy coquinite	400 – 1,200	Outcrop west and extends under mined areas to the east

*Three coal-bearing formations are recognised in the Blackwater Group: the Moranbah, Fort Cooper, and Rangal Coal Measures

Figure 6 Solid Geology

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Goonyella, Riverside and Broadmeadow Mines
Solid Geology

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)

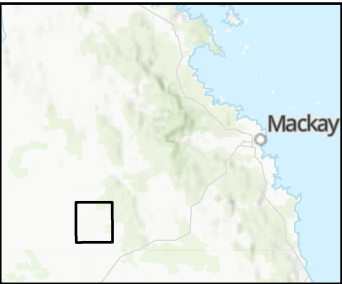
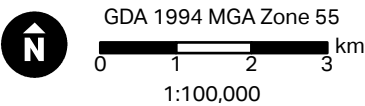
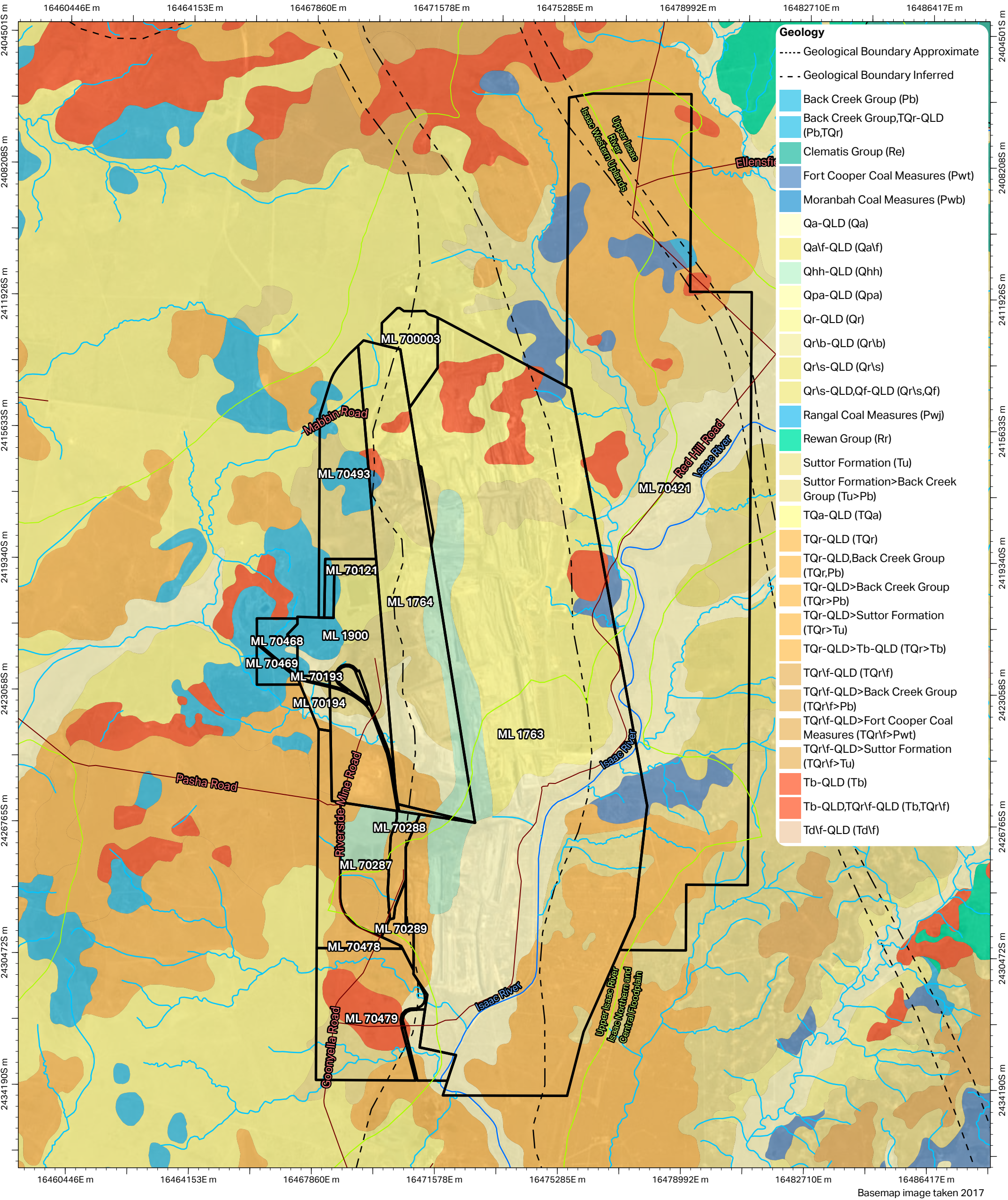


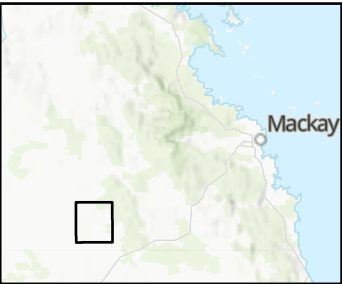
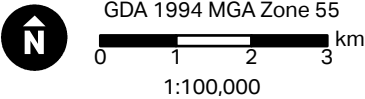
Figure 7 Surface geology

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Goonyella, Riverside and Broadmeadow Mines
Surface Geology

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)



6.1.5 Basin Closure

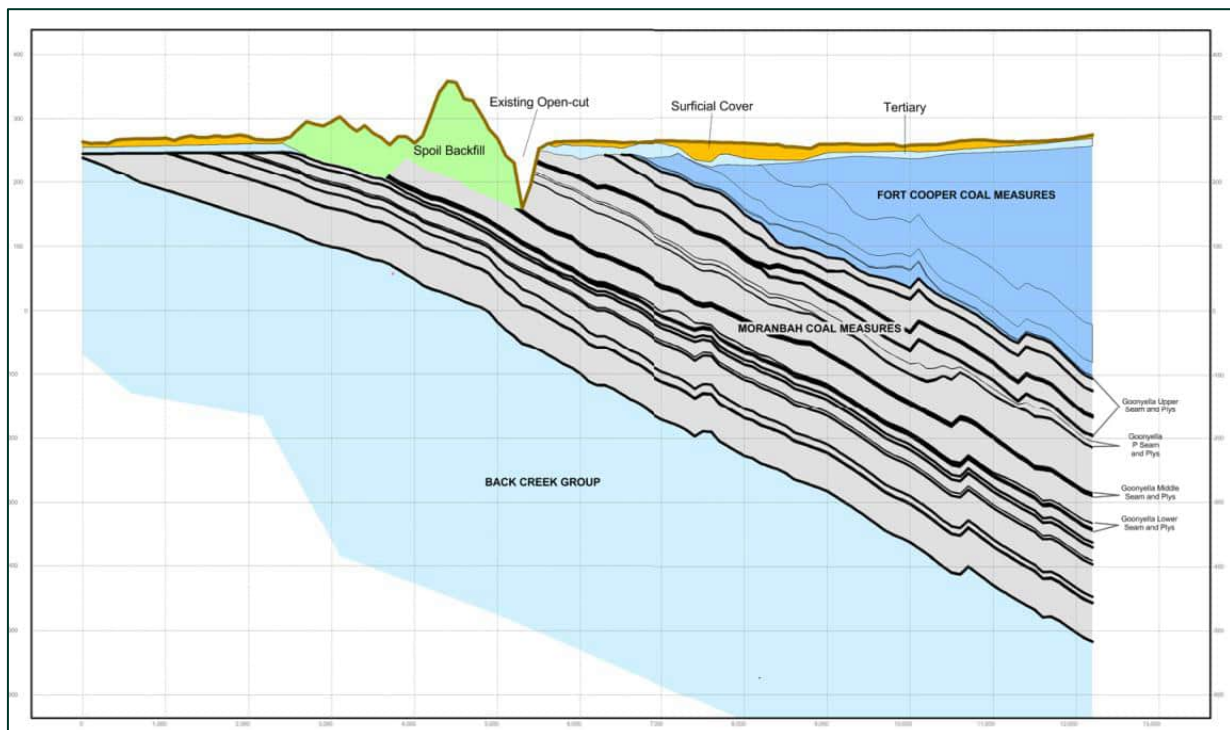
A period of tectonic compression in the Middle to Late-Triassic terminated any further sedimentation within the basin resulting in gentle folding and regional faulting (e.g. The Jellinbah Thrust). The regional area is mantled by an irregular cover of poorly consolidated Tertiary sedimentary strata and basalt (fresh and weathered). The Tertiary cover unconformably overlies the sediments and main coal-bearing units of the Late Permian Blackwater Group.

6.2 Local geology

The geology in the Project area, as included in the geological section, includes (from youngest to oldest):

- Quaternary Alluvium
- Tertiary Suttor Formation
- Tertiary Basalt
- Triassic Rewan Formation
- Permian Coal Measures (RCM, FCCM, MCM)
- Permian Back Creek Group.

Geological section through GRB



6.2.1 Structural description

The regional tectonic setting is mainly characterised as a compressive environment, which led to the development of thrust faults and folds, particularly along the eastern margin. Majority of the thrust faults dip towards the east and propagate into the Permian sediments. The thrust fault system aligns with the northwest-trending synclinal axis of the Basin, as most fault segments trend in a northwest direction, indicating the continuation of earlier basement structures.

The Project area is located on the Collinsville Shelf in the north-west of the Bowen Basin. The Collinsville Shelf is an area that has undergone a period of major deposition and is characterised by low

structural disturbance. Formations dip east at approximately 5° with small-scale and wide-spaced normal and reverse faulting showing small displacement.

The Project area is located approximately 30 km west of the Jellinbah Fault system (also known as the Isaac Thrust Fault system). Jellinbah Fault system represents a major regional structure that extends along a northwest – southeast orientation. The fault is typically steeply dipping, with a significant vertical displacement of throws that range from 100 to 500 m. Individual faults are typically 10 to 80 km long. The vertical displacement has resulted in contact of significantly different geological units.

Approximately 16 km east of the active mines are fault splays that are from the Jellinbah Fault system. These splays have north and northwest orientations. The Jellinbah Fault system splays have resulted in throws within the Permian coal measures of approximately 50 and 100 m.

Igneous intrusions present as dykes and sills are rarely found intruded through coal seams, causing coking and heat-affected coal.

6.2.2 Quaternary Alluvium

The Quaternary alluvial deposits unconformably overlie the Suttor Formation, Tertiary basalt, and Rewan Formation in places (Figure 7). Quaternary alluvium is comprised of irregular sequences of clay, silt, sand and gravel that have been unconformably deposited in an eroded, valley-fill setting. Alluvium exists predominantly around rivers, creeks, and floodplains. The composition of the alluvium reflects a depositional environment that is dominated by meandering and braided river. The typical thickness of the alluvial deposits is between 15 and 35 m.

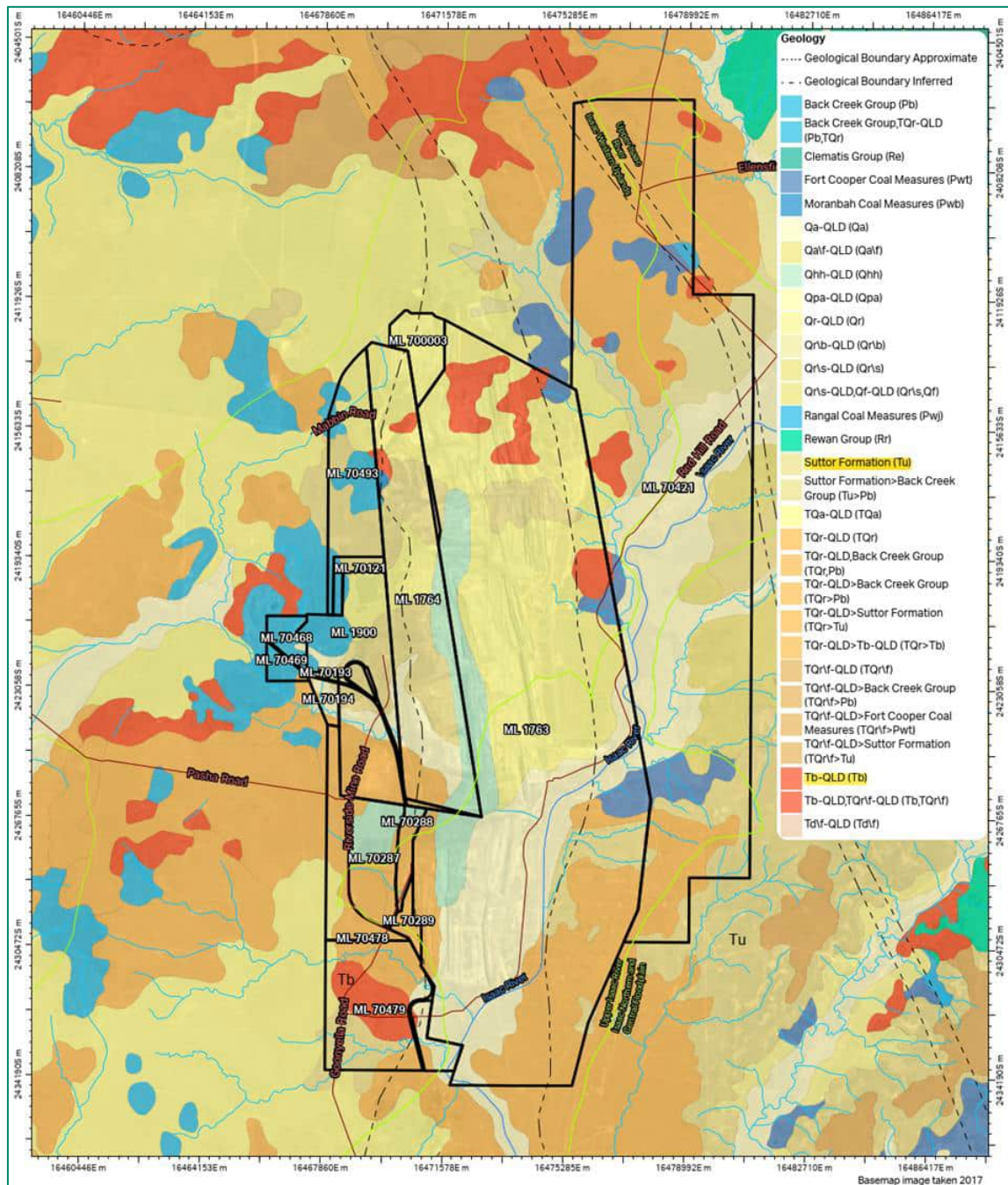
6.2.3 Tertiary age units

Tertiary age units mapped across the Project area (Figure 7) include the Suttor Formation (Tu), which comprises quartz sandstone, conglomerate, and sandy claystone, and the undifferentiated Tertiary sediments. These sediments consist of clay, silt, sand, gravel, colluvium, fluvial, and lacustrine deposits including cross-bedded.

The Tertiary age sediments, mainly colluvium, overlie Permian-Triassic bedrock. The thickness of the Tertiary sediments have an average thicknesses of 15 m. The Suttor Formation is mapped to the east adjacent to the Jellinbah Fault system (Plate 4).

Minor Tertiary age basalt (Tb) is mapped within or adjacent to the Project, as included in Plate 4.

Plate 4 Tertiary basalt (Tb) and Sutorr Formation (Tu) within the Project area



6.2.4 Permian Coal Measures

The Permian coal measures comprise, from youngest to oldest, the RCM, FCCM, and MCM. The Blackwater Group is the collective term for these coal bearing units.

6.2.4.1 Rangai Coal Measures

The RCM are comprised of up to 200 m of lithic sandstones, mudstones and at least two discrete coal seams of economic importance. The low ash upper-most Leichhardt seam displays few stone bands and generally lies up to 50 m above the Vermont seam, the latter seam distinct due to the presence of the Yarrabee Tuff, which separates the upper and lower plies. The Yarrabee Tuff is a basin-wide geochronological marker; the top of which is often regarded as the base of the RCM formation. Both the Leichhardt and Vermont Seams are subject to splitting and merging.

The RCM sub-crop to the eastern side of the area and dip east to a maximum depth, of approximately 400 m where the formation is juxtaposed the Burton-Jellinbah Fault Zone. Locally net coal thicknesses for the formation can be up to 8.0 m with the Leichhardt seam containing up to 4.0 m.

The RCM overlie the FCCM and comprise both fractured and well-cleated coal seams. The RCM outcrops and subcrops strike generally in a north-south direction, and dip at a shallow angle to the east. The transition between the RCM and FCCM is generally indicated by the Yarrabee Tuff.

The RCM are separated by fine to medium grained sandstone, siltstone, carbonaceous shale, and mudstone layers. These units are competent and effectively limit vertical seepage between coal seams. The FCCM has a thickness range from 25 to 200 m, with the average estimated at 150 m.

6.2.4.2 Fort Cooper Coal Measures

Comprising up to 450 m of interspersed sandstones, mudstones, tuff-bands, and high-ash coaly packages. The coal measures comprise at least seven main seam intervals of variable resource potential. These packages can be up to 80 m gross thickness and consist of a series of thin, high-ash coal bands, stone bands, and carbonaceous units with a low net-to-gross coal ratio.

The FCCM lie directly below the RCM and are contiguous across the Project area. The maximum depth to the top of the formation is approximately 800 m with the Fairhill seam showing most local potential with up to 57 m gross coal thickness.

The FCCM is made up of alternating layers of coal seams, with thin vitrinite-rich coal seams mixed with carbonaceous shale, and are interspersed with tuffaceous sandstone, lithic sandstone, and mudstone. The measures overlie the MCM and are regarded as laterally continuous. Outcrops and subcrops of the FCCM are found in the east of the Project area and extend underground, dipping beneath the RCM.

6.2.4.3 Moranbah Coal Measures

The MCM subcrop to the west of the Project area and are contiguous eastwards. The maximum depth to the top of the formation is approximately 700 m. Comprised of Permian sandstones, mudstones and tuffs interspersed with at least six discrete coal seams, the MCM form a 250 m to 350 m thick formation underlying the FCCM. Coal resources relate to regionally continuous GU, P, GM, and GL seams. Together these seams can total a net coal thickness approaching 30 m, with the GM capable of contributing in excess of 10 m.

The MCM are the lowermost coal-bearing sequence of the Blackwater Group and form the key coal resource targeted by BMA. The lithic sandstone, siltstone, mudstone, conglomerate, and coal of the MCM overlie the Back Creek Group.

The MCM contains thick coal seams interspersed with several thin minor seams. The main target seams, along with their plies, include the following:

- Goonyella Upper (GU) Seam - The GU seam and its associated splits range in thickness from 2 – 7 m with an average of approximately 3 m in the Project area. It is the equivalent to the Q-seam.
- P Seam - Formed of three main plies, the GP1, GP0, and the GP4, the P-seam package averages approximately 5 m in net coal thickness. The package is rich in tuff bands, most notably the P-tuff, which is recognisable across the basin by its distinctive gamma signature.
- Goonyella Middle (GM) Seam - The GM seam is the thickest coal seam in the MCM averaging 8 m in thickness locally. Thinning of the GM seam is seen to the southeast of the Project area due to seam splitting. The lower half of the seam hosts two tuff bands – the Penny and Tonstein bands.
- Goonyella Lower (GL) Seam - The GL seam is located approximately 50 m below the GM seam. The GL seam has an average thickness of 6 m with characteristic thinning to the south of the exploration area.

6.2.5 Back Creek Group

The Back Creek Group underlies the Blackwater Group, and outcrops immediately west of the Project area. This unit consists of quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite. The consolidated fine-grained sedimentary rocks are considered semi-permeable, acting as a confining layer to the overlying the Blackwater Group.

7.0 Hydrogeology

Based on the understanding of the geological setting presented in Section 6.2, the hydrogeological regime relevant to the Project area comprises the following key hydrostratigraphic units with enhanced groundwater potential:

- Quaternary alluvium – unconfined aquifer (sporadic discontinuous water-bearing strata of permeable unconsolidated sand or gravel) localised at and near to RHM along the Isaac River, Eureka Creek, and Goonyella Creek, and more regionally along the Isaac River where it is particularly well developed
- Permian age coal measures:
 - Low permeability interburden units with aquitard properties
 - Coal seams that exhibit water bearing properties associated with secondary porosity through cleats and fracturing.

The coal seams within the MCM are the primary aquifer at the Project. The coal seams can be characterised as confined aquifers (above and below by low permeable interburden), with the GUS, GMS, and GLS forming the main hydrostratigraphic units locally. The MCM overburden and interburden function as aquitards and are typically dry, or low yielding.

This section discusses hydrogeological units, which are recognised to be relevant to closure planning, covering hydraulic properties, groundwater occurrence, hydraulic gradients, recharge, discharge, groundwater quality, and water use.

7.1 Groundwater monitoring network

The Project groundwater monitoring bore network comprises a total of 46 monitoring sites. Water levels in 18 of the monitoring bores have not been measured since 2023.

The monitoring bore network was established in 2012 as part of the RHM approvals study (URS, 2013) to provide supporting data for the environmental approvals. The monitoring bore network intersected a range of hydrostratigraphic units, including:

- Alluvium
- Tertiary
- MCM
- Back Creek Group

Groundwater monitoring data compiled between 2012 and 2020 has been lost due to monitoring data corruption. Groundwater monitoring data across the monitoring bore network, augmented and revised overtime, has been compiled regularly since 2020. The locations of the current monitoring bore network are shown on Figure 8.

It is noted that the RHM groundwater model was constructed and calibrated based on available geological and groundwater data available up to 2013. The resultant model report is included in **Appendix A** to provide additional details of the available data used for the RHM groundwater model. The model report includes the location and details (including spatial extent) of bores used for geological and hydrogeological data.

The PRC Plan refinement of the existing RHM groundwater model, using transient groundwater level data from 2020 to 2024, allowed for the augmented conceptualisation of groundwater conditions, evaluation of the influence of approved mining, and the transient calibration (refinement) of the existing model.

The groundwater model was then, with the use of uncertainty analysis, used to predict post-closure groundwater conditions.

Figure 8 Project groundwater monitoring bore network

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7.2 Hydraulic conductivity

GRB groundwater hydraulic testing included slug (rising and falling head) tests, packer tests and stress and permeability tests performed on monitoring network bores across the Project area. This section presents a summary of the available site-specific hydraulic data.

7.2.1.1 Quaternary alluvium

Aquifer hydraulic properties of Quaternary alluvium material (Isaac River bed sands) and flood plain deposits were obtained from investigations undertaken at Moranbah North mine (JBT Consulting 2010). These hydrogeological investigations determined that permeability of the alluvium ranged from 8.9 to 45.4 metres per day (for some investigation sites water dissipated so rapidly that measurements could not be taken, indicating permeability higher than this range).

These investigations also found that the Quaternary flood deposits (river bank sediments) were generally finer grained than the bed sands, and returned permeability values between 0.01 and 10 metres per day. This testing indicated that the river bank sediments were less permeable than the bed sands, and would be regarded as being of low to moderate permeability, compared to the higher permeability of the bed sands.

Onsite, hydraulic testing of the Quaternary alluvium associated with the Eureka Creek provided a hydraulic conductivity value of 0.001 metres per day, typical for silty clay (URS, 2013).

The most recent tests across the Project area were undertaken between 2022 and 2024, and involved rising and falling head slug tests. Testing revealed a hydraulic conductivity range between 5×10^{-8} to 0.12 m/day.

7.2.1.2 Tertiary sediments

A review of bore logs within the RHM footprint showed that the Tertiary sediments are dominated by low permeability clays and sandy clays with isolated areas of loose more permeable sand.

The interpreted hydraulic conductivity value of 6.6×10^{-4} metres per day (m/day) obtained from the variable (falling) head test at the Airstrip Pit (IESA 2001a) is low, indicating predominantly clay intersected within this area (URS, 2013).

Past tests performed in the sandstone/siltstone, sands and clays of the Tertiary Formation indicated a hydraulic conductivity range of 2×10^{-7} to 24.6 m/day. The hydraulic conductivity of 24.6 m/day is atypical, as it was the sole one that was exceedingly high.

7.2.1.3 Permian coal measures

Interpreted hydraulic conductivity values estimated from the MCM aquifer testing results indicate that the cleats and joints in the coal are less open with depth, with a corresponding decrease in permeability. WDS (2011) conducted an engineering study for coal seam degassing required prior to mining of the RHM, using data derived from packer testing in 31 seam/site combinations in the MCM and FCCM. This study found a relationship for permeability variation with depth, ash, and gas content as part of this study that resulted in the ranges of hydraulic conductivity to be (URS 2013):

- GMS 0.009 to 0.1 m/day
- GLS 0.06 to 0.82 m/day
- Interburden 9×10^{-7} to 9×10^{-5} m/day.

Note: No GUS testing was conducted by WDS in 2011.

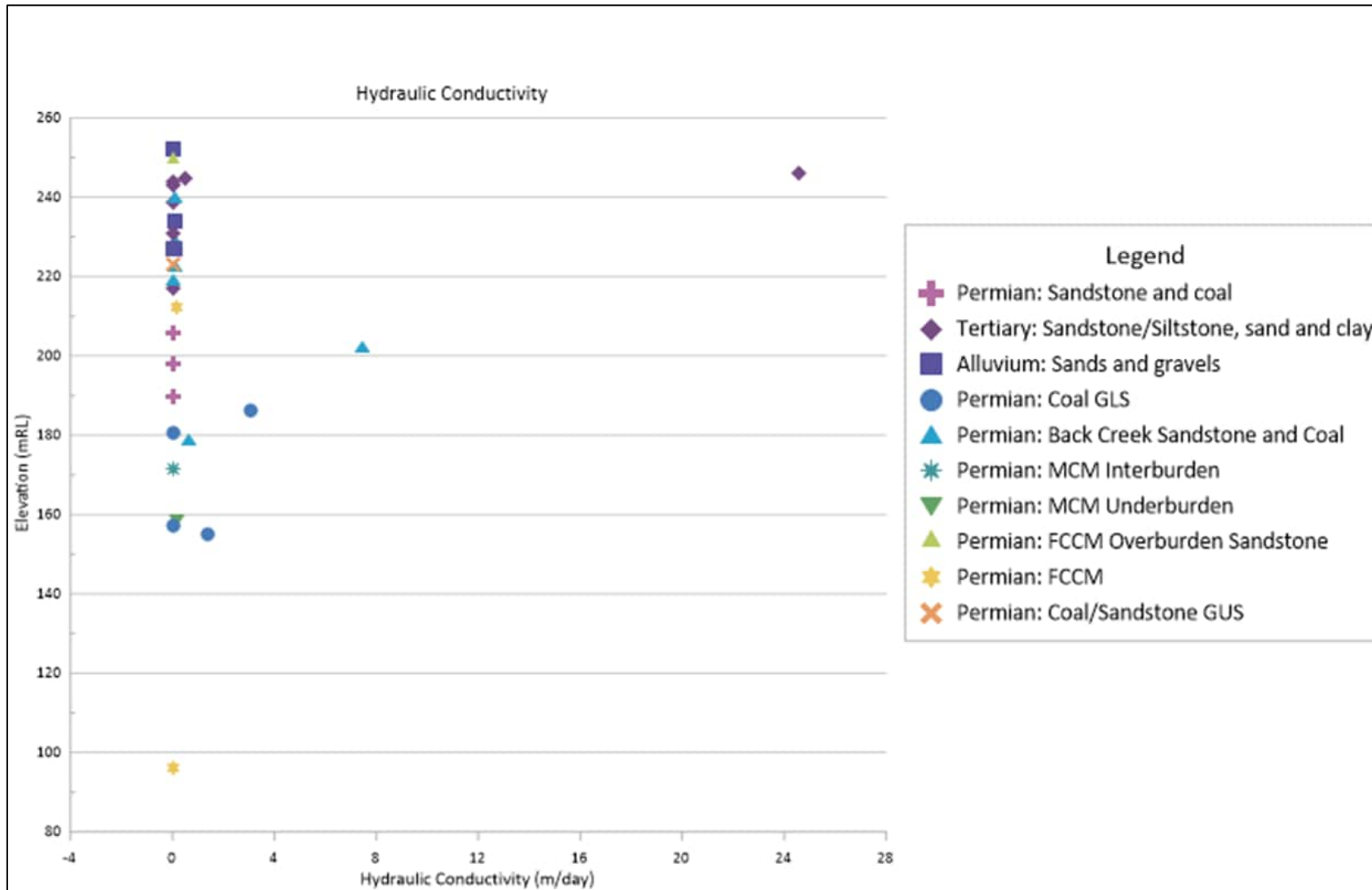
The hydraulic conductivity of the MCM that were tested between 2020 and 2024 across the Project area was variable and indicating a decrease with increasing depth, corroborating previous studies conducted in the MCM coal seams.

The MCM testing revealed hydraulic conductivity estimates:

- Overburden between 6×10^{-4} and 5×10^{-2} m/day
- GUS and GMS were estimated at 0.02 m/day
- GLS ranged from 7×10^{-7} and 3 m/day.
- Interburden and underburden at 1×10^{-5} and 2×10^{-2} m/day, respectively.

Testing data from 2020 to 2024 is summarised in Figure 9.

Figure 9 Summary of hydraulic data



7.3 Groundwater distribution, flow, recharge, discharge

7.3.1 Quaternary alluvium

7.3.1.1 Distribution and flow

Quaternary alluvial deposits in the survey area occur predominantly within the Isaac River floodplains as shown in Figure 7 (labelled Qa-QLD). Along the Isaac River these deposits consist of clay, silt, sand and gravel, to a depth of up to 37 metres, as historically recorded in monitoring bore GW1 and exploration bore 43840 (Plate 5).

Investigations into the Isaac River alluvium at the Moranbah North Mine (located immediately to the south of GRB) indicated that the thickness of bed sands in the Isaac River was two to three metres (JBT Consulting 2010).

The alluvium associated with Eureka Creek consists of approximately nine metres of silty sand and poorly sorted sand and gravel at monitoring well GW8, with no alluvium present at GW7. The historic monitoring and exploration bores are included in Plate 5.

The Isaac River alluvium has limited effective storage, provides only limited volumes of baseflow, and does not contain groundwater all year round. Limited groundwater resources may, however, occur in the deeper and relatively narrow parts of the channel.

Due to the generally shallow saturated thickness and the lack of continuity of the more permeable gravel and sand sections, the Quaternary alluvium is not considered a significant aquifer as it has limited sustainable yield. However, during periods of creek or river flow, the alluvium may become fully saturated and discharge to sub-cropping coal seams or other underlying aquifers.

Drilling and monitoring on site indicates that, where groundwater does occur, depth to groundwater in the Quaternary alluvium is approximately 3 to 13 metres below ground level (mbgl). The groundwater level in the alluvium, measured in a study by Thatcher (1976), was about 20 metres above the piezometric (confined) water level in the coal at the same location. These groundwater levels indicate a marked separation between the alluvium water table and the piezometric levels associated with the deeper coal seam aquifer groundwater (i.e., there is no hydraulic connection between the alluvium groundwater and the confined aquifers). It is, thus, unlikely that changes in piezometric levels in the coal would markedly impact on the water table associated with the alluvium.

Owing to the paucity of data for the Quaternary alluvium (Figure 10 and Figure 11), limited information exists regarding groundwater flow. However, regionally groundwater flow within the alluvium follows topography and drainage patterns.

Plate 5 Historic monitoring and exploration bores

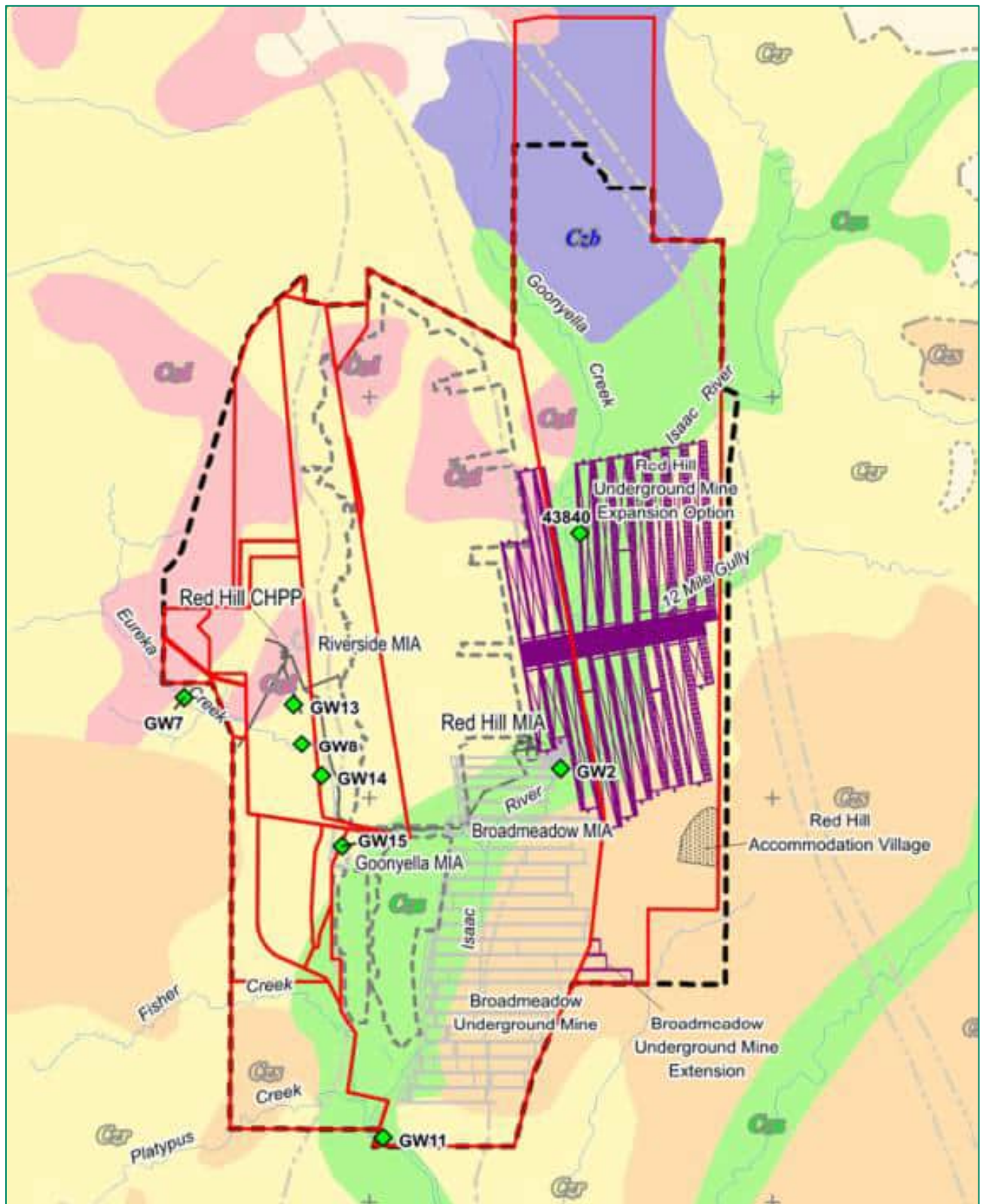
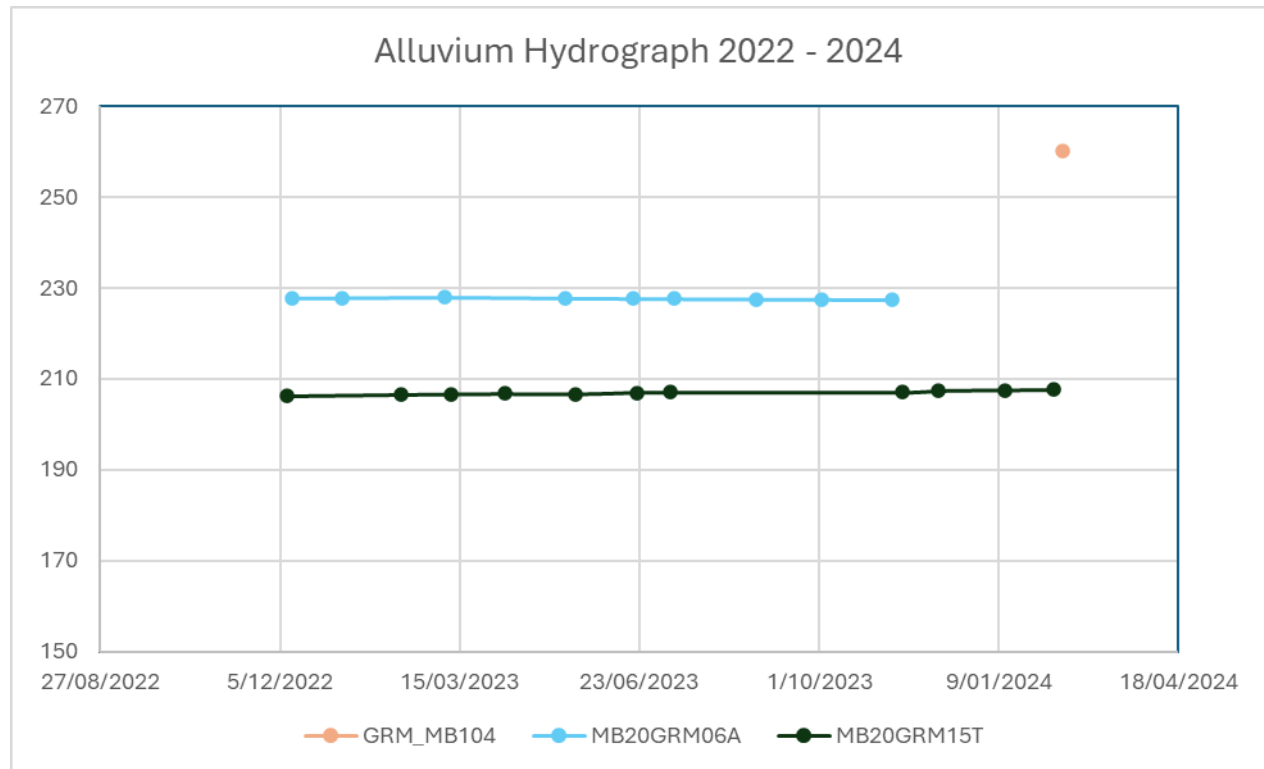


Figure 10 Hydrograph of alluvial groundwater trends**Notes:**

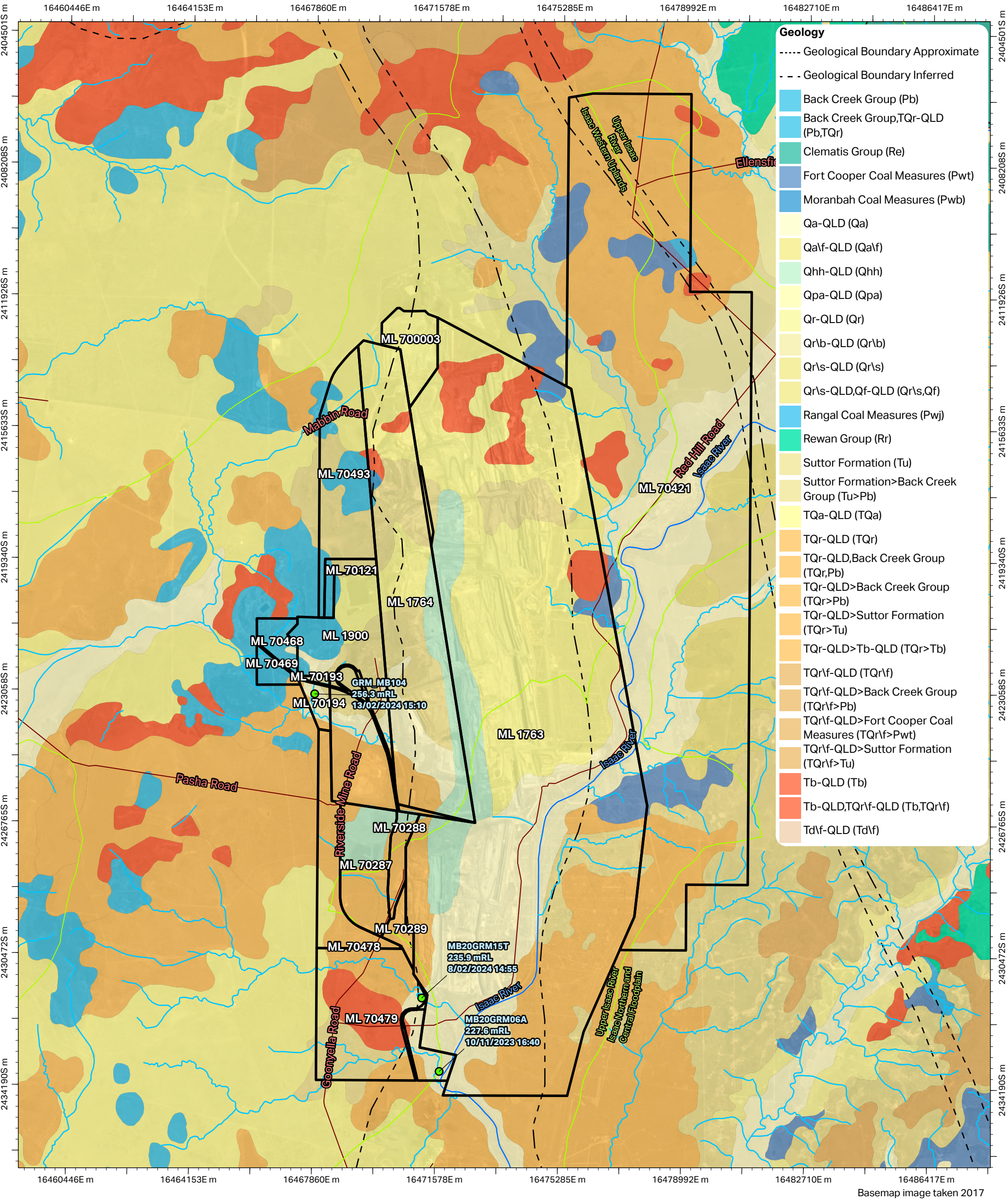
GRM_MB104 water level is 8.86 mbgl

MB20GRM06A water level is around 9.5 mbgl, bore is 13.35 m deep

MB20GRM15T water level is on average 4.5 mbgl, bore is 7 m deep

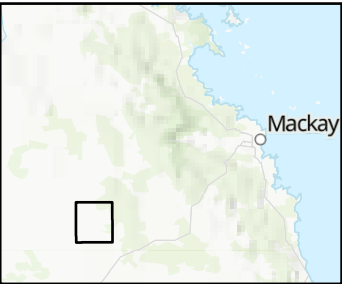
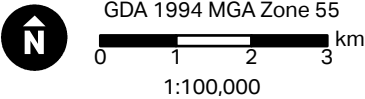
Figure 11 Alluvium groundwater elevations

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Goonyella, Riverside and Broadmeadow Mines
Alluvium Groundwater Elevations

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)
- Monitoring Bore - Alluvium



7.3.1.2 Recharge and discharge

The alluvial aquifer is characterised as a porous media aquifer where groundwater occurs within the voids between individual grain particles. The volume of groundwater associated with the alluvium depends on the interconnection of permeable units, saturated thickness, and the ability to store groundwater, (i.e., effective storage allowing for baseflow to creeks and rivers during the dry season). The alluvial aquifers are considered to be strongly linked (recharged during flow events) to surface water (SKM 2009).

The Isaac River and creeks at the Project are ephemeral and recharge of the alluvium is by:

- Losses from surface water flow or flooding (losing system)
- Direct rainfall and overland flow recharge, where alluvium is exposed, and no substantial clay barriers occur in the shallow sub-surface.

Available hydrologic data suggests that water infiltrates / drains to the base of the alluvium relatively quickly after rainfall events where more permeable units are at surface. The available transient groundwater level data, Figure 11, indicates saturation is sporadic and can produce semi-permanent, localised, thin, aquifers. The groundwater level data does not indicate marked variation in dry/wet seasons (noting limited manual data measurements), which could indicate isolated pockets of water not readily recharged or discharged.

Groundwater discharge from the alluvium occurs through:

- Evapotranspiration from vegetation where depth-to-groundwater is shallow, such as in the creek beds and along the banks
- Short duration baseflow from the permeable sands and gravels within the alluvium material.

Infiltration and recharge to the underlying older formations underlying the creeks is not evident based on the marked hydraulic disconnect between the depth to water in the alluvium and the confined piezometric levels associated with the confined coal seam aquifers (Section 7.3.1.1).

Surface water loss, via the alluvium, to the longwall mining panels (goaf and subsidence related) is discussed in Section 13.3.6.1.

During a ground penetrating radar (GPR) survey of the Isaac River at Moranbah North Mine, accessible during the dry season, it was noted that all test pits dug for the GPR survey within the bed sands were dry, or only damp in the base layer. This indicates that the Isaac River alluvium has limited effective storage, provides only limited volumes of baseflow, and does not contain groundwater all year round.

7.3.2 Tertiary Formation

7.3.2.1 Distribution and flow

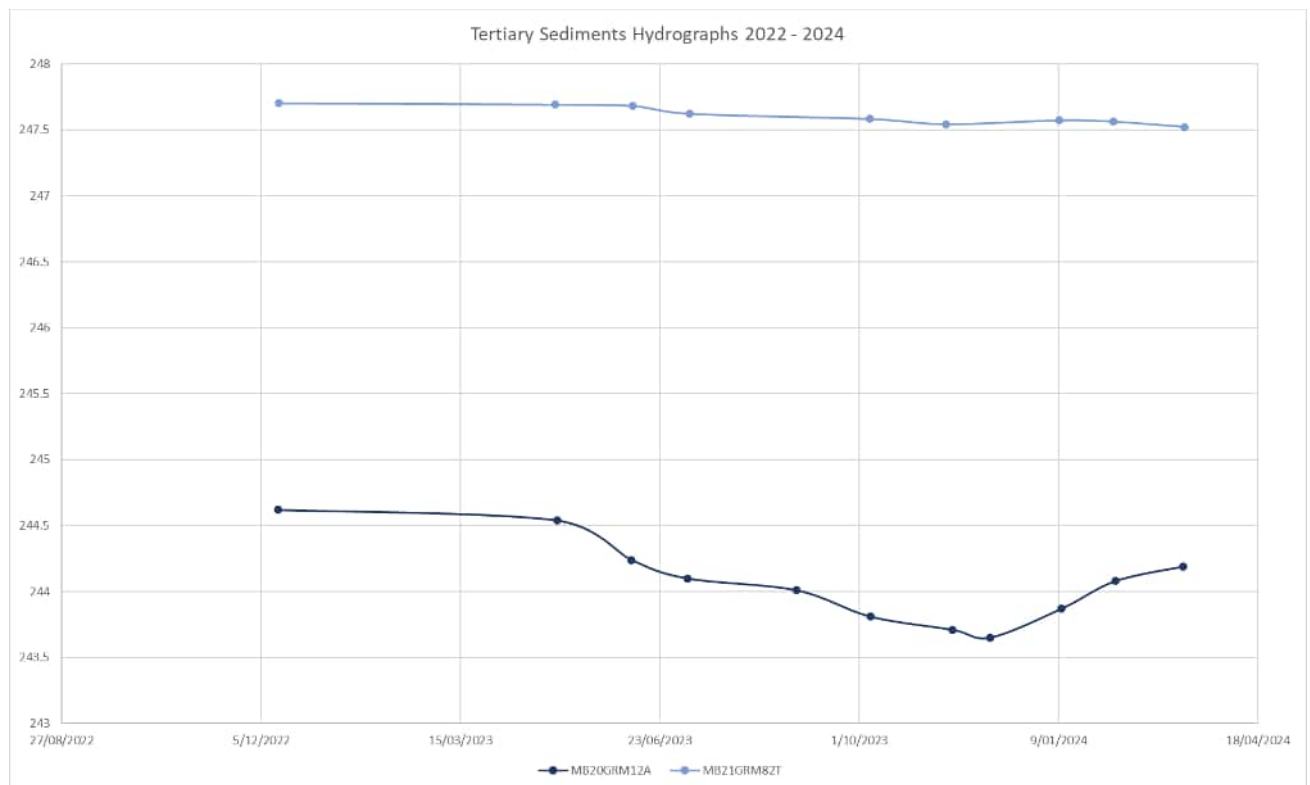
The undifferentiated Tertiary sediments and Suttor Formation is mapped across the Project area, noting that the mapped outcrop is not continuous. In areas where the Tertiary units are eroded inliers of older Permian rocks are mapped. In other locations the Tertiary units are concealed by younger alluvium.

The undifferentiated Tertiary sediments can occur as lenses of paleochannel gravels and sands separated by sandy silts, sandy clays and clays. A review of the borehole logs showed the undifferentiated Tertiary sediments vary in thickness up to approximately 80 metres with a typical thickness of up to 15 m.

Groundwater level in the Tertiary deposits was measured to be around 10 mbgl, deeper and hydraulically disconnected from the alluvium (as detailed in Section 7.3.1). There is also a distinction between the semi-confined to confined Tertiary and the coal measures potentiometric levels indicating a separation (hydraulic disconnect) between these hydrostratigraphic units.

In the Tertiary units, groundwater flow mimics topography and drainage systems.

Figure 12 Hydrographs of Tertiary Formation groundwater elevation



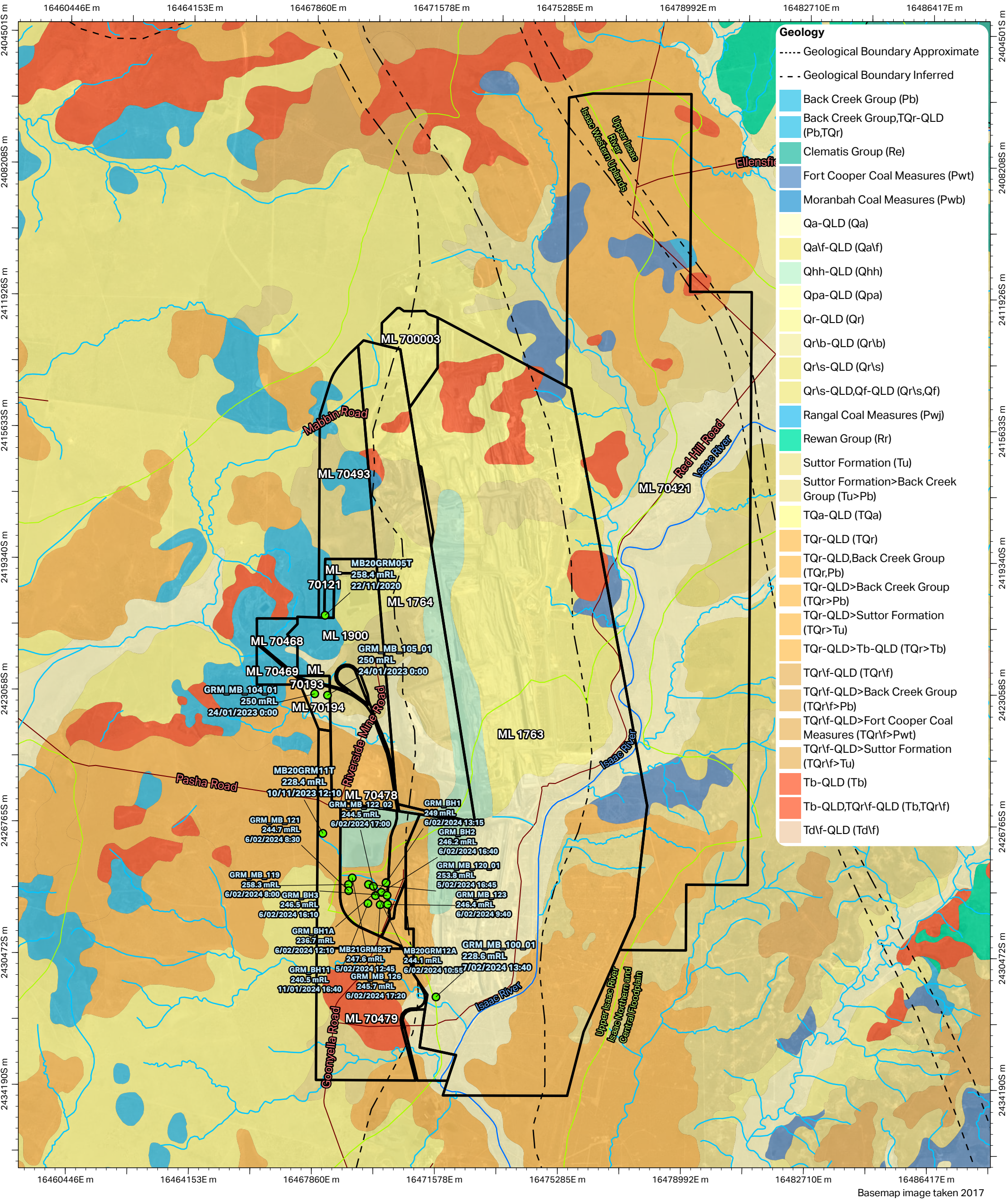
MB20GRM12A has an average depth-to-water of 9.4 mbgl, bore depth 18 m

MB21GRM82T has an average depth-to-water of 10.9 mbgl, bore depth 29.3 m

Additional groundwater level data for the Tertiary sediments was obtained from monitoring bores constructed across the Project area. These bores have limited geological data but bore depths and locations, plus the use of geological contact data, allowed for the identification of monitoring bores constructed within the Tertiary sediments. These monitoring bores plus groundwater elevation data is included in Figure 13.

Figure 13 Tertiary groundwater elevations

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Goonyella, Riverside and Broadmeadow Mines
Tertiary Groundwater Elevations

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)
- Monitoring Bore - Tertiary

7.3.2.2 Recharge and discharge

Potential for groundwater exists within the more permeable sand and gravel sections of the Tertiary sediments, and represents a semi-confined to confined aquifer depending on location, degree of weathering, the nature of the overlying alluvium, and clay content, as recognised in the transient groundwater level data included in Figure 12.

Recharge mechanisms include:

- Direct infiltration of rainfall
- Overland flow / ponding where Tertiary sediments outcrop and no substantial clay barriers exist in the subsurface

Little or no recharge from overlying Quaternary alluvial aquifers is identified. Groundwater elevation data for MB20GRM15T at 235.9 mAHD (Figure 11) and GRM_MB_100_01 at 228.6 mAHD (Figure 13), located in proximity to each other, indicates a marked separation (7.3 m) between the two hydrostratigraphic units (i.e., no hydraulic connection between the alluvium water table and the semi-confined Tertiary sediments).

Primary discharge mechanisms in the Tertiary sediment aquifers are likely to be:

- Through flow
- Evapotranspiration
- Groundwater extraction.

7.3.3 Permian – Triassic strata

The Permian -Triassic formations within the Project area comprise the two Permian formations, which are the Blackwater Group (which contains the MCM, FCCM, and RCM) and the Back Creek Group. These units are included on Figure 6. As with the rest of the Bowen Basin, the coal seams are the main aquifers within the Permian sequences, with the overburden and interburden rocks in most mines being described as essentially impervious to groundwater movement (AGE 2008). The MCM coal seams, GLS, GMS and GUS, constitute the most extensive aquifers at the Project.

The coal seam aquifers are confined above and below by low permeability geological formations (Section 7.2.1.3) and movement of water through the aquifer (transmissivity) is likely to be through the more permeable (cleats) coal rather than the confining units. The confining units also have low vertical hydraulic conductivity (leakance), such that water flows into the aquifer (recharge) is limited.

Groundwater occurs within the coal seam cleats and fissures and within open fractures that intersect the seams. Other sediments in the coal overburden and interburden sequence are relatively impermeable (either due to high clay content or significant cementing) and form aquitards. The Permian and Triassic strata may, therefore, be categorised into the following hydrogeological units:

- Hydrogeologically 'tight' and hence very low yielding to essentially dry claystone, mudstone, sandstone, siltstone and shale that comprise the majority of the strata.
- Low to moderately permeable coal seams, which are the primary water bearing strata within the Permian sequence.
- Localised fracture or fault systems which are open and have not been infilled by clay/carbonate deposition.

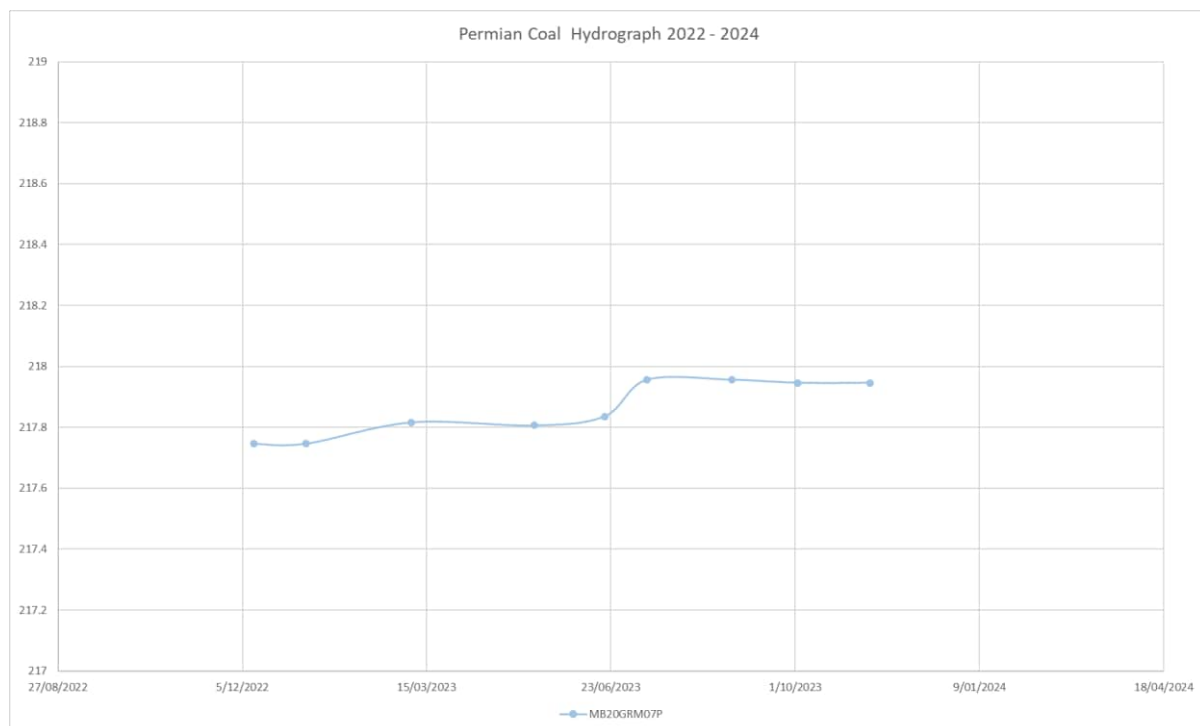
Groundwater levels in the Permian age formations have historically been measured during hydrogeological investigations at the Project and used for assessing potential inflows to pits and underground workings. Other studies included the establishment of boxcut or pit dewatering bores for mine design and production purposes (AECOM, 2013). Evidence from piezometric observations for the coal seam aquifers during these previous investigations suggests the groundwater levels were different for each seam, with the GUS seam being one to two metres higher than the GMS seam, and the GLS seam being up to 14 metres lower than the GMS seam at the same location (i.e., no hydraulic connection between the coal seams due to interbedded aquitards). This variation in hydraulic heads

between coal seams indicates limited potential for induced flow. The piezometric levels in the coal seams varied from 15 to 69 mbgl.

Prior to development of the GRB mine complex operations, groundwater flow direction in the coal seam aquifers is inferred to have been from the north and west to the south and east across the site. This flow direction is based on recharge to the coal seams occurring at the subcrops in the west and north of the site and discharge occurring downgradient in the Isaac River sub-basin. The current (2020 to 2024) groundwater flow patterns have been altered locally with groundwater flow towards the existing mine pits and underground workings due to mine dewatering and depressurisation.

Recent transient groundwater level data for Permian coal within the Project area is available for MB20GRM07P, included in Figure 14. The average groundwater depth was 18.1 mbgl (± 0.2 m) and the bore depth is 85 m.

Figure 14 Transient groundwater level data for Permian coal



The most recent available groundwater level elevation data for the Permian GMS and GLS, across the Project area, are included in Figure 15 and Figure 16, respectively.

Groundwater elevation data in the area containing the Quaternary alluvial monitoring bore MB20GRM15T indicates the following:

- Alluvium water table at 235.9 mAHD (Figure 11)
- Tertiary sub-artesian potentiometric level of 228.6 mAHD at GRM_MB_100_01 (Figure 13)
- Permian GMS groundwater elevation of 187.5 mAHD in GRM_MB_102.02 (Figure 15)
- Permian GLS groundwater elevation of 215.7 mAHD in MB20GRM18P (Figure 16).

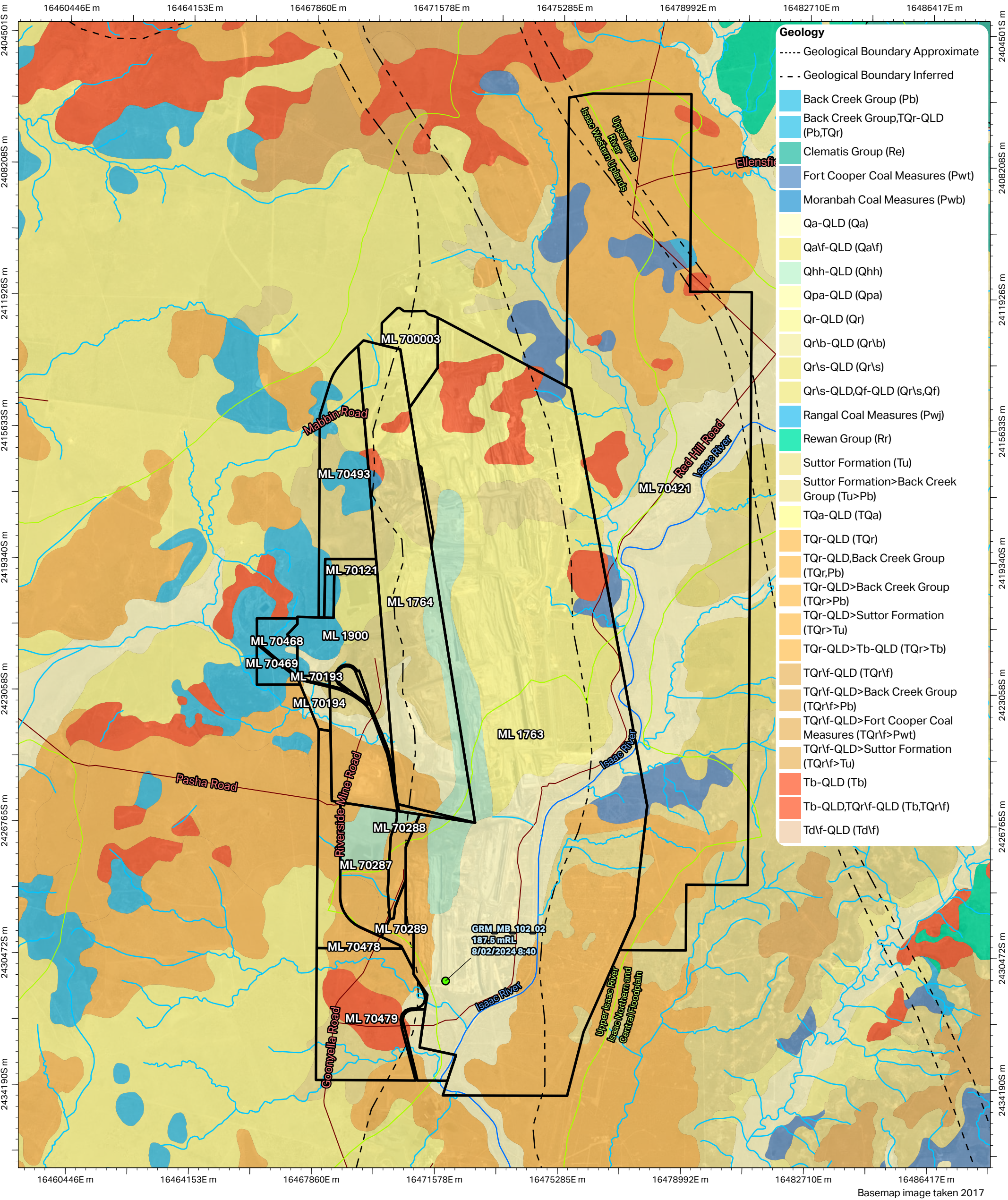
These data indicate:

- No hydraulic connection between the different hydrostratigraphic units
- Confining aquitards above and below the coal resulting in different potentiometric levels associated with the coal seams
- Upward vertical groundwater gradients from GLS to GMS
- Vertical downward groundwater gradients from alluvium, to Tertiary, to Permian coal

- Marked separation between the Tertiary and the Permian units, even with an upward vertical groundwater gradient within the coal seams.

Figure 15 GMS groundwater elevations

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Geology

----- Geological Boundary Approximate

- - - Geological Boundary Inferred

Back Creek Group (Pb)

Back Creek Group,TQr-QLD (Pb,TQr)

Clematis Group (Re)

Fort Cooper Coal Measures (Pwt)

Moranbah Coal Measures (Pwb)

Qa-QLD (Qa)

Qa'f-QLD (Qa'f)

Qhh-QLD (Qhh)

Qpa-QLD (Qpa)

Qr-QLD (Qr)

Qr'b-QLD (Qr'b)

Qr's-QLD (Qr's)

Qr's-QLD,Qf-QLD (Qr's,Qf)

Rangal Coal Measures (Pwj)

Rewan Group (Rr)

Suttor Formation (Tu)

Suttor Formation>Back Creek Group (Tu>Pb)

TQa-QLD (TQa)

TQr-QLD (TQr)

TQr-QLD,Back Creek Group (TQr,Pb)

TQr-QLD>Back Creek Group (TQr>Pb)

TQr-QLD>Suttor Formation (TQr>Tu)

TQr-QLD>Tb-QLD (TQr>Tb)

TQr'f-QLD (TQr'f)

TQr'f-QLD>Back Creek Group (TQr'f>Pb)

TQr'f-QLD>Fort Cooper Coal Measures (TQr'f>Pwt)

TQr'f-QLD>Suttor Formation (TQr'f>Tu)

Tb-QLD (Tb)

Tb-QLD,TQr'f-QLD (Tb,TQr'f)

Td'f-QLD (Td'f)

Goonyella, Riverside and Broadmeadow Mines
GMS Groundwater Elevations

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)
- Monitoring Bore - GMS

N

GDA 1994 MGA Zone 55

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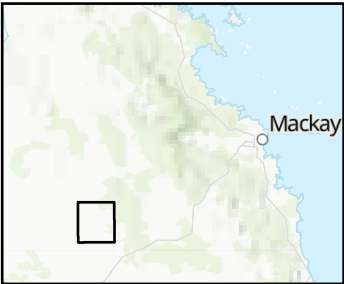
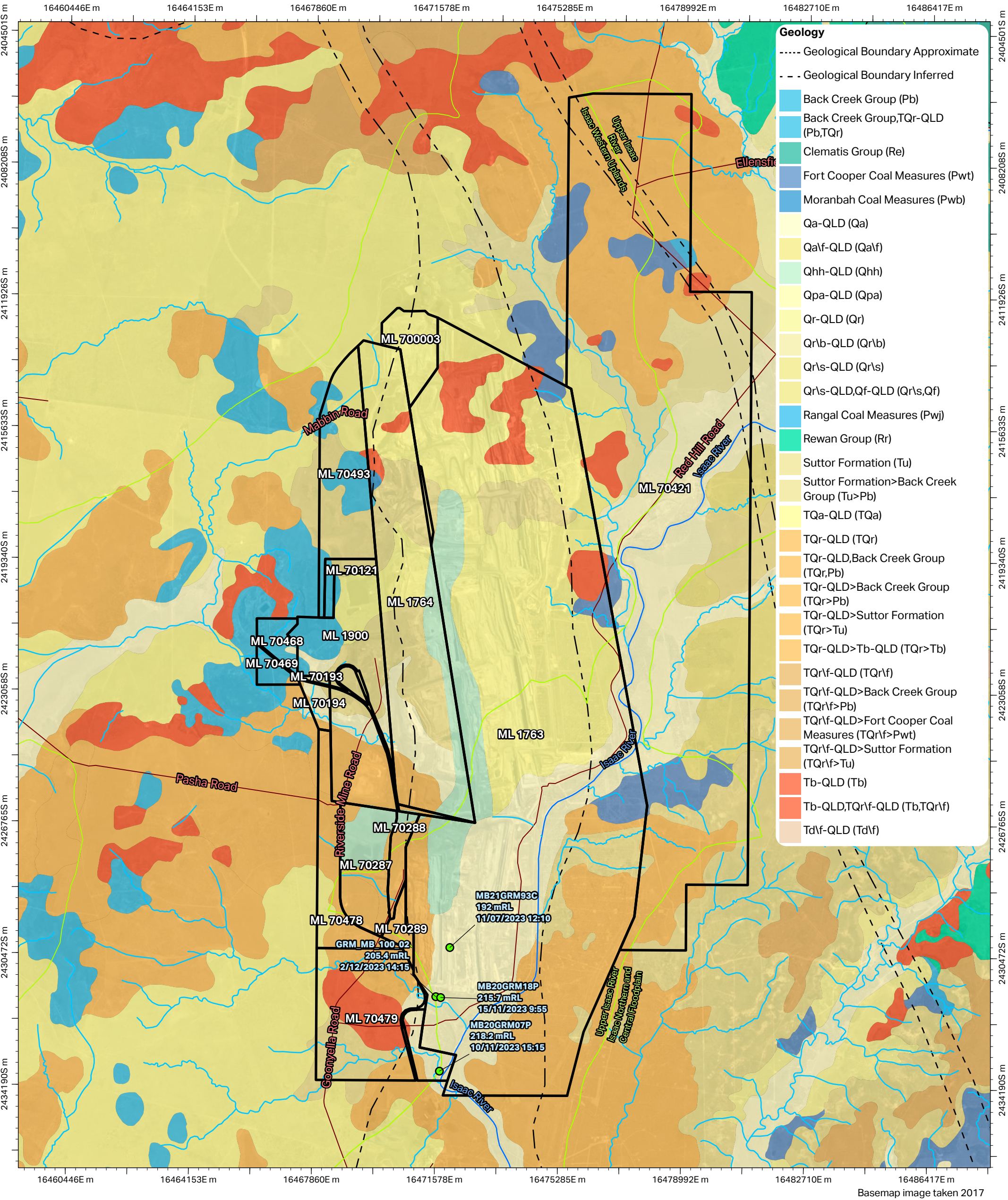


Figure 16 GLS groundwater elevations

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Geology

----- Geological Boundary Approximate

- - - Geological Boundary Inferred

Back Creek Group (Pb)

Back Creek Group,TQr-QLD (Pb,TQr)

Clematis Group (Re)

Fort Cooper Coal Measures (Pwt)

Moranbah Coal Measures (Pwb)

Qa-QLD (Qa)

Qa'f-QLD (Qa'f)

Qhh-QLD (Qhh)

Qpa-QLD (Qpa)

Qr-QLD (Qr)

Qr'b-QLD (Qr'b)

Qr's-QLD (Qr's)

Qr's-QLD,Qf-QLD (Qr's,Qf)

Rangal Coal Measures (Pwj)

Rewan Group (Rr)

Suttor Formation (Tu)

Suttor Formation>Back Creek Group (Tu>Pb)

TQa-QLD (TQa)

TQr-QLD (TQr)

TQr-QLD,Back Creek Group (TQr,Pb)

TQr-QLD>Back Creek Group (TQr>Pb)

TQr-QLD>Suttor Formation (TQr>Tu)

TQr-QLD>Tb-QLD (TQr>Tb)

TQr'f-QLD (TQr'f)

TQr'f-QLD>Back Creek Group (TQr'f>Pb)

TQr'f-QLD>Fort Cooper Coal Measures (TQr'f>Pwt)

TQr'f-QLD>Suttor Formation (TQr'f>Tu)

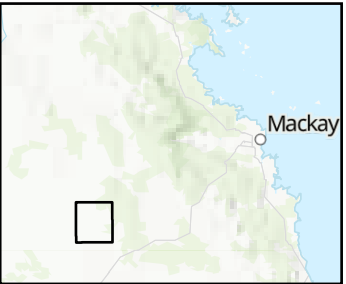
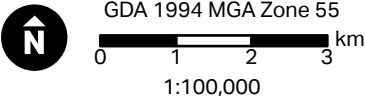
Tb-QLD (Tb)

Tb-QLD,TQr'f-QLD (Tb,TQr'f)

Td'f-QLD (Td'f)

Goonyella, Riverside and Broadmeadow Mines
GLS Groundwater Elevations

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)
- Monitoring Bore - GLS



7.3.3.1 Distribution and flow

Prior to development of the GRB mine complex operations, groundwater flow direction in the coal seam aquifers appears to have been from the north and west to the south and east across the site. This flow direction is consistent with recharge to the coal seams occurring at the subcrops in the north and west and discharge occurring downgradient in the Isaac River sub catchment in the Bowen Basin. The current groundwater flow pattern has been altered locally with groundwater flow towards the existing mine pits and underground workings due to mine dewatering and depressurisation.

The occurrence of groundwater in the interburden is limited. Aquifers in the interburden are discontinuous with heterogeneous hydraulic properties creating isolated, lens-like aquifers. Due to the heterogeneity and discontinuity of the interburden aquifers within the Permian strata, the groundwater flow direction cannot be determined on a regional scale for these aquifers.

7.3.3.2 Recharge and discharge

Groundwater recharge in the coal seam aquifer occurs from:

- Infiltration of rainfall and overland flow in outcrop and sub-crop areas
- Leakage between aquifers by faulting and other structural discontinuities in overburden and interburden sediments.

Downward seepage or vertical flow from overlying alluvial or tertiary aquifers is not recognised, based on vertical groundwater elevation data, to occur.

Primary discharge mechanisms in the Permian -Triassic strata include:

- Dewatering for mine progression
- Downgradient flow within the Permian -Triassic strata away from the outcrop areas
- Possible movement to other hydrostratigraphic units / coal seams via structural discontinuities.

7.3.4 Underground mining influencing groundwater flow

Underground mining using the thick seam mining method (longwall top coal caving) will result in subsidence of the overlying strata in the mined-out areas behind the longwall, resulting in aquifer alteration due to the goaf. This caving and subsidence can cause fractures and joints in the overlying strata.

AGE (2002) state that following the passage of longwall panels and stabilisation of subsidence, fracturing in the bulk of the strata will generally close up, allowing strata permeability to return to near to the pre-mining levels.

Within the zones above and adjacent to the longwall panels the vertical and horizontal strata permeability will be markedly and permanently altered due to sub-surface fracturing. The vertical extent of these fractures is dependent on numerous factors, such as mine design, geological conditions, surface topography, and the distance between the mine workings and the ground surface.

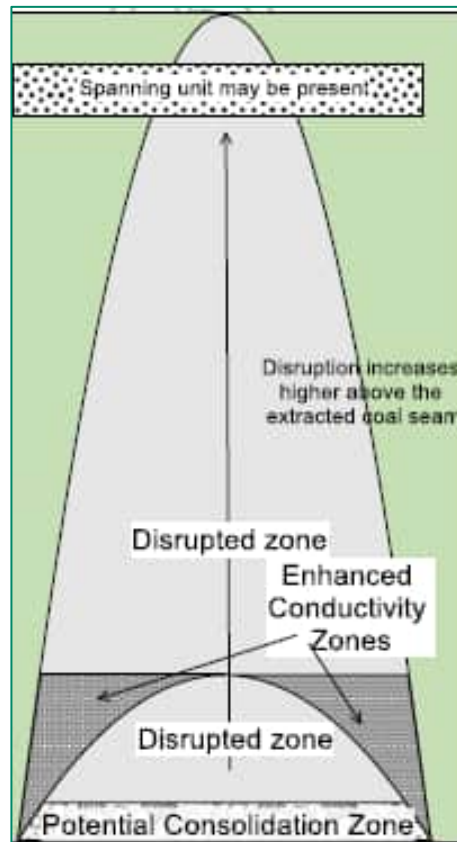
Unfortunately, the location of existing bores with groundwater level data, included in Figure 8, are not within or immediately adjacent to the Broadmeadow underground mine panels. The lack of alluvium, Tertiary and Permian groundwater level data at the Broadmeadow underground mine does not allow for the evaluation of possible vertical hydraulic connection due to longwall mining. The influence of the longwall mining was, however, assessed using geotechnical modelling.

7.3.4.1 Longwall modelling

BMA appointed Byrnes Geotechnical to undertake a geotechnical study is required to provide assessment of possible hydraulic conductivity and porosity changes due to BMA longwall and pillar extraction mining (Byrnes Geotechnical, 2024). This draft study reviewed historic approaches to estimating alteration to aquifer hydraulic properties based on geotechnical modelling, a review of previous studies and finds, allowing for a revised conceptualisation of alteration. The report is included in **Appendix B**.

The resultant geotechnical model derived from the Byrnes Geotechnical study, depicted in Plate 6, indicates differing zones of alteration above the panels. The shape and extent of these zones is markedly different to previous simulations of alteration adopted in groundwater modelling.

Plate 6 BMA longwall and pillar extraction mining geotechnical model



The BMA longwall and pillar extraction mining geotechnical model considers that the simple triangular shape (Plate 7) of the disrupted zone is replaced by a parabolic shape following some numerical analysis of failure in bedding rock masses.

It is noted that:

- The height of the disrupted zone is a function of the average thickness of the bedded units in the overburden. The default height is two times the extraction width which is equivalent to the panel geometry that represents the step from subcritical to supercritical.
- The enhanced conductivity zone (ECZ) geometry is based on the D zone angles (Figure 17), with overall shape defined by two parabolas. The ECZ is the locus for high inflows.
- If the surface subsidence developed between adjacent chain pillars was more than 400 mm, then there would be a fracture connection, albeit possibly tortuous, between the surface and the underground workings.

Plate 7 Triangular conceptual inflow model (Younger, 2011)

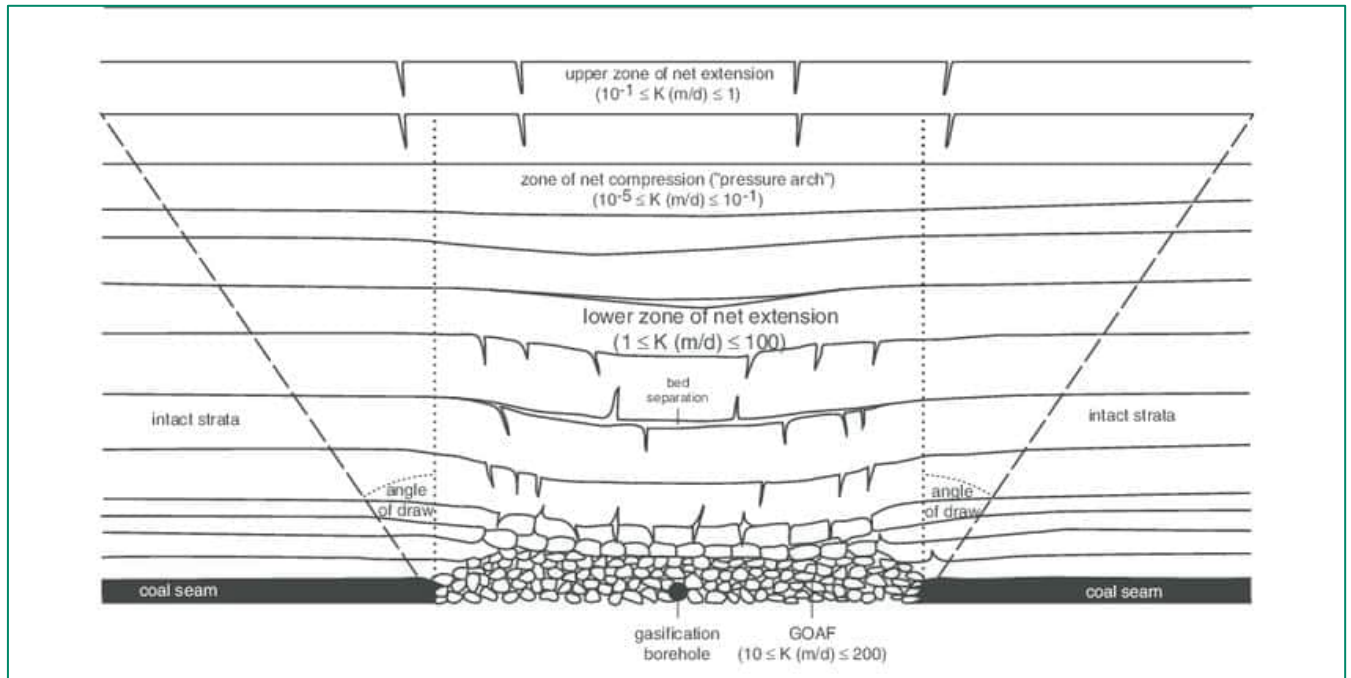
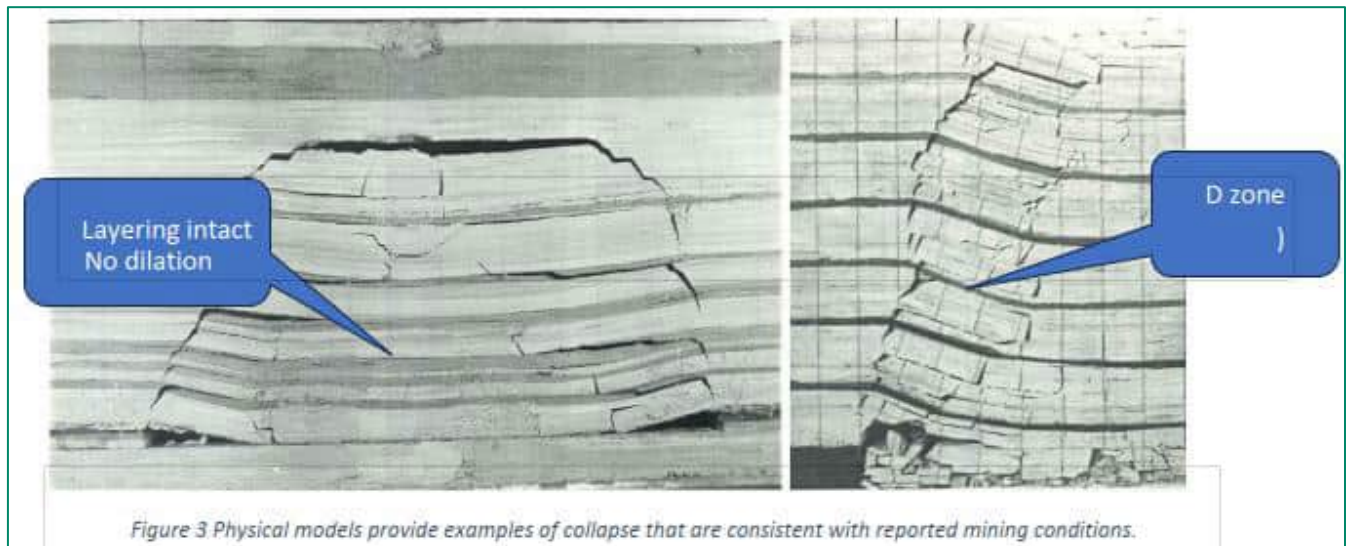


Figure 17 Physical model showing alteration shape and collapse



7.3.4.2 Alteration due to longwall mining

The geotechnical model provides a basis for the prediction of hydraulic conductivity associated with the supercritical longwall geometry of the BMA longwall operations. It's important to note that there is no validation of the method available and Brynes geotechnical notes that it would be difficult to undertake given the large volume of longwall mining.

Mine inflows are not useful in this context as they are most likely related to the ECZ and not the larger disrupted zone and there is the problem of the low conductivity in the potential consolidated zone (PCZ).

The Geotechnical model is applicable to the Permian and Tertiary sequences but does not include the possible role of Quaternary alluvium and surficial cover.

Output from the Geotechnical Model includes the conductivity changes up to twice the excavation width, such that it can be sliced at any actual mining depth.

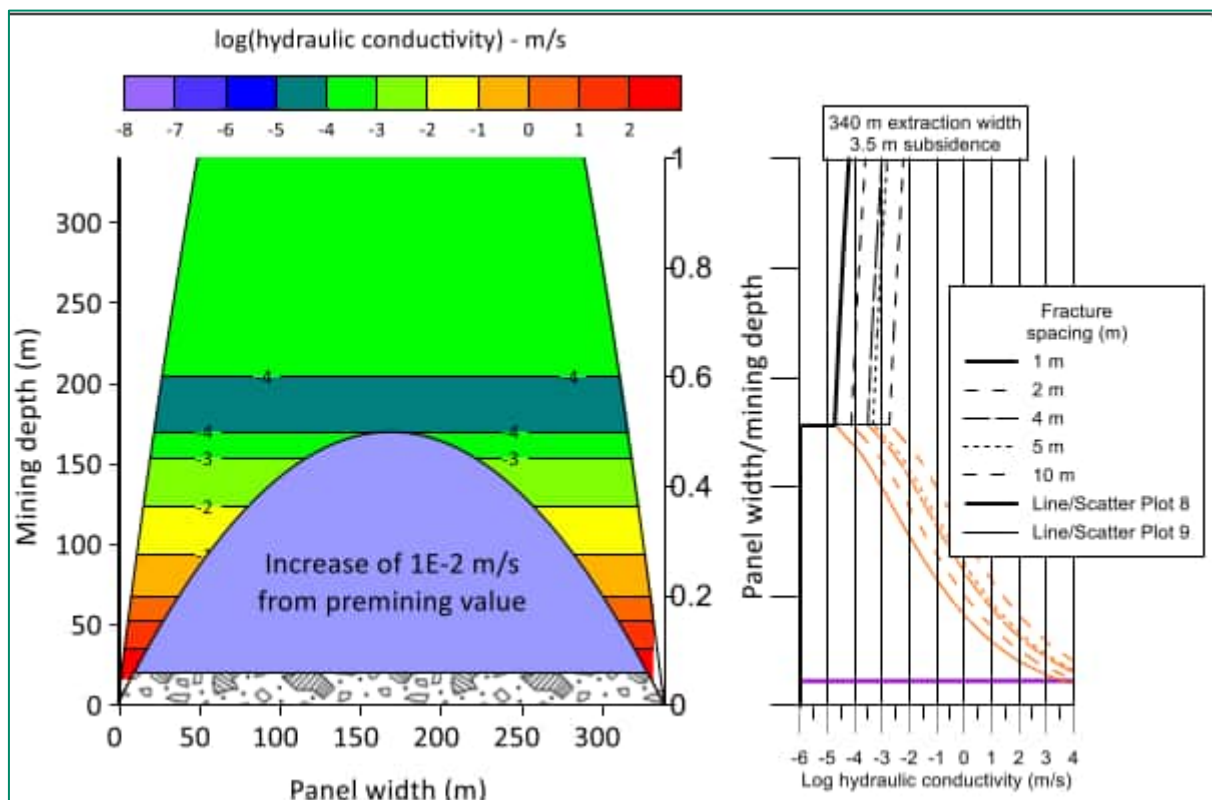
The input variables to the Geotechnical model are:

- Maximum vertical subsidence, or more precisely the difference in the maximum subsidence at /near the panel centreline relative to the subsidence above the chain pillars.
- The extraction width.
- The spacing of the cracks, where these may be mining-induced or the natural geological joints. This is a highly uncertain parameter, and its selection will require substantial judgement.

An example is presented in Figure 18, which also includes a sensitivity study on the choice of fracture spacing.

Note the Byrnes Geotechnical report (**Appendix B**) is still in draft and was not finalised at the time of writing.

Figure 18 Example of hydraulic conductivity prediction for Broadmeadow underground mine with sensitivity to fracture spacing



7.3.4.3 Groundwater modelling approach

The alteration due to longwall mining, as conceptualised and modelled by Byrnes Geotechnical, predicts a complex heterogeneous hydrostratigraphic unit/s within, adjacent, and above the longwall panel post mining. It is also noted that Mine inflows are most likely related to the smaller more permeable ECZ at the edge of the panels rather than the larger disrupted zone.

The approach adopted to include for the alteration of the longwall mining was to assess the historic groundwater ingress into Broadmeadow GMS underground and simulate the altered target coal seam and overlying aquitards as an equivalent porous medium (EPM).

The EPM is a porous medium of a continuous solid matrix and pore-inclusions with an equivalent porosity that is higher than the porosity of the initial medium was used. Thus, an equivalent permeability across the entire mine panel was used in lieu of complex parametrisation within each panel to simulate high permeable areas (ECZ) and low permeable zones (PCZ).

Model calibration to match the actual groundwater extraction from the Broadmeadow GMS underground mining (Plate 8), allowed for the refinement of alteration to be adopted at all longwall mining panels across the Project.

The model calibration is detailed in Section 13.0. The model calibration using the groundwater extraction results plus the EPM approach indicated alteration resulting in hydraulic properties as follows:

- GMS goaf Horizontal hydraulic conductivity (K_h) = 1.1 m/day
- GMS goaf Vertical hydraulic conductivity (K_v) = 0.00005 m/day
- GMS goaf Specific capacity (S_c) confined storage = 0.0015
- GMS goaf Specific yield (S_y) unconfined storage = 0.15

The K_v in the overlying model layer (interburden aquitard) was 0.0005 m/day after longwall mining. The goaf K and S parameters were adjusted by comparing computed extracted groundwater volumes from the goaf areas to the measured and recorded groundwater ingress pumped from the underground between 2018 and 2023.

The yellow highlighted areas in Plate 8 are the GMS underground longwall panels included in the original (RHM Model) mine plan (2010 to 2023).

Plate 9 includes the goaf aquifer hydraulic parameters included after longwall mining was complete.

Goaf K_v in model layer 10 (GMS) is similar to the pilot point estimates (Section 14.3) and the K_v in model layer 9 (MCM interburden) was increased to 5 E-5 m/day.

Specific yield, as a result of longwall mining, increased from 0.001 to 0.15, and the storage coefficient increased from 1E-5 to 0.0015.

Plate 8 Historic GMS mine panels (2010 to 2023)

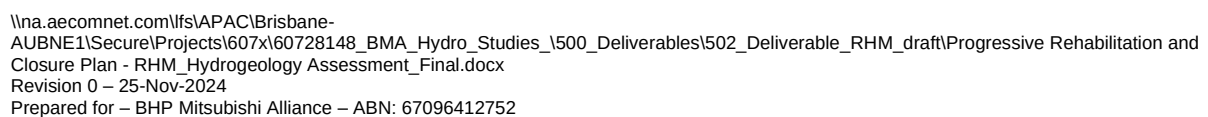
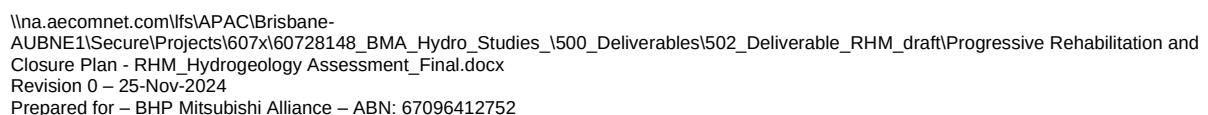


Plate 9 Representation of hydraulic conductivity distribution at the GMS mine panels after mining alteration



8.0 Water Quality

8.1 Baseline groundwater quality

Available hydrochemistry data for the key hydrostratigraphic units across the Project area included data from 2001 to 2020, which was used to describe the historic conditions. More recent data, from 2020 to 2024, allowed for the evaluate of current groundwater quality and a comparison to historic data. This allowed for the evaluation of possible alteration due to approved mining activities at the Project.

8.1.1 Historic data

Groundwater quality data from previous investigations at GRB and RHM, from 2001 to 2010 (Table 7) have informed this section and from RHM from 1998 to 2011.

Groundwater chemistry is typically neutral to weakly alkaline (pH) for all formations.

The groundwater from the Quaternary alluvium is dominated by sodium and bicarbonate ions. The alluvial aquifer has variable salinity as the depth of the aquifer and its distance from the area of recharge are likely to influence the result at a given sample point and appears to increase with depth and the distance from the area of recharge (i.e., residence time increases the salinity of the groundwater). Generally, the alluvial groundwater has lower salinity than the Permian age confined formations.

The Tertiary and Permian age formations have variable salinity (measured as electrical conductivity), ranging from brackish to saline.

The Permian MCM and Back Creek Group has moderate to high salinity principally due to elevated levels of sodium and chloride ions. The Back Creek Group groundwater contains a relatively higher proportion of sulphate due to marine influence during deposition compared to the MCM (URS 2013).

Table 7 Groundwater quality results (2001 – 2010)

Lithology	Number of Samples	Electrical Conductivity (µS/cm)		pH	
		Range	Median	Range	Median
Alluvium	2	521 – 561		6.88 – 7.55	
Tertiary Basalt	3	2,670-15,384	13,100	8.19 – 8.67	8.38
Tertiary Sediments	1	5,060		9.3	
Permian Interburden	6	7,030 – 18,800	12,805	7.38 – 8.38	8.06
GMS coal seam	5	2,450 – 16,127	9,110	6.65 – 7.9	7.12
GLS coal seam	30	387 – 31,300	24,050	2.71 – 8.76	7.99
Back Creek Group	3	4,530 – 24,030	22,660	5.98 – 6.79	6.74
Undifferentiated samples from airlift during exploration	75	100 – 30,000	12,593	6.89 – 9.18	7.68
EPP (Water) - 50th Percentile					
Shallow groundwater (<30 m)		2,150		7.75	
Deep groundwater (>30 m)		6,100		7.8	

Notes:

- Electrical Conductivity value based on TDS value for livestock (EC [µS/cm] = 1.67 × TDS [mg/L])
- EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34.

8.1.2 Recent data

Groundwater quality monitoring results, compiled between 2020 and 2024, show that the alluvium indicated high variability, with salinity varying from fresh to highly saline.

Tertiary sediments have salinity that ranges from moderate to highly saline. The GMS coal seam salinity ranges from brackish to highly saline. The GLS coal seam and Back Creek Group samples indicate high salinity.

Table 8 Groundwater quality results (2020 – 2024)

Geology	Number of Samples	Electrical Conductivity (µS/cm)		pH	
		Range	Median	Range	Median
Alluvium	27	492 – 41,000	696	5.25 – 8.1	7.42
Tertiary Sediments	57	11,400– 42,200	21,700	5.52 - 8.33	6.59
FCCM	6	167 – 36,500	22,300	7.24 – 8.99	7.65
Permian Interburden	28	2,120 – 17,800	3,305	6.22 - 8.47	7.62
GMS coal seam	13	6,720 – 26,100	9,610	7.15 - 8.32	7.68
GLS coal seam	4	14,900 – 42,200	24,400	6.34 - 8.54	7.50
Back Creek Group	2	17,200 – 24,452	24,700	6.37 – 8.08	7.62
EPP (Water) - 50th Percentile					
Shallow groundwater (<30 m)		2,150		7.75	
Deep groundwater (>30 m)		6,100		7.8	

8.1.3 Water quality data review

Historic data

Alluvium major ions and nutrients minimum values from the 1998 to 2011 monitoring data:

- Did not exceed the EPP (Water) 50th percentile water quality objectives for the shallow (<30 m depth) groundwater
- All the maximum concentrations and several median values exceeded the 50th percentile water quality objectives.

The maximum analysis concentrations for the MCM major ions were above the 50th percentile water quality objectives for both the shallow and deep groundwater. The MCM sodium and chloride median values exceeded the 50th percentile water quality objectives for shallow groundwater.

The median and maximum values for the Back Creek Group major ions were greater than the shallow and deep groundwater 50th percentile water quality objectives, except for bicarbonate. Sodium, chloride, and sulphate of the Back Creek exceeded water quality objectives for shallow groundwater (Table 9).

Recent data

During the 2020 to 2024 monitoring, the minimum and median values for groundwater samples from the alluvium major ions remained below the shallow groundwater 50th percentile water quality objectives. However, the maximum values were found to be above the 50th percentile water quality objectives except for chloride, which was slightly below the objective.

MCM analyses indicated exceedance of the 50th percentile water quality objectives for the median and maximum values of the major ions, with the exception of the bicarbonate. Minimum values were all below the objectives.

All Back Creek Group major ions exceeded the water quality objectives for both the shallow and deep groundwater water quality objectives, with the expectation of the bicarbonate which was below the objectives for all geological units (Table 10).

Table 9 Groundwater quality results (1998 – 2011)

	Water Quality Objectives		Alluvium				MCM				Back Creek Group			
	EPP(Water) – 50th Percentile, Shallow (<30 m depth) ¹	EPP(Water) – 50th Percentile, Deep (>30 m depth) ¹	Count	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count	Min (mg/L)	Med (mg/L)	Max (mg/L)
Parameter														
Major Ions														
Sodium	747	1,100	13	40	1,096	3,560	3	824	3,470	4,400	2	40	-	94
Calcium	84	145	13	<0.01	49	469	3	34	214	422	2	13	-	39
Magnesium	108	115	13	<0.01	25	570	3	86	542	805	2	7	-	20
Potassium			13	1.4	6	28	3	29	35	38	2	3	-	3
Chloride	1,309	1,900	13	64	2,024	7,510	3	1,390	7,000	9,750	2	10	-	71
Bicarbonate	536	330	13	85	497	5,656	3	10	417	774	2	180	-	293
Sulphate	140	138	13	0.2	4	626	3	223	692	763	2	6	-	26
Fluoride	0.28	0.155	11	<0.1	0.2	1.2	3				2	0.2	-	0.4
Nutrients														
Nitrite + Nitrate as N	0.95	2.15	13	0.02	0.2	0.9	3	0.05	0.09	0.33	2	0.125	-	0.315
Total Phosphorous as P			13	0.03	0.5	5.08	3	0.78	1.49	1.56	2	0.47	-	0.75

1 – EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34 groundwater.

Table 10 Groundwater quality results (2020 – 2024)

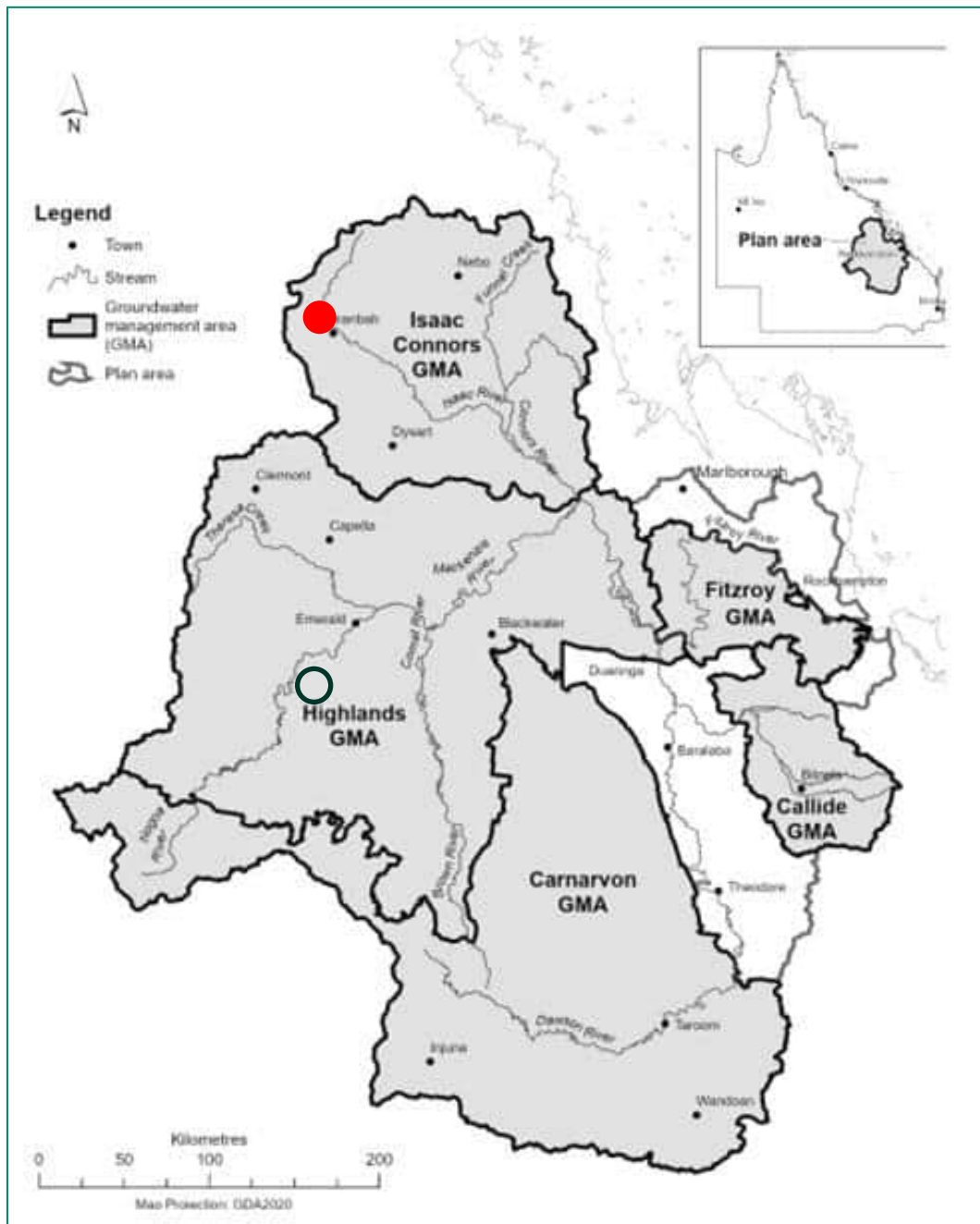
	Water Quality Objectives		Alluvium				MCM				Back Creek Group			
	EPP(Water) – 50th Percentile, Shallow (<30 m depth) ¹	EPP(Water) – 50th Percentile, Deep (>30 m depth) ¹	Count	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count	Min (mg/L)	Med (mg/L)	Max (mg/L)
Parameter														
Major Ions														
Sodium	747	1,100	27	49	116	8,140	89	293	2,450	8,770	24	3,160	4,115	4,540
Calcium	84	145	27	11	23	290	89	40	211	662	24	160	276	358
Magnesium	108	115	27	8	18	915	89	41	425.5	1,230	24	403	458.5	558
Potassium			27	1	3	64	89	3	14	34	24	13	15	37
Chloride	1,309	1,900	27	24	75	13,000	89	414	7,460	16,900	24	6,420	7,710	8,320
Bicarbonate	536	330	27	1	256	492	89	166	469	1,360	24	313	478	520
Sulphate	140	138	27	13	30	3,400	89	36	555	2,160	24	438	552	655
Fluoride	0.28	0.155	27	0.1	0.1	0.7	89	0.1	0.2	400	24	0.1	0.4	400
Nutrients														
Nitrite + Nitrate as N	0.95	2.15	27	0.01	0.125	2.42	89	0.01	0.035	0.44	24	0.01	0.04	0.67
Total Phosphorous as P			27	0.01	0.06	0.34	89	0.01	0.055	19,000	24	0.09	0.16	0.44

1 – EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34 groundwater.

The comparison of water quality data, to the relevant water quality objectives, does not readily indicate a marked difference in water quality over time. The variation in data is considered related to differing groundwater monitoring locations (reflecting the heterogeneous nature of the sediments across the Project), the number of samples, and the difference in residence time (different recharge / climate conditions).

8.2 Groundwater Environmental Values

Water plans have been developed by the State regulators, under the Water Act to sustainably manage and allocate water resources in Queensland. The Project is located within the Isaac Connors Groundwater Management Area (GMA) as defined in Schedule 3 of the Water Plan (Fitzroy Basin) 2011 (current as of 2 September 2022). Plate 10 indicates the Isaac Connors GMA and the approximate Project location.

Plate 10 Water Plan (Fitzroy Basin) 2011 Schedule 3 Groundwater Management Areas (Project is red dot)

GRB lies within or in proximity to the Isaac Connors Groundwater Management Area (GMA – Zone 34) of the Fitzroy Basin under the Water Plan (Fitzroy Basin) 2011 (Plate 11). Within the GMA, alluvial groundwater is managed as Groundwater Unit 1 and water within the hard rock aquifers as Groundwater Unit 2 (sub-artesian aquifers). Volumetric limits apply to extraction of groundwater within the GMA for non-stock and domestic purposes.

Groundwater resources in the GRB are also scheduled under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 as Isaac Groundwaters of the Isaac River Sub-basin of the Fitzroy Basin water plan (WQ1310). The legislated environmental values (EVs) for these groundwaters are:

- Biological integrity of aquatic ecosystems.
- Human use EVs:

- Suitability of water supply for irrigation
- Farm water supply/use
- Stock watering
- Primary recreation
- Drinking water supply
- Cultural and spiritual values.

The WQ1310 WQOs for groundwater at GRB are shown in Table 11.

The EPP Water and Wetland Biodiversity provides water quality objectives (WQOs) for the scheduled EVs in WQ1310. WQOs are long-term goals for water quality management and the purpose of the WQOs is to support and protect EVs. They are numerical concentration levels or narrative statements of indicators established for receiving waters to support and protect the designated EVs for those waters. They are based on scientific criteria or water quality guidelines but may be modified by other inputs (e.g. social, cultural, economic). Where groundwater quality analysis results exceed a particular WQO for a particular EV, it is considered indicative that the groundwater may be unsuitable for supporting that particular EV.

The EPP Water and Wetland Biodiversity also provides limited WQOs specifically for underground aquatic ecosystem protection in Fitzroy Basin groundwaters. These WQOs vary across the Fitzroy Basin and are defined on the basis of groundwater Chemistry Zones. The applicable Chemistry Zone for the GRB is Isaac Groundwater (Zone 34; Sodic Sequence - Saline: Na, Cl). These WQOs are classified by groundwater depth ('shallow' being <30 m depth, and 'deep' being >30 m depth) and are summarised in Table 12. The management intent of Zone 34 WQOs is to "maintain each of 20th, 50th and 80th percentile values", i.e. that there should be no change to existing water quality (no statistical change in the natural range of values) (DES, 2022).

Plate 11 Fitzroy Basin Groundwater Zones (Project red dot)

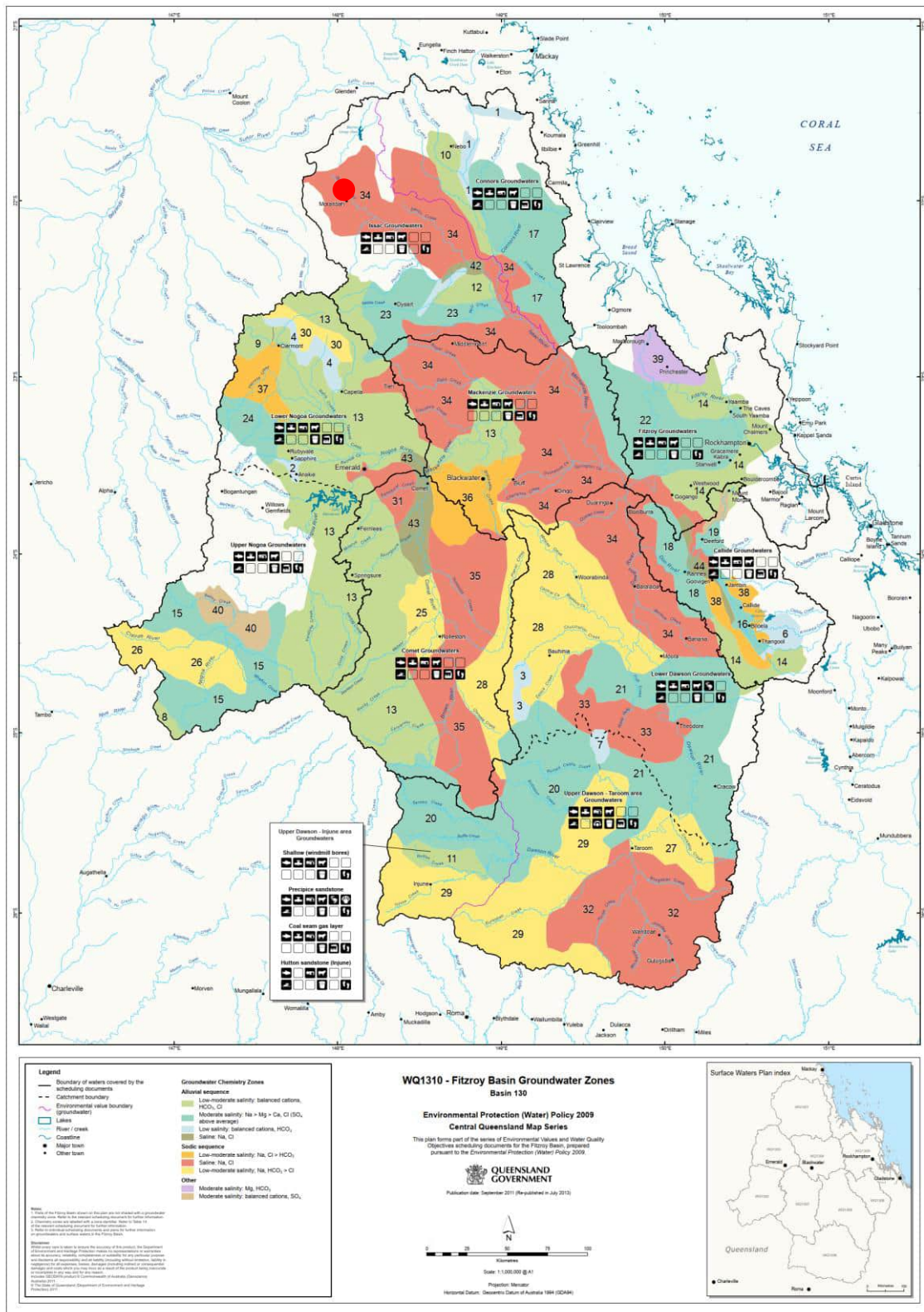


Table 11 WQOs for Isaac River sub-basin EVs

Water quality indicator	Unit	ADWG Guidelines ¹		Isaac River Sub-basin EVs ²		
		Health	Aesthetic	Irrigation	Stock	Aquatic 95% spp ³
pH	pH units	6.5 – 8.5				6.5 – 8.5
Al	mg/L		0.2		5	0.055
Ca	mg/L				1,000	
Cl	mg/L		250			
Mg	mg/L				2,000	
Mn	mg/L	0.5	0.1	10		1.9
Na	mg/L		180			
SO ₄	mg/L				1,000	
Zn	mg/L		3			0.008
As	mg/L	0.01		2	0.5	0.024
Cd	mg/L	0.002			0.01	0.0002
Cr	mg/L	0.5			1	0.001
Co	mg/L			0.1	1	
Cu	mg/L	2	1		1	0.0014
Pb	mg/L	0.01			0.1	0.0034
Hg	mg/L	0.001			0.002	0.0006
Ni	mg/L	0.02			1	0.011
Se	mg/L	0.01			0.02	0.005
Ag	mg/L	0.1				0.05

Table notes:

1. Table 4 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Drinking water EV.
2. Table 2, Table 9, Table 10 and Table 11 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Aquatic ecosystem – moderately disturbed.
3. Table 3.4.1 of Australian and New Zealand Guidelines for Fresh and Marine Water Quality: trigger values for slightly-moderately disturbed systems (95% level of protection).

Table 12 Isaac River Sub-basin Zone 34 WQOs for groundwater resources (aquatic ecosystem protection)

Water quality indicator	Unit	Shallow groundwater (<30m) percentile			Shallow groundwater (>30m) percentile		
		20 th	50 th	80 th	20 th	50 th	80 th
EC	µS/cm	498	2,150	8,910	3,419	6,100	16,000
Hardness	mg/L as CaCO ₃	163	674	2,228	359	919	3,208
pH	pH units	7.1	7.75	8.1	7.4	7.8	8.03
Alkalinity	mg/L	154	435	752	156	275	536
Ca	mg/L	18	84	215	46	145	442
Mg	mg/L	27	108	389	35	115	491
Na	mg/L	135	747	1,500	480	1,100	2,565
Cl	mg/L	171	1,309	3,185	753	1,900	5,905
SO ₄	mg/L	12	140	318	25	138	398
HCO ₃	mg/L	187	536	878	188	330	650
NO ₃	mg/L	0	0.95	5.3	0.01	2.15	14.92
SiO ₂	mg/L	21	36	52	16	25	36
F	mg/L	0.1	0.28	0.5	0.02	0.155	0.4
Fe	mg/L	0	0.03	0.14	0	0.05	0.246
Mn	mg/L	0	0.01	0.16	0	0.05	0.291
Zn	mg/L	0	0.015	0.06	0.01	0.025	0.317
Cu	mg/L	0	0.01	0.03	0.017	0.03	0.03
SAR	-	4.37	10.85	18.21	10.5	15.6	24.65
RAH	meq/L	0	0	2.3	0	0.24	6.25

In order to understand the groundwater resources within the GRB area, available water quality data Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34 groundwater have been compared to the:

- Australian Drinking Water Guidelines (ADWG) (NHMRC, 2011)
- ANZG (2018) guidelines for irrigation (long-term and short-term), stock water supply, and 95% level of protection for aquatic ecosystems in slightly-moderately disturbed systems
- Isaac River Sub-basin Zone 34 WQOs for groundwater resources (aquatic ecosystem protection) for deep and shallow groundwater.

8.2.1 Groundwater quality comments

Median groundwater salinity values were greater than the 50th percentile WQOs nominated in the (Water) for groundwaters in the Isaac River Sub-basin. The available dataset does, however, indicate that groundwater results cover a wide range for each hydrostratigraphic unit (due to depth, distance from recharge, and age of water). The lower end of the range of results are within the WQOs.

Alluvium

- Major ion concentrations for alluvial groundwater are less than the EPP (Water) 50th percentile water quality objectives for shallow (<30 metre depth) groundwater.
- The maximum concentration of zinc recorded is above the ANZG (2018) water quality guideline for aquatic ecosystems.

MCM

- The median concentration of sodium for groundwater from the MCM is less than the EPP (Water) 50th percentile water quality objective for deep (>30 m depth) groundwater.
- The median concentrations of chloride and bicarbonate were above their respective water quality objectives.
- The median concentration of manganese was above the relevant water quality objective, while the median concentrations of nutrients (nitrate and nitrite, total phosphorous) and some dissolved metals (chromium, copper, and zinc) are all above the ANZG water quality guidelines for aquatic ecosystems.
- The median concentrations of manganese and iron are above the relevant water quality objectives, while the median concentrations of nutrients (nitrate and nitrite, total phosphorous) and some dissolved metals (boron, cadmium, chromium, copper, nickel, selenium, and zinc) are above the ANZECC/ARMCANZ (2000) water quality guideline for aquatic ecosystems.

Based on the historic and more recent groundwater quality data for the Project area, the groundwater quality does not readily comply with the guideline WQOs. The limited variation over time, considering the historic and recent water quality sample results, indicate the natural groundwater quality reduces the suitability for use (Isaac Connors Groundwater Management Area EVs) and aquatic ecosystems.

9.0 Groundwater Receptors

9.1 Groundwater Bores

A search of the Department of Regional Development, Manufacturing and Water (DRDMW) Groundwater Bore Database (GWBD) was carried out for registered bores within and adjacent to the Project. The search, across the mine lease areas and a 5 km buffer around the mine leases, indicated that there are 238 registered bores (Figure 19). These registered bores, summarised in Table 13, include:

- Sixteen (16) bores are abandoned and destroyed, with the rest are reported as existing on the GWDB bore cards.
- 190 of the registered bores are reported as used for groundwater monitoring.
- Six (6) are used for water supply, with three reported as no longer being used.
- 20 are recorded as exploration bores.
- Six (6) are reported as use unknown.

Table 13 Registered groundwater bores in proximity to GRB

Use	Number of bores	Percent total
Groundwater monitoring (mine monitoring, water resource investigation, etc.)	190	85
Water supply	6	3
Exploration	20	9
Unknown	6	3
Total		100

A search of the Queensland Water Entitlement Database showed that none of the 224 existing registered groundwater bores located within 10 km of the Project had water licences (i.e., there are no licensed water users identified within the search area) This indicates that the bores reported as water supply bores (on the bore cards) are entitled to be used for stock and domestic purposes, which do not require a water licence and allocation.

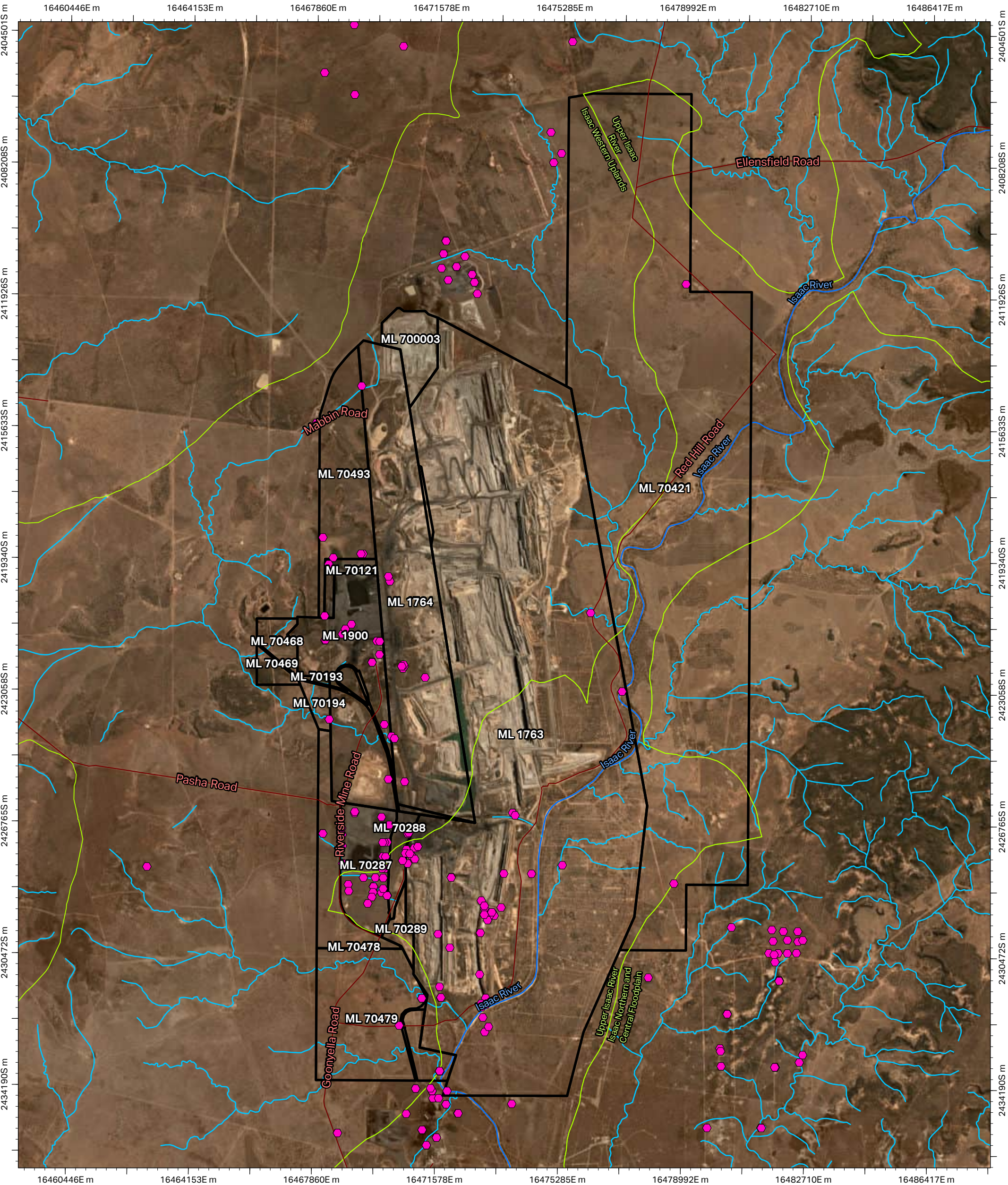
Table 14 Registered water supply bores in proximity to the Project

RN	Easting	Northing	Name	Depth	Comment
182313	604240	7594890	Cleanskin Gully	25.34 mbgl	No longer used Water level 14.02 mbgl
81696	608182	7586081	Skeleton Bore	63.7 mbgl	No details Water level 28.41 mbgl Yield 1.3 L/s
81700	591815	7587788	Harvey's Bore	No data	No data
182311	599005	7610760	Old Mill Bore	117.1 mbgl	No details Water level 90.66 mbgl Yield 1.9 L/s
182312	596795	7610020	Tex's bore	118.9 mbgl	No longer used Water level 34.13 mbgl Yield 4.5 L/s
132496	586258	7611031	?	79.6 mbgl	Back Creek Group Water level 50 mbgl Yield 1.1 L/s

The water supply bores, included in Figure 56, are discussed in detail in Section 15.8.1, which includes an assessment of potential long term (closure) impacts to the water supply bores.

Figure 19 Registered groundwater bores

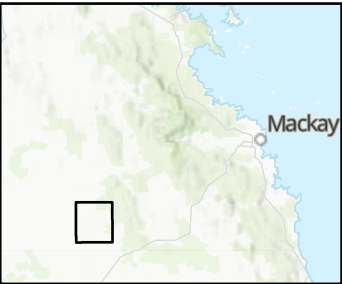
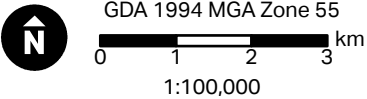
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Basemap image taken 2017

Goonyella, Riverside and Broadmeadow Mines
Registered Bores

- Mine Lease
- Subcatchment boundary
- Watercourse (Major)
- Watercourse (Minor)
- GWDB registered bores



9.2 Groundwater Dependent Ecosystems

A groundwater dependant ecosystem (GDE) is a natural ecosystem that requires “access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis, so as to maintain their communities of plants and animals, ecosystem processes and ecosystem services” (Richardson, S., et al., 2011). GDEs can require access to groundwater on a permanent (obligate) or intermittent (facultative) basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services (Doody et al., 2019).

GDEs can be classified as either:

- Aquatic GDEs (i.e. ecosystems dependent on the surface-expression of groundwater, such as aquatic species that inhabit groundwater-fed surface pools).
- Terrestrial GDEs (i.e. ecosystems dependent on the sub-surface presence of groundwater, including some riparian vegetation communities with rooting depths that intersect the groundwater table).
- Subterranean GDEs (aquifer and cave ecosystems, such as stygofauna that can live within aquifer systems).

Broad-brush national scale desktop mapping of potential GDEs is available in the Bureau of Meteorology (BoM) National Atlas of GDEs (GDE Atlas). The GDE Atlas classifies ecosystems based on the potential for dependence on groundwater through desktop collation of multiple lines of scientific evidence. Ecosystems have been mapped as either:

- High potential for groundwater dependence (indicating a strong possibility the ecosystem is interacting with groundwater).
- Moderate potential for groundwater dependence.
- Low potential for groundwater dependence (indicating it is relatively unlikely the ecosystem will be interacting with groundwater and will include ecosystems that are not interacting with groundwater).

The broadbrush GDE Atlas mapping of potential aquatic and terrestrial GDEs indicates that areas with possible high, moderate, and low potential for groundwater interaction occur in the vicinity of the Project area (Figure 20).

Figure 20 indicates moderate and high potential Aquatic GDEs and moderate and low potential Terrestrial GDEs are mapped within the GRB mine lease. There are isolated areas of high potential Aquatic and Terrestrial GDEs, where aquatic GDEs are associated with rivers and tributaries. The only high potential Terrestrial GDEs are identified approximately 10 km north of the northern boundary of the mine.

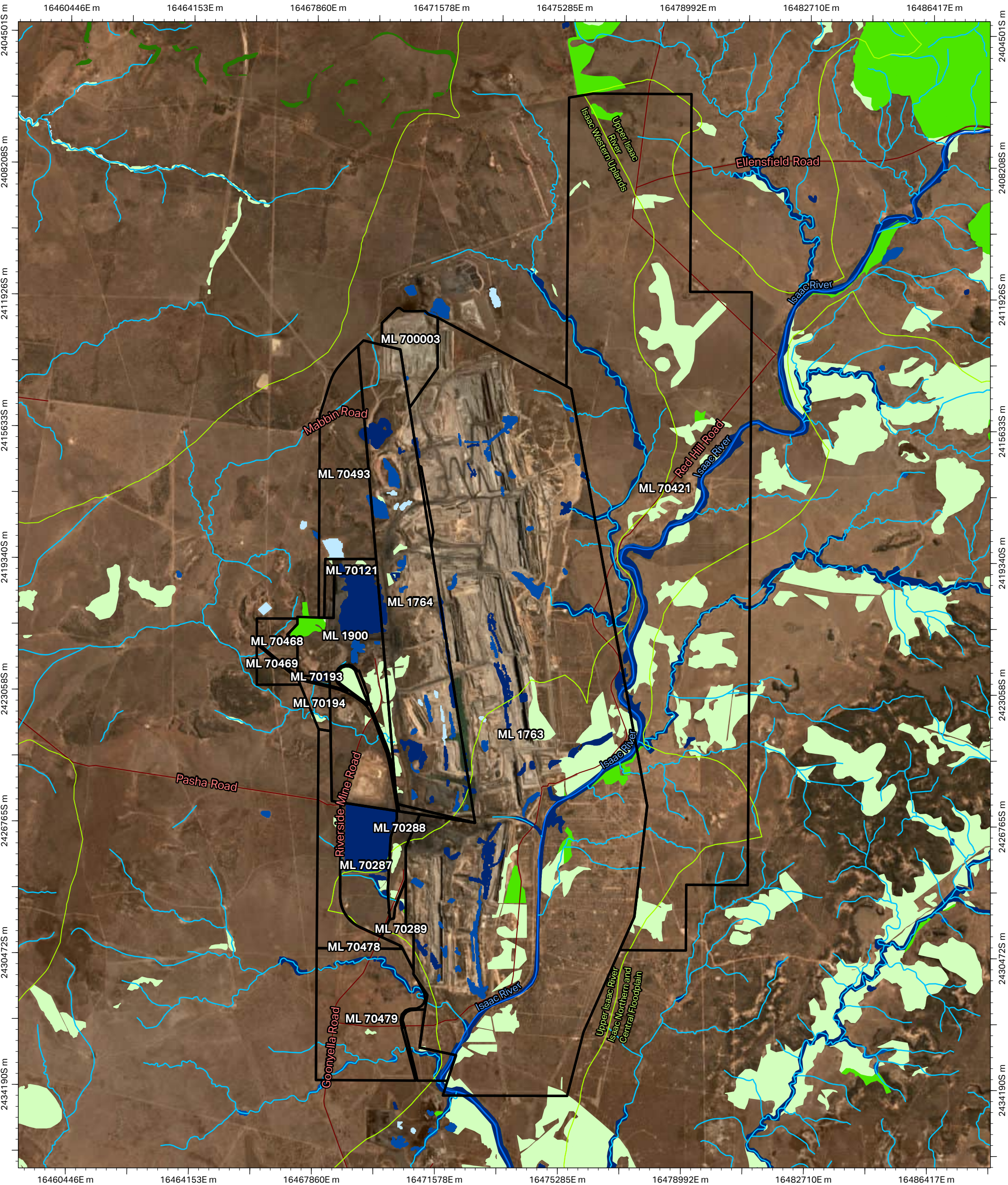
It is noted that the potential aquatic GDEs, mapped at GRB in Figure 20, are tailings dams, mine water storages and mining voids. Thus, the mapping is recognised to identify potential GDEs only.

The remaining potential Aquatic and Terrestrial GDEs outside of the GRB mine leases fall between moderate and low potential GDEs, with low potential GDEs identified predominantly around the GRB boundaries. The groundwater study for the PRC Plan considers post mining conditions as the risks and management of these potential GDEs has been assessed as the mining activities are approved and licensed activities. These mined areas will not be present (rehabilitated) during closure.

Sampling for stygofauna was undertaken as part of the Red Hill Mining Lease EIS; no stygofauna were found in any of the accessible groundwater bores on site (URS 2013).

Figure 20 Mapped GDEs

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Basemap image taken 2017

Goonyella, Riverside and Broadmeadow Mines
Potential GDEs (Aquatic, Terrestrial, and Springs)

Mine Lease

Subcatchment boundary

Watercourse (Major)

Watercourse (Minor)

Aquatic GDEs

High potential GDE

Moderate potential GDE

Low potential GDE

Terrestrial GDEs

High potential GDE

Moderate potential GDE

Low potential GDE

N

GDA 1994 MGA Zone 55

0

1

2

3

km

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10.0 Mining activities

10.1 Mine plans

Goonyella, Riverside, Broadmeadow, and Red Hill mining is through both open pit and underground methods. Drill and blast/truck and shovel are the employed mining process for the open pit. The open pit depth will range from approximately 60 m below ground level to greater than 300 m; depth is controlled by the target coal seams.

The underground operations are an extension of the open pits. It allows for mining of the coal further down dip. Mining is mechanised and is conducted by longwall. Once the coal has been removed from the mines, it is conveyed to the preparation plant for processing, sorting, and then distribution.

Mining at the GRM will continue until 2059 and the target seam for this mine is the GLS, with the final void used to access the underground RHM. The void will stay dewatered until end of mining at RHM.

The underground operations for the Broadmeadow GMS will continue until 2031, and will stay dewatered to allow for the mining of Broadmeadow GLS. Mining is planned to continue from 2031 until 2055 within the Broadmeadow GLS. Access to the GLS will be through the Broadmeadow GMS portal.

RHM underground mining is planned to commence in 2063 and will last until 2091. Access into the mine will be through the GRM void. Continual mining, which impacts on groundwater resources, was assessed to allow for predicting groundwater conditions post-closure at RHM.

Predictive modelling to predict groundwater level, flow patterns, and potential for ingress into the residual voids adopted the mine plan schedules, and decommissioning activities as detailed in Table 15.

Table 15 Mine plans and decommissioning activities until end-of-mining for Project PRC Plans

Mine	Planned start / Continued mining	End-of-mining	Closure	Comments
Goonyella / Riverside open cut mining	Prior to 2019	2059	2092	Target GLS Figure 21
Existing / residual pits				
Broadmeadow	n/a	2009	2053	
Isaac	n/a	1997	2053	
Ramp 32 East	2025	2026	2032	
Thiess	n/a	2031	End of mining	
Ramp 32 South	2033	2036	End of mining	
Broadmeadow underground - GMS	2007	2031	2053	GMS seam continued longwall mining Figure 22
Broadmeadow underground - GLS	2031	2055	2056	Same portal as Broadmeadow GMS, mining below the GMS longwalls Figure 23
Broadmeadow underground	2057 2058, 2059, 2060			Decommissioning Injection of water to fill workings
Red Hill underground mine - GMS	2063	2091	2092	Access through Goonyella / Riverside highwall GMS (50 m above GLS) Figure 24
RHM	2093 2094, 2095, 2096			Decommissioning Injection of water to fill workings
Recovery	2097 onwards			All mining complete

Figure 21 Goonyella / Riverside open cut mining plan (plus Ramp 32)

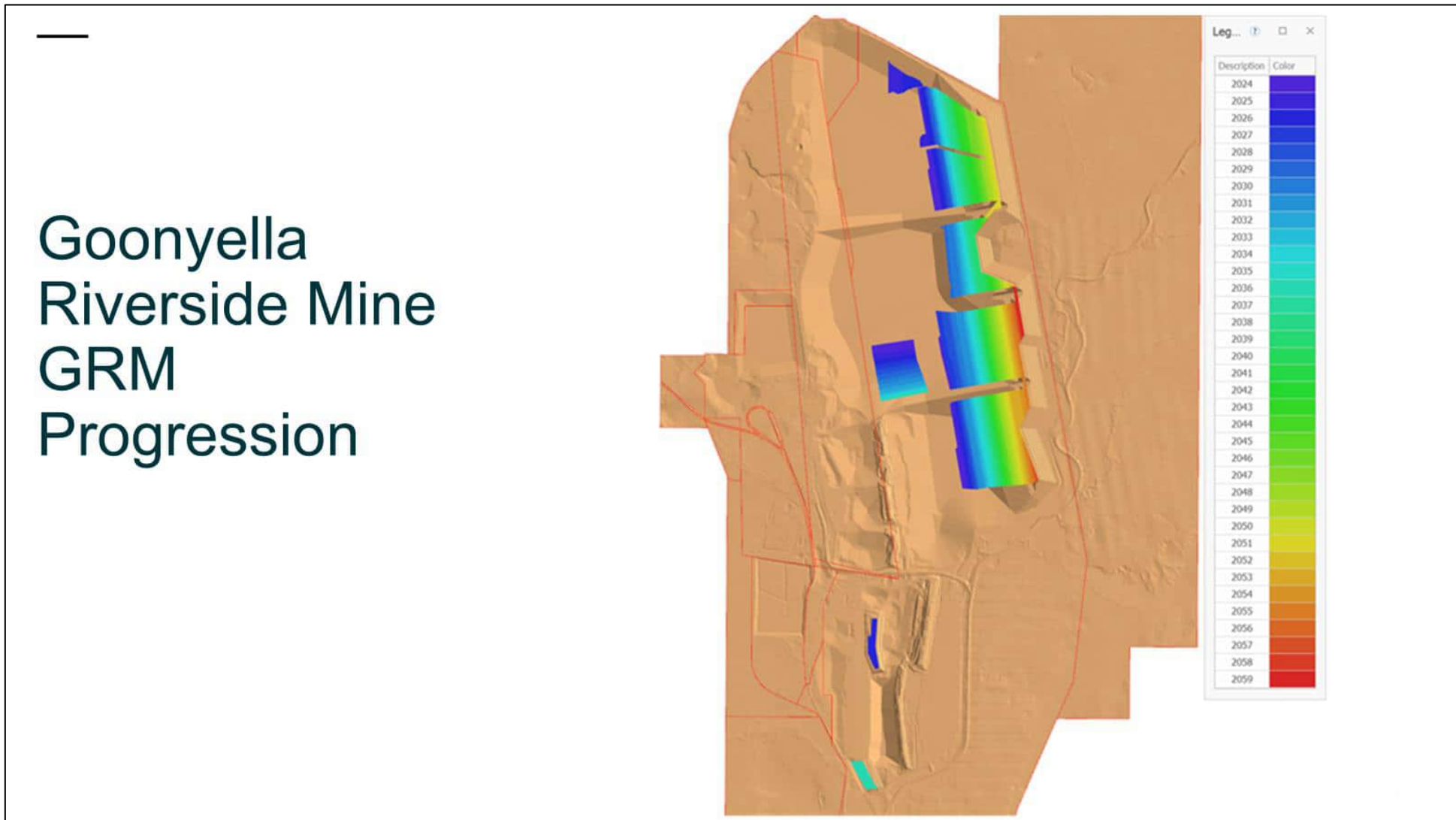


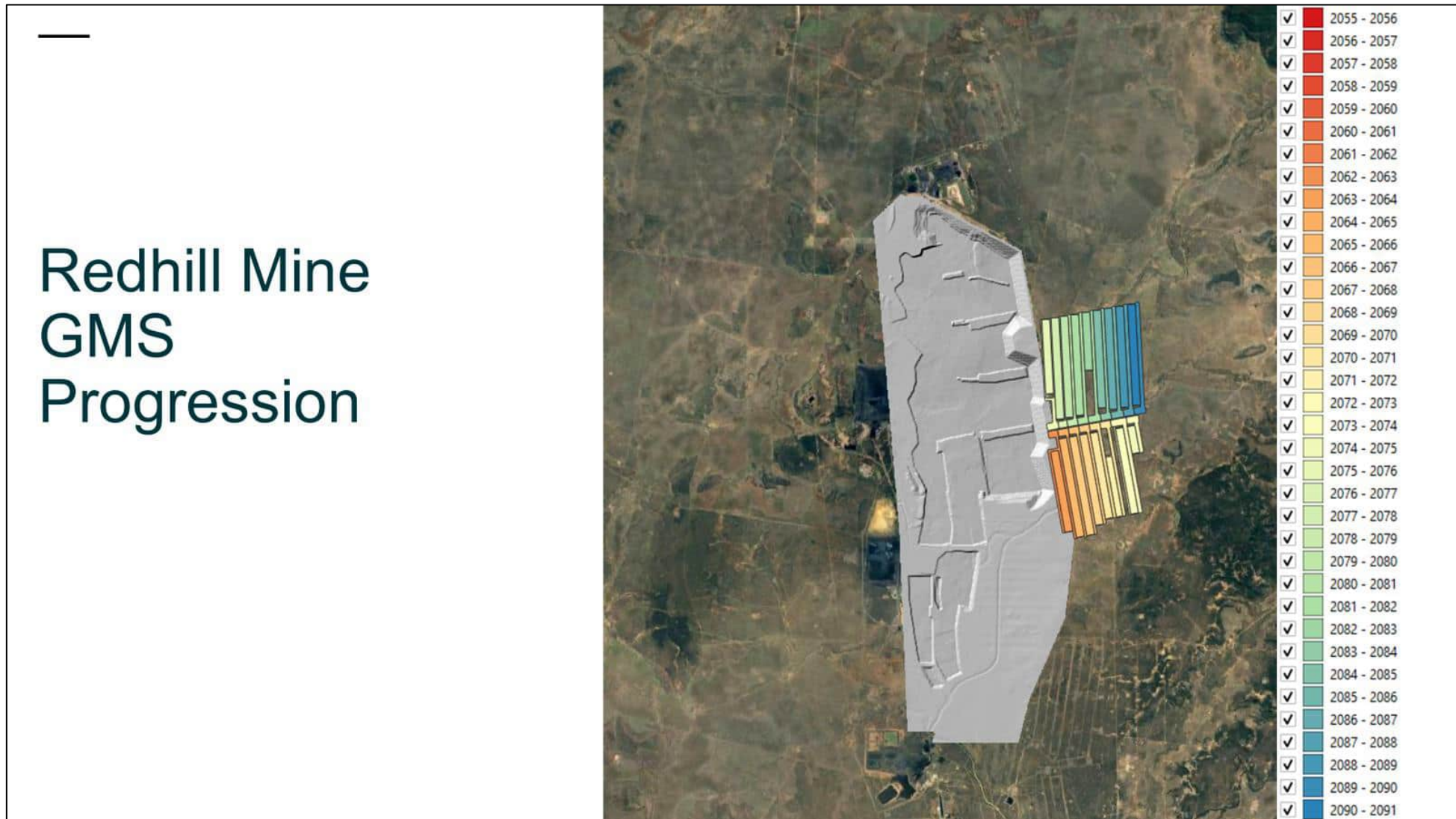
Figure 22 Broadmeadow underground mine plan – GMS



Figure 23 Broadmeadow underground mine – GLS



Figure 24 Red Hill underground mine plan



10.2 Mine Pit Inflows

Groundwater inflows from the Permian coal measures to GRB's active and residual pit voids are generally small in volume and do not typically need to be actively managed via advance dewatering or other groundwater management methods, with evaporation from the pit void walls and floors accounting for most of the groundwater. Small volumes of groundwater inflow, when they occur, are generally managed via the use of in-pit sumps to capture water that is then used for dust suppression purposes or circulated via the mine water management system for use in coal washing.

Groundwater inflow estimates for GRB for a typical year (2020 – 2021) are provided in Table 16 below based on BMA's annual Associated Water Take reporting to the Queensland Department of Resources (DoR). Estimates are based on BMA's site water balance calculations using site climate data, pit void storage, and pumped outflow data in accordance with the DNRME (2020) Associated Water Take Guideline, and as such inflow estimates are considered conservative. Refer to Figure 2 for pit locations.

Table 16 Estimated groundwater inflow at GRB mine workings (2020 – 2021)

Open Cut Pits	Annual estimate (ML/year)
Dampier Pit	0 (0)
Red Hill Pit	26 (±5)
Denham Pit	63 (±11)
Cleanskin Pit	67 (0)
Riverside Pit (Ramp 8)	11 (±2)
Riverside Pit (Ramp 6)	255 (±30)
Broadmeadow Pit	27 (0)
Isaac Pit	0 (±1)
Eureka Pit	79 (±4)
Airstrip Pit	0 (±45)
Lenton Pit	2 (0)
Broadmeadow underground	60 (±7)

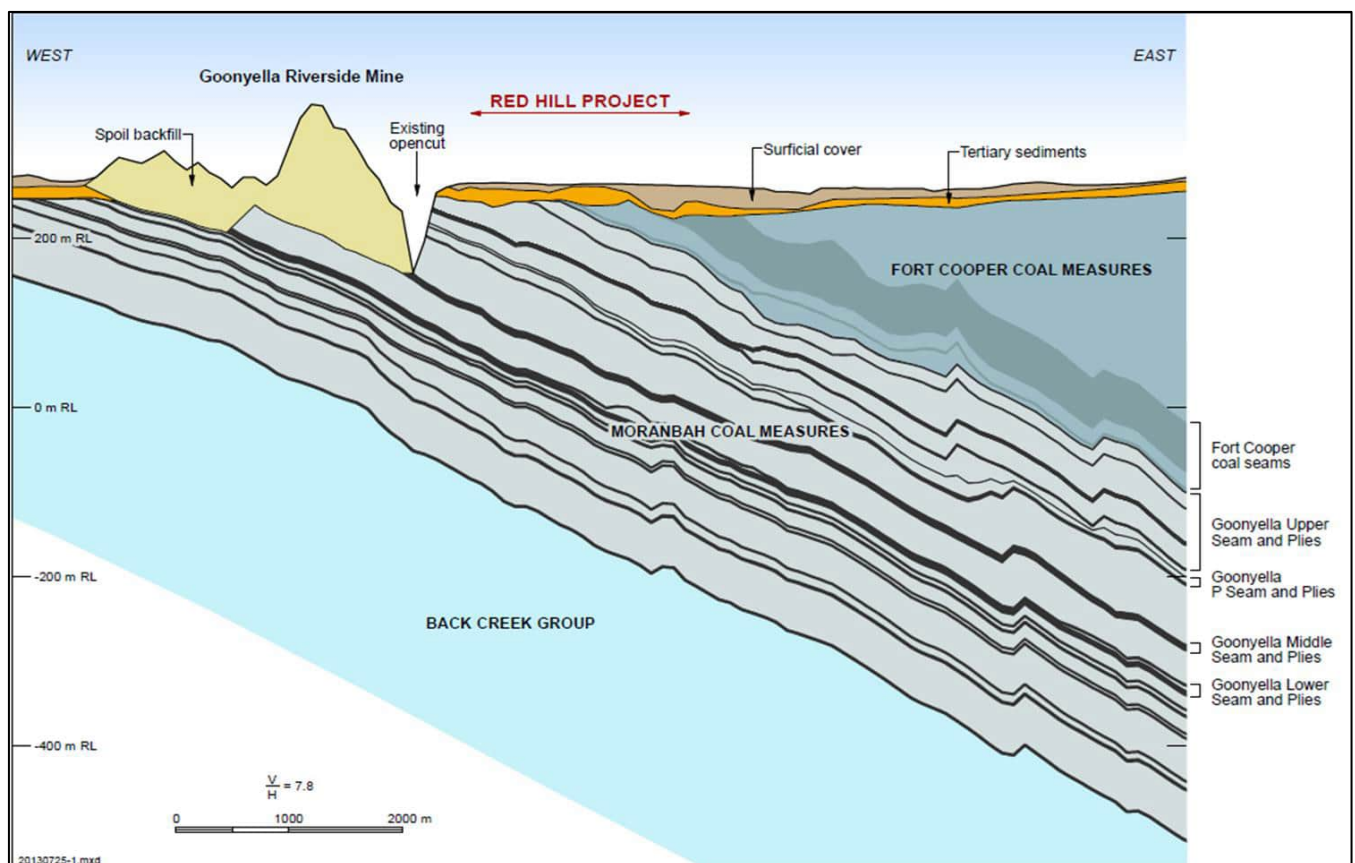
11.0 Conceptualisation – End of Mining

Conceptualisation of the groundwater regimes has been developed based on the review of the hydrogeological information for GRB and RHM presented in the above report sections. Hydrogeological conceptual models (HCMs) are typically presented as conceptual cross-sections. Figure 25 presents the HCM for RHM.

11.1 Overview

The geology of Project area comprises the stratified sequences of the MCM at the westernmost extent of the Bowen Basin syncline that dip towards the east. Mining at GRB and RHM targets the coal seams of the MCM. Surficial cover across the Project area includes alluvium associated the Isaac River floodplains and tributaries, primarily Eureka Creek. Surficial cover outside of these water lines consists of Quaternary to Tertiary age sediments (Plate 12).

Plate 12 Lithological cross section



The primary hydrogeological features at RHM include:

- Cainozoic sediments:
 - Quaternary alluvium – unconfined
 - Undifferentiated Tertiary sediments– unconfined / semi-confined
 - Tertiary Sutor Formation - unconfined / semi-confined.
- Permian – Triassic coal measures with
 - Low permeability interburden aquitards
 - Coal seams have higher groundwater potential due to secondary porosity through cleats.

Surficial cover

Groundwater within the alluvium is recorded at depths of 4.5 to 9.5 mbgl (Figure 10). Regionally, groundwater flow within the alluvium is a subdued reflection of topography, with groundwater flowing in an east-south-easterly direction.

Losing conditions from water courses to the underlying alluvium are evident during flow periods. Recharge to the alluvium is considered to be primarily from stream flow or flooding. Direct infiltration of rainfall also occurs where there are no substantial clay barriers in the shallow sub surface.

On a regional scale, discharge is via evapotranspiration from riparian vegetation growing along creek beds and minor short duration baseflow events after significant rainfall/flooding.

The Tertiary Sutor Formation and undifferentiated Tertiary sediments comprise unconsolidated sediment aquifer/s, which has a depth to groundwater in monitoring wells at RHM around 10 mbgl (Figure 12). The clean sand and gravel lenses in the Tertiary sediments are permeable but are of limited lateral and vertical extent.

Coal seams

Regionally, groundwater within the Permian-Triassic coal measures flows in a south-easterly direction, but the flow system is modified on a local scale by mining activities in the region with ongoing discharge to mine workings, including at GRB.

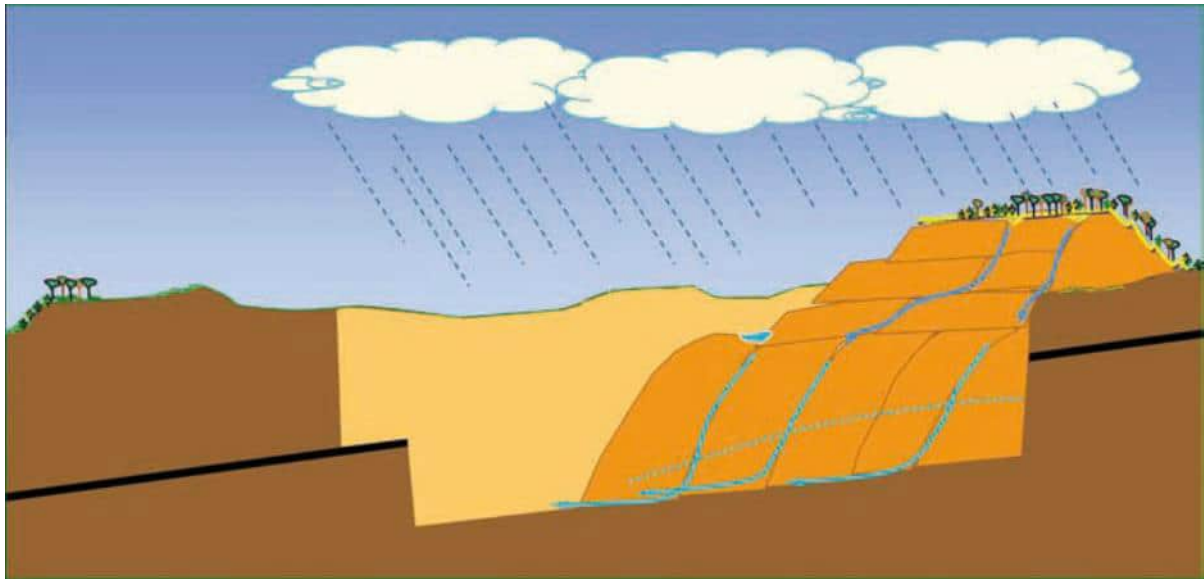
Review of water quality data indicates water within the Permian coal measures is generally saline at GRB but can range between brackish to highly saline. Groundwater within the coal measures at GRB exceeds guideline criteria for irrigation, drinking water, and protection of aquatic ecosystems, and only variably meets the guideline criteria for stock water supply with guideline exceedances for salinity and sulfate.

11.2 Hydrogeological conceptualisation

For the conceptualisation of groundwater response to mining, the recharge and discharge mechanisms at several (mine area) locations across the GRB and RHM were considered. These conceptual cross sections include the envisaged end-of-mining groundwater conditions. These conceptual models were considered when undertaking the predictive groundwater modelling.

Recharge mechanisms include:

- Rainfall recharge.
- Enhanced recharge through spoil (loose, unconsolidated).
 - Discrete ingress flow patterns and intermittent saturation within the spoil (as conceptualised by NSW Department of Primary Industries included in Plate 13, noting this is a fully backfilled mine void which has been rehabilitated).
- Possible induced flow from over- and under-lying hydrostratigraphic units towards the dewatered target coal seams.
- Vertical groundwater movement (in response to vertical groundwater gradients and underground longwall alteration).
- Surface water losing systems.

Plate 13 Conceptual model of movement of water in a typical rehabilitated mine void and spoil pile

Discharge mechanisms include:

- Mine dewatering resulting in groundwater drawdown into open cut and underground workings.
- Groundwater flow into the open cut workings where the pits intersect saturated hydrostratigraphic units (including the surficial cover).
- Evaporation from pits resulting in groundwater drawdown and local groundwater flow into open cut workings.
- Evapotranspiration.
- Groundwater extraction.

11.3 End of Mining

The potential impacts to the groundwater system at end of mining, as relevant to the hydrogeology assessment for the transitional PRC Plan, relate to how the groundwater system is dewatered, artificially recharged (through reinjection into the underground workings), and then recovers after all active mining ceases (Table 15). Therefore, it is important to understand the nature of the groundwater system/s at the conclusion of mining immediately prior to the closure period.

A visual representation of the end of mining HCM for the RHM is provided in a conceptual cross section. The cross section depicts the different mining activities at GRB and the planned RHM. The west to east cross-section across the Goonyella Pit and RHM is included in Figure 25.

Key features relevant to groundwater conditions at the end-of-mining include:

- Groundwater drawdown within the MCM, associated with passive dewatering into the GRB residual voids, results in inwards hydraulic flow gradients in the coal measures.
- Drawdown in the MCM at the end of mining is at, or close to, the maximum expected to occur as a result of GRB and RHM.
- Residual voids capture seepage from spoil emplacements
- Residual voids capture seepage from TSFs
 - Runoff from the spoil and TSFs is directed down ramps into the residual voids.
- Little to no impact on surficial aquifers, which is intermittently saturated, including the Isaac River Alluvium.

- Little to no impact on environmental receptors.
- No impact on anthropogenic receptors (i.e., private groundwater users).

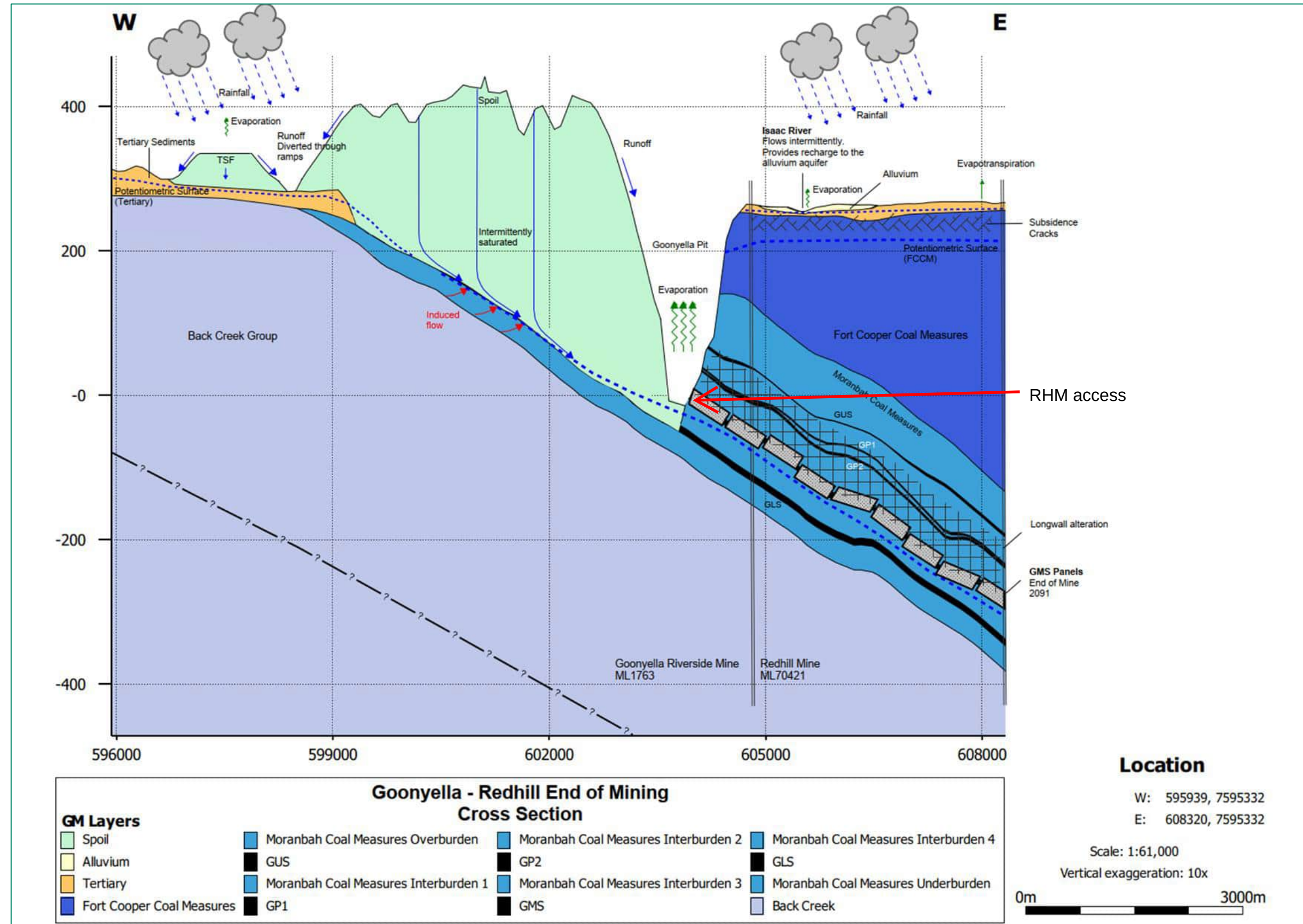
11.4 Continual mining

The timing and extent of mining, at Goonyella / Riverside Mine, Broadmeadow Mine (both GMS and GLS), and RHM, is planned (and included in the PRC Plan) to continue sequentially leading to continued groundwater extraction during mining within the Project area. Section 10.1 presents the mine plans, including the end-of-mining dates.

The HCM considers groundwater drawdown at the end-of-mining at different time periods, corresponding with different mine end dates. Based on the proximity of mines and continuous sequencing plus mine locations (such as Broadmeadow GLS underneath GMS), little or no groundwater recovery (and thus contribution to the final voids at GRB) is envisaged until all mining ceases or when underground workings are artificially flooded with water.

The prediction of groundwater response to continuous mining, spatial and overtime, was included in the predictive groundwater modelling (Section 13.0).

Figure 25 Goonyella Pit and RHM underground mine – Cross-section west to east at end of mining



12.0 Potential Impacts

Potential impacts associated with shallow sources of potential groundwater contamination at GRB (mine water and waste storage facilities, which will be used by RHM) are being assessed for the PRC Plan by a separate Contaminated Land Assessment. Therefore, this hydrogeology assessment focuses on the larger scale impacts to the Project area groundwater system. However, the movement of potential contaminants in groundwater that might be associated with seepage from mine waste storage facilities and rock dumps is considered within this hydrogeological assessment.

Predictive groundwater modelling includes particle tracking simulations, where particles were included in the saturated model cells and the migration over time mapped. Particles moved in response to groundwater head differences, aquifer hydraulic properties, and evaporation from the residual voids (acting as groundwater extraction).

These predictions through the generation of hydrographs for hypothetical observation points within and adjacent to the residual voids (GRB) plus mining (including RHM) drawdown contours, allowed for the evaluation of the residual voids acting as source or sinks to the groundwater system. This then allowed for the evaluation of the risk of residual void water and/or RHM mine water (filled mine workings, Section 14.2.1) migrating from the mine leases during closure.

12.1 Groundwater System Post-Mining

The potential impacts to the groundwater system at the end-of-mining, as relevant to the hydrogeology assessment for the PRC Plan, are relative to how the groundwater system recovers from active mining including the groundwater flow regime that results from the final landform. Therefore, it is important to understand the nature of the groundwater system at the conclusion of mining immediately prior to the closure period.

The nature of the RHM groundwater system/s at the end of mining, and potential groundwater system impacts that may have arisen at the end of mining, can be summarised as:

- Groundwater level drawdown of the target GMS coal seam, extending north, south, and west of the RHM underground workings (noting that these workings are then filled with water over three years at the end of mining, during decommissioning, as detailed in Section 14.2.1).
- Groundwater level drawdown of the Permian coal measures, associated with passive dewatering into the active GRB mine pit voids.
 - The magnitude of this drawdown will be most significant in the immediate vicinity of the residual voids, but extend northwards, eastwards and southwards of GRB by several kilometres and interact with drawdown from nearby mining activities.
- Little to no groundwater level drawdown of the alluvium away from the Project due to limited hydraulic connection between the hydrostratigraphic units (Section 7.3.3). The conceptualisation (HCM) cross section (plus predictive modelling) indicate:
 - No groundwater-related effect on surface water flows of the Isaac River
 - Low potential for groundwater level drawdown impacts to potential GDEs
- One of the six water supply bores, located in proximity to the Goonyella residual void, will be impacted (dewatered) as a result of approved mining (Section 15.8.1).
- The comparison of historic and recent groundwater quality data does not readily indicate impacts associated with spoil, rock dump, and TSFs.

12.2 Groundwater System Post-Closure

The potential impacts to the groundwater system at the end-of-mining, as relevant to the hydrogeology assessment for the PRC Plan, are relative to how the groundwater system recovers from active mining including the groundwater flow regime that results from the final landform. Therefore, it is important to

understand the nature of the groundwater system recovery and pseudo-steady state conditions post closure.

The predictive groundwater modelling allows for the assessment of groundwater level recovery, groundwater flow patterns, and the influence of residual voids (included in the final landform #2.3) on the groundwater resources and receptors.

The post-closure conceptualised groundwater can be summarised as:

- There will be limited recovery in groundwater levels post-closure, with groundwater recovery characterised as 'slow' within the Bowen Basin. Limited recovery of groundwater levels naturally was considered due to:
 - Limited rainfall recharge
 - Long term mine dewatering across a large area and several mining areas, which has resulted in groundwater being removed from storage which needs to be replaced before marked changes in groundwater levels will be observed
 - High evaporation over large residual void areas (particularly the Goonyella Pit)
 - Low permeability within the sediments surrounding the residual voids.
- Consideration of the climate data, limited runoff (catchment around residual voids) and limited groundwater ingress would result in the high probability of the residual void water levels being below pre-mining groundwater levels (i.e., residual voids likely to act as groundwater sinks post-closure).
 - The residual void water level recovery is expected to be below the base of weathering or any shallow Cainozoic aquifers (i.e., limited potential for discharge into the surrounding surficial units, including alluvium).
- Ongoing groundwater discharge to the residual voids driven by the inwards hydraulic gradient between the void lakes and the surrounding groundwater system will be maintained by ongoing evaporative discharge from the voids.

The predicted post mining conditions, considering the GRB residual voids, are presented after Section 13.0, the groundwater modelling. These predictions indicate the likelihood for impacts to receptors is low.

13.0 Groundwater Modelling

The existing RHM predictive groundwater model (**Appendix A**) was adopted for the PRC Plan's hydrogeological assessment (Figure 26). The refinement of the existing model, including increasing the model domain and model boundary conditions, was used to promote efficiencies in the delivery of the outputs for the PRC plan.

Figure 26 Extent of the original RHM model domain

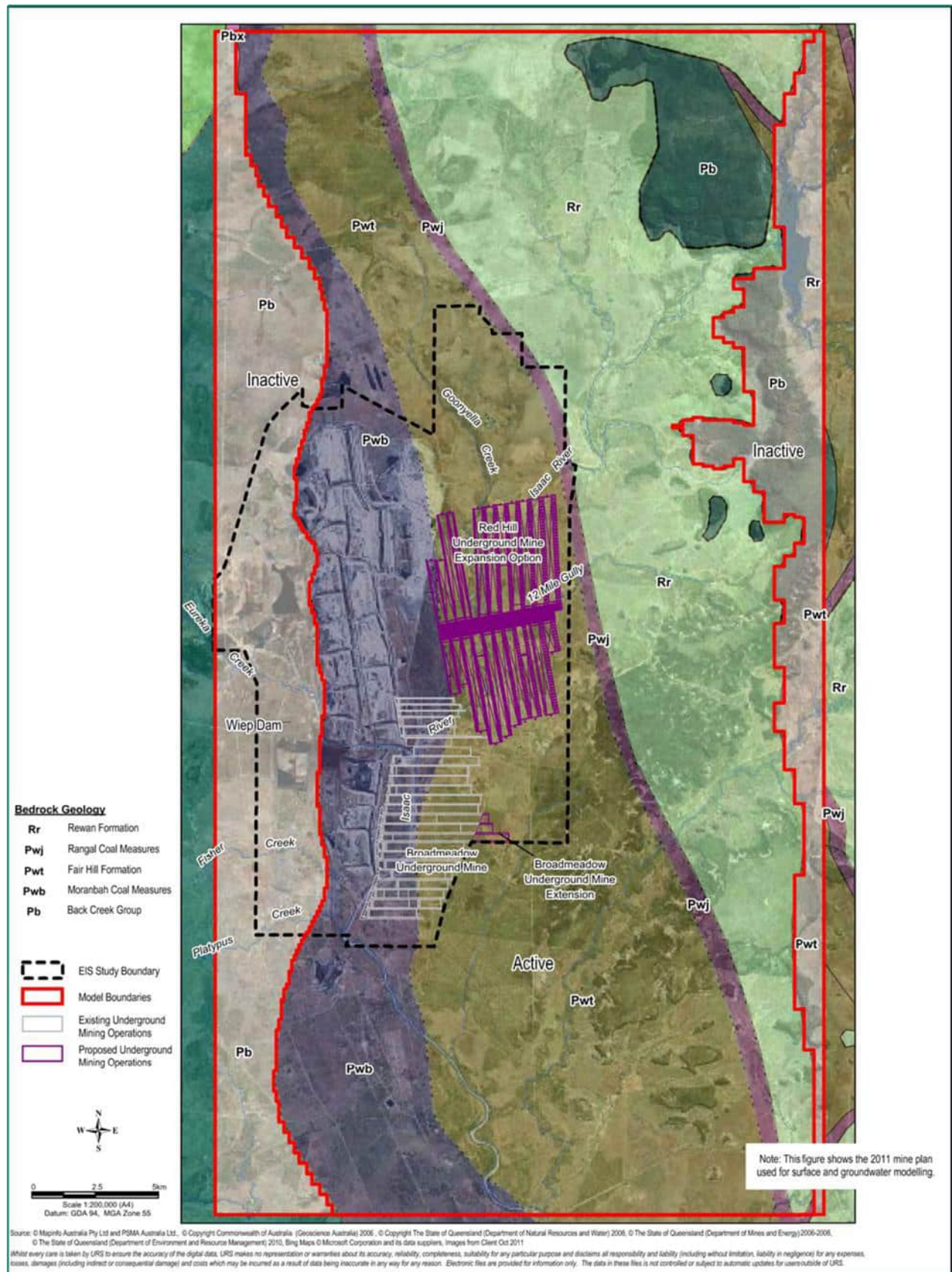
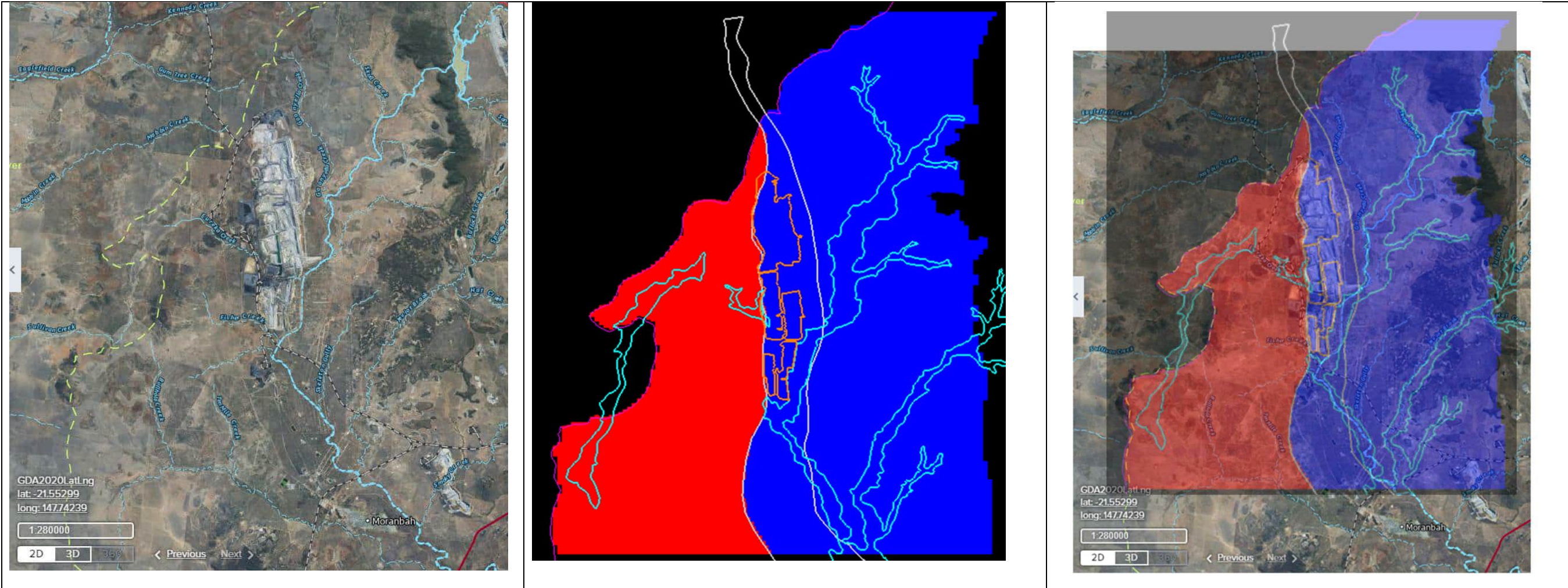


Figure 27 Extent of the refined GRB / RHM model domain



Yellow dashed line is the Isaac River catchment boundary

The red area of the model domain includes the Back Creek Group subcrop, the blue area indicates the coal bearing Permian age sediments. The contact between the two areas illustrates the GLS coal seam subcrop.

13.1 Model Details

AECOM utilised the existing RHM numerical (MODFLOW-SURFACT) groundwater – surface water interaction model with refinement from data compiled since the existing model was constructed and calibrated in 2013.

The use of the existing MODFLOW-SURFACT model, after review of the available more recent geological and hydrogeological data compiled in the report above, was considered suitable based on the following:

- Selection of the model software package
 - The MODFLOW-SURFACT model software package is suitable for dewatering and recovery model simulations in the open cut and underground mine workings. It converts from saturated flow to an unsaturated flow equation as the groundwater elevation drops below the base of the model cell. The key point of MODFLOW-SURFACT is that the cell does not go dry, is never excluded from the numerical calculations, and as heads rise again the model switches the cell back to saturated flow.
- The model allows for the refinement of model grid cell size to ensure the correct relationship between the key features (residual voids) and the model cell sizes (for accurate modelling / predictions).
- The model can simulate possible contaminant migration within groundwater using particle tracking during predictive groundwater modelling.
 - The fate and transport of residual void water can be depicted using particle tracking, where flow directions, extent of migration within groundwater, and variation in flow during the post-mining rebound of groundwater levels and the saturation of sediments in the footwall and hanging wall overtime.
- Model boundary conditions, type and location (sufficiently far from the mine workings to not influence model predictions), were assessed and revised. Noting the eastern model boundary remains as a no flow boundary at the outcrop/subcrop of the Back Creek Group, uplifted along the Burton Fault (Figure 26 and Figure 27).
- The cumulative impacts of the differing mine workings, timeframes, and decommissioning across the Project.

13.2 Model Objectives

The groundwater modelling, as required for input into the PRC Plan, aimed to:

- Assess the potential groundwater related impacts at completion of mining and until conditions stabilise post rehabilitation (Section 15.0).
- Assist in demonstrating the suitability of the final landform for the post mining land uses (i.e., evaluate the residual voids included in the final landform to determine influence on groundwater resources) (Section 15.0 and 17.0).
- Demonstrate that the final landforms are non-polluting with respect to potential poor quality water leaving the mine leases within groundwater (Section 15.6 and 15.7).
- Demonstrate that there are minimal additional impacts to groundwater receptors post-closure caused by the final landforms (Section 15.8).

The predictive groundwater modelling aimed to provide understanding, for Landform Design #2.3 (as included in Section 10.1), of:

- Groundwater interactions with the residual voids (Section 15.4, 15.6, and 15.7).
- Changes in hydrogeological conditions (including groundwater levels) from the active mining to stable post-mining conditions (Section 15.4.3).

- Impacts to water quality off lease through migration within groundwater.
 - The prediction of potential off lease water quality impacts from mining activities was included to determine appropriate measures for the containment and management of potential contaminant impacts on EVs should these contaminants migrate within the groundwater system (Section 15.6 and 15.7).
- Long term influence on alluvial and Tertiary age hydrostratigraphic units that may host GDEs or future land users (e.g., stock water and/or non-potable domestic use) (Section 15.8).
- Influence of groundwater on surface water resources (Section 13.3.6, 15.8.2, and 17.2).
- Possible on-going water management and reduction requirements (Section 16.0).

The modelling approach methodology was developed to meet the modelling objectives to inform the PRC plan, ensure alignment with the guideline, and consideration to address uncertainty in predicted outcomes.

13.3 Model Design

13.3.1 Approach

The MODHMS (Hydrogeologic Inc., USA) groundwater modelling package was utilised to construct the required groundwater model. MODHMS is based on the standard MODFLOW groundwater modelling code. The MODFLOW code was developed by the United States Geological Survey (McDonald and Harbaugh 1984) for three-dimensional, finite-difference, modular, groundwater flow modelling.

The MODFLOW code is the most widely used code for groundwater modelling and is considered an industry standard. MODHMS incorporates additional computational modules to enhance the simulation capabilities and robustness. MODHMS was selected as it allowed for:

- The modelling of variable saturation conditions, allowing for unsaturated and saturated conditions thus avoiding dry-cell problems
- Coupled flow and mass transport simulations (if required)
- The inclusion of discrete features, such as the backfill area of open cuts
- Integrated groundwater and surface water modelling (if required).

An existing numerical groundwater model was refined based on the more recent (since 2013) available data to represented current groundwater flow conditions (2020 to 2024) due to the existing approved GRB mine complex dewatering.

The outcome of this transient modelling of the existing approved GRB mine complex impacts (drawdown extent) was used as initial conditions for the predictive model, which undertook four predictive scenarios capturing the different mine plans, decommissioning, injection, and recovery after mining ceased.

The four predictive scenarios are summarised in Table 17, and discussed in the prediction Section 15.0.

Table 17 Prediction phases incorporated in the groundwater modelling

Prediction periods	Mining activities
Phase 1: 2024 to 2056	Existing Broadmeadow and Isaac pits remain dewatered Thiess, R32 South, and R32 East have pit water levels Broadmeadow GMS underground mining continues to 2031 Broadmeadow GLS underground mining 2031 to 2055 Broadmeadow underground workings remain dewatered in 2056 Goonyella open cut mining is ongoing
Phase 2: 2057 to 2060	Broadmeadow GMS underground mining altered by goaf Broadmeadow GLS underground mining altered by goaf #-years of water injection into Broadmeadow underground workings
Phase 3: 2061 to 2092	Red Hill Mining conducted 2063 to 2091 Remains dewatered during decommissioning in 2092
Phase 4: 2093 to 2199	RHM changed to goaf 3-years of water injection into RHM Recovery post 2097

The modelling approach comprised the following:

- Simulations of dewatering cones (drawdown contours) and extent at the end of mining (over time in response to different mine plans).
- Groundwater extraction volumes with time into residual voids and mine dewatering activities
 - Groundwater ingress estimates to include in residual void water balance modelling (coupled water balance).

13.3.2 Model conceptualisation

Every numerical groundwater model has a conceptual model as its foundation. The conceptual model is an understanding of how the groundwater system operates and is an idealised and simplified representation of the natural system.

The conceptualisation (Section 11.0) of the groundwater resources across the Project area was developed based on geological and hydrogeological data, including topographical maps, geological information from coal exploration bores drilled across the GRB mine complex and RHM footprint areas, geological modelling developed by BMA, results from previous hydrogeological investigations in the Bowen Basin, relevant data from hydrogeological and gas drainage studies conducted by BMA, and groundwater monitoring data.

The conceptual model, which formed the basis of the predictive model, included for the upper units of the Back Creek Group, the Blackwater Group (MCM and FCCM), and the overlying Tertiary and surficial sediments of the Bowen Basin. The conceptualisation (as included in the Section 11.0 HCM cross section) allowed for the groundwater model construction to include for:

- The outcrop/subcrop of the Back Creek Group to the west of the Project (Figure 27).
- A system of thrust faults, approximately 10 kilometres (km) to the east of the RHM footprint, that result in the Back Creek Group having been uplifted against the Rewan Formation (Figure 26).
- An arbitrary distance of approximately 25 kilometres to the north and south of the GRB and RHM mines that was judged to be beyond the influence of potential mine dewatering (Figure 26).

The model domain for the Project PRC Plans, considering the conceptualisation based on data assessment, was increased to the west, corresponding to the Isaac River catchment and further north and south, to ensure:

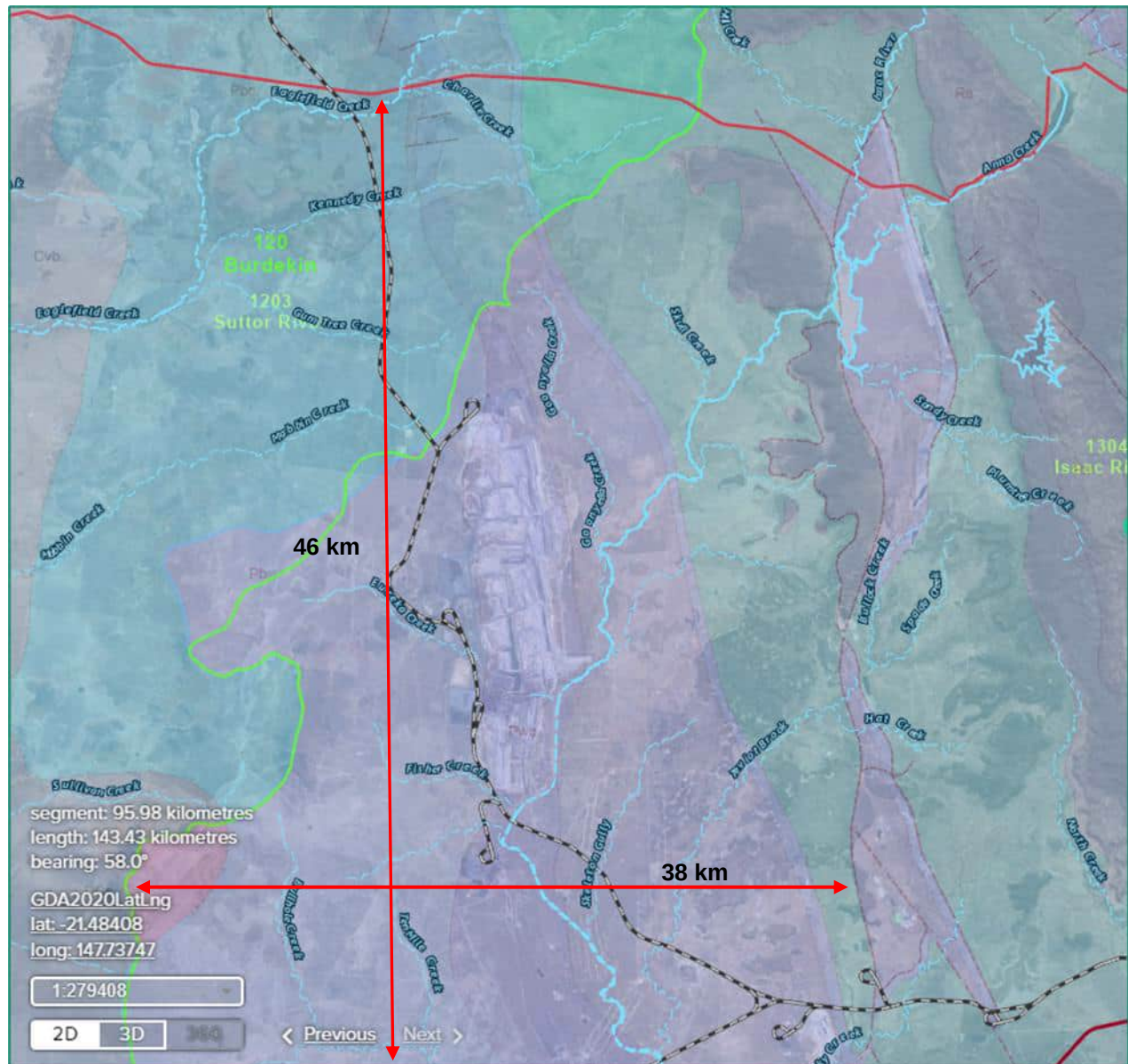
- The model boundaries encompassed all mine activities
- Includes for possible seepage / contaminated groundwater migration

- The model boundaries were sufficiently far from the mine activities so as not to impact on predictions (Figure 27).

13.3.3 Model extent and grid

The refined numerical groundwater model was constructed across an area of 46 km by 38 km as shown in Plate 14 and Figure 27, with the Project area situated towards the centre of the model domain based on boundary conditions.

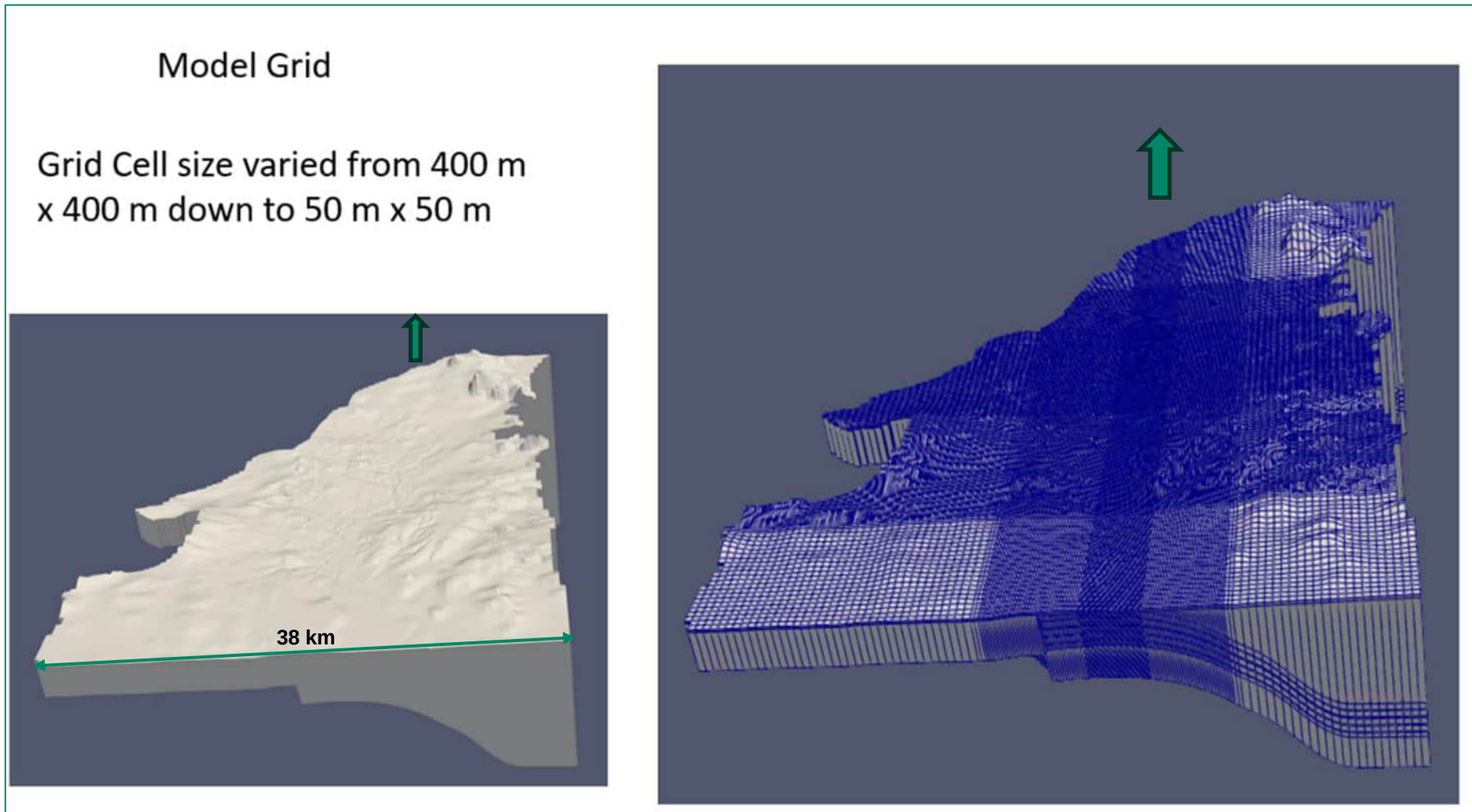
Plate 14 Catchment and geological structure boundaries



The model was constructed with a refined grid of 50 by 50 metres for the mining areas and with grid spacing of 100 x 100 meters up to 400 by 400 metres outside the mining areas, as shown in Plate 15.

The finite difference model comprised:

- A model area of 1,748 square kilometres
- 422 rows and 223 columns
- 1,117,410 active cells for a fourteen-layer model.

Plate 15 Depiction of the 3D groundwater model and cells, showing dip and strike of the lithology

13.3.4 Boundary conditions

Model boundaries, included in Figure 27, which indicates the active model cells (red and blue), were based on the model refinement to simulate groundwater conditions.

The model boundaries (Plate 16) include:

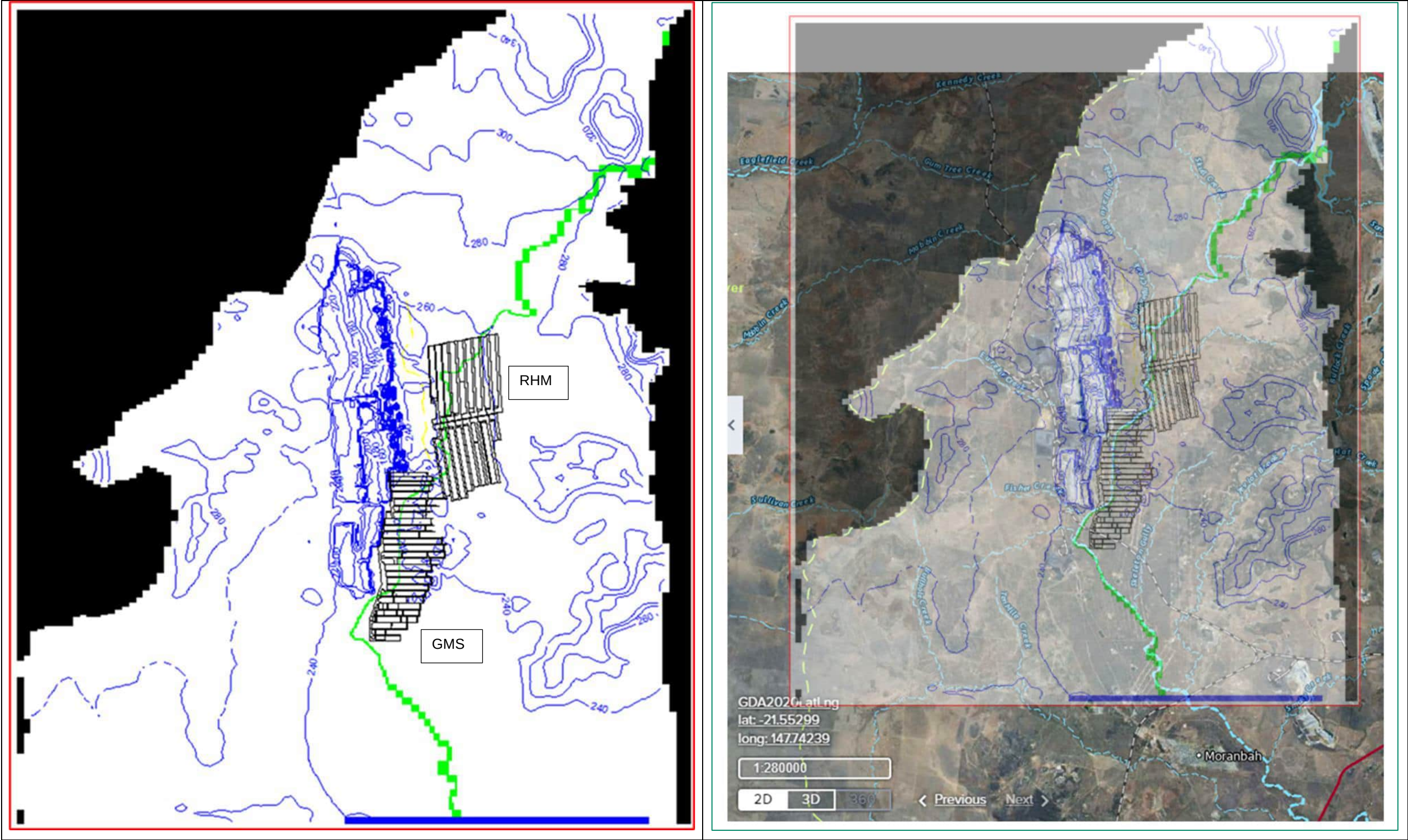
Top inflow boundary comprising recharge and evaporation. Available precipitation and evaporation data was reviewed / verified.

Horizontal inflow boundary based on groundwater level data, which is used to determine the model's east, west, north, and south boundary conditions. Geological log data and groundwater level information was used to set up representative prescribed head boundaries, sufficiently far from the GRB and RHM footprints as follows:

- Eastern boundary – No flow boundary due to thrust faults (Rewan Formation – Back Creek Group contact at surface)
- Western boundary – No flow boundary at the Isaac River catchment boundary, both the Back Creek Group and Tertiary units
- Northern boundaries (northwest corner) – No flow boundary for Tertiary sediments, and a range of constant head boundaries for the MCM
 - 20 mbgl for GUS
 - 25 mbgl for GP1 and GP2
 - 30 mbgl for GMS
 - 40 mbgl for GLSNo flow the rest of the layers
- Southern boundaries – Constant head for the alluvium and Tertiary (part) at 10 mbgl (blue section along southern boundary Plate 16)
 - Similar no flow and constant heads to northern boundary
 - Since few head observations were available near the boundaries, topographic elevations were used as reference elevations relative to groundwater levels. The groundwater levels were 20 to 40 mbgl for the northern and southern boundaries based on average depth to groundwater from available observations across the survey area.

Bottom inflow boundary considered below the site. Model bottom elevations were determined from floor and roof elevation data supplied by BMA. The no-flow boundary was assumed sufficiently far below the base of any mining (GMS and GLS) elevation based on available geological data.

Plate 16 Model Boundaries



Green model cells indicate the Isaac River
RHM – Red Hill Mine
GMS – Broadmeadow GMS mine (historic footprint)

13.3.5 Model layers

Publicly available digital elevation data with a 90 by 90 metre grid spacing was used to represent the ground surface in the model outside of the refined area (400 meter grid area in Plate 15), and BMA topographical data was used to represent the ground surface within the refined area (100 metre grid in Plate 15). The model layer elevations in the refined-grid area were generated based on the BMA geological model; while the layer elevations outside the refined area were extrapolated based on available data (Bowen Basin digital geology, Bowen Basin regional contouring of the top of the MCM on 50 metre intervals, and coal seam gas well logs) and assumptions.

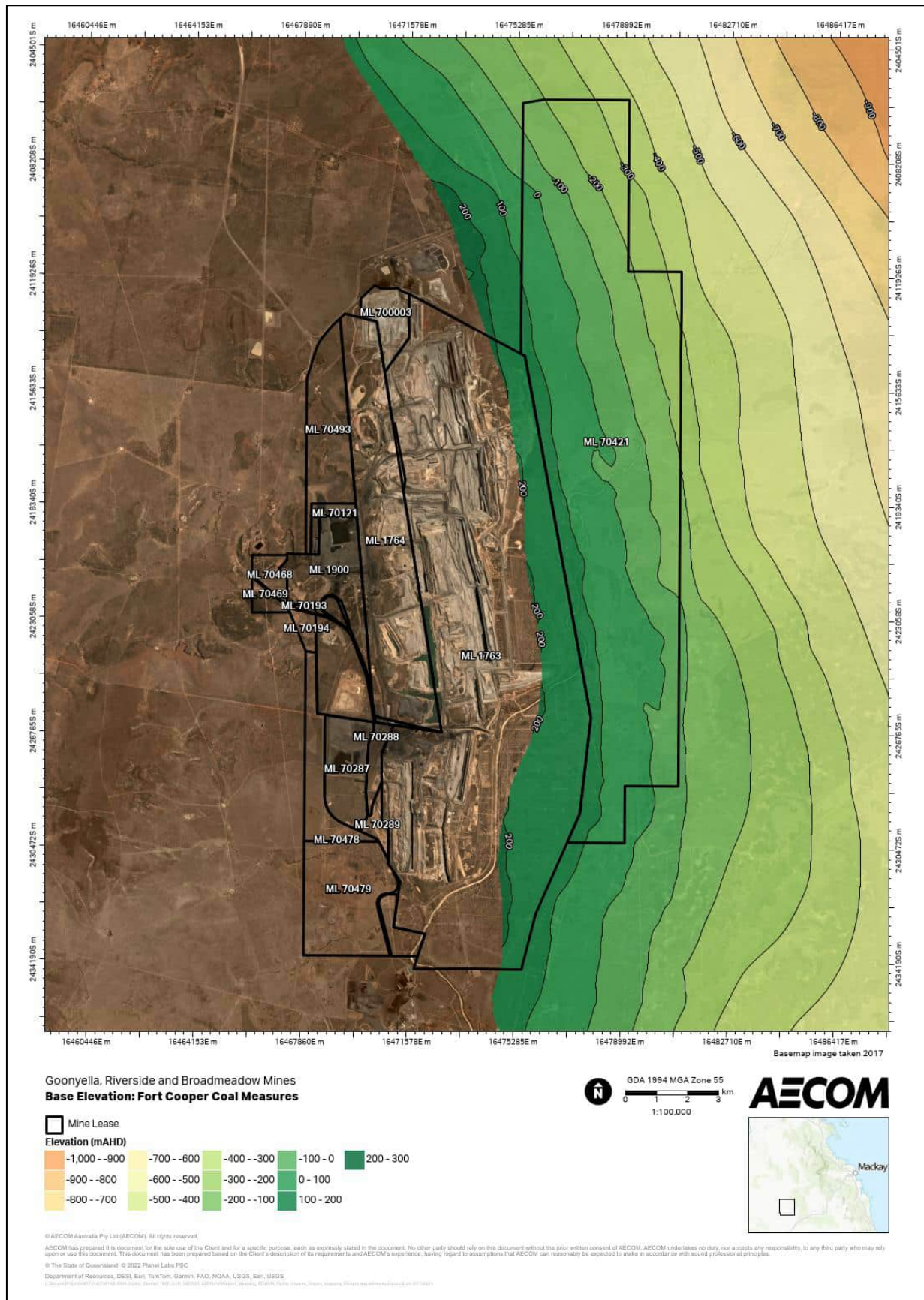
These data sets were used to create layer elevations throughout the model domain. Fourteen layers, representing the different lithological units across the survey area (Plate 15), were included in the model (Table 18). Plate 17 presents an example of the GMS coal seam floor elevations extrapolated from west (subcrop) to east.

Table 18 Model layers

Layer	Unit
1	Tertiary, alluvium
2	FCCM ¹
3	Overburden
4	GUS coal seam
5	Interburden
6	GP1 coal seam
7	Interburden
8	GP2 coal seam
9	Interburden
10	GMS coal seam
11	Interburden
12	GLS coal seam
13	Underburden
14	Back Creek Group

¹ The FCCM is depicted in the PRC Plan model as a single model layer, including for coal seams and interburden. This simplification allowed for the FCCM to be presented as an aquitard (based on available data in Figure 9) and facilitate model calibration and predictions noting the large model domain size and > 1 million model cells. The use of bulk hydraulic parameters allowed for the inclusion of the FCCM in the model.

Plate 17 FCCM subcrop and floor elevation example



13.3.5.1 Faults

It is important to note that faults can act as both conduits for groundwater flow and, in the case of coal seams, barriers to flow. The eastern boundary of the model is along the Burton Fault, where the Rewan Formation and Blackwater Group units are significantly offset, and is considered a no flow boundary.

Within the Project area, the MCM have undergone some minor to moderate faulting that may interrupt the continuity of the aquifer and act as boundaries to groundwater flow. In the model domain, the coal seams were simplified to allow continuous groundwater flow and to tie in with the interpolated levels beyond the Project area where data is limited. The effect of this simplification was to remove barriers to groundwater flow, which effectively extends the predicted drawdowns and increases groundwater inflows to the workings. The model is, therefore, considered to be conservative and allowed for the assessment of impacts over a larger area.

13.3.6 Rainfall Recharge

Recorded site specific climate data is summarised in Section 4.1. The average annual rainfall around the Project area is between 500 mm and 560 mm. High rainfall and evaporation occur in the summer months (December to February). Monthly evaporation rates are higher than monthly rainfall amounts throughout the year, indicating a net loss due to evaporation (i.e., a negative climate balance which has implications for final void water levels). The average evaporation rate is approximately 2 m per year.

Through a review of available data and previous modelling, recharge rates were determined to be less than one per cent of mean annual average rainfall, and evapotranspiration was not considered due to the depth to groundwater observed for the deep aquifers.

13.3.6.1 Alluvium recharge and discharge

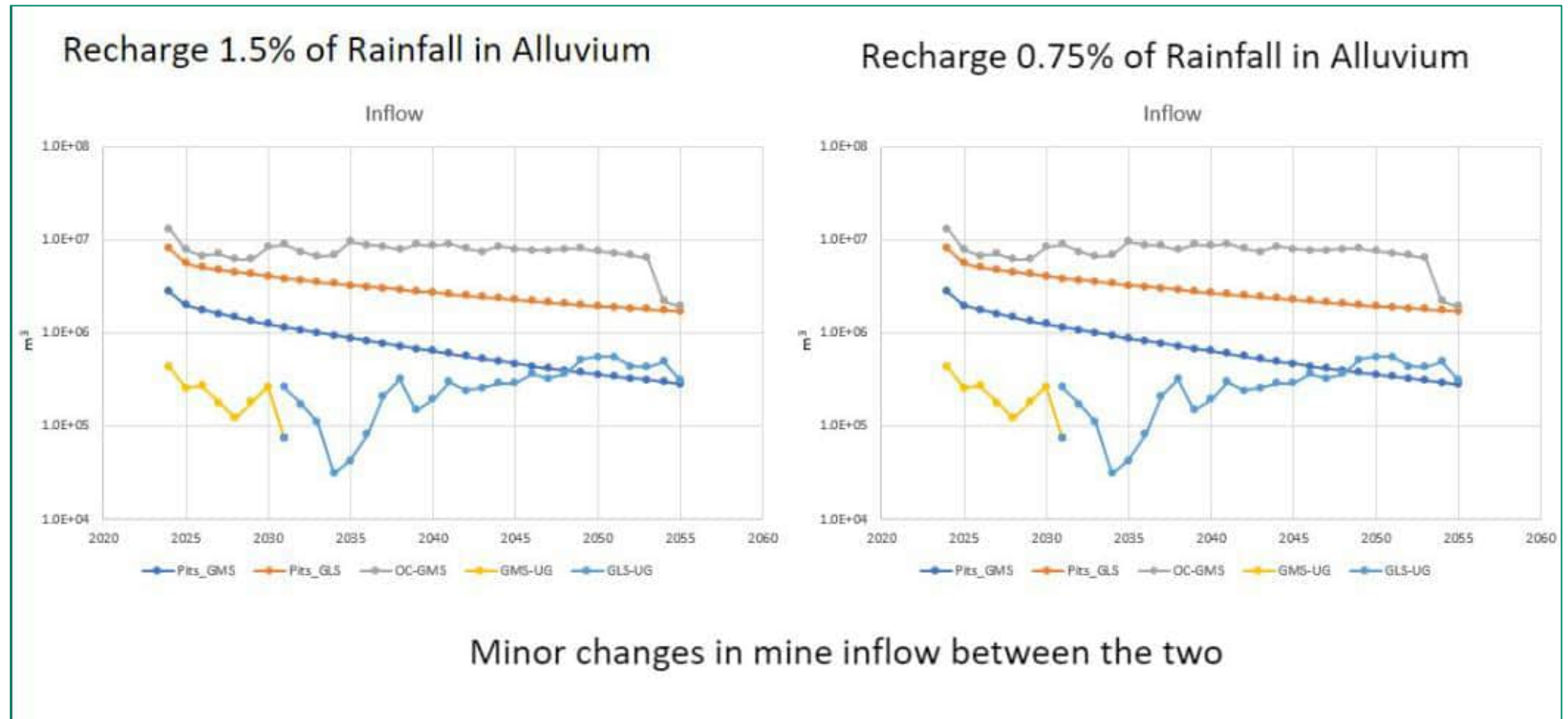
Variation in rainfall recharge, to assess sensitivity of rainfall recharge in the model, was included during modelling to assess recharge to alluvium. As the majority of alluvium monitoring bores were dry, allowing additional recharge to facilitate saturated conditions in the alluvium and flow towards the creeks and Isaac River. The groundwater model was used, allowing for differences in rainfall recharge, to assess the potential loss from the alluvium to the underlying hydrostratigraphic units (and resultant reduction in surface water contribution).

Recharge rates of 1.5 per cent (wet conditions) and 0.75 per cent (dry conditions) of annual rainfall was included in the model calibration and assessed through the model water budget (Section 14.4).

The mine inflow predictions, for the period to the end of the Broadmeadow underground mining, is included in Figure 28. This figure presents the estimates of groundwater ingress into the different mine pits, the ongoing Goonyella open cut mining, and the GMS and GLS underground mining.

The modelled inflows, allowing for wet and dry rainfall conditions to the alluvium, does not indicate increased ingress into the mine workings under the two simulations of recharge (i.e., 1.5% or 0.75% of mean annual rainfall acting as recharge).

The alluvium water table (discontinuous unconfined conditions) and the piezometric levels (confined conditions) associated with the deeper coal seam aquifer groundwater data indicate a marked separation (i.e., based on available data presented and assessed in Section 7.3.3 there is no hydraulic connection between the alluvium water table and the confined aquifers). Thus, the vertical movement from the alluvium, when saturated, is limited even taking possible subsidence alteration into account (i.e., the limited groundwater resources associated with the alluvium remains separated from the confined piezometric levels even if additional water is added to the alluvium (as recharge) or the separation between the water table and the piezometric levels are increased (due to mine dewatering leading to larger vertical groundwater gradients).

Figure 28 Groundwater ingress considering recharge variation to the alluvium (ingress in m³per year versus years)

Pits_GMS - Inflow estimates into residual voids which target the GMS seam

Pits_GLS - Inflow estimates into residual voids which target the GLS seam

OC_GMS - Inflow estimates for continued open cut GMS mining

GMS_UG - Inflow estimates for the GMS underground mining

GLS_UG - Inflow estimates for the GLS underground mining

13.3.7 Hydraulic parameters

The ranges of hydraulic conductivity (K) and storativity values, included in the original RHM model were derived from aquifer hydraulic testing and literature values where onsite data was not available. These aquifer hydraulic properties are included in Table 19 and were refined during model calibration (Section 14.3).

Table 19 Summary of calibrated parameters in the original RHM model

Model Layer	Unit	Kh (m/day)	Kv (m/day)
1	Tertiary, alluvium	0.49	0.049
2	FCCM	1.00 E-03	1.00E-04
3	Overburden	1.08E-04	1.08E-05
4	GUS coal seam	Distribution*	Distribution* x 0.1
5	Interburden	1.08E-04	1.08E-05
6	GP1 coal seam	Distribution*	Distribution* x 0.1
7	Interburden	1.08E-04	1.08E-05
8	GP2 coal seam	Distribution*	Distribution* x 0.1
9	Interburden	1.08E-04	1.08E-05
10	GMS coal seam	Distribution*	Distribution* x 0.1
11	Interburden	1.08E-04	1.08E-05
12	GLS coal seam	Distribution*	Distribution* x 0.1
13	Underburden	1.08E-04	1.08E-05
14	Back Creek Group	1.08E-04	1.08E-05

*K distribution derived from regression formula

The calibrated aquifer hydraulic parameters plus method used to derive the parameters are include in Section 14.3.4.

13.3.7.1 Simulation of mine dewatering using drains

In order to simulate mine dewatering, the MODHMS drain package was utilised. Using drains involved the setting of a reference (drain target) elevation (base of the target coal seam) and a conductance (leakage) term.

The bottom elevations of the drains were set at the base of the GLS or GMS coal seam to be mined. Groundwater levels in the model were compared to the elevation of the bottom of the drain in each model cell. When the groundwater level was above the bottom of the drain water was removed from the model domain at a rate determined by the head difference (within and adjacent to the workings) and the drain hydraulic conductance.

The drains were activated according to the Project mine plans (schedule and progression). Drain conductance was set at a high rate to ensure the groundwater level was lowered to the drain level (to simulate dry workings as required for mine safety).

This approach was adopted in order to:

- Estimate the total volume of groundwater to be removed at the end of mining
- Determine the groundwater drawdown / groundwater elevation heads prior to decommissioning and closure activities.

These data were used as initial inputs into the residual water balance modelling (Section 15.0).

Drains were then converted to constant head boundaries (MODHMS CHD package) in the model, to level predicted in the (surface water and groundwater) residual void water balance model (Section 15.4).

The introduction of the residual void water levels (as CHD) resulted in reduced groundwater gradients, around the residual voids. Using the CHD elevations allowed for evaluation of drawdown and long term groundwater conditions when the water levels in the residual voids reach pseudo-steady state.

These closure groundwater conditions allowed for the assessment of groundwater flow, potential contaminant migration in groundwater, and impacts post-closure (Section 15.6).

13.3.7.2 Simulation of mine dewatering considering goaf alteration

To further estimate groundwater ingress during mining activities, consideration and simulation of aquifer alteration (due to longwall mining (goaf)) was undertaken. The use of EPM, as detailed in Section 7.3.4, was included to alter aquifer parameters after longwall mining was complete.

14.0 PRC Plan Landform #2.3 Model

The post-mining final landform relevant to this hydrogeological assessment was provided by BMA (denoted Landform #2.3) and is shown as Figure 3. The final landform contains six residual (final) voids:

- Goonyella Pit
- Thiess / Ramp 21 Pit
- Ramp 32 East,
- Ramp 32 South,
- Broadmeadow Pit, and
- Isaac Pit.

The RHM, which is accessed via the Goonyella Pit highwall, is included in the PRC Plan landform #2.3 due to:

- The continuous nature of the geology and hydrogeology at GRB and RHM
- The proximity and physical connection of RHM to GRB (via the Goonyella Pit highwall)
- The continual mining and decommissioning activities which influence groundwater conditions
- Mine waste, generated because of RHM, being stored at GRB facilities.

14.1 Existing conditions

Open cut and underground mining at GRB has been ongoing since the 2013 groundwater model was constructed, as described in Section 1.1. The RHM original model was refined to include for the open cut mining, placement of backfill (referred to as spoil), the various pits plus the Broadmeadow GMS mining panels, which had been mined since the original model set-up.

The model was constructed using the historic mine plans to replicate the mine conditions for 2020 (the start of the transient groundwater calibration period), including the location of pits, spoil, and longwall panels (Plate 18).

The pits, highlighted in blue on Plate 18, are labelled in Figure 2.

The spoil, for use in the zone budget (refer to Section 14.2) required to estimate groundwater ingress sources (spoil or natural, for example), was further refined in the model set-up.

Plate 19 indicates the subdivisions of the spoil as follows:

- Red outlined areas – Historic spoil areas in 2020
- Yellow highlight areas – GMS open cut mining between 2012 and 2019 (backfilled with spoil)
- Pink areas – surface areas to be mined (open cut), 2019 to 2059).

The Broadmeadow mine areas, included as goaf in the model set-up, are shown in Plate 20.

The GMS mining is delineated as:

- Yellow areas – GMS underground mining (2010 to 2019) based on historic mine plan
- Green areas- future GMS longwall panels post 2019.

Plate 18 2020 pit locations and spoil locations (red areas)

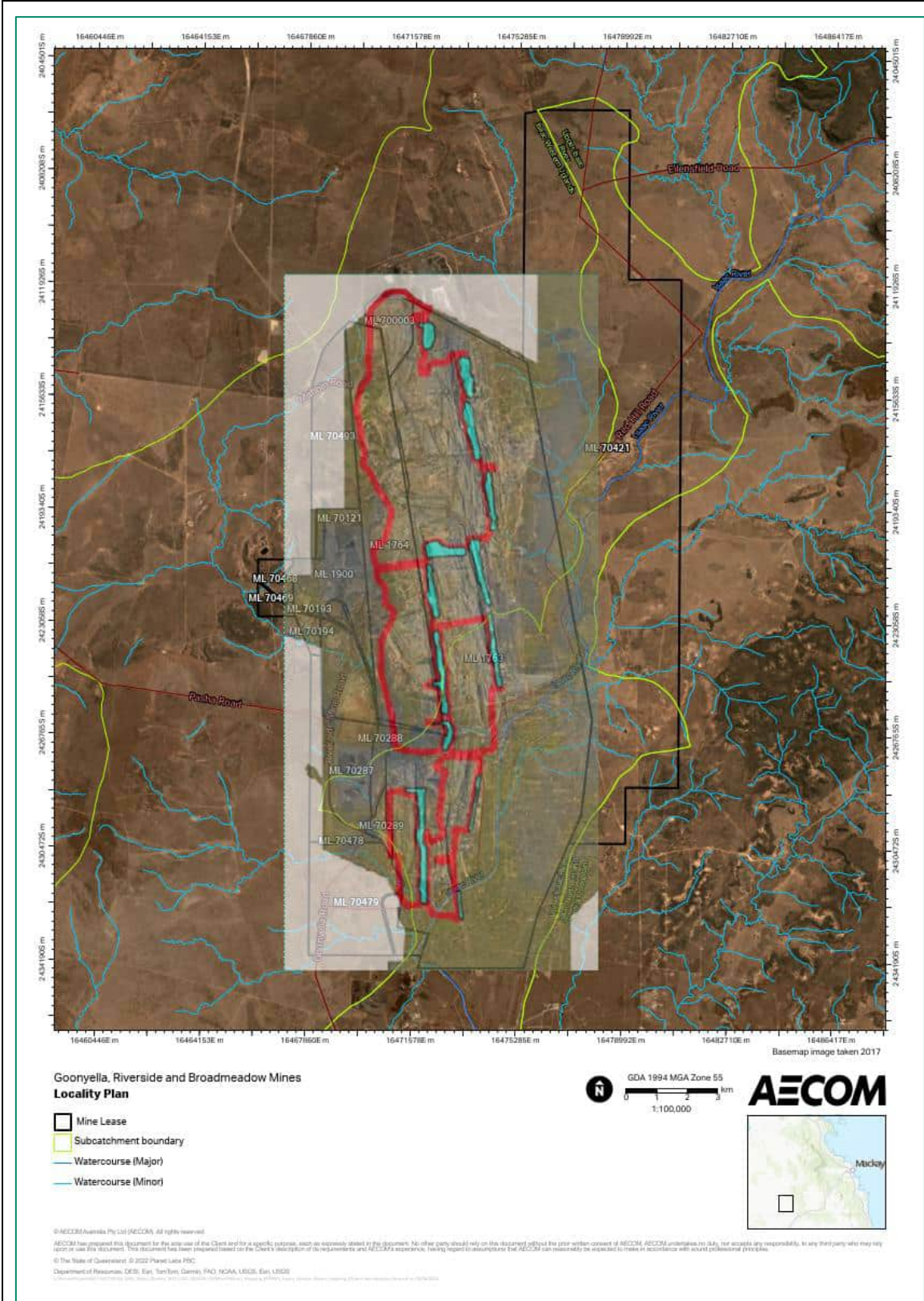


Plate 19 2020 spoil subdivisions

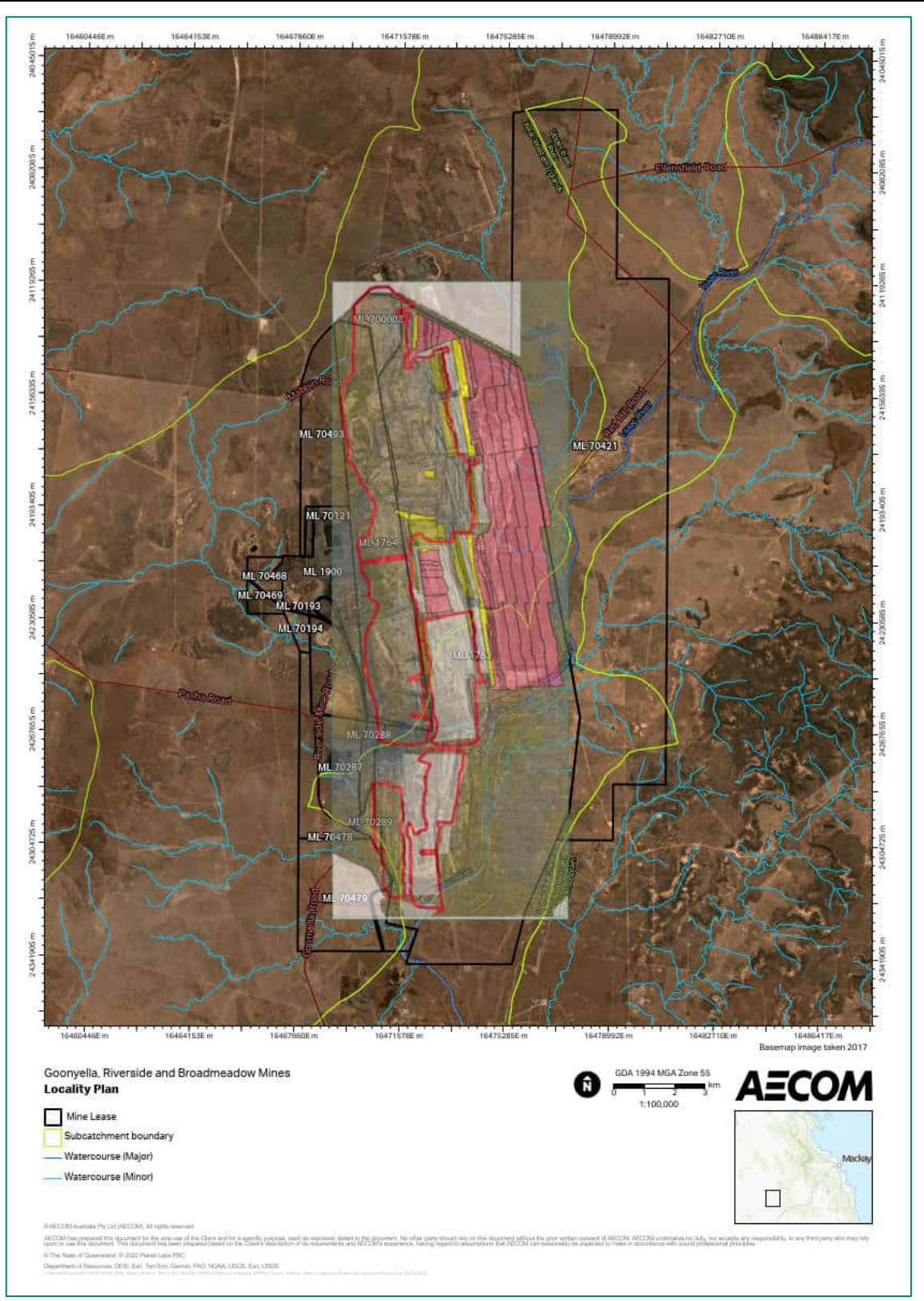


Plate 20 Goaf areas up to 2019 - see overleaf

14.2 Model Setup

The mine plan/s (Plate 21) schedules (overlapping and continual over time), decommissioning, and alteration of geology and groundwater (aquifer hydraulic parameters) required the model to be set-up to simulate mine dewatering, water injection into the underground workings, and alteration (goaf and spoil backfill areas).

The objective of the groundwater modelling was to provide input (predictions of groundwater ingress into the residual voids post closure) to the water balance model, which considers all inputs and outputs from the residual voids. Long term pit water levels can then be estimated.

To provide the groundwater contribution, from spoil and natural geology, the model was set-up to include zones. The predictive model can then be used to assess ingress or outflow from the residual voids using a model zone budget.

The water budget zones, corresponding to mine areas (pits, spoil, or natural (undisturbed geology), are included in Figure 29.

Figure 29 Budget zones

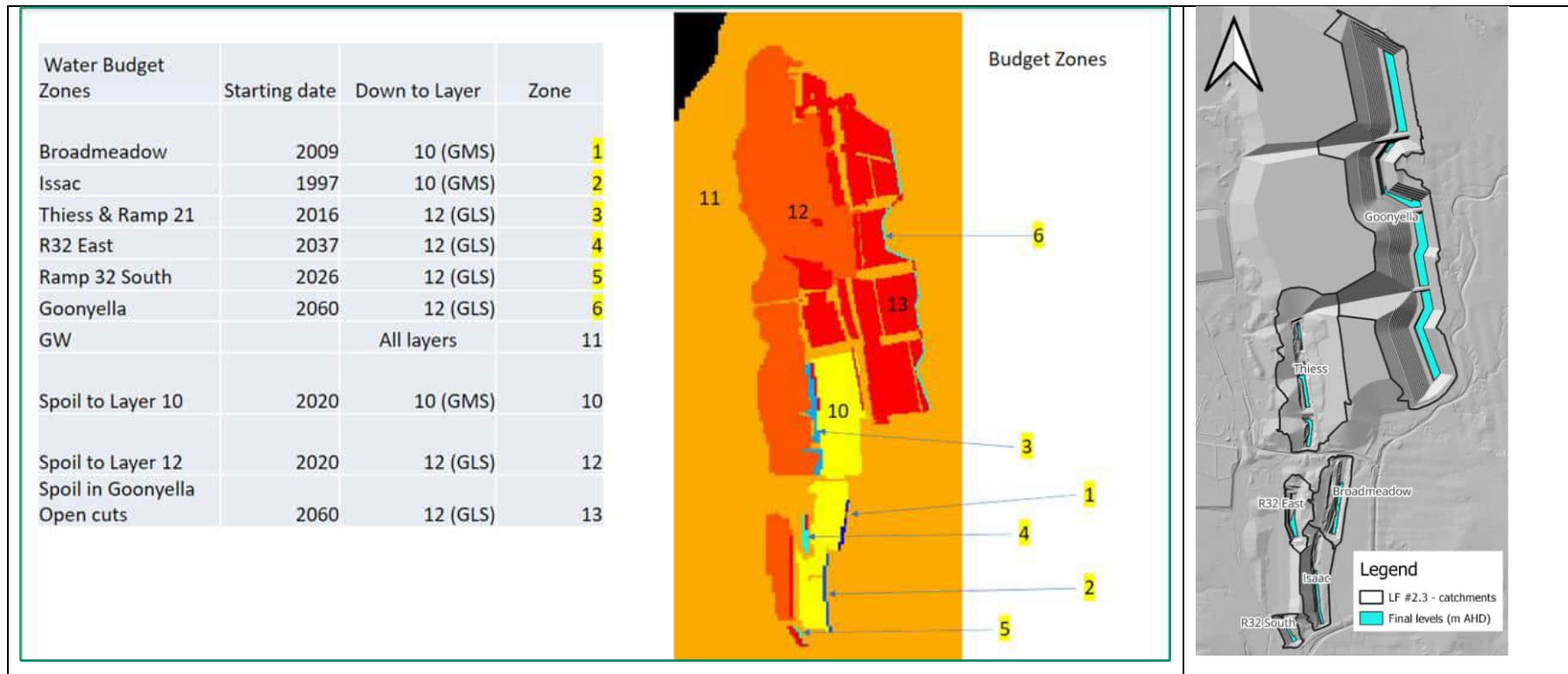
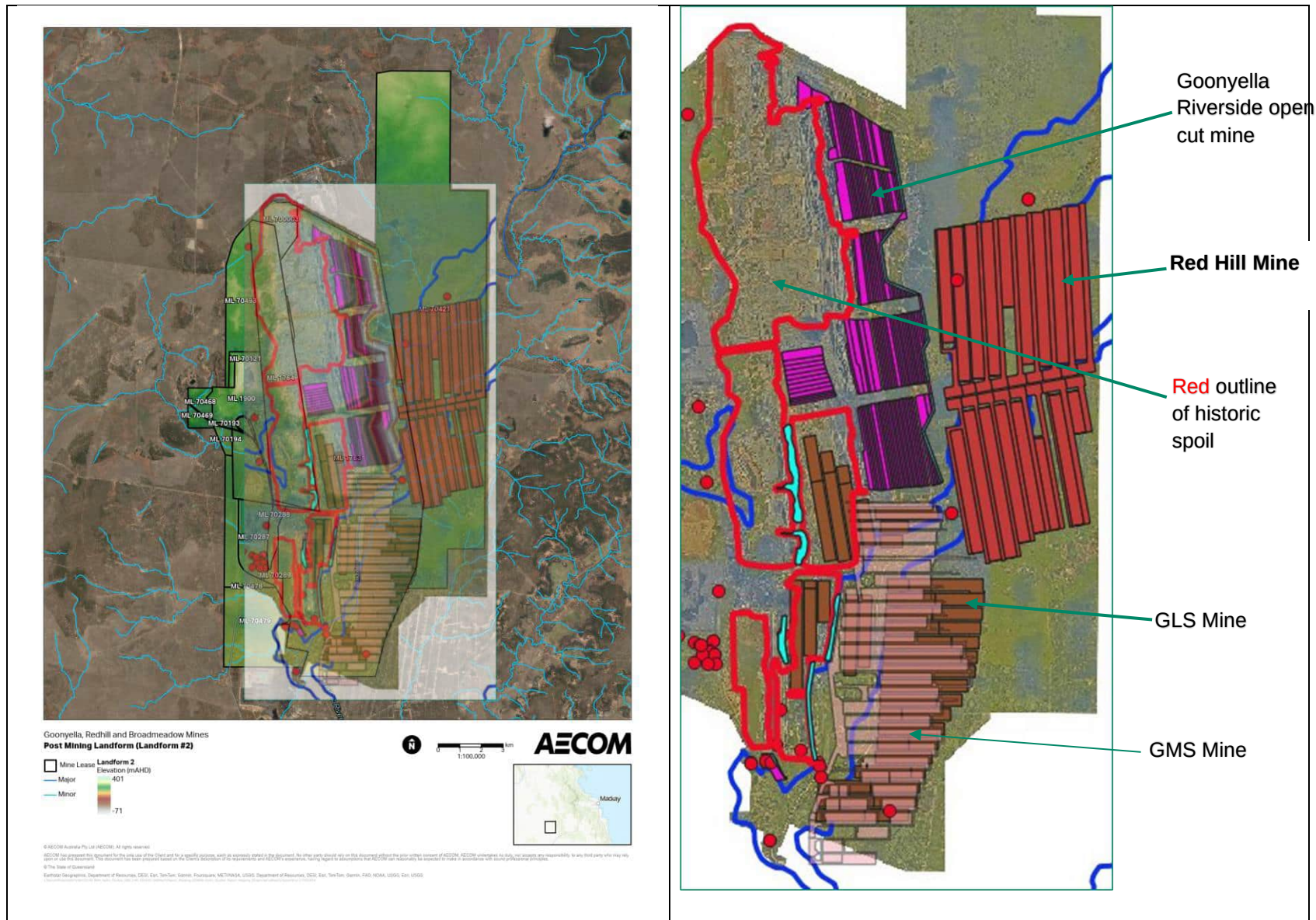


Plate 21 Mine areas historic and future



14.2.1 Introduction of water into the underground workings

Geotechnical assessments at the Project recommended the flooding of the underground workings with water to facilitate long term stability. The introduction of water into the underground workings, as part of the decommissioning (Table 15), was included in the modelling.

Options to simulate the introduction of water included changing the mine workings drain cells to constant head boundaries (based on the portal entrance elevations), injection down the portals, or simulating injection via vertical bores.

BMA, based on historic groundwater volumes removed from the Broadmeadow GMS workings and mine plans, provided estimates of water to be introduced into the underground workings over three (3) years.

The Broadmeadow underground mining areas is estimated to require 5.34 GL over a 3 year period. RHM is estimated to require 4.94 GL over a 3 year period. This approach was adopted to aid with the PRC Plan assessment, it is considered that the timing of the introduction of water may lengthen based on water availability.

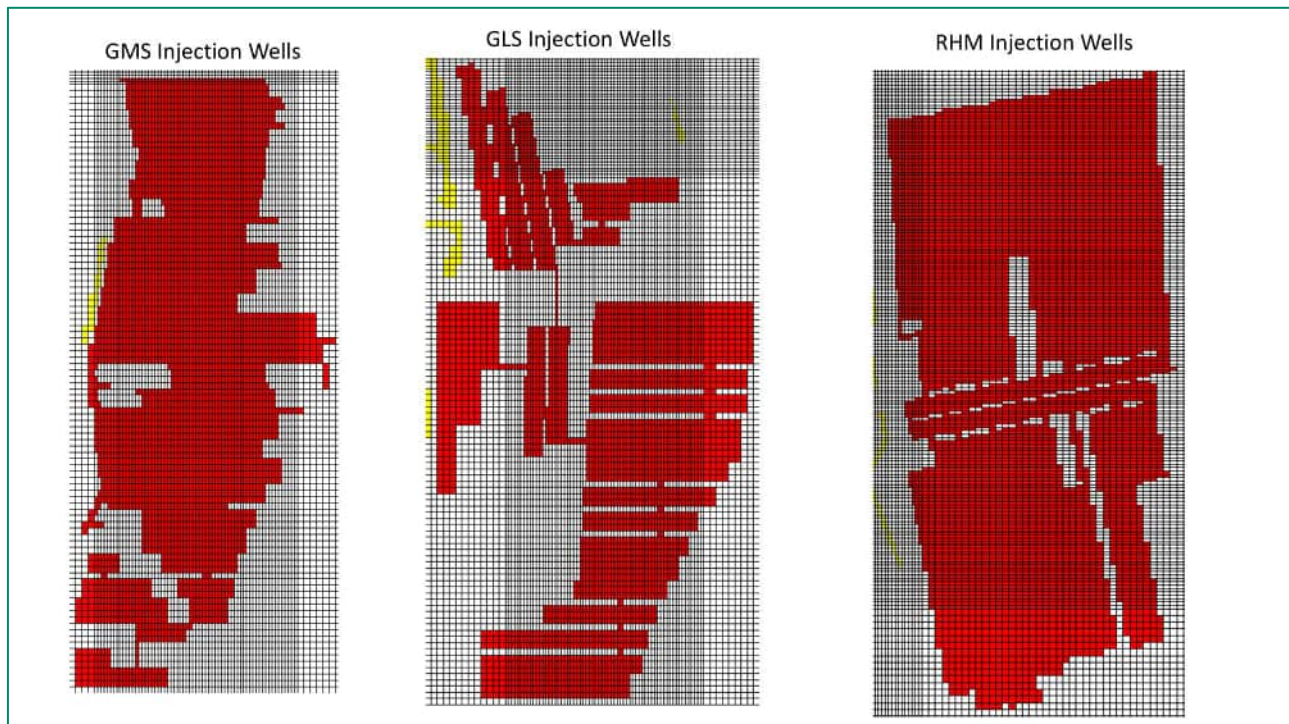
To best simulate this volume of water over a three year period the model was set-up to allow for the introduction of water into each of the model cells across the underground workings footprints.

The introduced water was divided up between the two Broadmeadow underground mines based on size, where:

- The Broadmeadow GMS mine plan covered an area which contained 4,171 model cells. Water introduction was simulated by introducing 6.22 m³/day into each of the model cells for 3 years.
- The Broadmeadow GLS mine plan covered an area which contained 3,684 model cells. Water introduction was simulated by introducing 6.18 m³/day into each of the model cells for 3 years.

The RHM mine plan covers 6,005 model cells, the water introduced into each of the RHM model cell was 7.51 m³/day for 3 years.

Model cells over all the underground workings, which will receive the introduced water, are included on Plate 22.

Plate 22 Red model cells allowing for the introduction of water into the model

14.3 Calibration

The refined numerical groundwater includes a transient calibration (2020 to 2024) based on the most recent groundwater monitoring data. The initial conditions were derived from the prior pseudo-steady conditions covering the period from 1996 to 2009 (**Appendix A**) plus the historic mining (2010 to 2019), and average climate conditions during these periods.

The calibration used 260 target heads for 50 bores across the Project area (Figure 8). The transient calibration captured the historical mining at GRB. Mining was represented in the model using the MODFLOW drain package, with the drain cells set to the base of the target coal seam for each pit, and within the target GMS coal seam for the Broadmeadow underground mine.

Calibration of the model was carried out with the objective being to replicate the groundwater levels measured at the Project, as well as some registered bores, in accordance with Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

The transient calibration targets, datasets and monitoring points, plus corresponding model layers are included in **Appendix C**.

14.3.1 Approach

The calibration approach included:

1. Model calibration to depict the hydrogeological framework, aquifer hydraulic properties, and boundary conditions.
2. Achieve correlation between the model output and measured/observed field data.
3. Determine optimal set of parameter values and boundary conditions that minimise the discrepancy between simulated and observed data.

The calibration targets included:

- Transient Head Targets, for data available from 2020 to 2024 (Q1).
- Aquifer test data (hydraulic conductivity parameter constraints).

The modelling tools used included PEST++ with the Iterative Ensemble Smoother algorithm, referred to as PESTPP-IES.

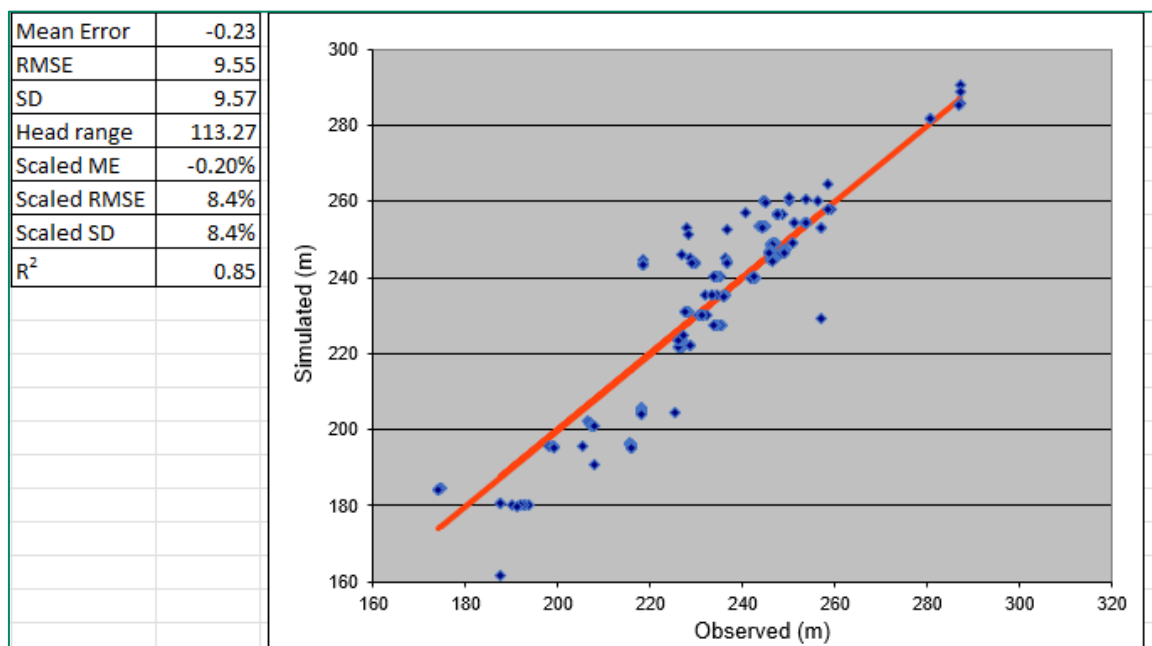
The calibration results were assessed through the evaluation of calibration criteria, including:

- The root mean square error (RMSE)
- The mean error (ME)
- Coefficient of determination (R^2).

14.3.2 Calibration statistics

Calibration for the model (Plate 23) achieved the following statistics: a 9.55 m root mean square (RMSE) error, equating to an 8.4% scaled root mean square (SRMSE) error, which is within the recommended range (i.e. 10%) in the Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

Plate 23 Calibration results (entire dataset)



Two groundwater monitoring bores, GRM_BH2A and GRM_BH3A, located immediately adjacent to a mine water dam (Plate 24), could not readily be calibrated. The water levels within these bores were markedly lower than the surround monitoring bores and there is no obvious mine dewatering impacts (within the Tertiary sediments above the Back Creek Group basement lithology).

Removal of these two anomalous groundwater elevation data points (possibly related to poor bore construction grouting) allowed for an improvement in the transient groundwater model calibration statistics (Plate 25).

The revised calibration statistics (Plate 25) included an 8.66 m root mean square (RMSE) error, equating to a 7.6% scaled root mean square (SRMSE) error.

Plate 24 GRM_BH2A and GRM_BH3A bores

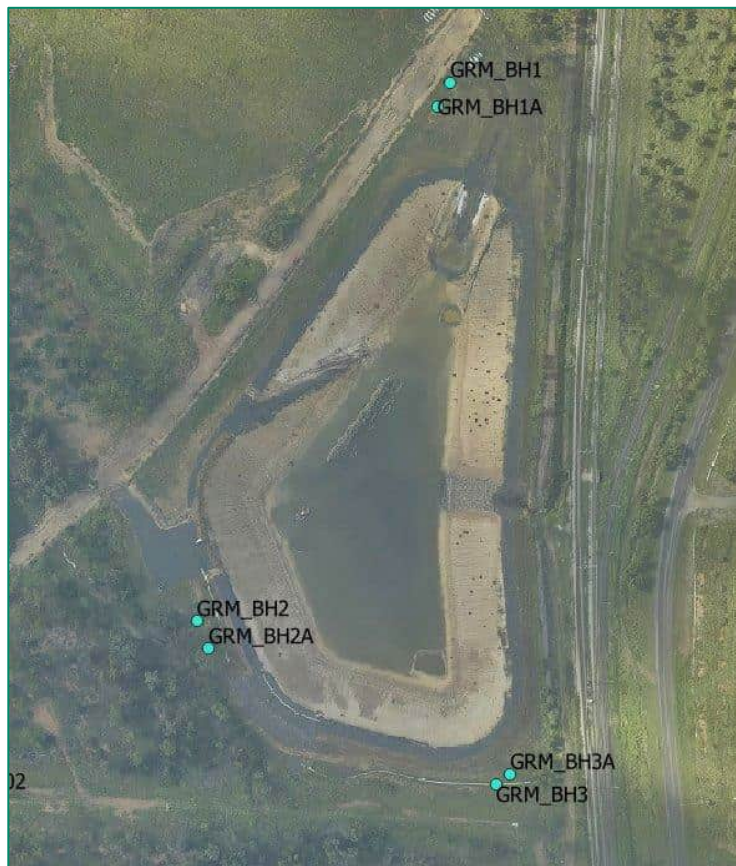
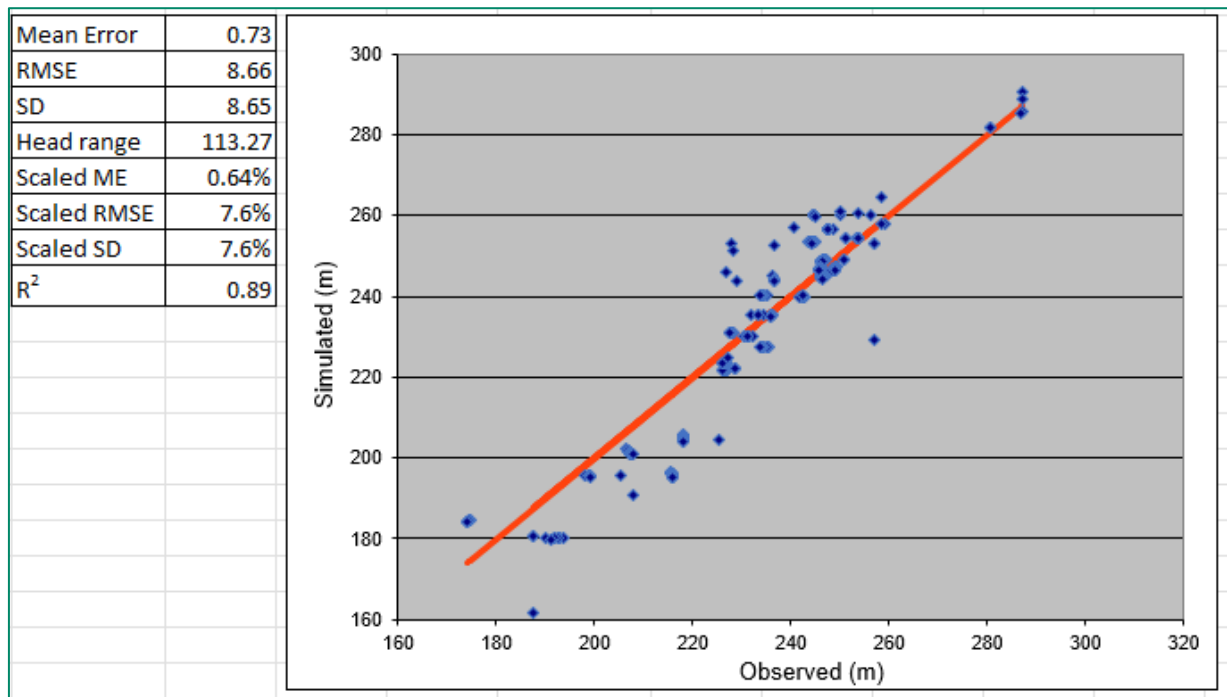


Plate 25 Edited dataset calibration results



14.3.3 Transient data hydrographs

The transient water level data recorded between 2020 to 2024 is presented in hydrographs with the model simulation results. The hydrographs indicate trend matching across the model domain (Figure 30).

14.3.4 Calibrated aquifer hydraulic parameters

The calibration approach, Section 14.3.1, using the parameter estimation software (PEST) allowed for the estimation of aquifer parameters for each of the model layers. Table 20 presents the parameters, hydraulic conductivity and storage, plus the depth range for each layer across the model domain.

The method for deriving the aquifer hydraulic properties included:

- Pilot – Using pilot points within the model domain
- Uniform – Homogeneous distribution in the aquitard layers
- Pilot plus regression, where the cut-off depth for switching between pilot point and regression estimates is determined by PEST.
 - Noting that for depths shallower than the cut-off then the pilot point estimate is adopted, if deeper than the cut-off then the value from the regression equation is adopted.

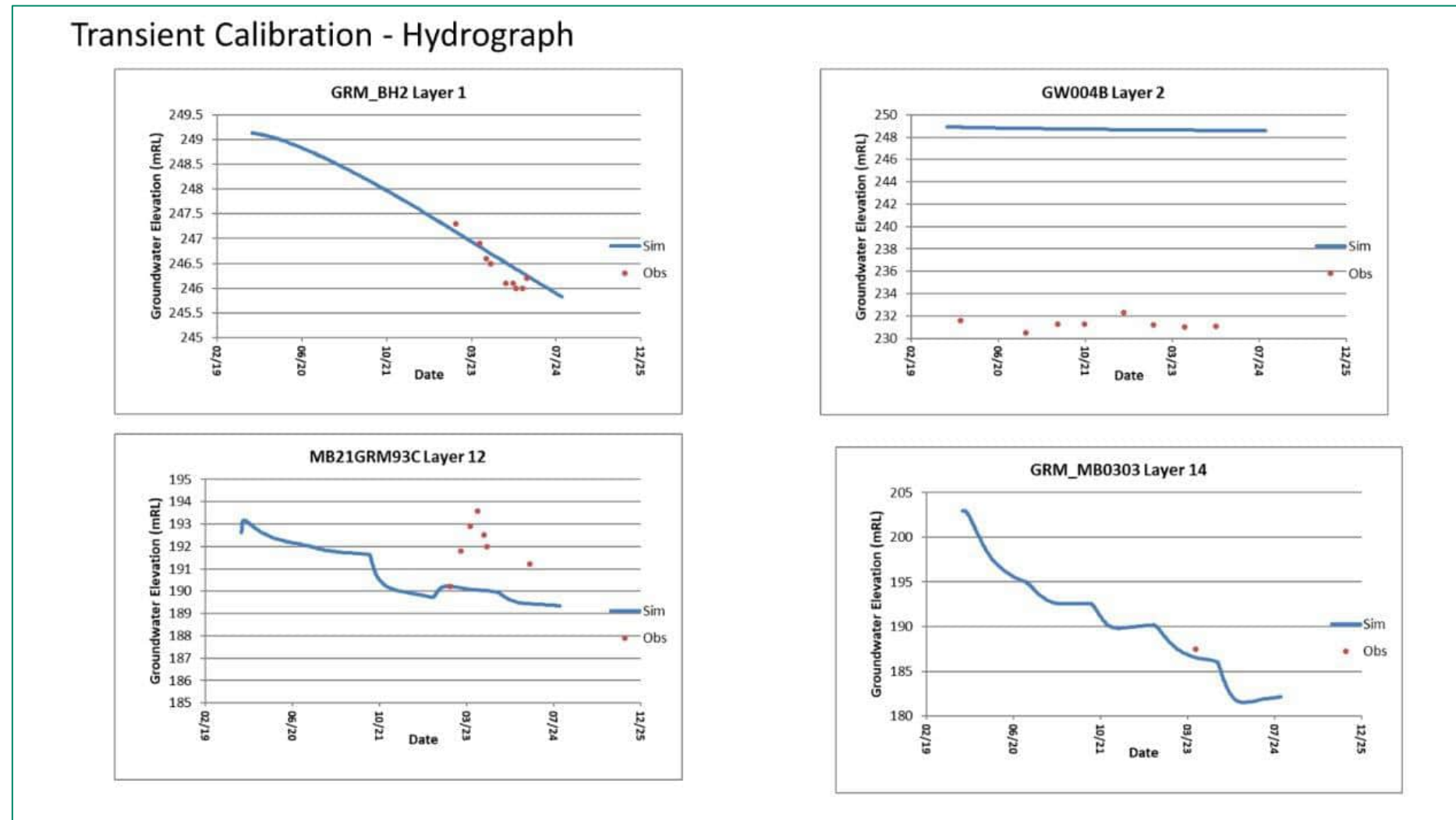
The regression equation is $aa \cdot \exp(-bb \cdot \text{depth})$, where:

aa = 0.2703

bb = 0.016

Layer	Kx_Max	Kx_Min	Cut-off depth (m)	
4	0.025	1.00E-05	500	
6	0.025	1.00E-05	267.49	
8	0.025	1.00E-05	0	Only regression, no pilot point estimates
10	0.025	1.00E-05	336	
12	0.025	1.00E-05	435.64	

Figure 30 Groundwater model calibration transient hydrographs examples



Blue line – simulated (sim) model water level hydrograph

Obs – Available transient groundwater level measurements

Table 20 Summary of hydraulic parameters in the PRC Plan model

Model Layer	Unit	Kh / Kv (anisotropy)	Kh min (m/day)	Kh max (m/day)	Sy min	Sy max	Sc min	Sc max	Thickness From (m)	Thickness To (m)	Method
1	Tertiary, alluvium	10	1.0E-02	1.0E+01	5.0E-02	2.0E-01	1.0E-06	1.0E-04	15	20	Pilot
2	FCCM	10	1.0E-05	1.0E-01	5.0E-03	1.0E-01	1.0E-06	1.0E-04	42	880	Pilot
3	Overburden	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	30	50	Uniform
4	GUS coal seam	100	1.0E-05	5.0E-02	5.0E-03	5.0E-02	1.0E-06	1.0E-04	2.5	5	Pilot+Reg.
5	Interburden	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	25	40	Uniform
6	GP1 coal seam	100	1.0E-05	5.0E-02	5.0E-03	5.0E-02	1.0E-06	1.0E-04	2.5	4	Pilot+Reg.
7	Interburden	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	15	40	Uniform
8	GP2 coal seam	100	1.0E-05	5.0E-02	5.0E-03	5.0E-02	1.0E-06	1.0E-04	2.5	5	Regression
9	Interburden	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	30	40	Uniform
10	GMS coal seam	100	1.0E-05	5.0E-02	5.0E-03	5.0E-02	1.0E-06	1.0E-04	2.5	8	Pilot+Reg.
11	Interburden	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	30	50	Uniform
12	GLS coal seam	100	1.0E-05	5.0E-02	5.0E-03	5.0E-02	1.0E-06	1.0E-04	2.5	5	Pilot+Reg.
13	Underburden	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	30	40	Uniform
14	Back Creek Group	100	1.0E-05	5.0E-02	1.0E-02	1.0E-01	1.0E-06	1.0E-04	200	500	Pilot

Pilot + Reg. - Pilot plus regression

The resultant distribution of the aquifer parameters within the model layers and spatially across the model domain is as included in the following figures:

- The calibrated horizontal hydraulic conductivity values for the surficial sediments (model layer 1) is included in Figure 31.
- The calibrated horizontal hydraulic conductivity values for GMS (model layer 10) is presented in Figure 32.
- The calibrated horizontal hydraulic conductivity values for GLS (model layer 12) are included in Figure 33.

These figures include the Isaac River (black line) and mine footprints (light blue and brown) and show the heterogeneity of the sediments included in the model. It is noted that the hydraulic conductivity within the model, within the mine footprints, varies over time (prediction periods) and with depth (model layers). The figures included here, to depict the spatial and vertical heterogeneity, are based on the P4 (end of 2199) aquifer hydraulic properties.

14.3.4.1 Aquifer hydraulic parameters for historic spoil and goaf

As per Section 14.1, the model was set-up to include for historic mine workings prior to model predictions (2024 Q2 onwards) and for inclusion in the transient calibration period (2020 to 2024 Q1).

The location and extent of spoil within the model set-up is shown in Figure 34. The areas of historic goaf within the model are as included in Plate 20.

The aquifer hydraulic parameters for the goaf, are as detailed in Section 7.3.4.3, included:

- GMS goaf Horizontal hydraulic conductivity (K_h) = 1.1 m/day
- GMS goaf Vertical hydraulic conductivity (K_v) = 5E-05 m/day
- GMS goaf Specific capacity (Sc) confined storage = 1.5E-03
- GMS goaf Specific yield (S_y) unconfined storage = 0.15

The K_v in the overlying model layer (interburden aquitard) was also increased to 0.0005 m/day.

For the spoil, using model parameters supplied by BMA as used in the Saraji Mine PRC Plan (SLR, 2023), was assigned the following aquifer hydraulic parameters:

- Spoil Horizontal hydraulic conductivity (K_h) = 1.0 m/day
- Spoil Vertical hydraulic conductivity (K_v) = 0.1 m/day
- Spoil Specific capacity (Sc) confined storage = 1.5E-04
- Spoil Specific yield (S_y) unconfined storage = 0.15

The recharge across the spoil was increased to 1.0% of the mean annual rainfall.

These hydraulic parameters are included in the model layers 1 to 10 (if mining targeted the GMS) or model layers 1 to 12 (GLS), where the lithology has been mined and replaced with backfill.

Figure 31 Hydraulic conductivity within the surficial sediments

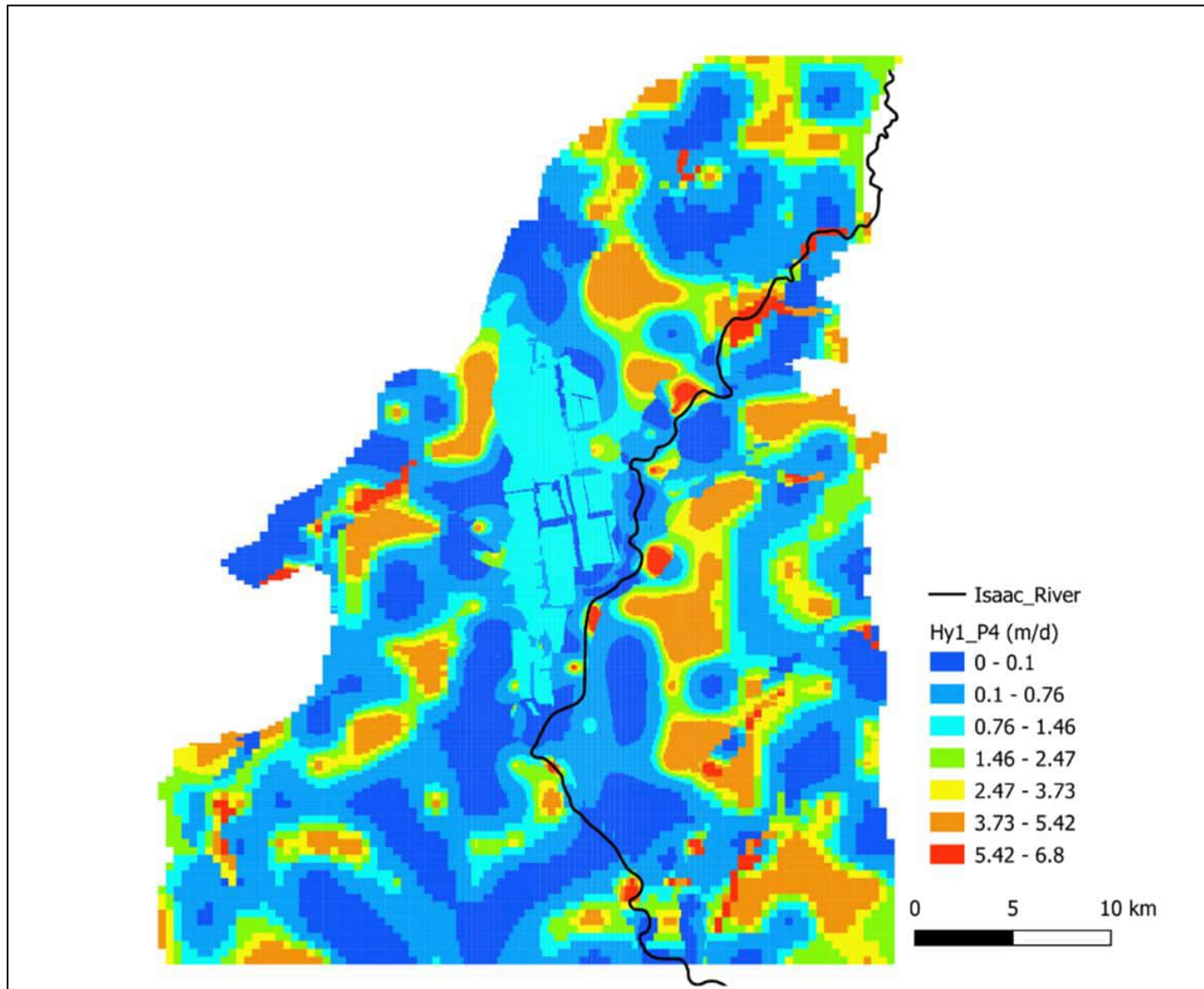


Figure 32 Hydraulic conductivity within the GMS model layer 10 – RHM target seam

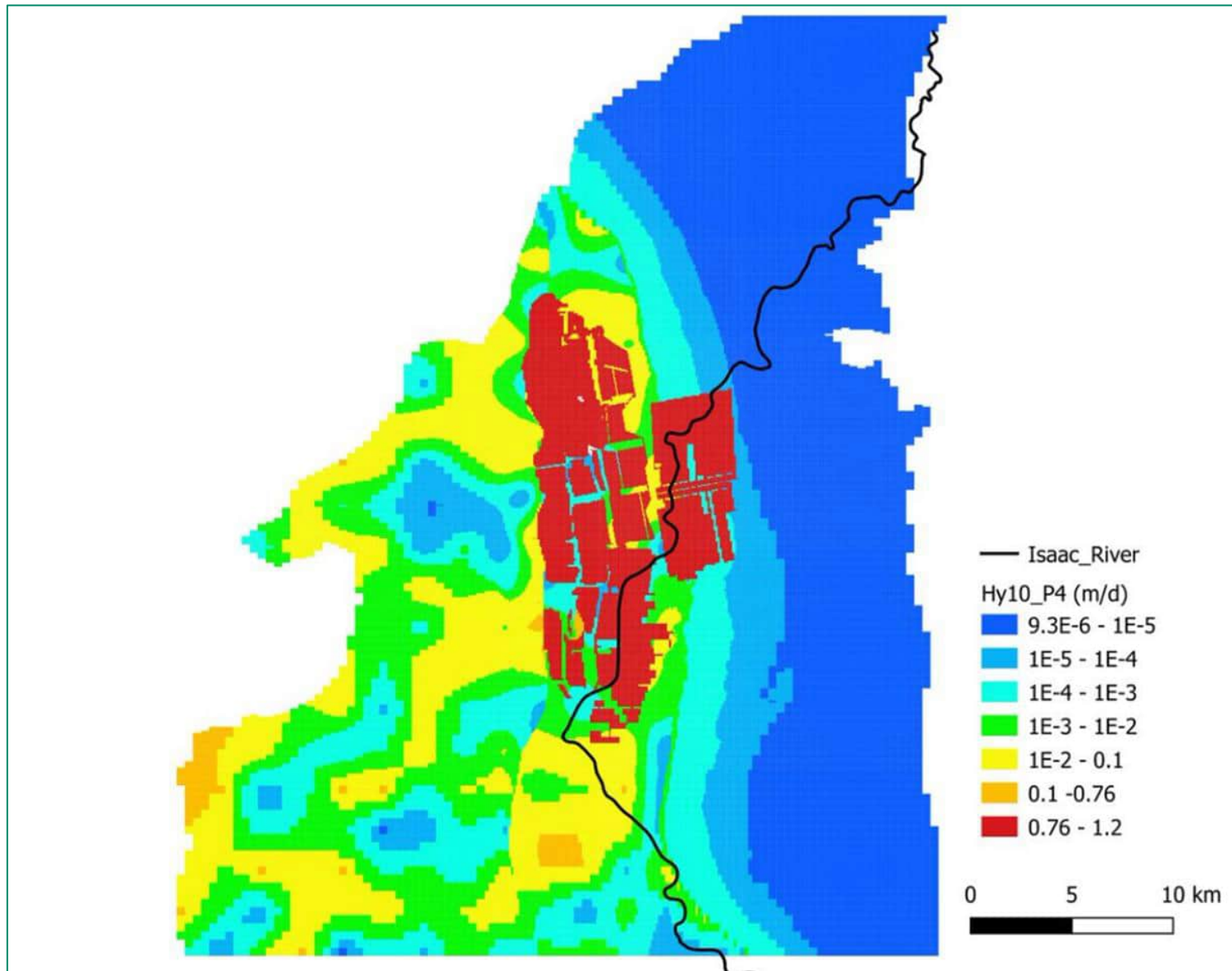


Figure 33 Hydraulic conductivity within the GLS model layer 12

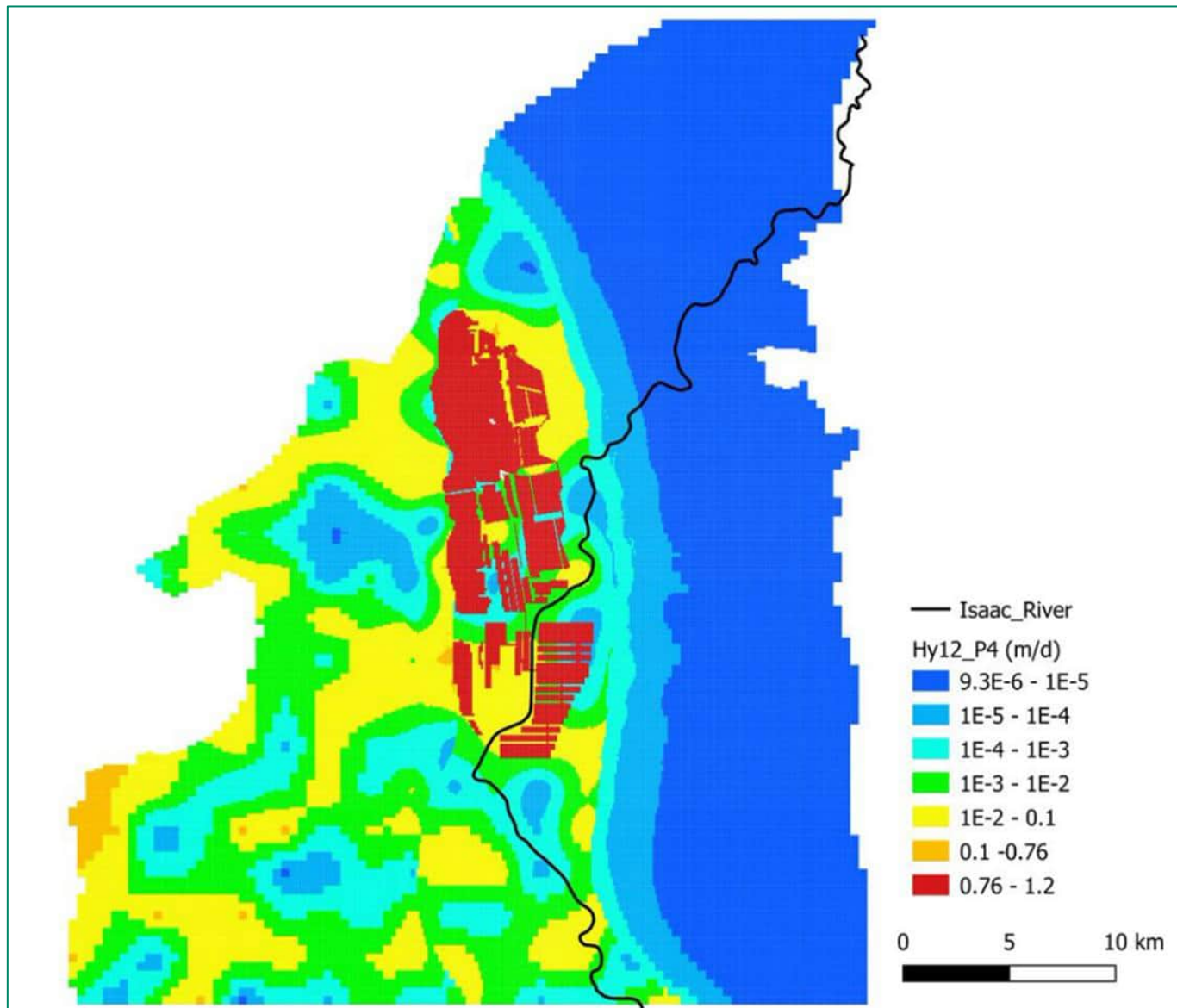
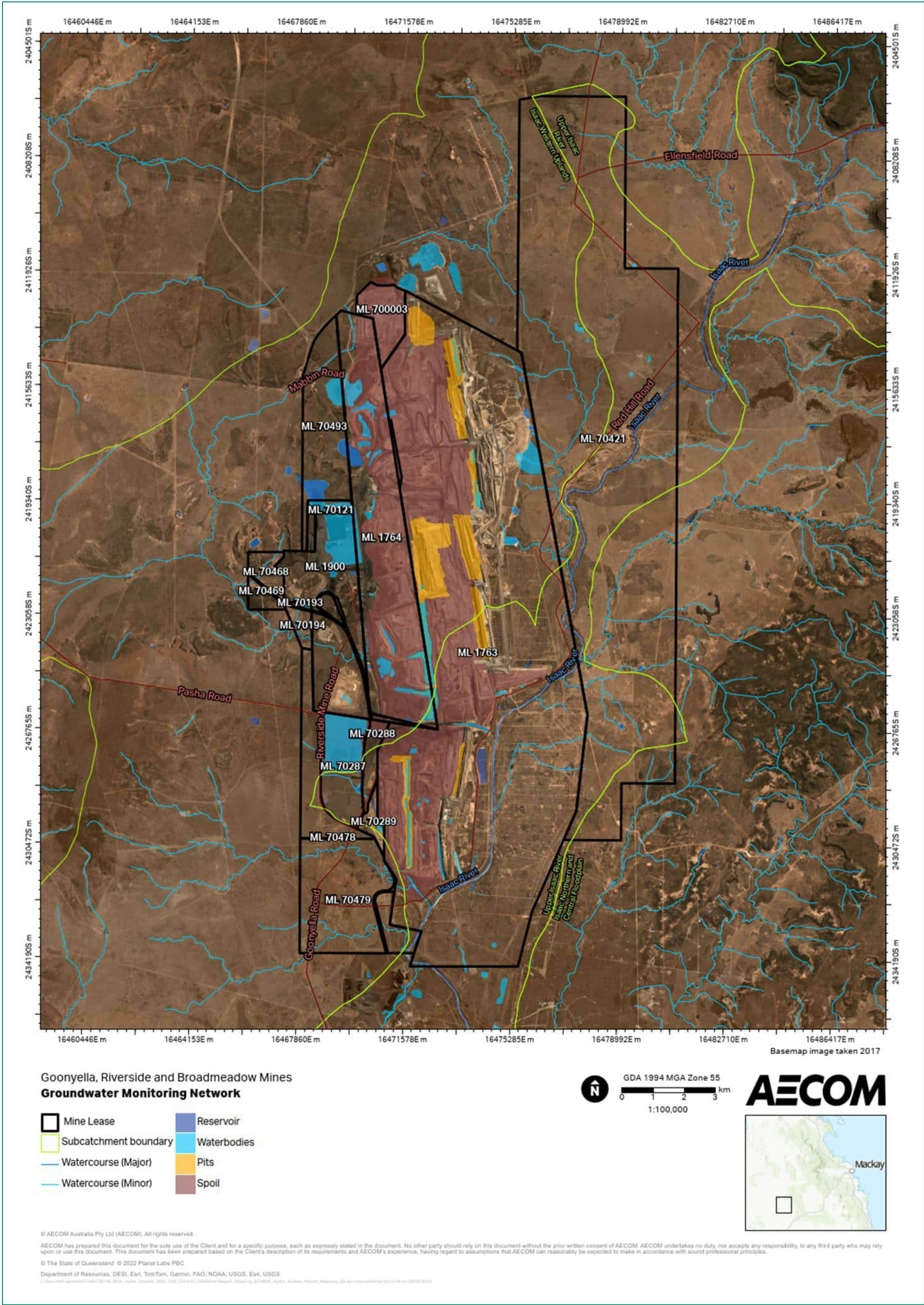


Figure 34 Historic spoil included in the model for the start of predictions in 2024



14.4 Model Water Budget

A model water budget was compiled for the calibration period 2020 to end of 2023 (actual Q1 2024), considering the inflows and outflows from the model.

The resultant model water budget is included in Table 21.

Table 21 Calibration model water budget (2020 to 2023)

Cumulative Volumes	IN (m ³)	OUT (m ³)
Storage	80,040,064	31,753,570
Constant Head	1,715,496	189,055
Drains	0	52,179,584
Recharge	14,250,555	0
Evaporation	0	10,426,460
River leakage	0	1,547,646
TOTALS	96,006,115	96,096,315
IN - OUT	-90,200	
Percent discrepancy	-0.09	

The predictive groundwater model included four different phases of prediction, as discussed in Section 15.0. A model water budget was generated for a predictive run, which included the underground mining and continued open cut mining (at Goonyella Pit). This predictive run, 2024 to 2055, allowed for the evaluation of alluvium recharge (discussed in Section 13.3.6.1) as well as an assessment of in and out flows in the numerical model. These results are included in Table 22.

The percent discrepancy is close to 0% for the calibration water budget and approximately 0.1% for the predictive water budget, indicating good model convergence. The inflow storage (IN storage) is a significant inflow to the groundwater system, contributing a major portion to mining dewatering (drains), which indicates substantial extractions from aquifer storage.

Table 22 Prediction model water budget (2024 to 2055)

Cumulative Volumes	IN (m ³)	OUT (m ³)
Storage	4.46E+08	1.11E+08
Constant Head	8,439,281	999,161.9
Drains	0	3.82E+08
Recharge	90,986,808	0
Evaporation	0	47,265,681
River leakage	0	4,635,597
TOTALS	5.45E+08	5.46E+08
IN - OUT	-599,647	
Percent discrepancy	-0.11	

14.5 Model Performance and Limitations

The groundwater modelling was conducted in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), the Murray Darling Basin Commission (MDBC) Groundwater Flow Modelling Guideline (MDBC, 2001) and the released IESC Explanatory Note for Uncertainty Analysis (IESC, 2018). **Note:** These are mostly generic guides and do not include specific guidelines on special applications, such as underground coal mine modelling.

The 2012 Australian Groundwater Modelling Guidelines has replaced the model complexity classification of the previous MDBC guideline by a "model confidence level" (Class 1, Class 2, or Class 3 in order of increasing confidence) typically depending on:

- Available data (and the accuracy of that data) for the conceptualisation, design and construction.
- Calibration procedures that are undertaken during model development.
- Consistency between the calibration and predictive analysis.
- Level of stresses applied in predictive models.

The model confidence level for a transitional PRC Plan is not readily identified, as the model will be revised on a regular basis in response to additional data compilation, changes in mine activities and mine schedules, plus ongoing remediation and decommissioning activities and plan changes. It is noted that the 2012 Australian Groundwater Modelling Guidelines state that a Class 2 model may be used for assessing impacts associated with mine dewatering (Barnett et al. 2012).

The subjective qualitative criteria allowing model classification, per Table 2.1 of the 2012 Australian Groundwater Modelling Guidelines is compiled in Table 23. The classification of the PRC Plan model was assessed subjectively by the groundwater modeller and reviewed by a Technical Director level hydrogeologist, whereby:

1. The classification table was subjectively reviewed, and the specialists mutually decided, in their professional opinion, which box most appropriately describes the various characteristics of the model.
2. Thereafter, the assessors assigned an overall classification class for the model based on the characteristics selected, i.e. which class has the most selected characteristics.

The assessment shown in Table 23 indicates that, overall, the PRC Plan (GRB and RHM) groundwater model can be classified as primarily Class 2 using the 2012 Australian Groundwater Modelling Guidelines classification system. This is considered an appropriate level for this transitional PRC Plan context.

The PRC plan model is considered to contain components of Class 1, Class2 and Class 3, which is typical of groundwater models.

Table 23 Groundwater Model Classification Table

Class	Model Characteristics					
	Data		Calibration		Prediction	
1		Few or poorly distributed data points		Not possible		Predictive timeframe >> calibration timeframe
		Unavailable or sparse data in areas of greatest interest		Unacceptable levels of error		Temporal discretisation is different to calibration
		No metered groundwater extraction data	X	Inadequate distribution of data		Transient prediction but steady state calibration
		Remote climate data		Targets incompatible with model purpose		Unacceptable validation
		Little or no useful data on land-use, soils, or river flows and stage elevations				
2	X	Some data but may not be adequate throughout domain	X	Reasonable calibration statistics with errors in parts of the model	X	Predictive timeframe > calibration timeframe
	X	Some metered groundwater extraction data	X	Long-term trends not replicated in all parts of domain	X	Long stress periods compared to calibration
	X	Streamflow and stage measurements are available at some points		Transient calibration not extending to present day		New stresses not in calibration
		Reliable irrigation application data available in part		Weak seasonal replication		Poor validation
				No use of calibration targets compatible with model purpose		
			X	Validation not undertaken		
3		Spatial and temporal distribution of data adequate	X	Scaled RMS error or other calibration statistics are acceptable		Predictive timeframe ~ calibration timeframe
	X	Clearly defined aquifer geometry	X	Long-term trends adequately replicated where important	X	Temporal discretisation in predictive model consistent with transient calibration
		Reliable metered groundwater extraction data		Seasonal fluctuations adequately replicated	X	Similar stresses to those in calibration
	X	Rainfall and evaporation data is available	X	Transient calibration is current		Steady state prediction consistent with steady state calibration
	X	Aquifer testing data to define key parameters	X	Model is calibrated to heads and fluxes		Model validation suggests calibration is appropriate
	X	Good quality and adequate spatial coverage of DEM	X	Key modelling outcomes dataset used in calibration		Steady-state predictions when the model is calibrated in steady-state

Class	Model Characteristics					
	Data		Calibration		Prediction	
		Streamflow and stage measurements are available at many points				
		Reliable land-use and soil-mapping data available				
		Reliable irrigation application data available				

Notes: Based on Table 2.1 of the 2012 Australian Groundwater Modelling Guidelines (Barnett et al. 2012)2.

Grey highlighted cells = model has been subjectively assessed to meet the classification criteria for that Class

15.0 Model Predictions

15.1 Prediction Conditions

As per Section 14.3 the refined numerical groundwater model included initial groundwater conditions based on prior pseudo-steady conditions covering the period from 1996 to 2009 plus the historic mining (2010 to 2019). The model included transient calibration using data from 2020 to 2024.

This allowed for the establishment of groundwater heads (elevations) across the model domain, which included drawdown as a result of active (mine dewatering) and passive (seepage ingress into pits) plus artificial recharge from residual pits which contain or store water.

Examples of the head (elevation) contours, for alluvium, GMS, and GLS (target coal seams), at the start of model predictions are included in Figure 35.

For reference the layout of the head contours across the model domain are as included in Plate 16 and as included below.



15.2 Prediction Periods

To capture the complex interaction between the different mine plans, decommissioning, and injection, activities, as detailed in Table 15 and summarised in Table 17, four distinct periods were included in the predictive modelling.

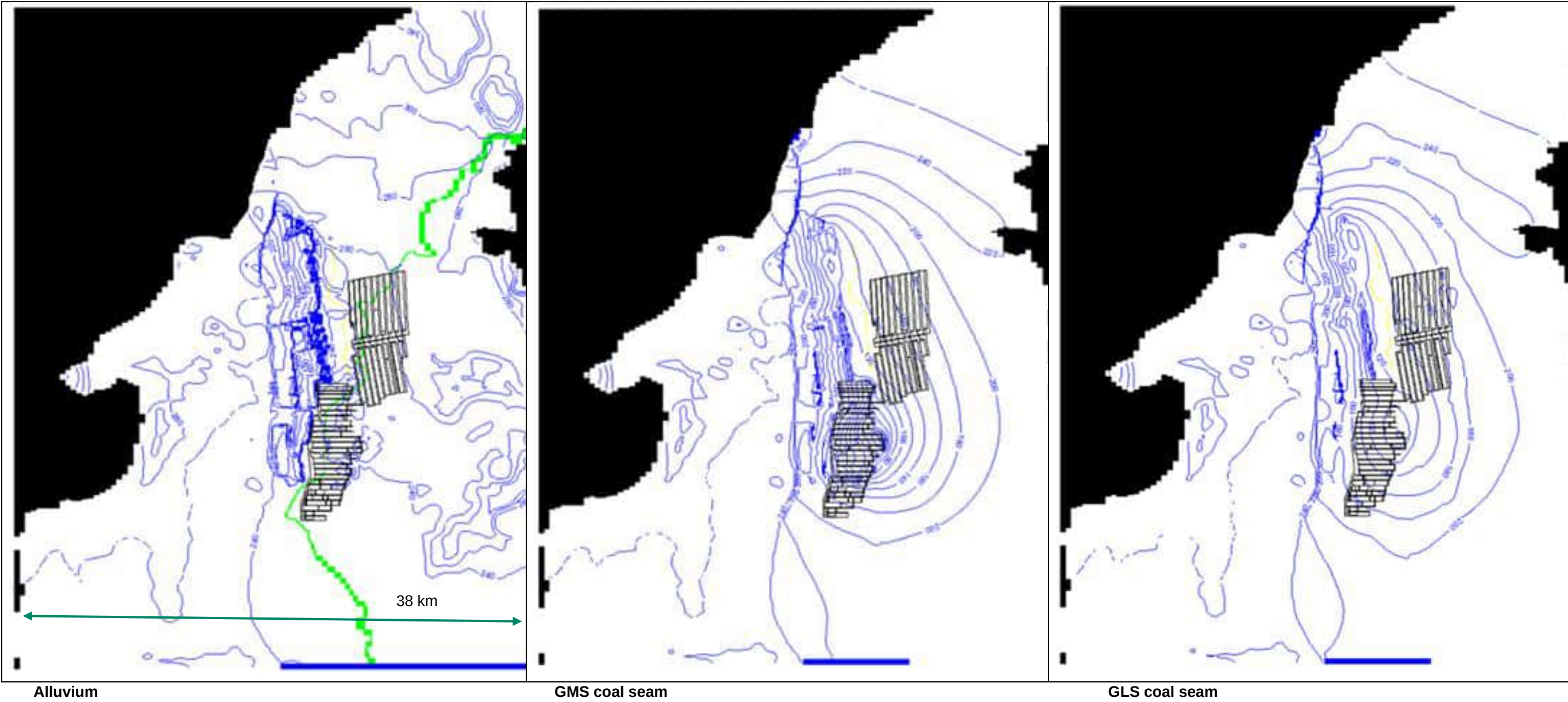
The activities and changes in the model for each prediction period were made to accurately capture:

- The cumulative impacts of the different mining (target seams, schedules, mining methods, and locations).
- The periods of decommissioning and introduction of water into the underground workings.
- The areas and timing of rehabilitation (backfilling of open cuts with spoil).
- The incorporation of residual voids (historic and over time).

The prediction phases are summarised as:

- **Prediction phase 1 (2024 to 2056)**
 - Broadmeadow and Isaac pits (GMS) remain dewatered to facilitate Broadmeadow underground mining (2024 to 2056)
 - Ramp 32 East is mined from 2027 to 2031 (drain model cells then converted to CHD, as per Section 13.3.7)
 - Ramp 32 South is mined up to 2036 and converted to CHD in 2037
 - Thiess Pit is included as CHD from 2024
 - Broadmeadow GMS underground includes historic goaf 2007 to 2023, continues longwall mining to 2031, and then remains dewatered till 2055 (to accommodate GLS underground mining)
 - Broadmeadow GLS underground occurs between 2031 to 2055
 - Broadmeadow GMS and GLS, in 2056, remain dewatered during decommissioning
 - Goonyella pit open cut mining continues (2024 to 2059) and includes historic spoil (2012 to 2023).
- **Prediction phase 2 (2057 to 2060)**
 - 2057, change Broadmeadow GLS underground (2031 to 2055) to goaf (parameters as per Section 7.3.4)
 - 2057, change Broadmeadow GMS underground (2007 to 2031) to goaf
 - 2057, change Goonyella open cut mining (2024-2056) to spoil
 - 2057, drain cells at both Broadmeadow GLS and GMS underground removed (1-yr decommissioning)
 - 3-yr injection into both Broadmeadow GLS and GMS underground workings.
 - Broadmeadow and Isaac pits and Goonyella Pit (GLS) have drain cells and remain dewatered
 - CHD for residual void water levels in Thiess (2057-2060), Ramp 32South (2057-2060), and Ramp 32East (2057-2060).
- **Prediction phase 3 (2061 to 2092)**
 - 2061, change Goonyella open cut mining (2057 to 2059) to spoil
 - 2061, CHD included in Broadmeadow, Isaac, Thiess, Ramp 32 East, Ramp 32 South (2061-2092) pits
 - 2063 to 2091, Red Hill Mine mining (drain cells) included, finishing in 2091, Goonyella pit remains dewatered to facilitate RHM mining
 - 2092, Red Hill Mine completion year, stay dewatered during decommissioning.
- **Prediction phase 4 (2093 to 2199)**
 - 2093, 1-year decommissioning (drain cells in RHM removed, only Goonyella pit remain), change RHM to goaf (parameters as per Section 7.3.4)
 - Drain cells in Goonyella pit (2093-2096)
 - CHD in Broadmeadow, Isaac, Thiess, Ramp 32 East, Ramp 32 South (2093-2199)
 - CHD in Goonyella Pit (2097 to 2199)
 - 2094 to 2096, 3-years injection into RHM
 - 2097 to 2199 all mining activities ceased, recovery period.

Figure 35 Groundwater elevation contours, in mAHD, at the start of predictive modelling (2024)



Green model cells depict the Isaac River
Yellow model cells depict the Goonyella residual void footprint
RHM mine plan and Broadmeadow GMS mine plan added for reference

15.3 Initial Ingress Estimates

For the closure plan input, the predictive groundwater model aimed to assess groundwater ingress into the mine voids that will remain post-closure. These pits are as included in Section 14.2, to aid in determining closure groundwater conditions. Figure 29 includes the residual voids incorporated in the model set-up as well as the zones.

The estimate of groundwater ingress, adopting drains in all of the residual mine pits, during the entire prediction period/s, allowed for the evaluation of **maximum groundwater extraction** and evaluation of the influence of reinjection, plus input into the residual mine water balance.

The estimates of groundwater ingress, as m³/year, for each pit are included below.

Plate 26 Broadmeadow Pit initial estimates of ingress

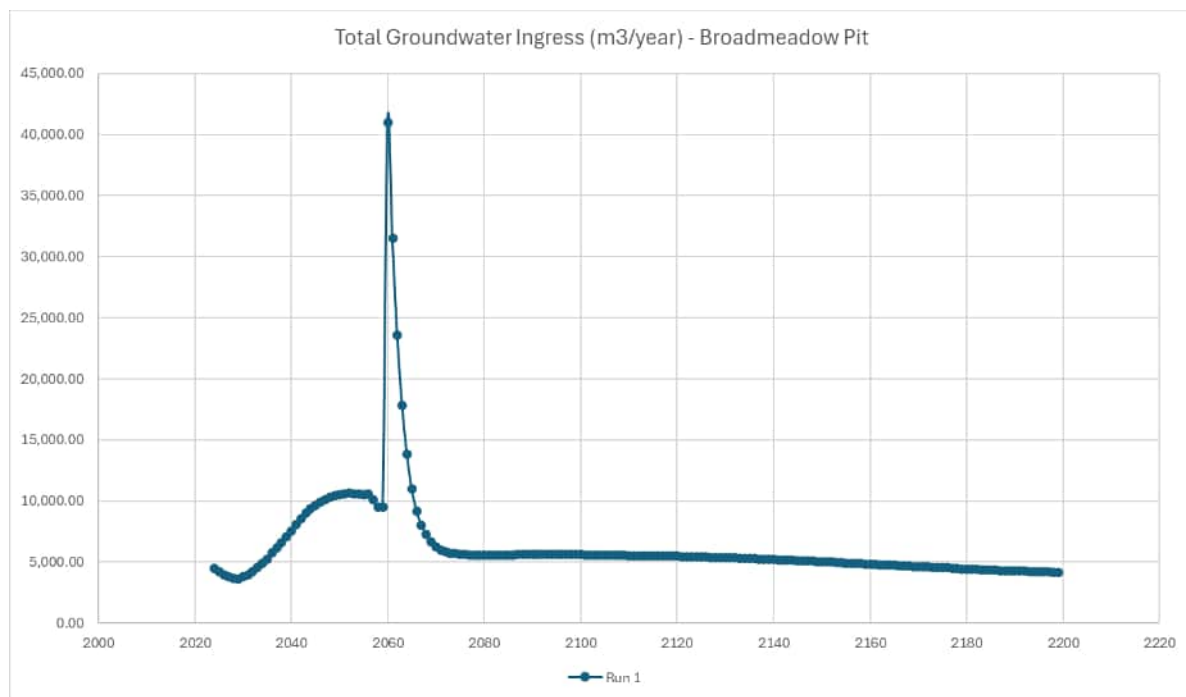


Plate 27 Isaac Pit initial estimates of ingress

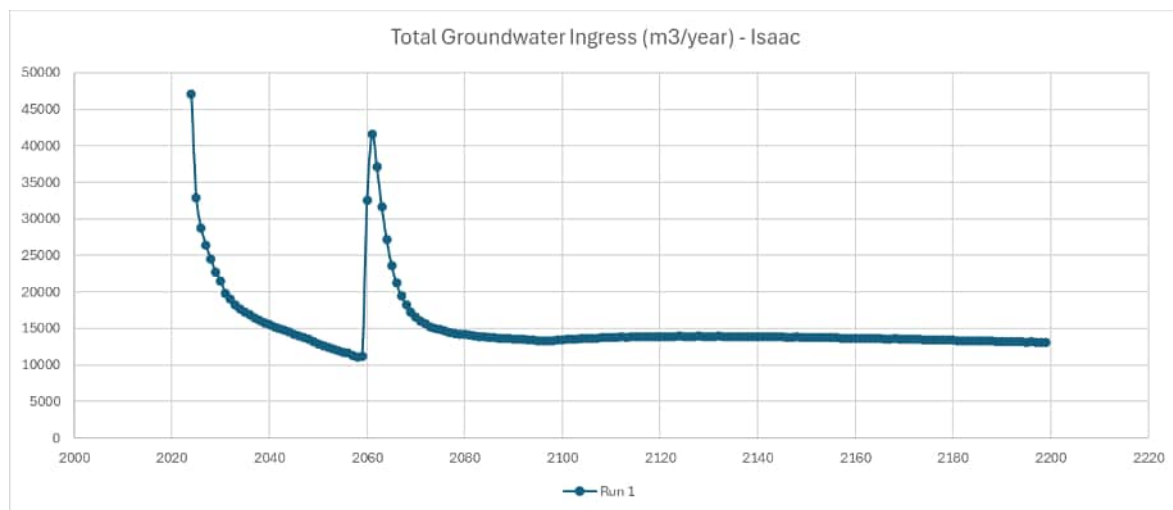


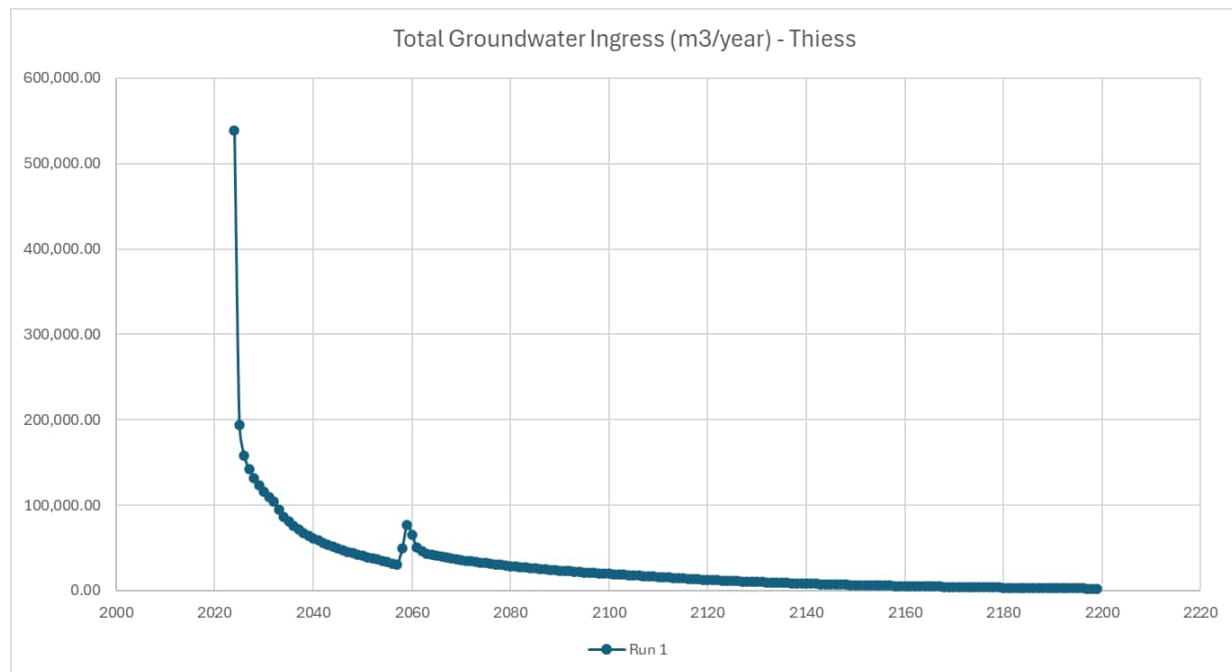
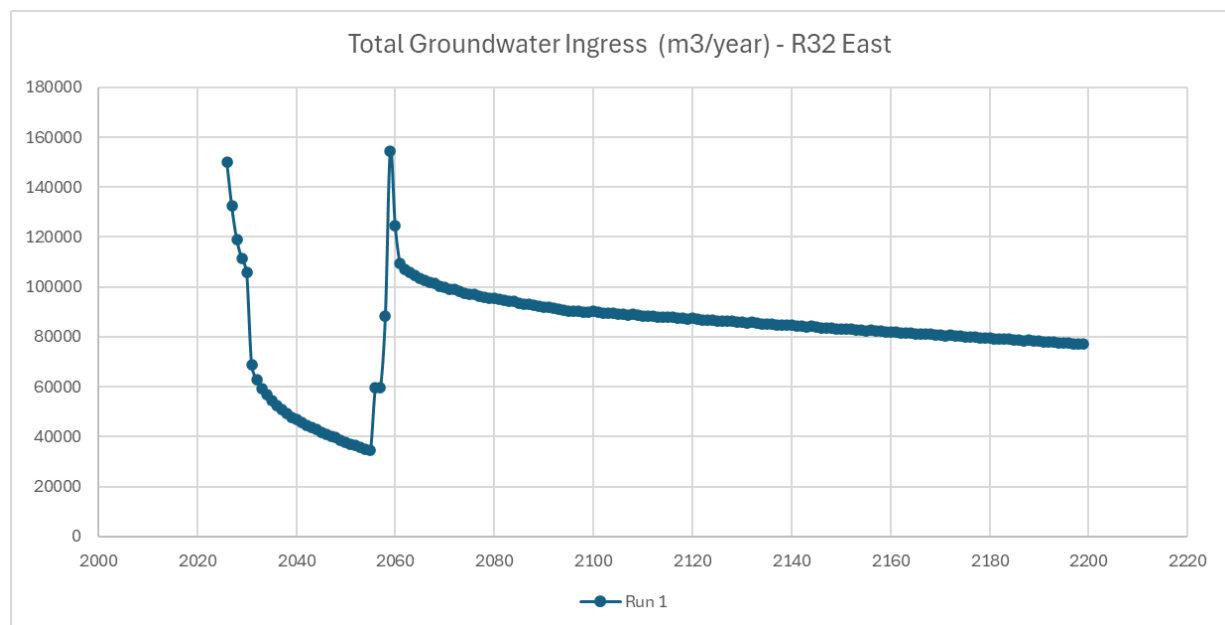
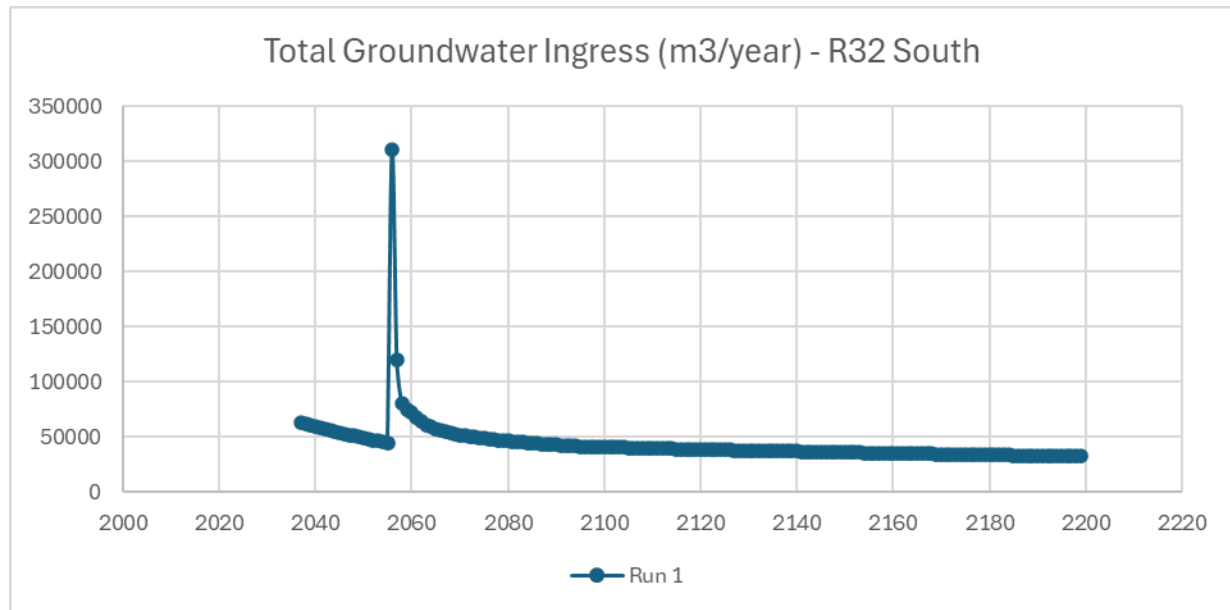
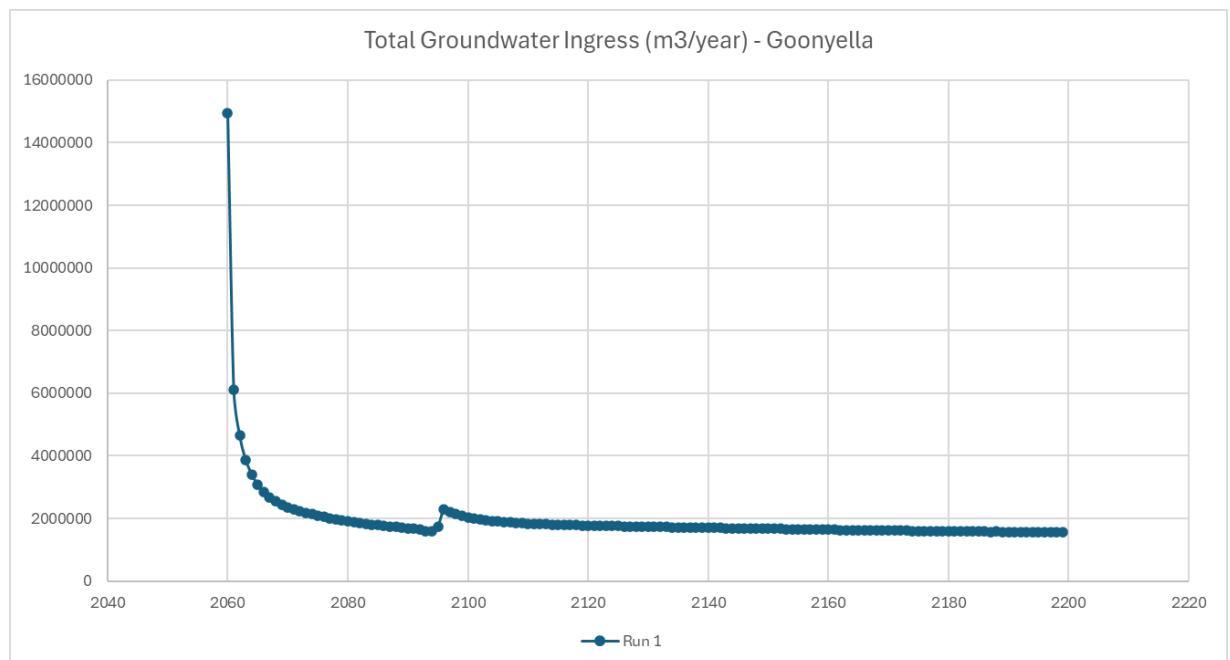
Plate 28 Thiess Pit initial estimates of ingress**Plate 29** Ramp 32 East Pit initial estimates of ingress

Plate 30 Ramp 32 South Pit initial estimates of ingress**Plate 31 Goonyella Pit initial estimates of ingress**

Note: These initial ingress estimates were based on the open cut pits being drained to base of the pits, such that the ingress estimates are based on surrounding groundwater levels and the permeability of the host material containing and adjacent to the open cut pits (where spoil has higher hydraulic conductivity to the natural rock). Thus, these estimates of ingress are maximum expected ingress rates and do not readily compare to the estimates in Section 10.2.

15.4 Integration with Residual Void Water Balance Model

The hydrogeological assessment was provided to the specialists commissioned to undertake the residual void/s water balance modelling.

The approach adopted followed the process detailed in the approach of mining closures compiled in the Review of current approaches to model residual mine voids for rehabilitation planning, technical paper 11 (Tomlin et al, 2023).

The approach consisted of coupled water balance and groundwater models, allowing for the capture and assessment of the key aspects of residual void water balances. The groundwater flow model ingress predictions were used with the surface water balance predictions, as a method referred to as 'quasi-coupling', to predict residual void water levels.

The coupled water balance approach allowed for:

- Iterative approach, which allowed for the refinement of the residual void water levels through including pit water levels in the groundwater model, revising the groundwater ingress rates (m^3/year), which was then used to generate the next set of pit water levels.

Predictions from the transient groundwater flow model includes the use of a high conductance to simulate the 'lake'. This allows for the production of groundwater inflow predictions for the estimation of residual void water elevation (during rebound and to the pseudo-steady state residual void water level).

It is noted that the surface water modelling allowed for the evaluation of climate (rainfall and evaporation) plus runoff on a daily basis across the prediction periods. Due to the large data sets, large groundwater model (117,410 active cells for a fourteen-layer model), and limited variation (groundwater ingress versus surface water contributions reliant on climate), the average annual residual void water levels (derived from the surface water balance modelling) were included in the groundwater modelling.

- Validation stage, the re-running of the groundwater model using the revised set of pit water levels was conducted for four iterations. Once the model simulations closely matched the previous ingress (surface water and groundwater predictions) as reflected in the pit water levels (i.e., converging data) no further iterations were necessary.
- Consistency Between Models – The model outputs exhibited good agreement in terms of water balances, fluxes, and water levels at these interfaces such that the interactions between the two systems were deemed adequately represented.

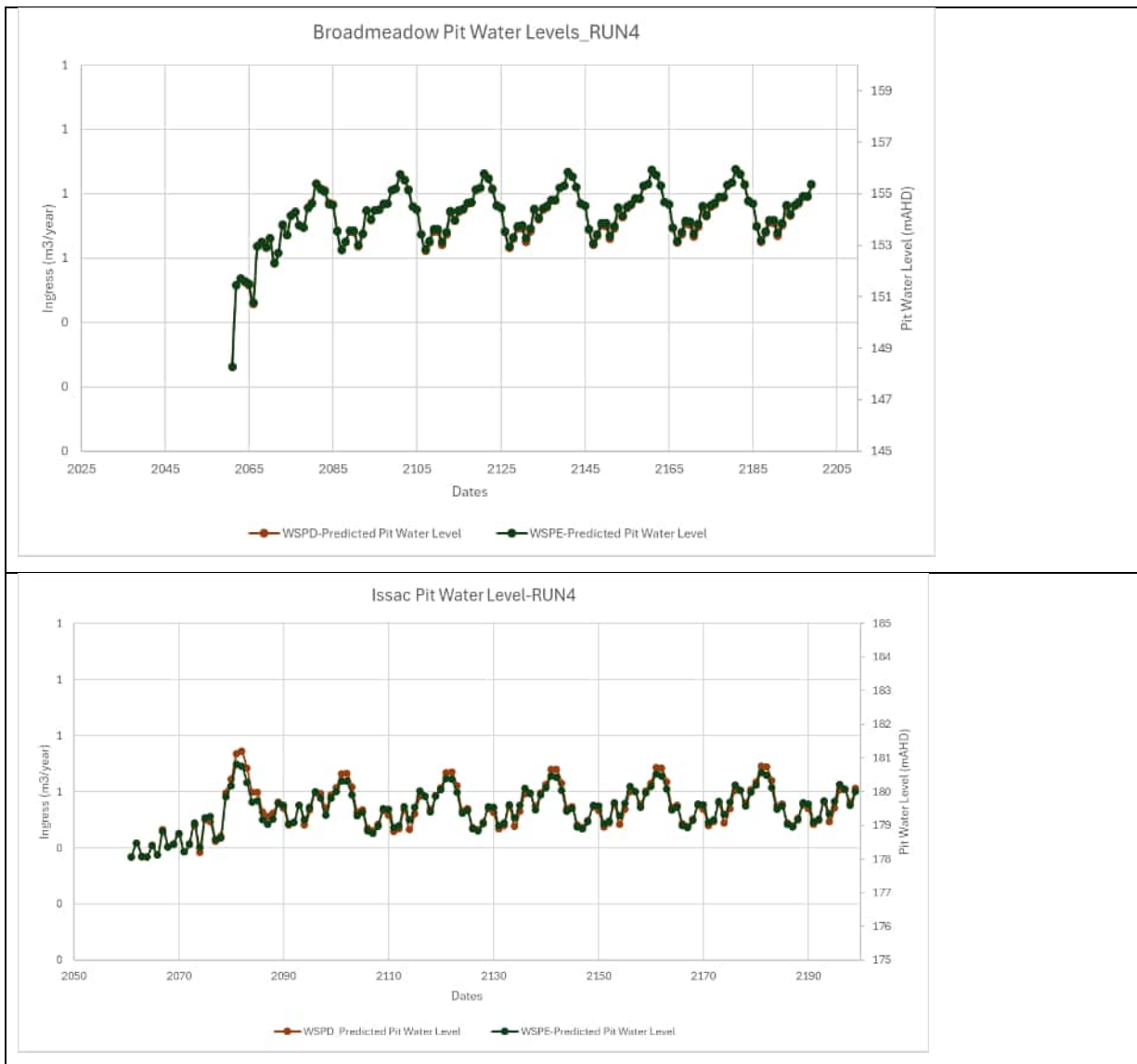
15.4.1 Iterations

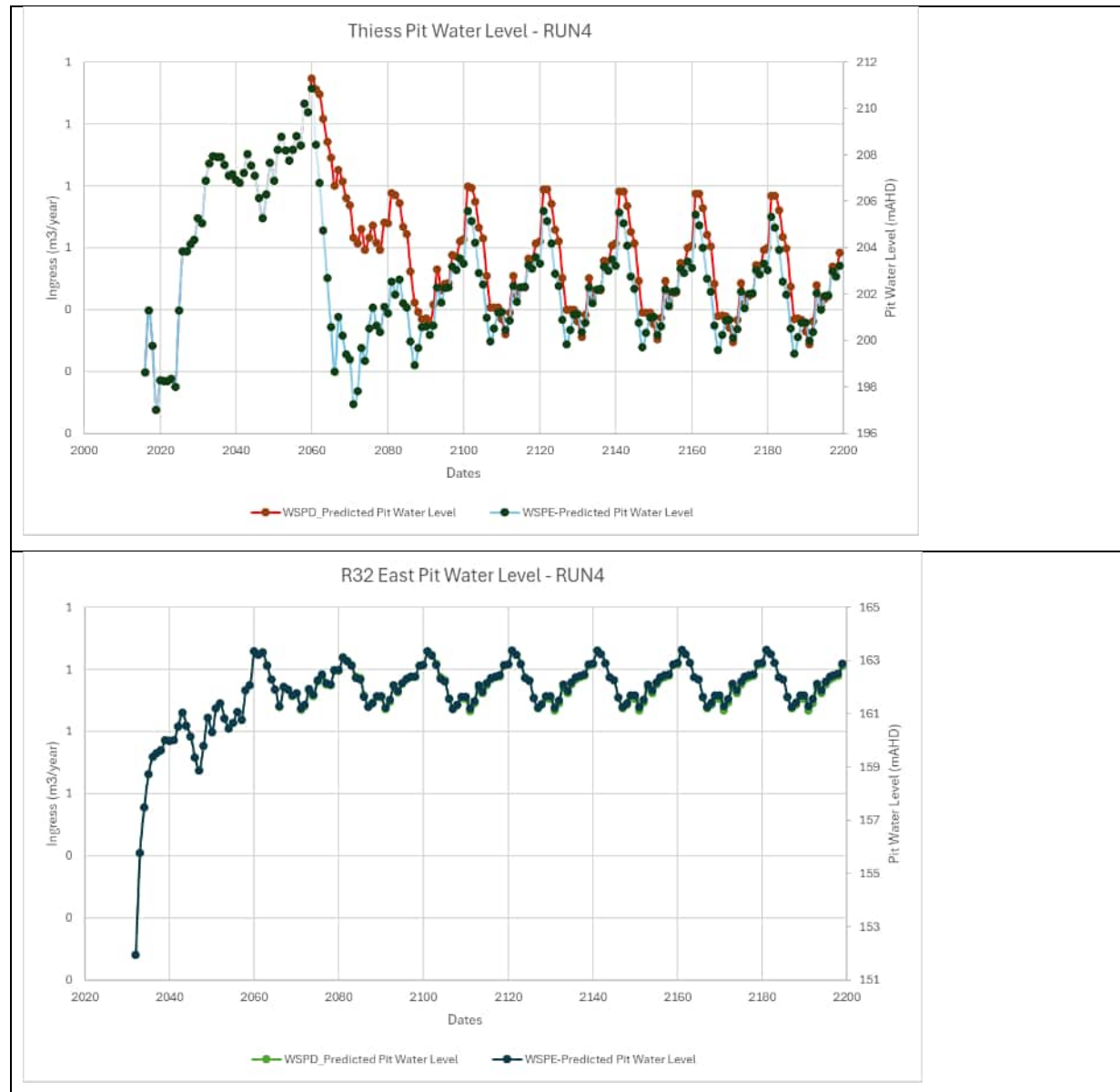
Four iterations of ingress and pit water levels were included in the residual water balance modelling, these included:

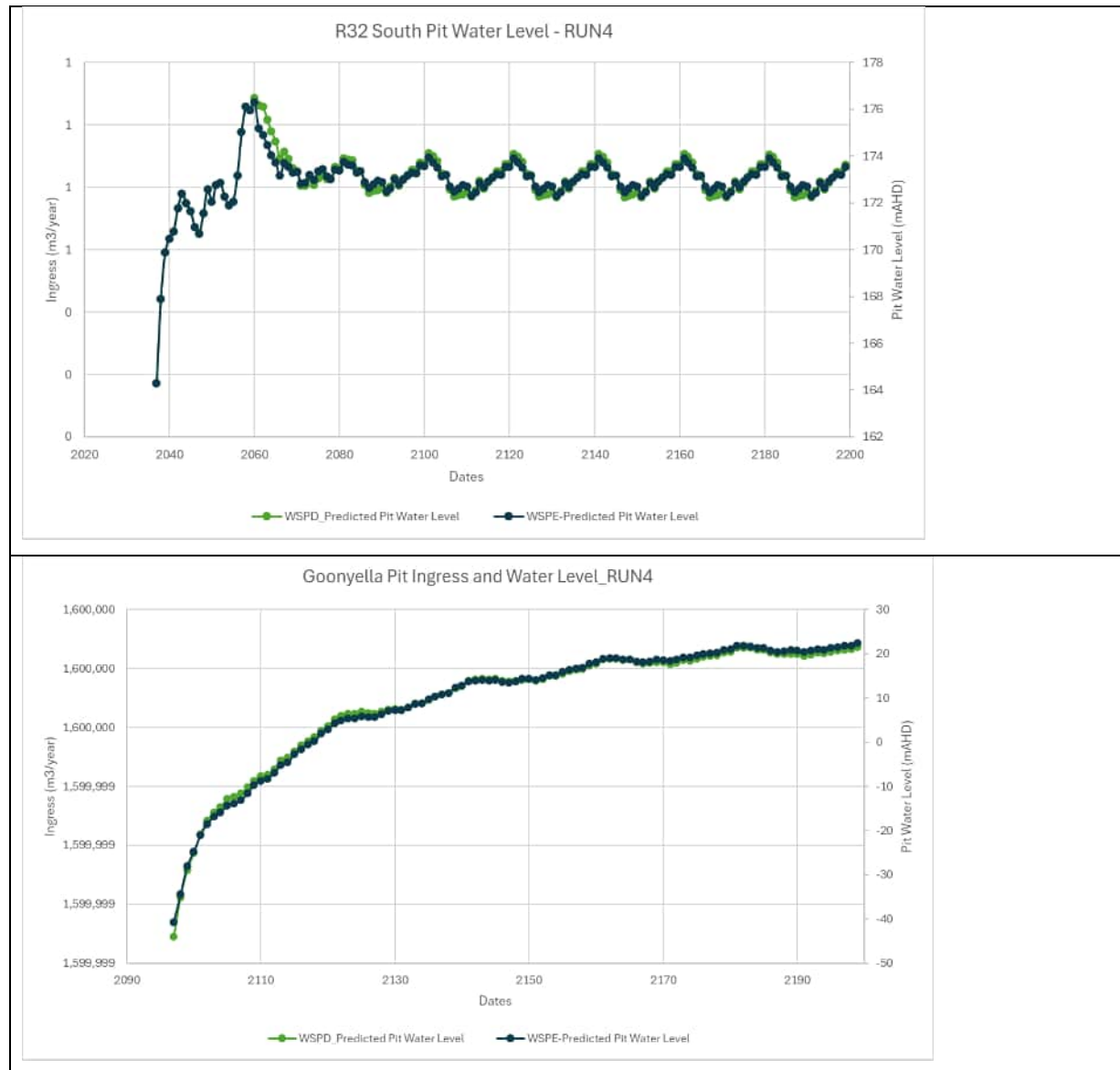
- Pit water levels (Rev A) and groundwater Model Run 1 using drain cells predictions (Section 15.3 data), which produced Pit water levels (Rev B)
- Pit water levels (Rev B) and groundwater Model Run 2 using CHD cells predictions, which produced Pit water levels (Rev C)
- Pit water levels (Rev C) and groundwater Model Run 3 using CHD cells predictions, which produced Pit water levels (Rev D)
- Pit water levels (Rev D) and groundwater Model Run 4 using CHD cells predictions, which produced Pit water levels (Rev E).

The Pit water levels Rev D and Rev E were closely matched, as included below (Plate 32).

Plate 32 Residual void water levels Rev D and Rev E







15.4.2 Residual Void Groundwater Inflow

The final predicted groundwater inflows to the residual voids from the groundwater model, using the Model Run 4 predictions. The net groundwater flux into or out of the residual voids, using the Model Run 4 predictions, were assessed using the groundwater model zone budget. This allowed for the evaluation of contribution from (or to) the spoil and natural / unmined geology, as detailed in Section 14.2.

The pit water levels from Rev D / Rev E compared to the groundwater elevation surrounding the residual voids determined the flow direction in or out of the surrounding saturated hydrostratigraphic units, including the spoil (installed to GMS or GLS depending on the historic mining).

It is noted that the residual void water balance modelling included consideration of wet, dry and mid climate conditions on a daily basis. The groundwater modelling adopted the average residual void levels from these three climate condition simulations. This approach, plus undertaking uncertainty analysis (Section 16.0), was adopted for the ingress predictions. This was done due to:

- The large groundwater model domain
- Long prediction periods,

- Complex alteration of the model to match mining activities during each prediction period.

Thus, the groundwater model (zone budget) provided annual groundwater flux estimates in or out of the different zones (spill, natural geology, etc.).

15.4.2.1 Broadmeadow Pit

The groundwater model zone budget indicates that ingress into this pit occurs predominantly from the spoil to the west of the pit (refer to Figure 29). Groundwater from the unmined geology to the east (down dip of Broadmeadow Pit) is limited with the potential for pit water to move towards the east (Plate 33).

Initial ingress into the Broadmeadow Pit is related to the change of the pit from drain cells (water level drawdown down to the base of the pit) and then including a CHD to simulate the pit water levels (including fluctuations). This change in the water level relates to the model requiring water from the surrounding model cells to fill the residual voids (from the drain elevation to the CHD residual void level instantaneously in the model) until gradients stabilise. This would occur over time once the mine dewatering ceases, and groundwater and surface water can enter the residual void. This is included in the model to facilitate the assessment of groundwater flux post-closure.

It is noted that ingress from the spoil into the Broadmeadow residual void will occur in perpetuity, driven by evaporation from the residual void. Groundwater from the surrounding natural (unmined) formations will flow into the residual void when groundwater elevations are higher than the residual void water level. Predictions indicate that the pit water will also flow into the natural formation due to lower groundwater levels after mining.

Hydrographs of hypothetical water level observation points in the model were generated to assess the residual void water level and groundwater 100 m up and down dip (west and east) of the Broadmeadow Pit. The full hydrographs, across the entire prediction phases, are included in **Appendix D**.

These water level hydrographs (Figure 36) indicate:

- The hydrographs reflect the mine decommissioning and water introduction activities in P4 prediction period (Section 15.2).
- The residual void water level fluctuates around 154 mAHD
- Groundwater levels in the GMS to the west (up dip) are some 160 mAHD (flow towards the pit)
- Groundwater levels in the GMS to the east (down dip) are some 143.5 mAHD (flow away from the pit).

These data plus groundwater drawdown contours (Section 15.4.3) are considered when evaluating flow path simulations (Section 15.6).

Plate 33 Broadmeadow groundwater flux predictions

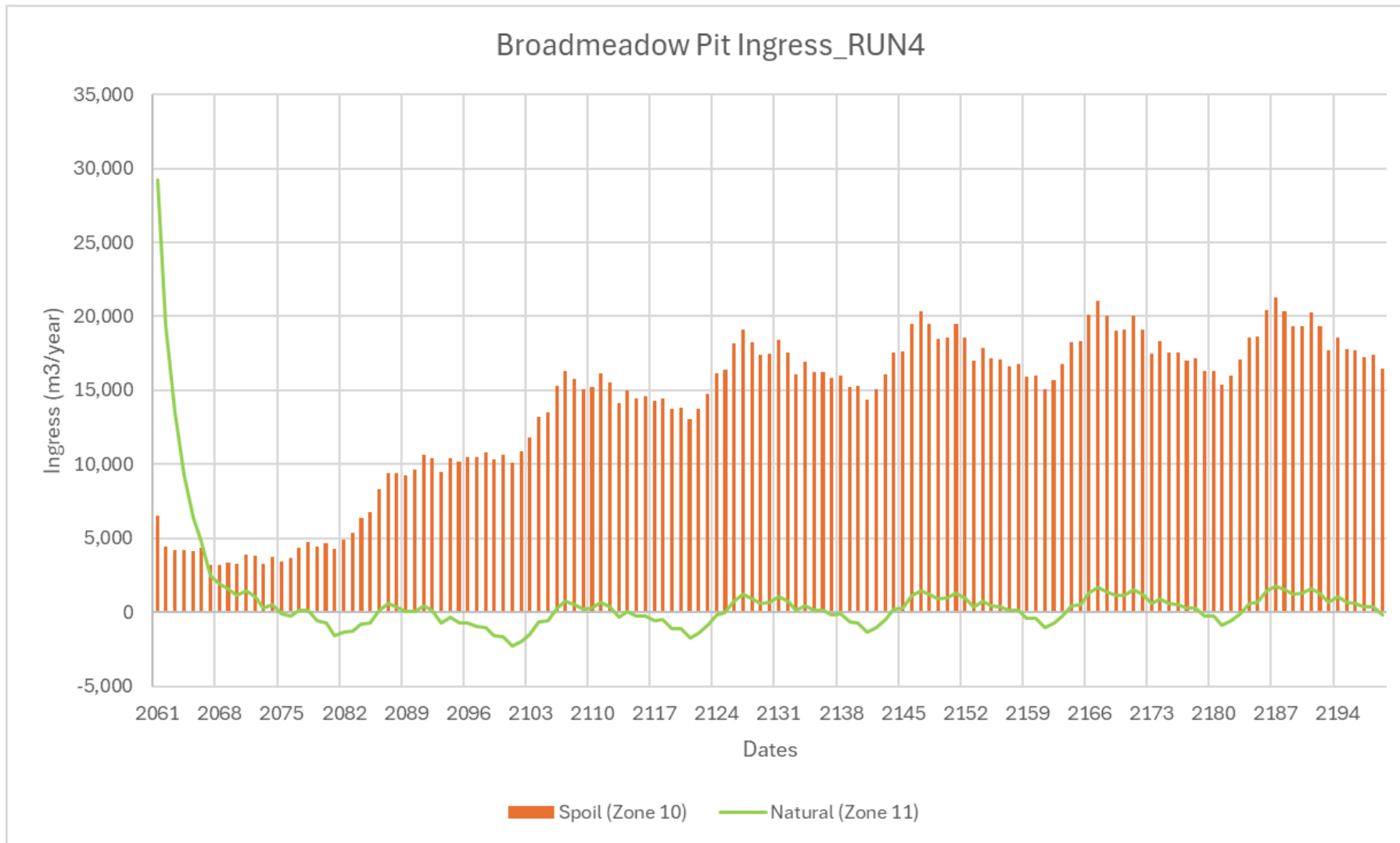
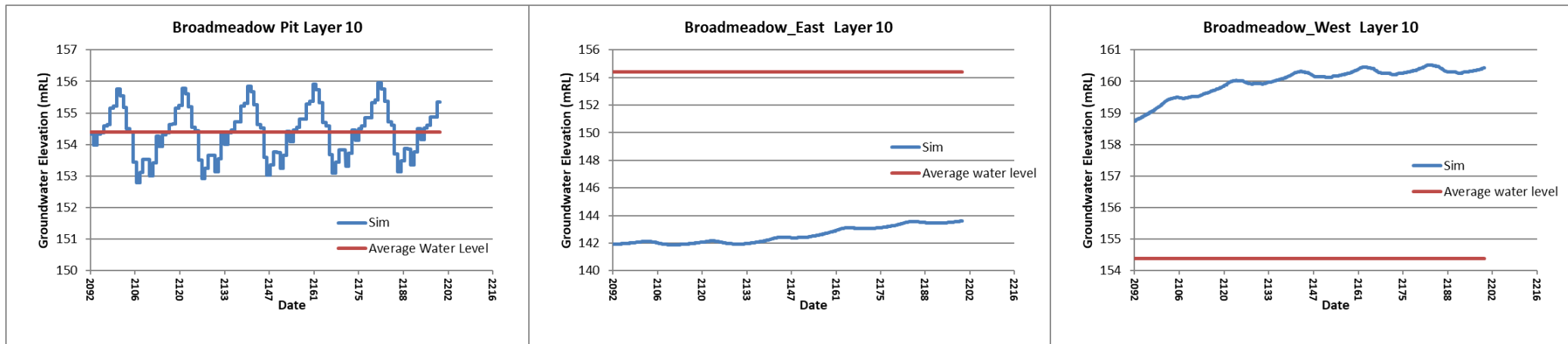


Figure 36 Broadmeadow Pit simulated water level hydrographs (2093 to 2199)

Where:

Broadmeadow Layer 10 provides predictions of residual void water level (red line is the average pit water level for reference)

Broadmeadow_East Layer 10 provides (simulated (sim)) groundwater levels in the GMS seam down dip of Broadmeadow Pit

Broadmeadow_West Layer 10 provides (simulated (sim)) groundwater levels in the GMS seam up dip of Broadmeadow Pit

15.4.2.2 Isaac Pit

The groundwater model zone budget indicates that water from within Isaac Pit flows into both the spoil to the west of the pit and the natural surrounding units (Plate 34). Groundwater flux into the pit is minimal and no ingress from the unmined geology to the east is predicted.

Hydrographs of hypothetical observation points in the model (as per Broadmeadow Pit) were generated to assess the water levels in the pit and in groundwater 100 m up and down dip (west and east) of the pit. These water level hydrographs Figure 37 indicate:

- A pseudo-steady residual void water level of 179.5 mAHD
- Groundwater levels in the GMS to the west (up dip) are some 179.5 mAHD (potential for flow in and out of the pit, albeit net flux is outward)
- Groundwater levels in the GMS to the east (down dip) are some 177 mAHD (facilitating flow outward from the pit).

Plate 34 Isaac pit net groundwater flux predictions

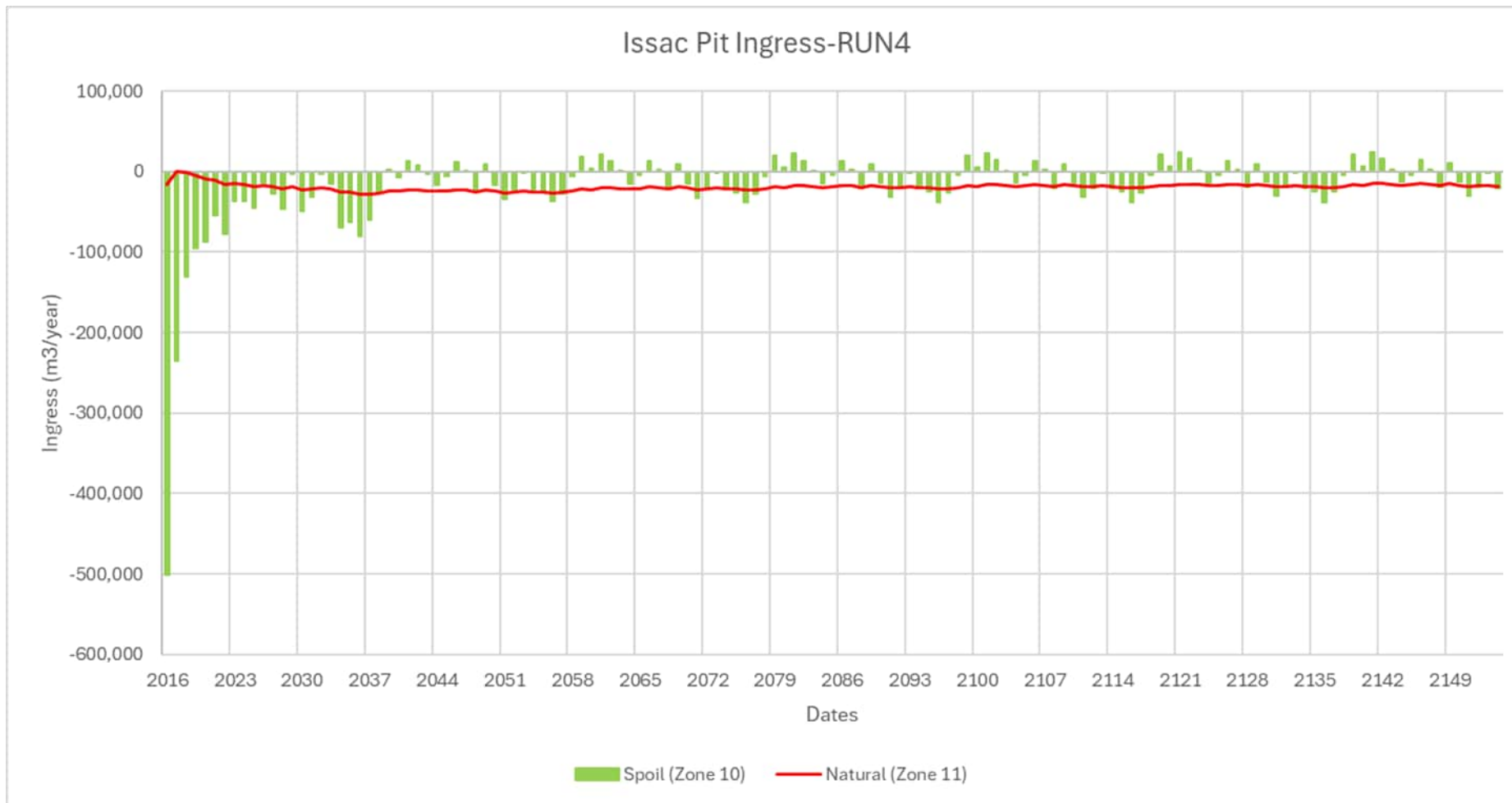
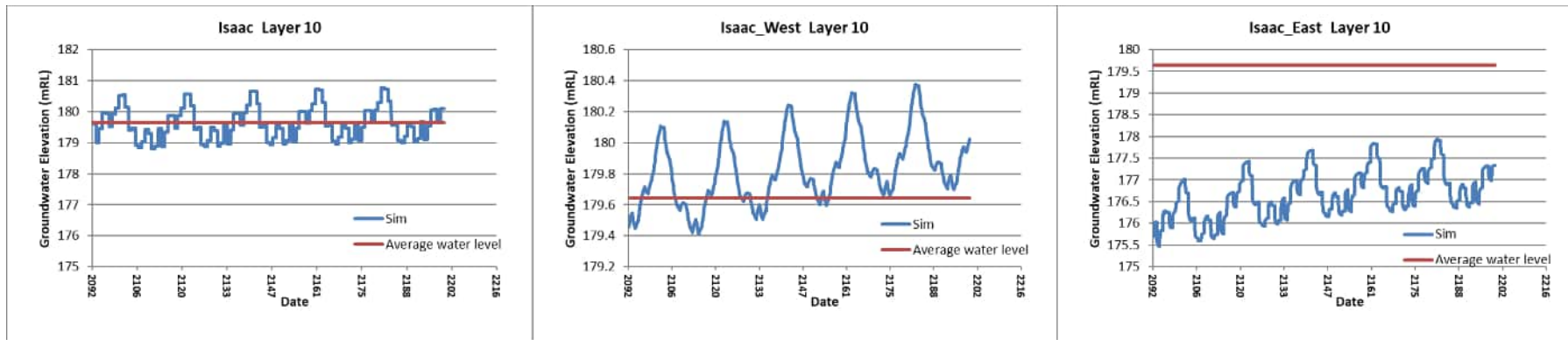


Figure 37 Isaac Pit simulated water level hydrographs (2093 to 2199)

Where:

Isaac Layer 10 provides predictions of residual void water level

Isaac_West Layer 10 provides predicted groundwater levels in the GMS seam up dip of Isaac Pit

Isaac_East Layer 10 provides simulated groundwater levels in the GMS seam down dip of Isaac Pit

15.4.2.3 Thiess Pit

The groundwater model zone budget indicates that water from within this pit flows into both the spoil to the west (up dip) of the pit and the surrounding natural units (Plate 35). Groundwater flow into the pit is minimal and no ingress from the unmined natural geology to the east is predicted.

Hydrographs of hypothetical observation points in the model were generated to assess the groundwater elevations 100 m up and down dip (west and east) of the pit and pit water levels. Due to the large extend of Thiess Pit, three locations along the large pit were selected for the inclusion of hypothetical observation points were included in the model to obtain simulated water level data. These water level hydrographs Figure 38 indicate:

North

- Pseudo-steady residual void water level at 203 mAHD
- Groundwater levels to the west (up dip) are some 201 mAHD (facilitating flow out of the pit)
- Groundwater levels to the east (down dip) are some 203 mAHD (flow in and out of the pit albeit net flux is outward).

Central

- Pseudo-steady water level in the residual void is predicted to be around 203 mAHD
- Groundwater levels to the west (up dip) are some 193 mAHD (facilitating flow out of the pit)
- Groundwater levels to the east (down dip) are some 192 mAHD (facilitating flow out of the pit).

South

- Pseudo-steady water level in the residual void is predicted to be around 203 mAHD
- Groundwater levels to the west (up dip) are some 194 mAHD (facilitating flow out of the pit)
- Groundwater levels to the east (down dip) are some 187 mAHD (facilitating flow out of the pit).

Plate 35 Thiess pit net groundwater flux predictions

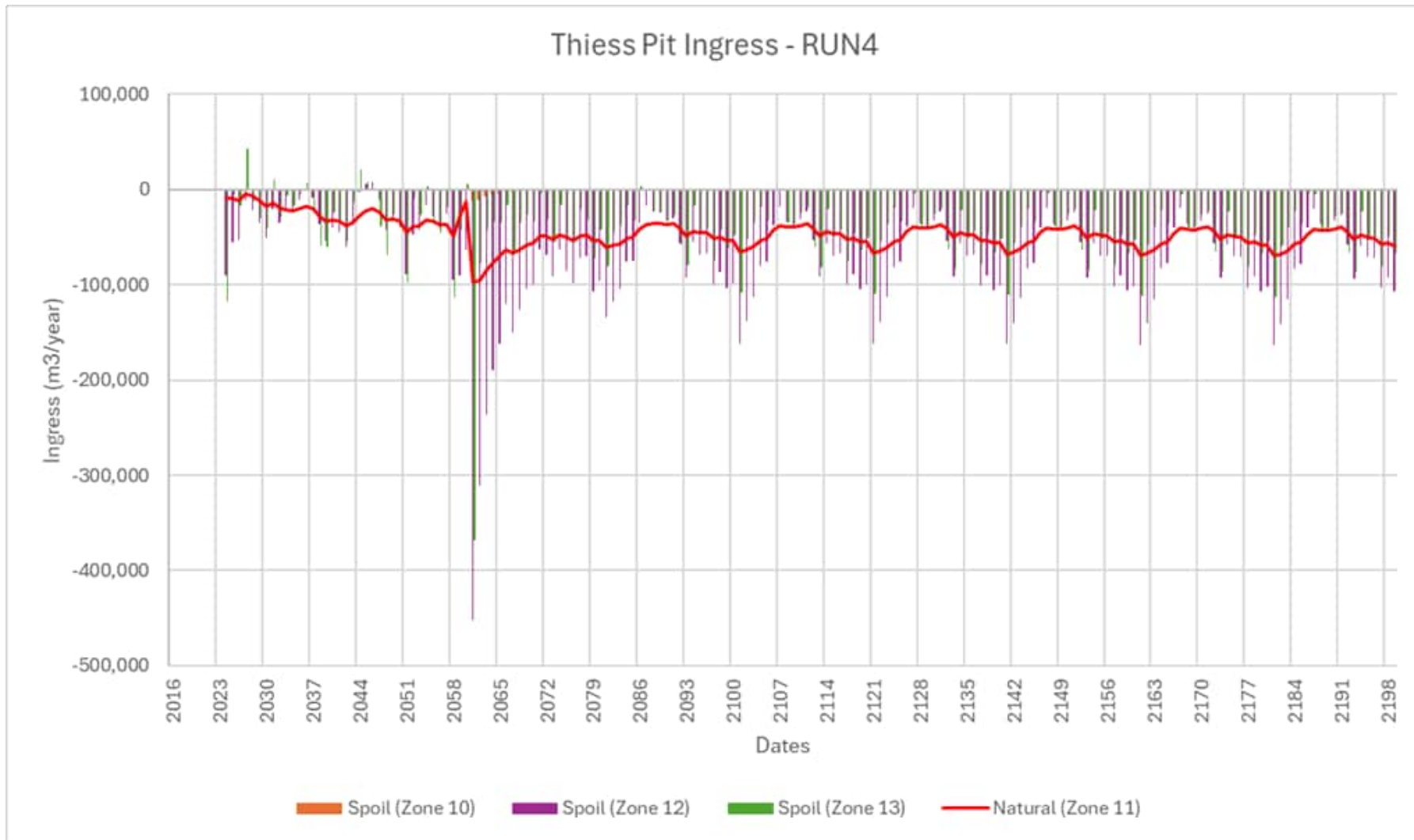
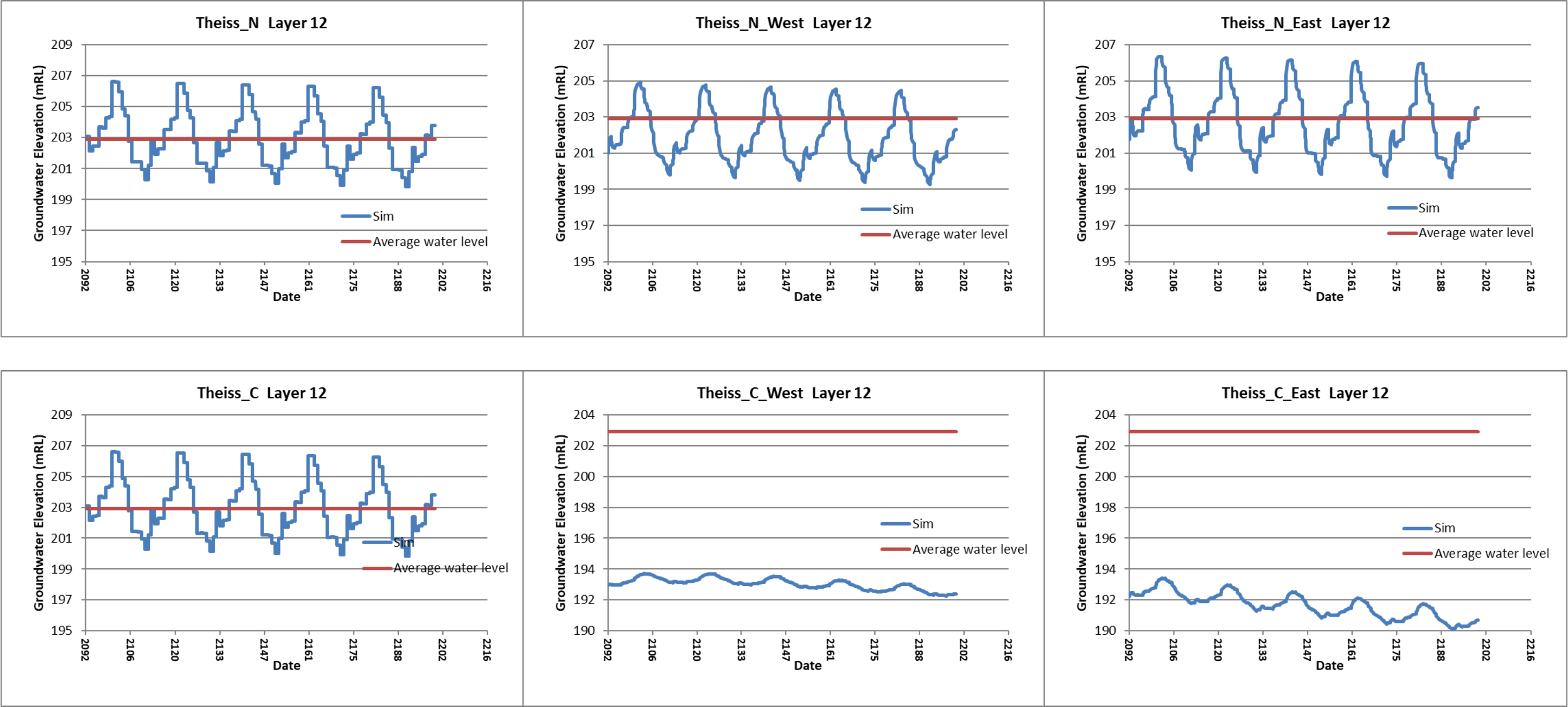
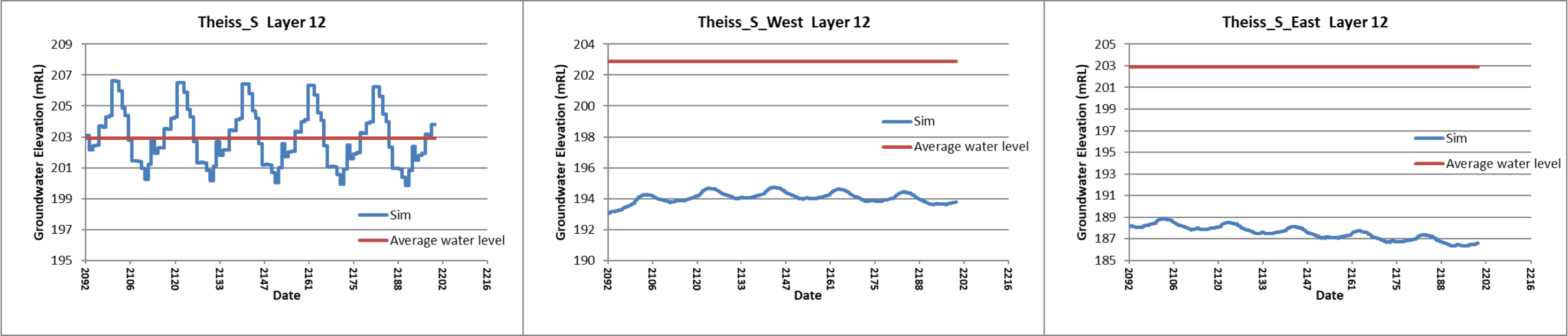


Figure 38 Thiess Pit hydrographs (2093 to 2199) north, central and south





Where:
Theiss N, Theiss C, and Theiss S provide predictions of residual void water level in the north, central, and southern portions of Thiess Pit, respectively
Theiss N West, Theiss C West, and Theiss S West Layer 12 provides predicted groundwater levels in the GLS seam up dip of Thiess Pit in the north, central, and southern portions of Thiess Pit, respectively
Theiss N East, Theiss C East, and Theiss S East Layer 12 provides predicted groundwater levels in the GLS seam down dip of Thiess Pit in the north, central, and southern portions of Thiess Pit, respectively

15.4.2.4 Ramp 32 East Pit

The groundwater model zone budget indicates that this pit acts as a groundwater “sink”, where groundwater from the surrounding natural rock flows into the residual void (Plate 36). Groundwater out of the pit is minimal and no ingress from the surrounding spoil is predicted.

Hydrographs of hypothetical observation points in the model were generated to assess the water levels in the pit and 100 m up and down dip (west and east) of the pit. These water level hydrographs Figure 39 indicate:

- Pseudo-steady water level in the residual void is predicted to be around pit water 162 mAHD
- Groundwater levels to the west (up dip) are some 169 mAHD (facilitating flow into the pit)
- Groundwater levels to the east (down dip) are some 162.5 mAHD (facilitating flow into the pit).

Plate 36 Ramp 32 East pit groundwater flux predictions

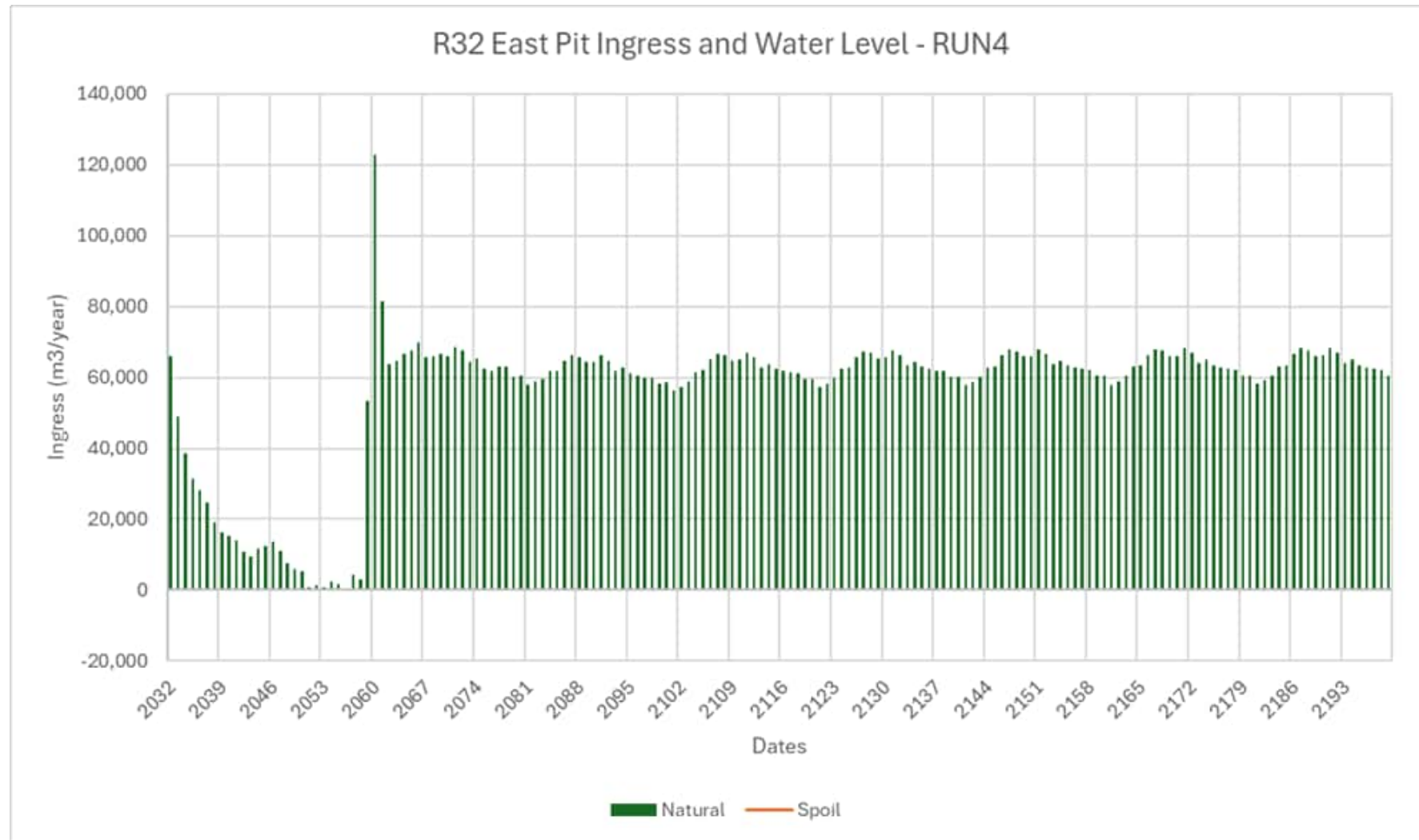
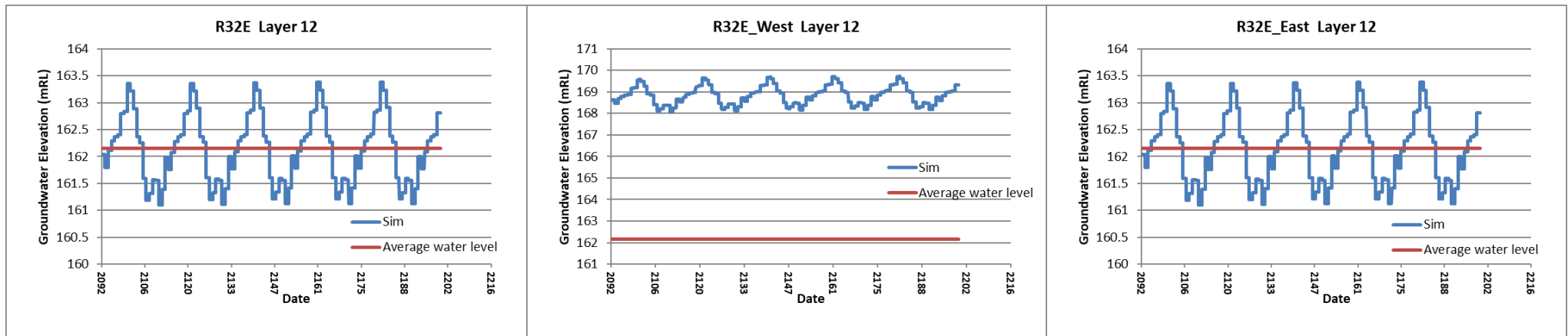


Figure 39 Ramp 32 East Pit hydrographs (2093 to 2199)

Where:

R32E Layer 12 provides predictions of Ramp 32 East residual void water level

R32E_West Layer 12 provides predicted groundwater levels in the GLS seam up dip of Ramp 32 East Pit

R32E_East Layer 12 provides simulated groundwater levels in the GLS seam down dip of Ramp 32 East Pit

15.4.2.5 Ramp 32 South Pit

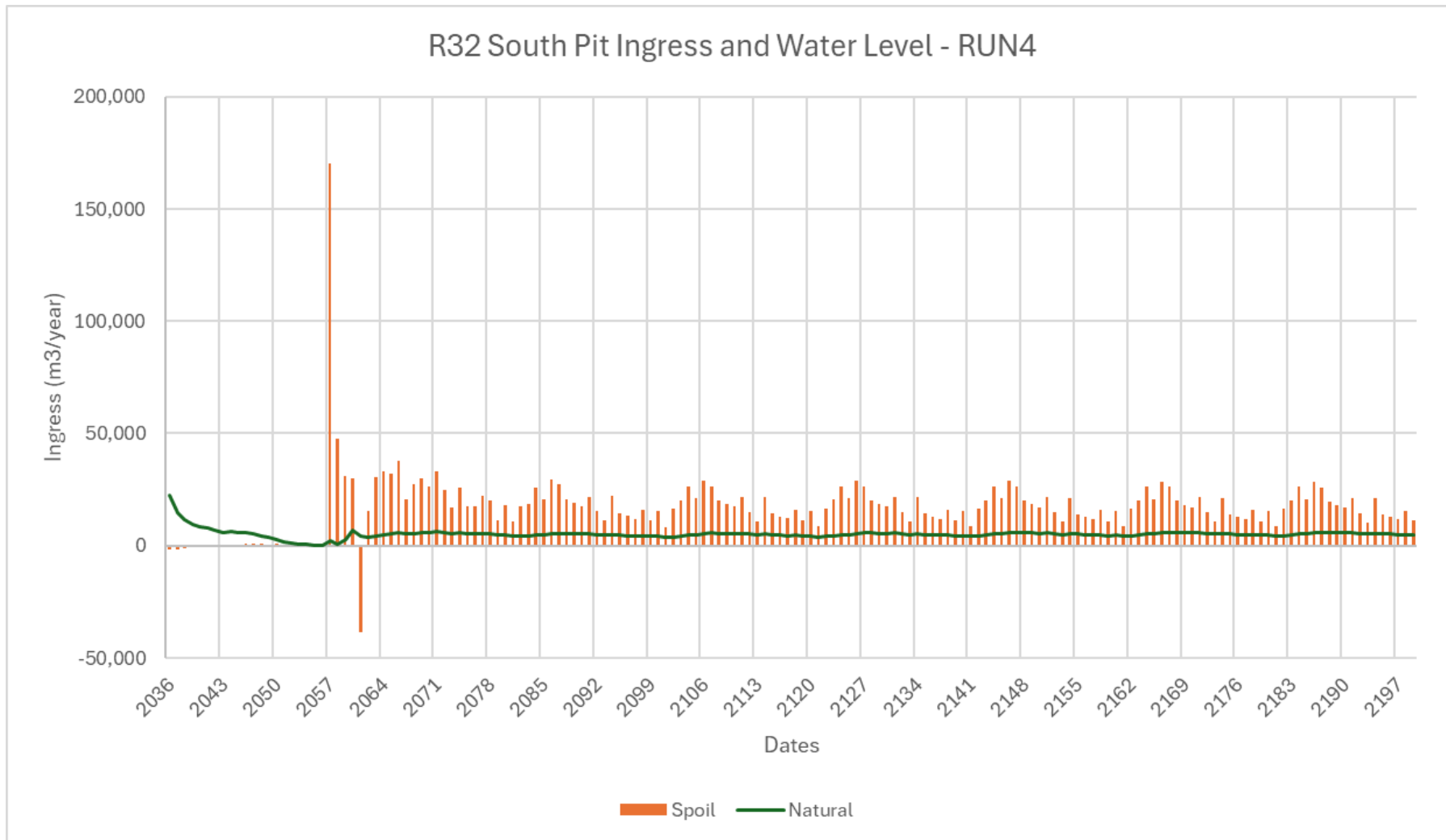
The groundwater model zone budget indicates that this pit acts as a groundwater “sink”, where groundwater from the surrounding natural rock flows into the residual void (Plate 37). Groundwater flow out of the pit is limited with ingress from the surrounding spoil and natural geology predicted.

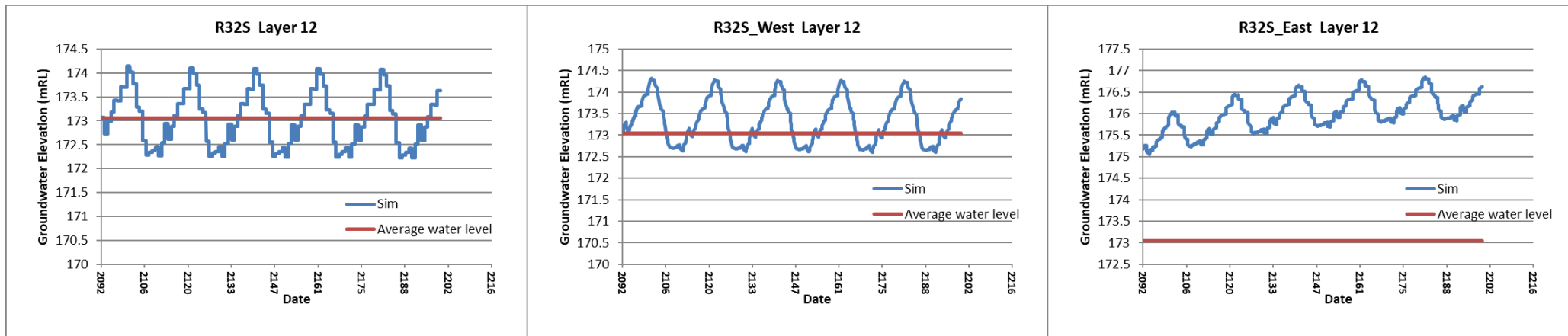
Hydrographs of hypothetical observation points in the model were generated to assess the water elevations in the pit and 100 m up and down dip (west and east) of the residual void.

These water level hydrographs indicate:

- Pseudo-steady water level in the residual void is predicted to be around pit water 173 mAHD
- Groundwater levels to the west (up dip) are some 173.5 mAHD (facilitating flow into the pit)
- Groundwater levels to the east (down dip) are some 176 mAHD (facilitating flow into the pit).

Plate 37 Ramp 32 South pit groundwater flux and hydrographs





Where:

R32S Layer 12 provides predictions of Ramp 32 South residual void water level

R32S_West Layer 12 provides predicted groundwater levels in the GLS seam up dip of Ramp 32 South Pit

R32S_East Layer 12 provides simulated groundwater levels in the GLS seam down dip of Ramp 32 South Pit

15.4.2.6 Goonyella Pit

The residual void at the end of the Goonyella open cut mining extends along the eastern mine lease boundary and includes the deepest mining voids in GRB (some 325 m deep).

The groundwater model zone budget output indicates that this residual void acts as a groundwater “sink”, where groundwater from the surrounding backfilled mine areas, residual voids (where outflow is predicted), and natural rock flow into the Goonyella residual void (Plate 38).

Hydrographs from hypothetical observation points east, west and within the void were generated at regular intervals along the length of the residual void, as indicated in (Plate 39).

All of the water level hydrographs confirm that the Goonyella residual void acts as a groundwater sink and indicate that the pit water (compared to the surrounding groundwater levels) are markedly lower than the water level depths across the Project, as included in the hydrographs above.

North

- Pseudo-steady residual void water level is around 20 mAHD (> 100 m deeper than other residual void water levels)
- Groundwater levels to the west (up dip) are some 22 mAHD (facilitating flow into the pit)
- Groundwater levels to the east (down dip) are some 30 mAHD (facilitating flow into the pit).

Note: The pit floor is some -35 mAHD at this location, the pit floor adopted in the residual void (surface water) water balance model is set at a uniform -45 mAHD (it is assumed that the specialist modellers used the deepest pit floor elevation in their water balance model).

This results in the water level dip or decrease at the start of the water level hydrographs when the groundwater model drain cells (at bottom of pit) are changed to CHD and adopt the predicted water balance model pit water levels (Section 15.4.1). This dip in the water level hydrographs is recognised in all of the hypothetical observation point hydrographs. This is particularly evident in the middle set of hydrographs where the Goonyella open cut mine only extends to a depth of around 25 mAHD in this area (mining is shallower in this area due to environmental constraints in this area).

The predictive groundwater model recovery over the long term allows for the prediction of pseudo-steady state water levels over time. This allows for the evaluation of post-closure conditions (groundwater levels, residual void levels, and groundwater flow patterns). This indicates that the difference in the start (depth of pit water level) does not influence the Goonyella residual void acting as a sink in the long term.

Middle

- Pseudo-steady residual water level is around 20 mAHD
- Groundwater levels to the west (up dip) are some 36 mAHD (flow into the pit)
- Groundwater levels to the east (down dip) are some 27 mAHD (flow into the pit).

Note: The change from actual drawdown in the shallower portion of the Goonyella Pit in this area and the adopting of the CHD to match the residual void water balance pit levels (Section 15.4.1) results in the decrease in water levels to the west and east of the pit, due to sudden dewatering (dropping the level to match the uniform -45 mAHD obtained from the residual void water balance model). This will not occur in reality. As per the statement included above the difference in the start (depth of pit water level) does not influence the Goonyella residual void acting as a sink in the long term.

Plate 38 Goonyella pit groundwater flux

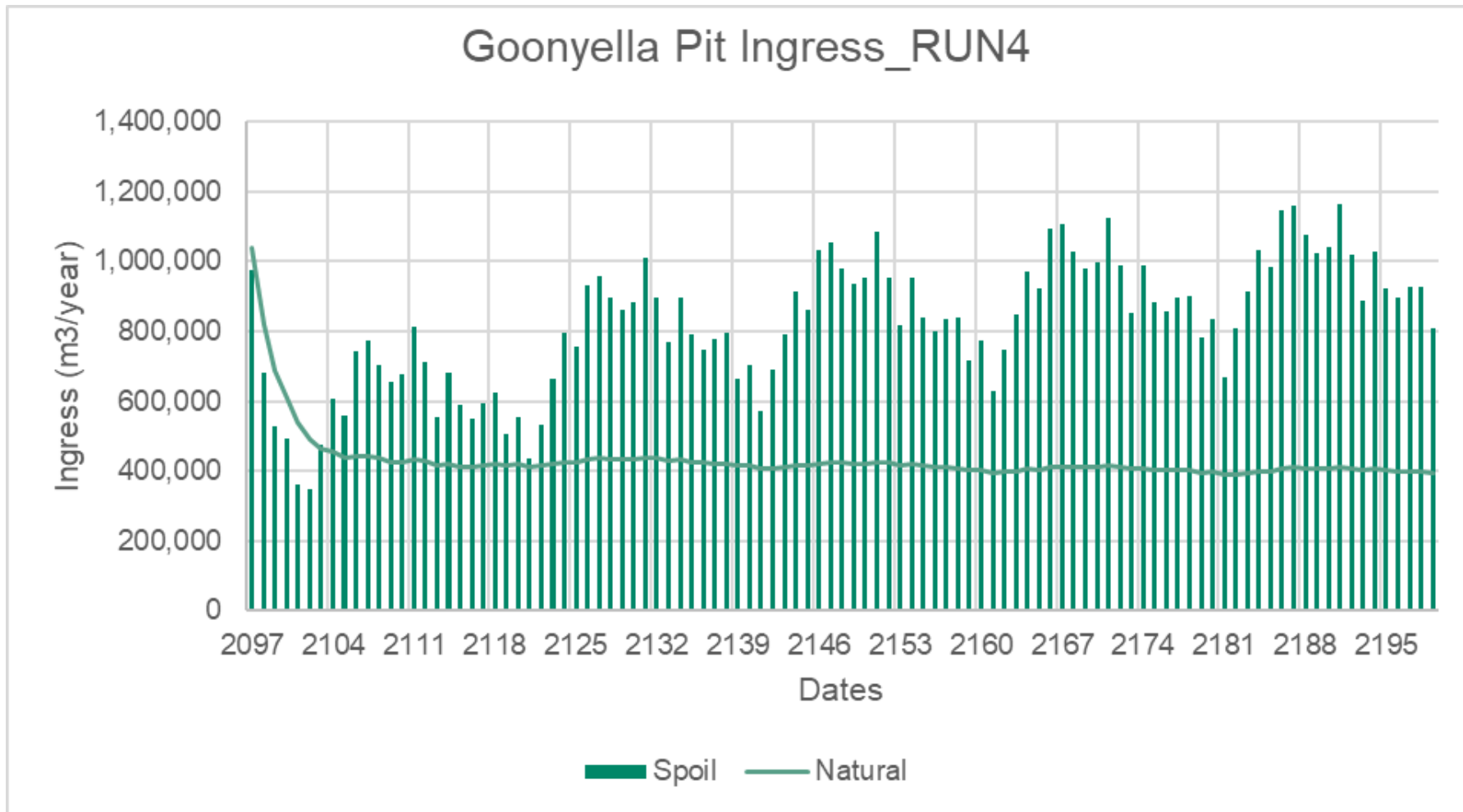
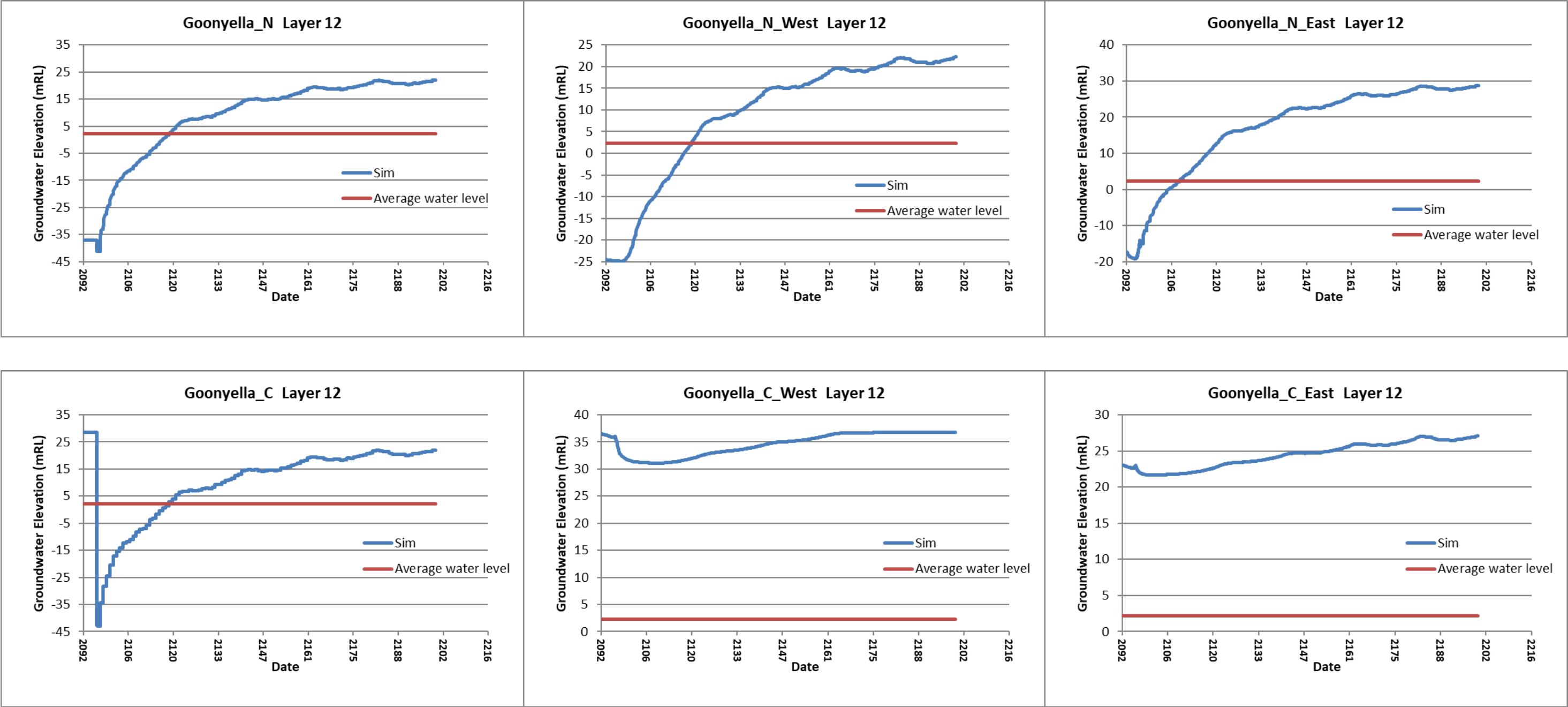
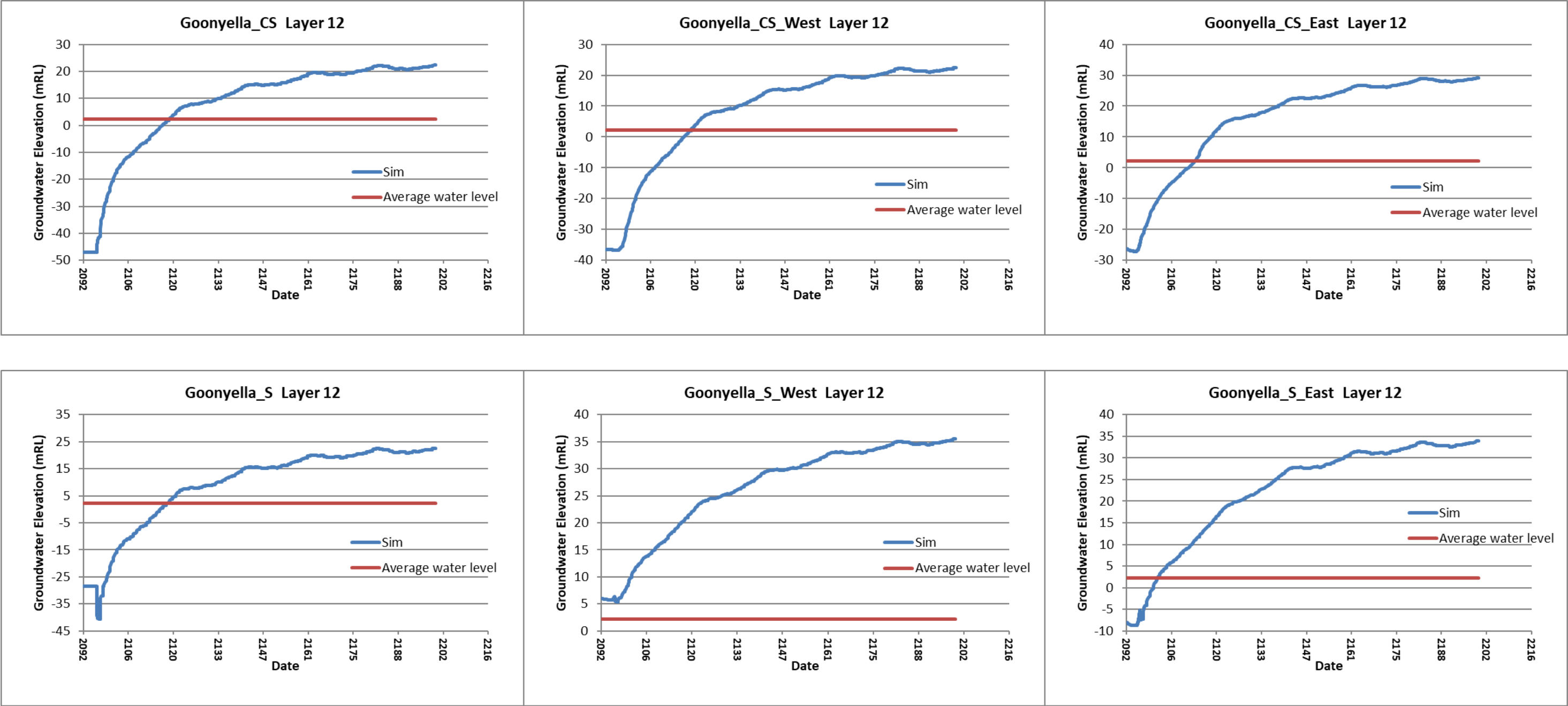


Plate 39 Goonyella pit hydrographs





Where:
Goonyella_N (north), Goonyella_C (middle), Goonyella_CS (central), and Goonyella_S (south) Layer 12 provide predictions of water levels in the north, middle, central, and south portions of the Goonyella residual void, respectively
Goonyella_N West, Goonyella_C West, Goonyella_CS West, and Goonyella_S West Layer 12 provide predictions of water levels up dip of the north, middle, central, and south portions of the Goonyella residual void, respectively
Goonyella_N East, Goonyella_C East, Goonyella_CS East, and Goonyella_S East Layer 12 provide predictions of water levels down dip of the north, middle, central, and south portions of the Goonyella residual void, respectively

Central

- Pseudo-steady residual void water level is around 20 mAHD
- Groundwater levels to the west (up dip) are some 20 mAHD (flow into the pit)
- Groundwater levels to the east (down dip) are some 30 mAHD (facilitating flow into the pit).

South

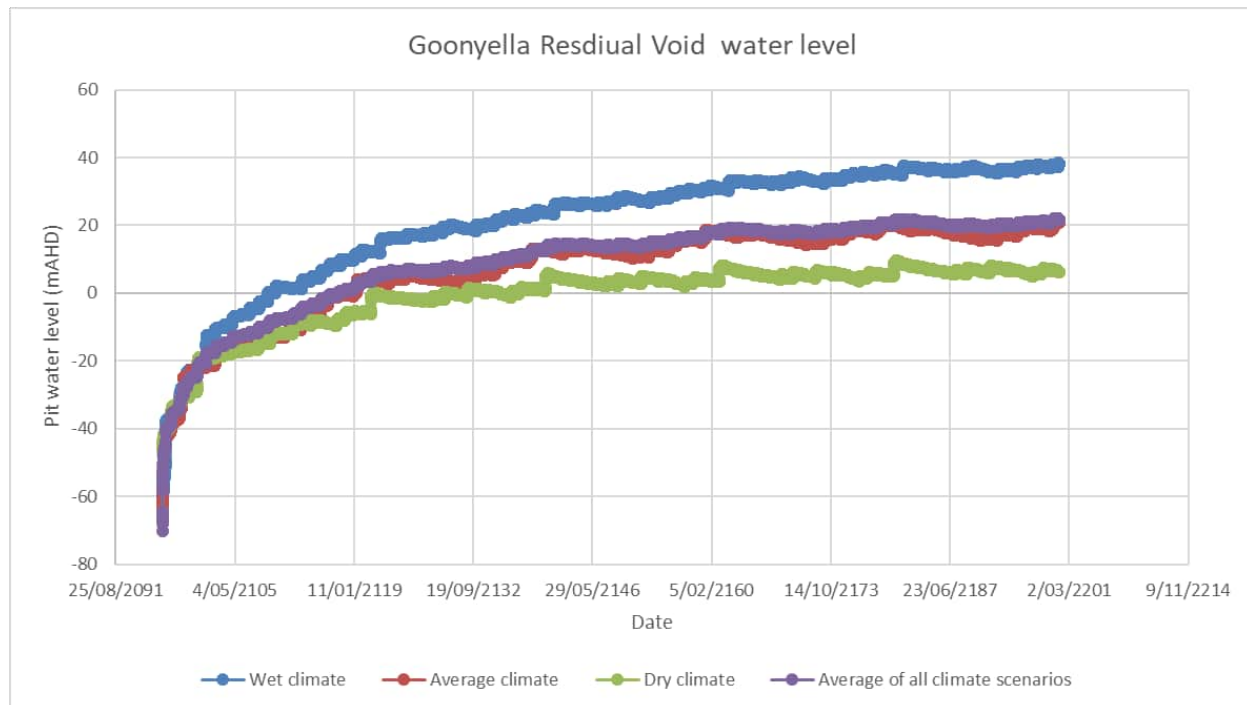
- Pseudo-steady pit water level is around 20 mAHD
- Groundwater levels to the west (up dip) are some 35 mAHD (facilitating flow into the pit)
- Groundwater levels to the east (down dip) are some 33 mAHD (facilitating flow into the pit).

15.4.3 Residual void water levels

The residual void water balance modelling included for wet, average, and dry climate conditions as inputs into the model predictions, this allowed for an assessment of variability in the residual void water levels and assessment of potential for decant and void water migration.

An example of the variation in the residual void water level, for the Goonyella residual void, is included in Figure 40.

Figure 40 Goonyella residual void predicted water level (WSP water balance model)



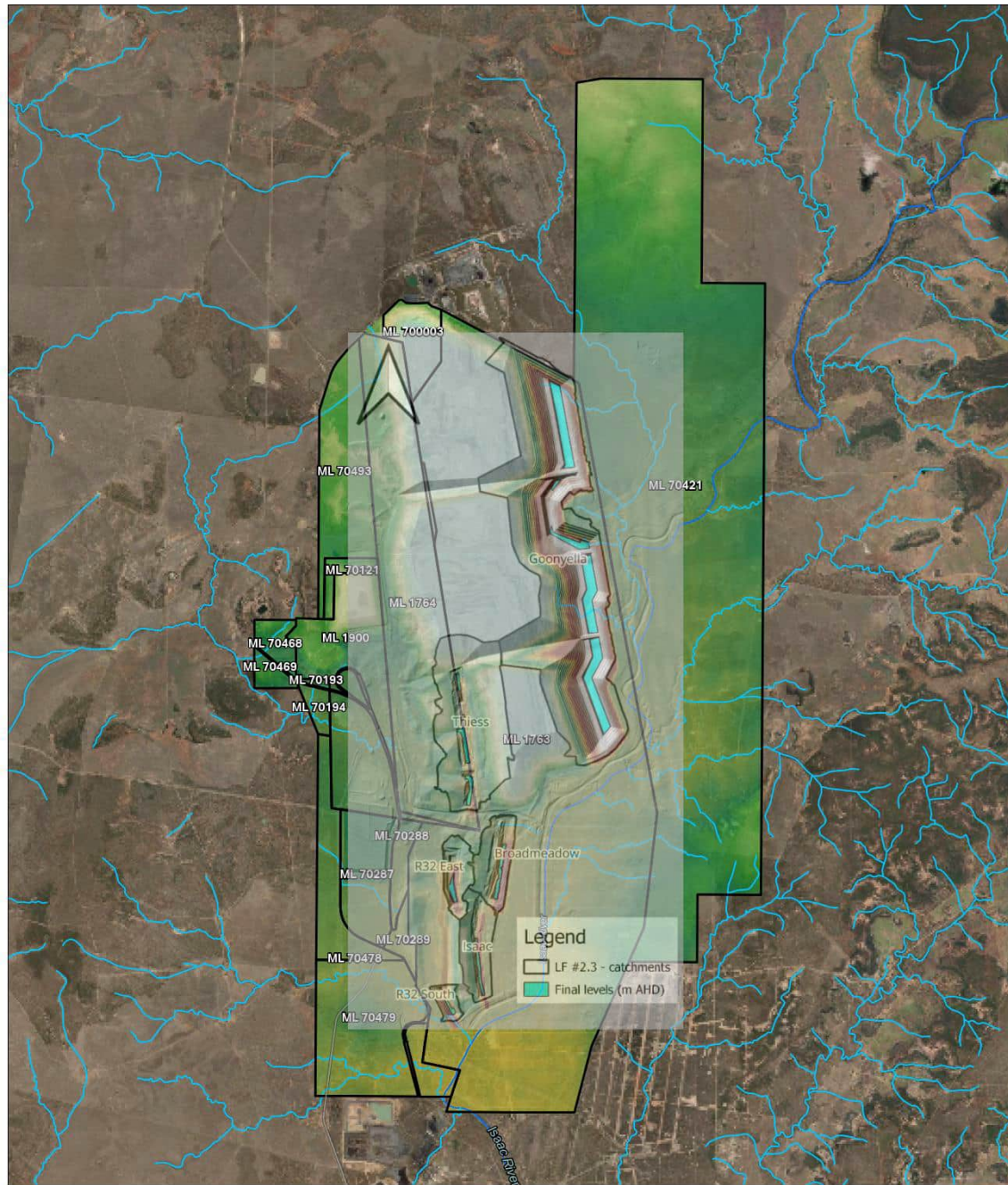
The void water level resulting from the average of the climate scenarios was adopted for the groundwater model predictions.

To allow for the potential variability of the residual void water levels with regards to the groundwater flux component an assessment of groundwater contribution into the water balance was conducted (Section 16.3.1).

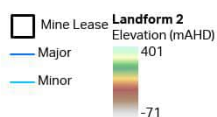
An uncertainty analysis of the groundwater flux predictions was then conducted to allow for a validation of residual voids acting as sources or sinks as well as a more detailed evaluation of potential for void water migration within the groundwater. These groundwater flux assessments are included in Section 16.3.

A depiction of the residual void water levels post-closure associated with Landform #2.3 is included in Figure 41.

Figure 41 GRB residual voids containing water post-closure (source: WSP, 2024)



Goonyella, Redhill and Broadmeadow Mines
Post Mining Landform (Landform #2)



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15.5 Predicted Groundwater Levels

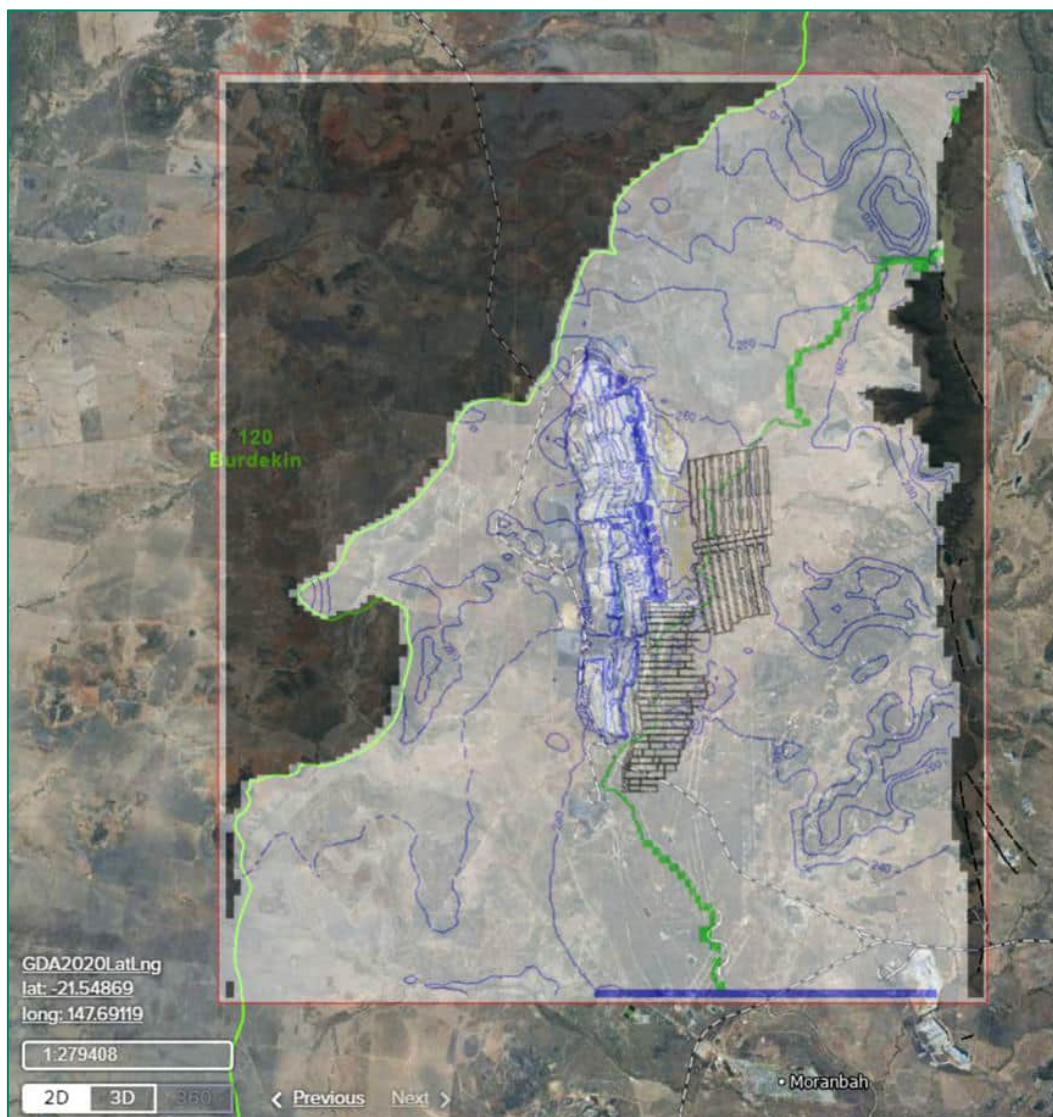
Groundwater level changes during the predictions periods were compiled and assessed to understand the change in groundwater flow patterns and gradients as a result of active (mine dewatering), the introduction of water into the underground workings, and passive (seepage ingress into) plus artificial recharge from residual pits which contain pit water.

Groundwater contours over time assisted with flow path simulations (using particle tracking) in Section 15.6 and understanding changes at receptors (Section 15.8).

Section 15.1 describes the groundwater elevation estimated for the start of model predictions in 2024. The groundwater elevation data indicates the groundwater contours, flow patterns and gradients that are predicted to occur across the model domain in 2024.

Complex mine activities detailed in Section 15.2 indicate the dewatering and recharge activities over time that will determine the groundwater levels at the end of mining activities, in 2027. The closure (end of all mining activities at GRB and RHM) groundwater levels and flow patterns are predicted post 2027 within prediction period P4 (Section 15.2).

Note: As reference the modelled contours include for the entire model domain as included in Plate 16 and Section 15.1 and presented below.



15.5.1 Water level change in the surficial cover

The drawdown and recovery of the groundwater levels in model layer 1 (Table 18), which includes surficial cover either alluvium or Tertiary sediments, was predicted based on the calibration groundwater elevations at the start of prediction period P1.

The changes at the end of each of the prediction phases including the end of P4 (considered representative of closure after an extended period of recovery, 2199) are included in Figure 42.

The water level change from 2024 over time indicates:

- Limited change over time (limited expansion or contraction of the extent of drawdown around the residual voids with time to P4)
- No change to the zero (no drawdown) contour across the Issac River (green model cells)
- The extent of drawdown in model layer 1, when comparing groundwater drawdown contours (location and extent) in 2024 (derived from calibration for start of predictions) reduces and then is recognised to stabilise over time (end of P3 and end of P4).

15.5.2 Water level change in the GMS target coal seam

The drawdown and recovery of the groundwater levels in the GMS (model layer 10, Table 18), was assessed based on the change in groundwater levels relative to levels derived at the start of P1.

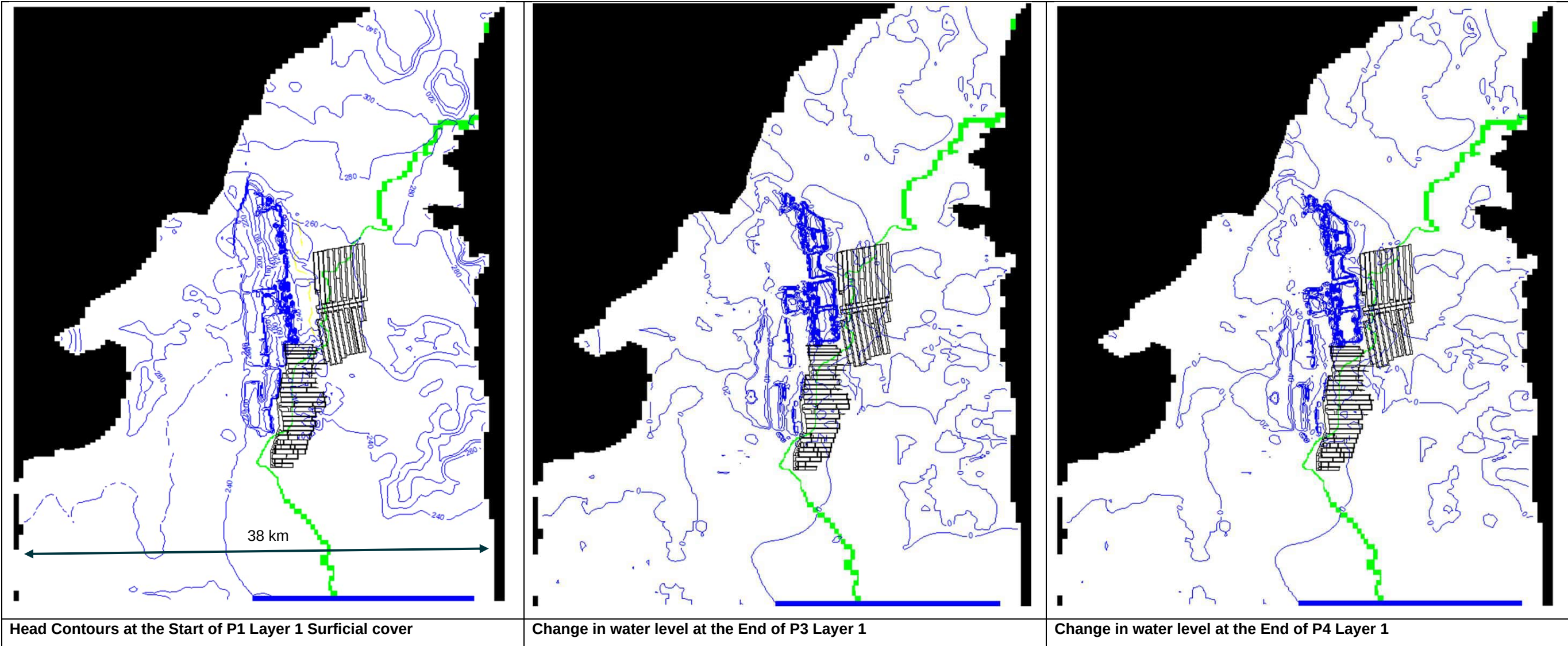
The changes at the end of each of the prediction phases including the end of P4 (after an extended period of recovery, end of 2199) are included in Figure 43.

The water level change over time indicates:

- The influence of RHM is evident in P3 water levels, resulting in larger drawdown
- Water introduced into the underground workings reduces the RHM drawdown to the east, as evident in P4 drawdown contours
- Water levels in portions of the Broadmeadow GMS workings do not recover to the 2024 (P1) levels, even after the introduction of water, due to the proximity to the Broadmeadow, Isaac, and Goonyella residual voids, which continue to remove water from the system
- The GMS dewatering is not predicted to result in induced flow from the Tertiary and Back Creek Group to the west of the mining areas.

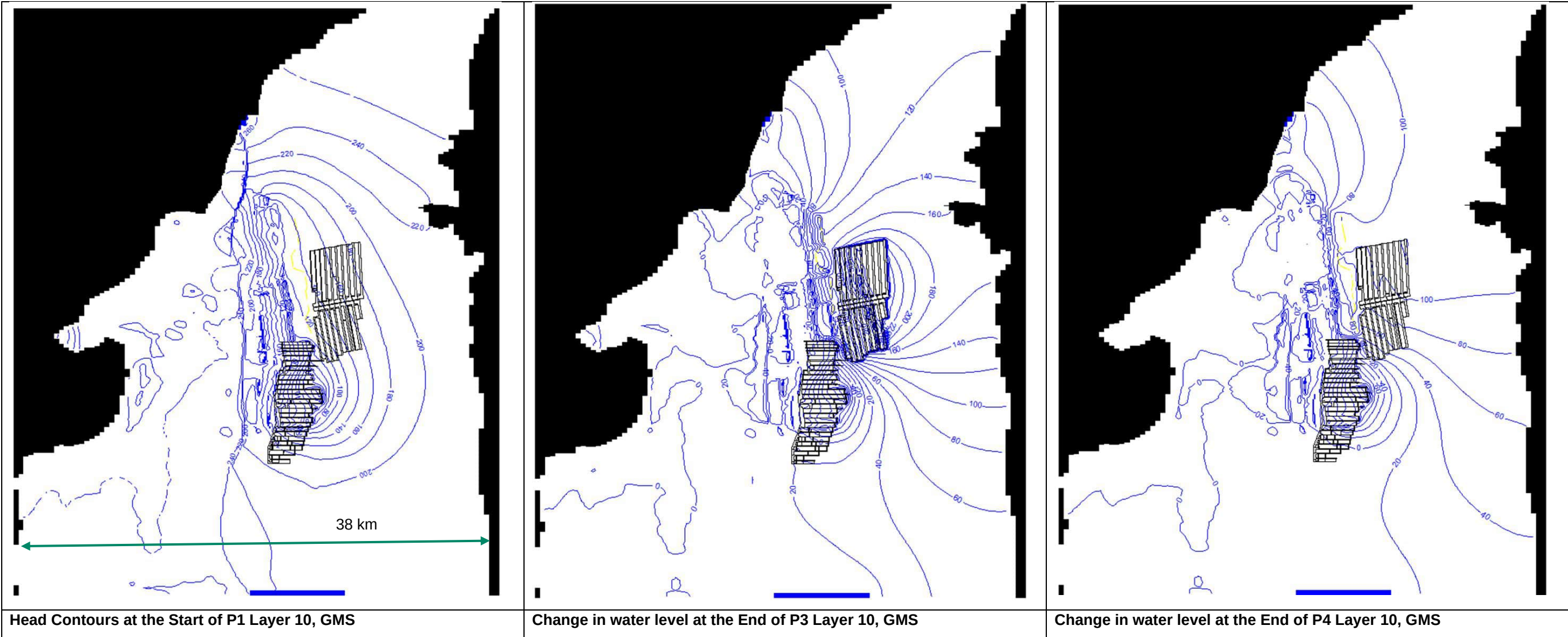
The change in water levels from mining activities (mining, rehabilitation, decommissioning, and water introduction during the prediction periods) to post-closure the difference in water level (rise and fall) is evident in Figure 43.

Figure 42 Initial groundwater elevation at start of P1 and change in water level (in m) at end of P3 and P4 in Model Layer 1



Green model cells are the Isaac River
Yellow model cells are the Goonyella residual void
RHM and Broadmeadow GMS mine layouts for reference

Figure 43 Groundwater elevations at start of P1 and water level change end of P3 and P4 (in m) in Model Layer 10 GMS



Green model cells are the Isaac River
Yellow model cells are the Goonyella residual void
RHM and Broadmeadow GMS mine layouts for reference

The predictive modelling, considering change in groundwater levels from the 2024 initial calibrated elevations, indicate:

- The drawdown in GMS at the end of P3 2092, at the end of RHM mining, is up to 550 m at the deepest part of the RHM.
 - The drawdown below the initial groundwater levels (P1) ranged from +200 m (water introduced into Broadmeadow GMS) and – 550 m (deepest mine workings in RHM) at the end of P3.
- During P4 the RHM is filled with water plus recovery and groundwater stabilisation occurs, as included in the P4 predictions at the end of 2199 (Figure 43).
- The water level change from P1 levels in GMS at the end of 2199 (P4 prolonged recovery and stabilisation after mining and the introduction of water) range from +190 m (water introduced into Broadmeadow GMS) and -140 m (in proximity to the Goonyella residual void).
 - Water introduced into the Broadmeadow GMS underground workings caused a 200 m change (rise) in 2092, which decreased slightly to 190 m in 2199. This reduction is related to the Goonyella residual void.

15.5.3 Water level change in the GLS target coal seam

The drawdown and recovery of the groundwater levels in the GLS (Model Layer 12, Table 18), was predicted based on changes relative to the initial groundwater levels and contours derived during model calibration and included at the start of prediction period P1.

The water level changes at the end of each of the prediction phases including the end of P4 (considered representative of post-closure after an extended period of recovery, 2199) are included in Figure 44.

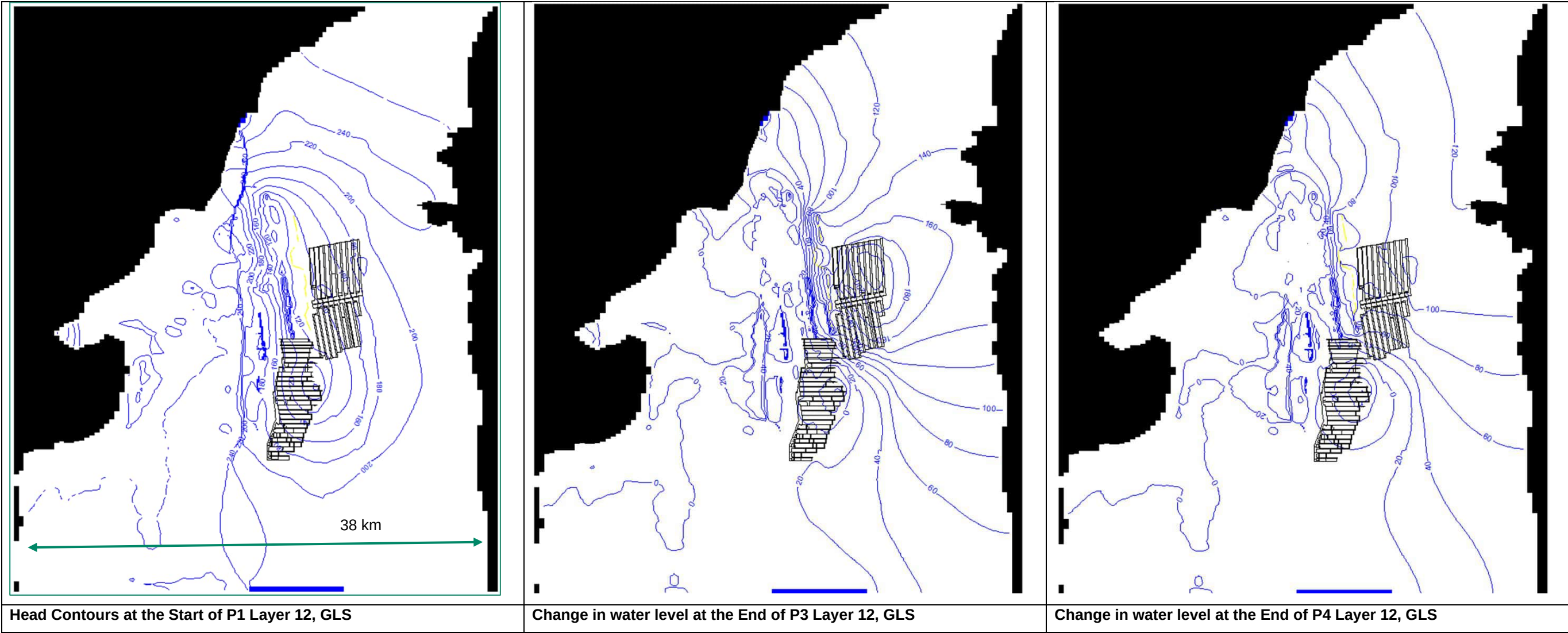
The water level comparison to start of P1 over time indicates:

- The influence of RHM is evident in P3 water level change
- The introduction of water reduces the RHM drawdown to the east, as evident in P4 drawdown contours
- Broadmeadow GLS is not readily drawn down after water introduced into the underground workings, even due to the proximity to the Goonyella residual void
- GLS dewatering is not predicted to result in induced flow from the Tertiary and Back Creek Group to the west of the mining areas (0 m water level change contours).

The predictive modelling, considering change in groundwater levels from the 2024 initial calibrated elevations, indicate:

- The drawdown in GLS at the end of P3 2092, at the end of RHM mining, is up to 240 m centred around the RHM.
 - The drawdown below the initial groundwater levels (P1) ranged from +60 m (water introduced into Broadmeadow GLS) and – 240 m (RHM) at the end of P3.
- During P4 the RHM (GMS) is filled with water and recovery and groundwater stabilisation occurs, as included in the P4 predictions in 2199.
- The water level change from P1 levels in GLS at the end of 2199 (P4 activities) range from +50 m (water introduced into Broadmeadow GLS) and -240 m (in proximity to the Goonyella residual void).
 - Water introduced into the Broadmeadow GLS underground workings caused a 60 m change (rise) in 2092, which decreased slightly to 50 m in 2199. This reduction is related to the Goonyella residual void.

Figure 44 Groundwater elevation in GLS at start of P1 and water level change (in m) at the end of P3 and P4 for in Model Layer 12 GLS



Green model cells are the Isaac River
Yellow model cells are the Goonyella residual void
RHM and Broadmeadow GMS mine layouts for reference

15.6 Flow Path Simulation

The groundwater model zone budget approach allowed for the evaluation of the groundwater flow either into or out of the residual voids (Section 15.4.2). In addition, the evaluation of the hydrographs generated for hypothetical water level observation points, provided an indication of residual voids acting as sinks or sources within the groundwater system post closure based on relative long term water level predictions (in the residual voids and up and down dip of the residual voids).

The migration of the void water was further assessed using particle tracking, to evaluate flow directions, extent of migration within groundwater, and variation in flow during the post-mining stabilisation of groundwater levels overtime.

Particles were introduced into the saturated model cells at different times during the model prediction phases, to assess migration to or from the residual voids. These data were then considered with groundwater contours (as described in Section 15.4.3), plus the groundwater model zone budget and hydrograph lines of evidence, to assess potential for transport of the void water from the mine leases over time.

The initial particle tracking, based on the large model domain and active cells, was conducted for a 10 year period during prediction period P4, to obtain an understanding of groundwater flow patterns and influence of mining activities (mining, rehabilitation, decommissioning, and water introduction during the prediction periods). Long duration post-closure particle tracking were conducted (Section 15.7) based on the 10-year results (i.e., targeted particle tracking was conducted for residual voids where migration from the residual voids were identified to allow for the assessment of potential contaminant migration within the groundwater to be further assessed).

15.6.1 Residual voids (excluding Goonyella Pit)

Particle tracking was conducted at the five (5) residual voids to assess possible void water migration within groundwater. The particle tracking was limited to 10 year running times to allow for the evaluation of possible particle movement and to provide validation of the groundwater flow predicted during the post-mining using groundwater contours and flow patterns, model zone budget (in or out) ingress, and hypothetical observation points hydrographs.

15.6.1.1 First 10 Years of P4 (2093-2102)

The prediction period (P4) includes water levels within the residual voids to be represented by CHD (including Goonyella Pit), the end of RHM mining, introduction of water into RHM, and recovery (no mining activities from 2097).

Figure 45 indicates the particle tracking (red lines) where particles originated in the five residual voids. Due to the fluctuation in the residual void water levels, particles were also included immediately adjacent to Broadmeadow Pit and Isaac Pit to further assess possible pit water migration (Figure 46).

The particle tracking during this P4 10 year simulation indicates continued residual void water loss from Thiess Pit, which is migrating within groundwater towards the drawdown caused by the deep Goonyella Pit residual void water levels.

Residual void water migration from Broadmeadow Pit can occur where the particles are predicted to migrate towards RHM GMS dewatering even though water has been introduced into RHM GMS mine workings.

Particles immediately adjacent to Broadmeadow Pit indicate potential for residual void water migration. This is not predicted for the Isaac Pit residual void.

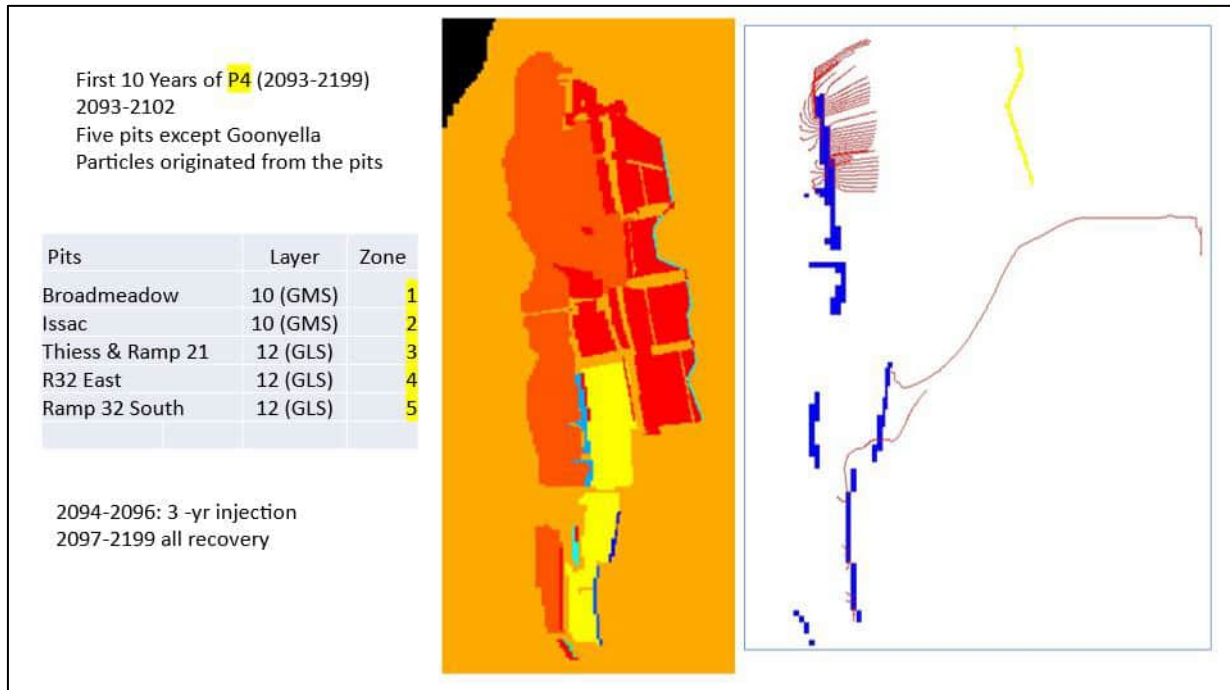
The particle pathways, running for 10 years at the start of P4, were included on groundwater elevation contours for selected years during the particle tracking simulation. These contours for Model Layer 12 (GLS) and Model Layer 10 (GMS) allowed for the identification of groundwater flow patterns and gradients in the saturated target coal seams or spoil (backfill) adjacent to the 5 residual voids.

Figure 47 to Figure 49 indicate flow from Broadmeadow Pit towards the dewatered RHM flooded underground (Figure 48), as the underground workings do not flood entirely when adopting the volumes supplied by BMA (Section 14.2.1).

The long particle travel path from Broadmeadow is recognised to reach the RHM and then change direction to the northeast, towards Goonyella Pit.

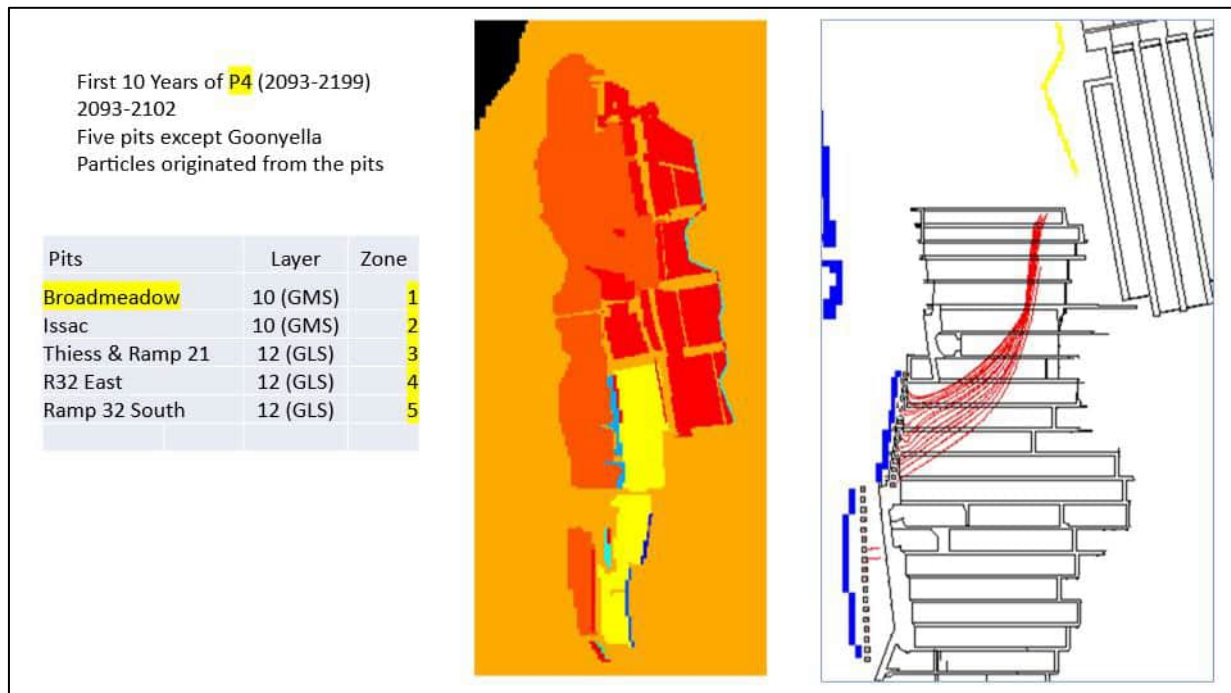
Note: The particles migrate for a period of 10-years, the groundwater elevations change over time based on mining activities which vary over time (as detailed in the prediction periods, Section 15.2), hence the need to illustrate the groundwater contours in and adjacent to the residual voids (including Goonyella Pit) to aid with evaluating the particle tracking.

Figure 45 First 10 Years of P4 – 5 residual voids



Blue model cells are the residual voids

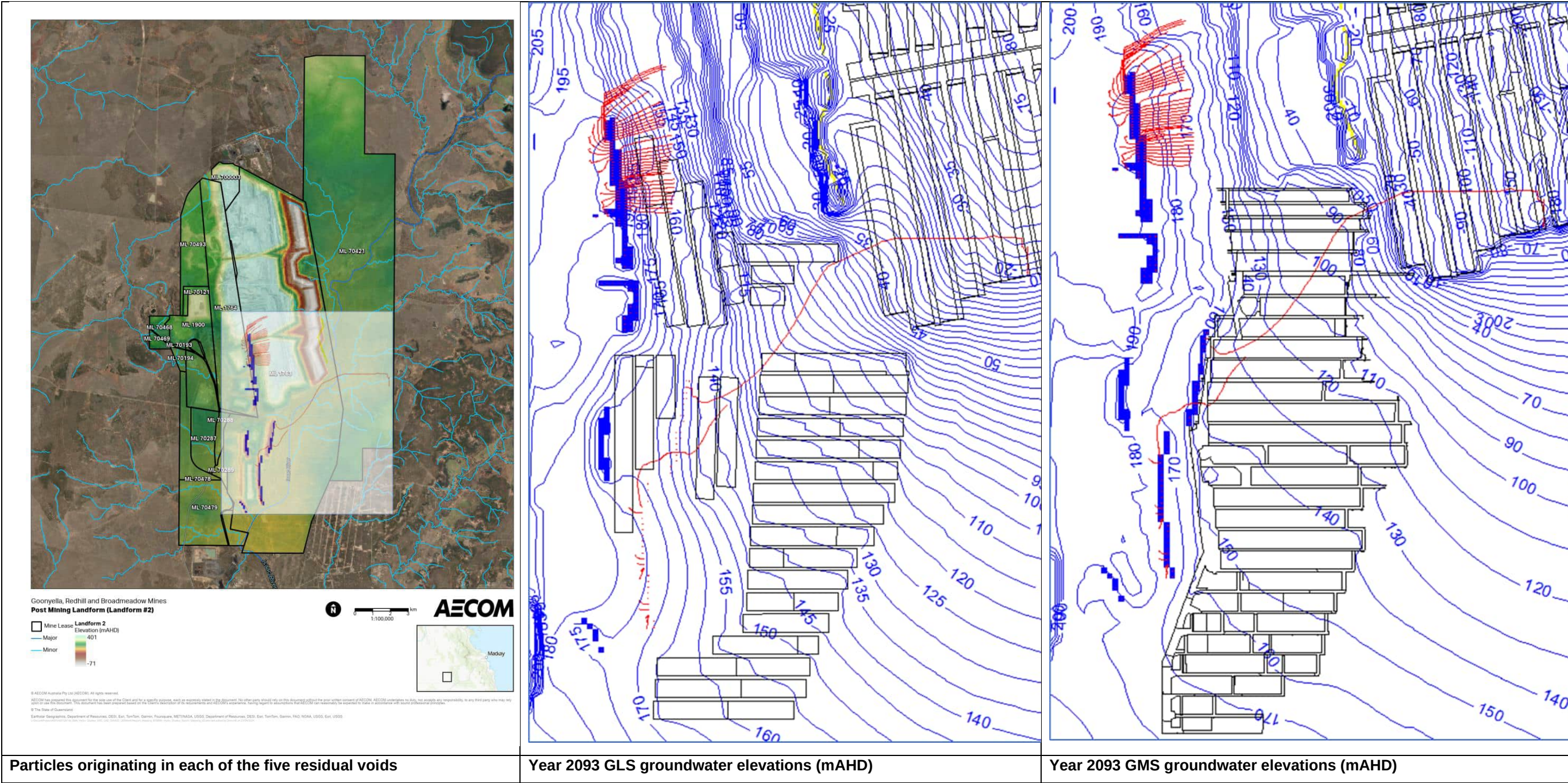
Red lines are particle flow tracks over the 10 year run

Figure 46 First 10 Years of P4 – 5 residual voids (particles outside Broadmeadow and Isaac Pits)

Blue model cells are the residual voids

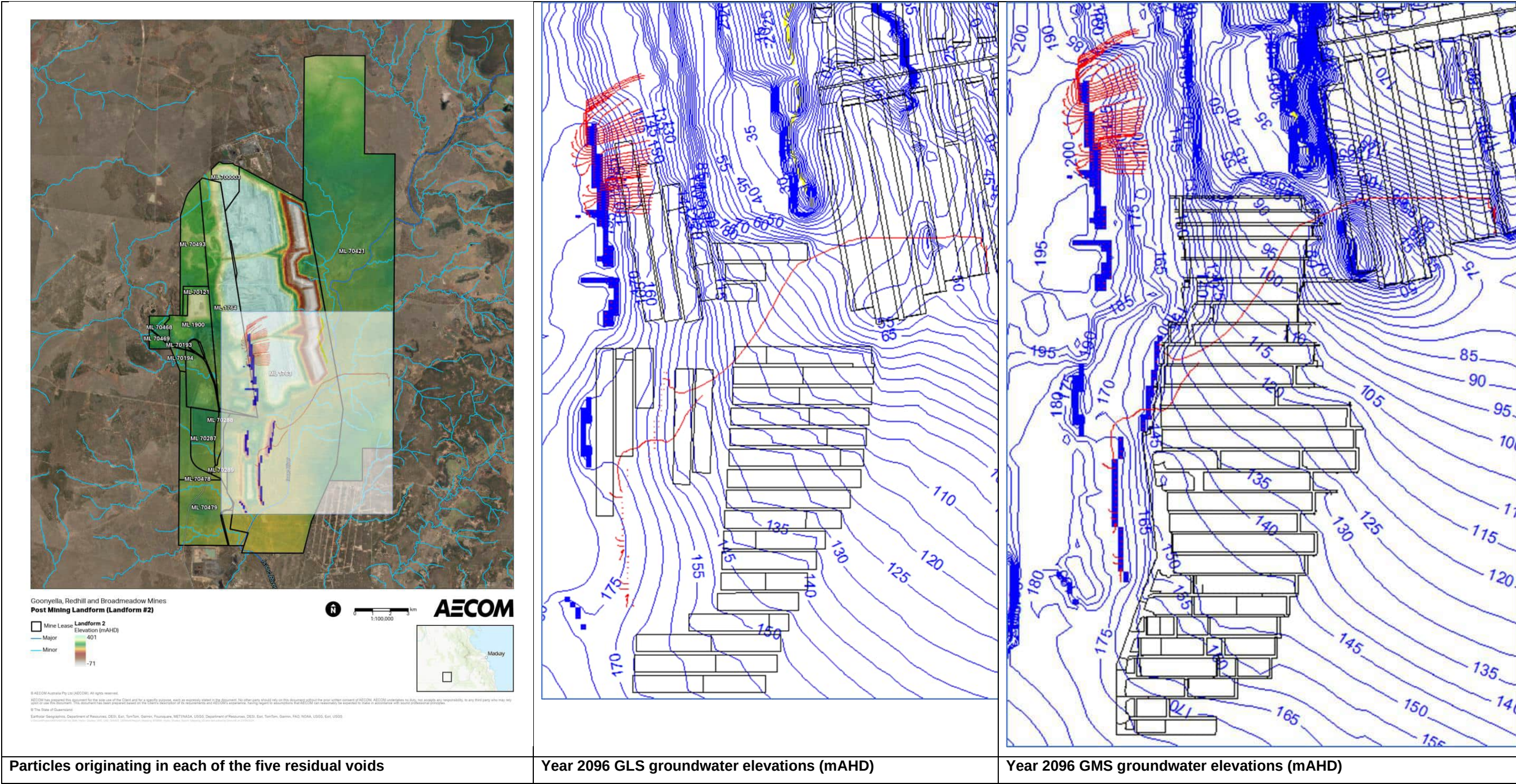
Red lines are particle flow tracks over the 10 year run

Figure 47 First 10 Years of P4 for 5 residual voids – Year 2093 contours



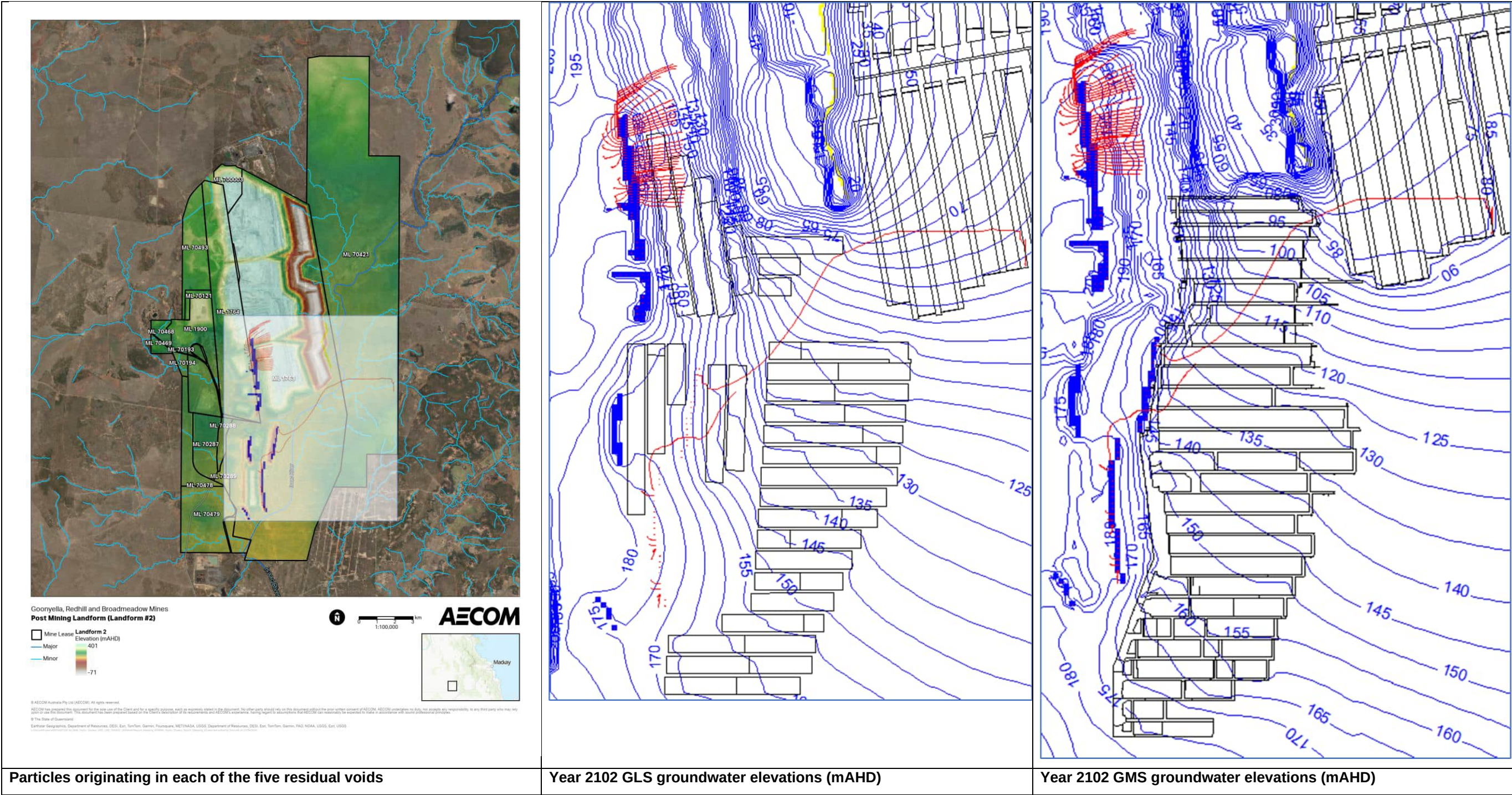
Blue model cells are the residual voids
Yellow model cells represent to the Goonyella residual void
Red paths are the particle tracking migration over a ten year simulation
RHM and GMS and GLS mine footprint s are included as reference locations

Figure 48 First 10 Years of P4 for 5 residual voids – Year 2096 contours



Blue model cells are the residual voids
Yellow model cells represent to the Goonyella residual void
Red paths are the particle tracking migration over a ten year simulation
RHM and GMS and GLS mine footprint s are included as reference locations

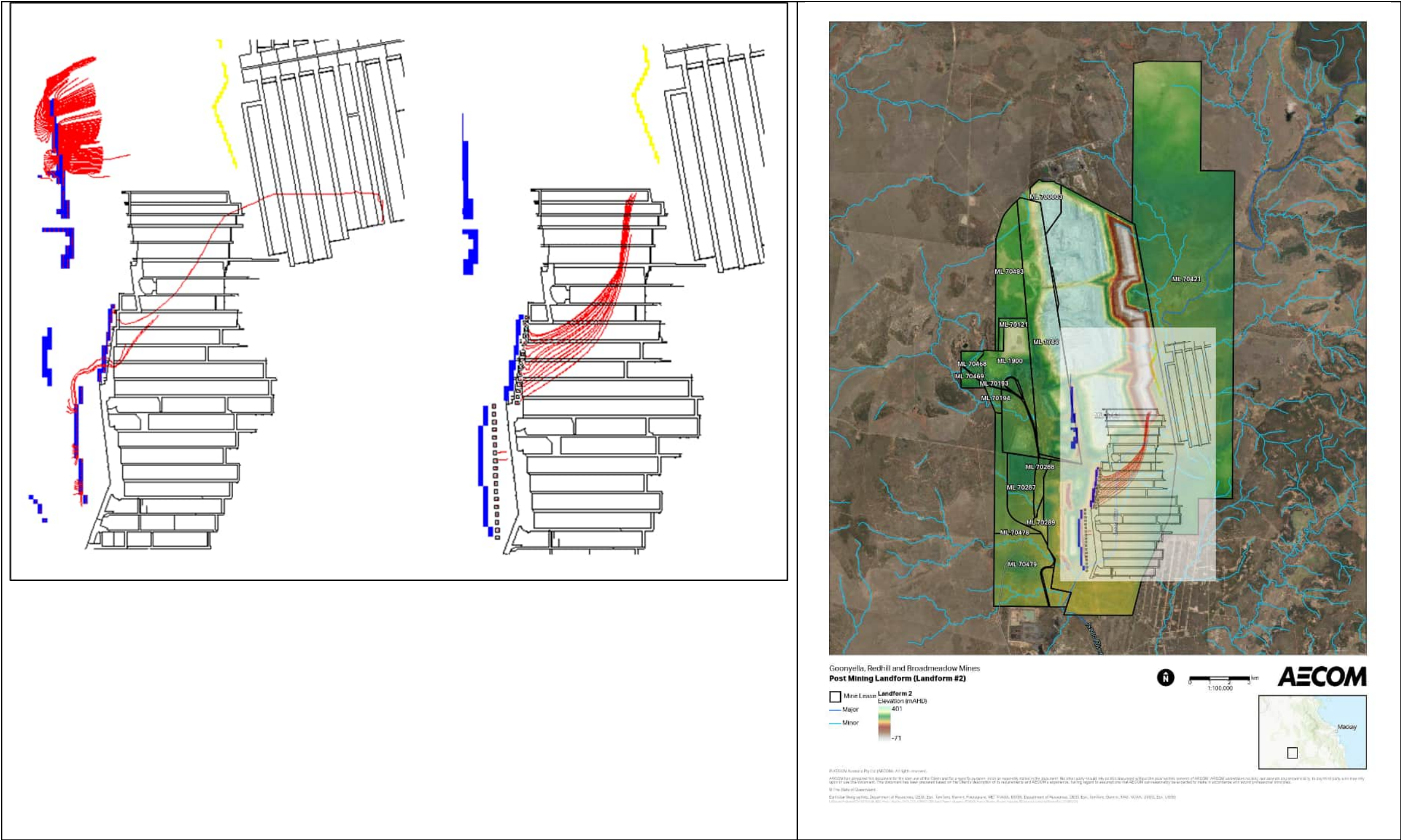
Figure 49 First 10 Years of P4 for 5 residual voids – Year 2102 contours



Blue model cells are the residual voids
Yellow model cells represent to the Goonyella residual void
Red paths are the particle tracking migration over a ten year simulation
RHM and GMS and GLS mine footprint s are included as reference locations

Figure 50 presents the particle tracking from inside and outside the residual voids at a higher resolution. Migration away from the residual voids is recognised to be influenced by the Goonyella Pit dewatering, such that particles move away and then return to the voids or change direction towards the north, due to the drawdown at Goonyella Pit.

Figure 50 First 10 Years of P4 for 5 residual voids – higher resolution particle tracking



Blue model cells are the residual voids
Yellow model cells represent to the Goonyella residual void
Red paths are the particle tracking migration over a ten year simulation
RHM and GMS mine footprint s are included as reference locations

15.6.2 Goonyella Pit residual void

To aid with the assessment of each residual void and to allow for ease of evaluation and discussion, the particle tracking for the five residual voids (Section 15.6.1) included the mining activities associated with Goonyella Pit (mine dewatering and residual void water levels) but did not include particles for particle tracking around the Goonyella residual void.

Particle tracking for the Goonyella Pit required the inclusion of particles adjacent to the residual void, to allow for evaluation of pit water migration. This was done as any particle included within the residual void, based on the depth and surrounding groundwater levels (Section 15.4.2.6), would not migrate within groundwater.

The particle tracking, similar to the five residual voids, included 10 year simulations for prediction period P4.

15.6.2.1 First 10 years of P4 (2093 – 2102)

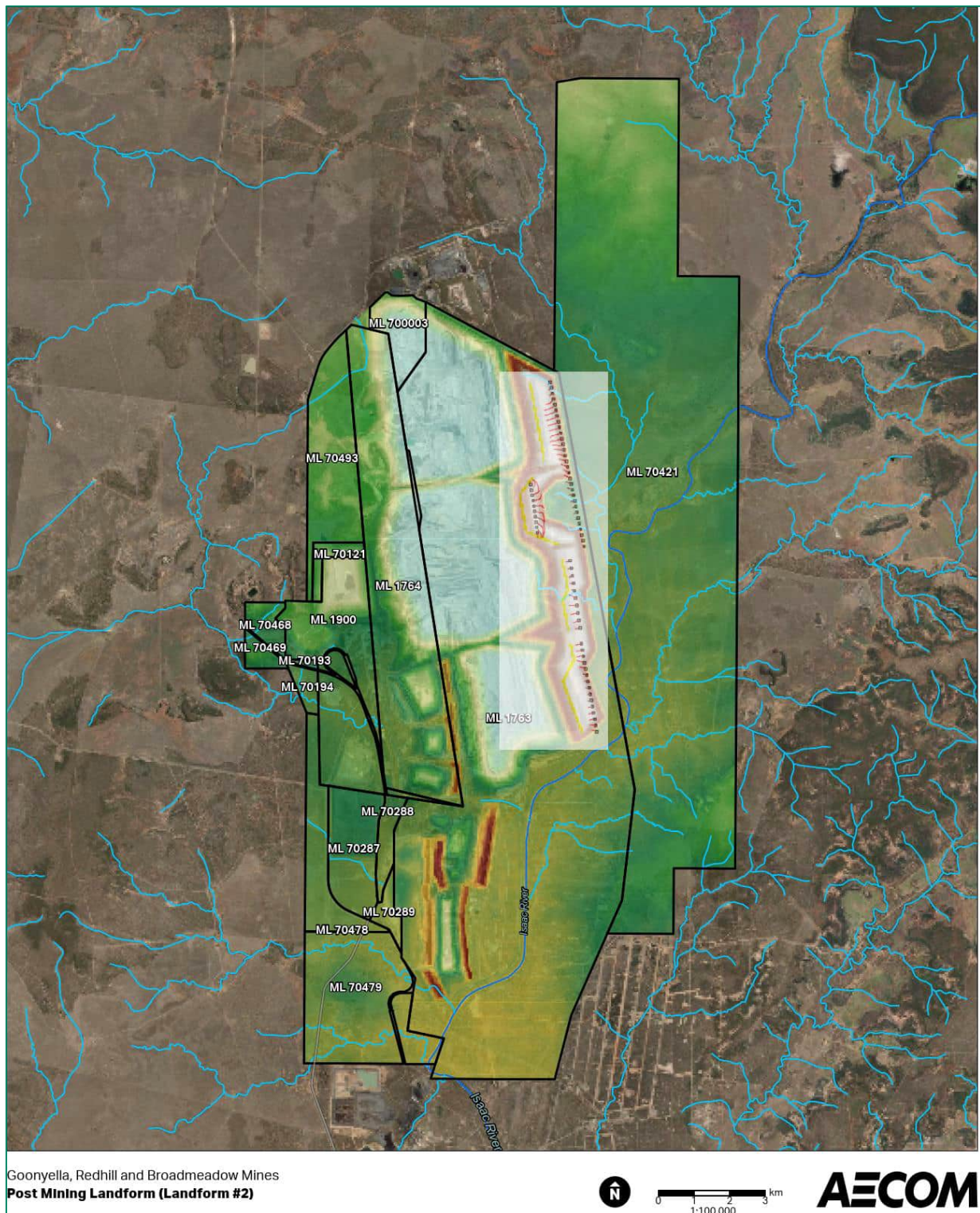
The particle tracking during this time period is included in Plate 40, and indicate flow into the deepest Goonyella Pit locations.

The particles adjacent to the shallow central portion of Goonyella Pit, are recognised to migrate back towards the Goonyella Pit during this phase of prediction. This relates to the reinjection of RHM and the stabilisation of flow patterns around Goonyella Pit, which dominates the groundwater flow pattern, as included in Figure 51.

The groundwater flow pattern indicates steep groundwater gradients around Goonyella Pit in 2102. The purple model cells are dry in Figure 51, including immediately west (up dip) of the central shallow section of the Goonyella Pit, indicating the particles from this section of the pit can only flow east due the dry conditions to the west.

These varying groundwater flow patterns, saturated and unsaturated model cells, plus predicted long term pseudo-steady water levels across the Project was assessed to allow for the evaluation of all residual voids post-closure (i.e., particle tracking for all residual voids was conducted from 2199 (post P4 prediction period) to 2299, a 100-year particle tracking simulation in Section 15.7.

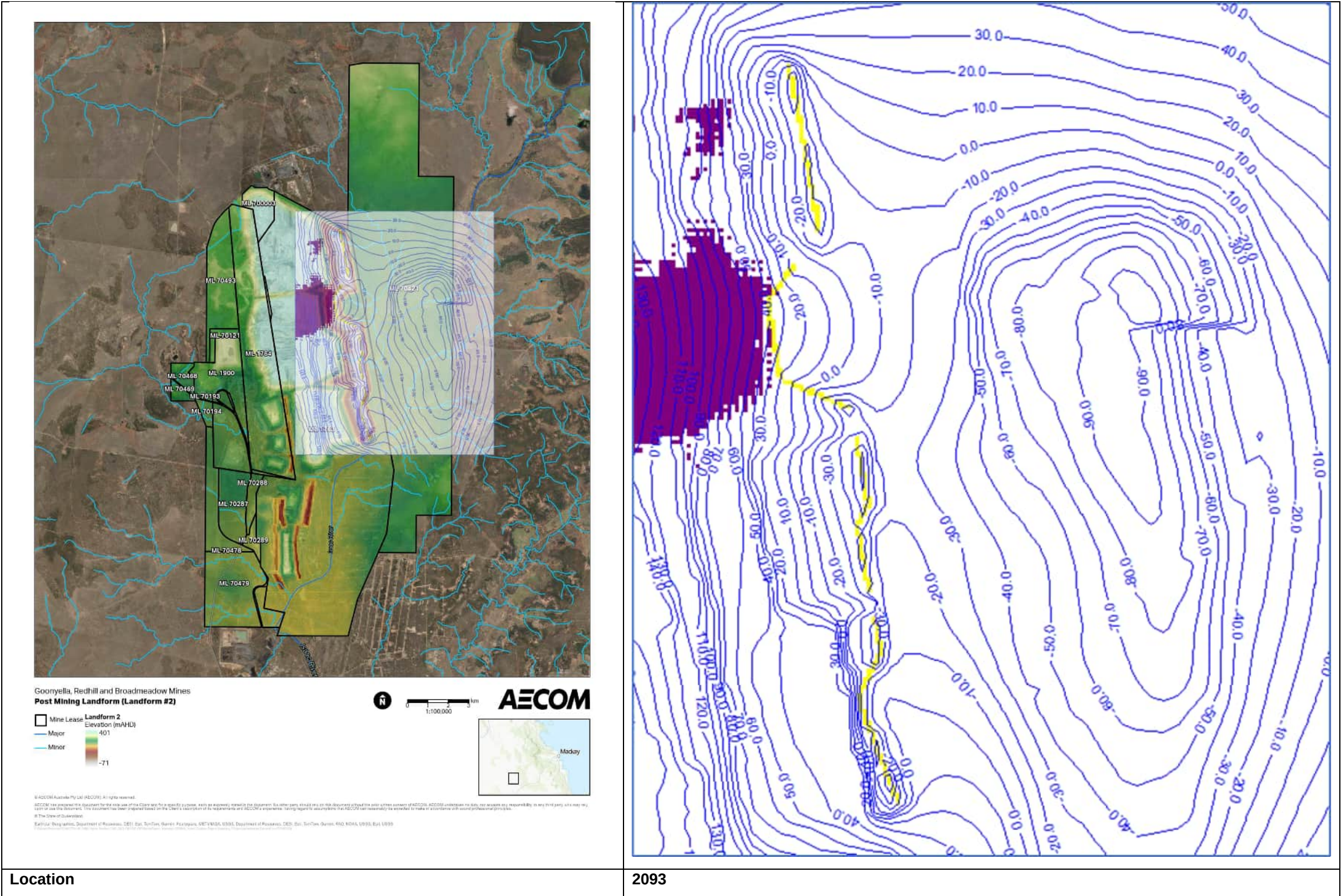
Plate 40 Goonyella Pit particle tracking first 10 years of P4



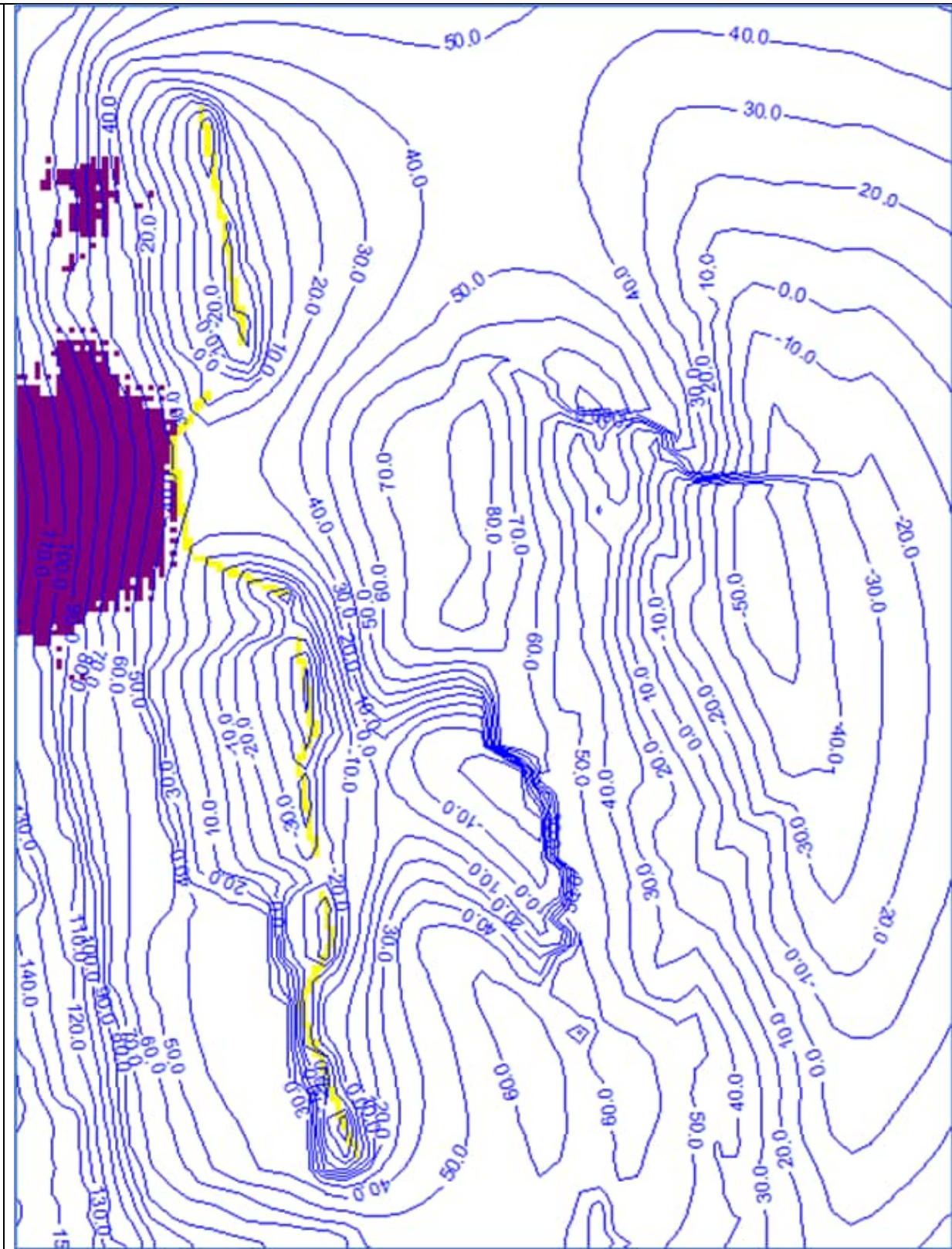
Yellow model cells are the Goonyella residual void

Grey model cells are cells used for the Goonyella residual void particle tracking

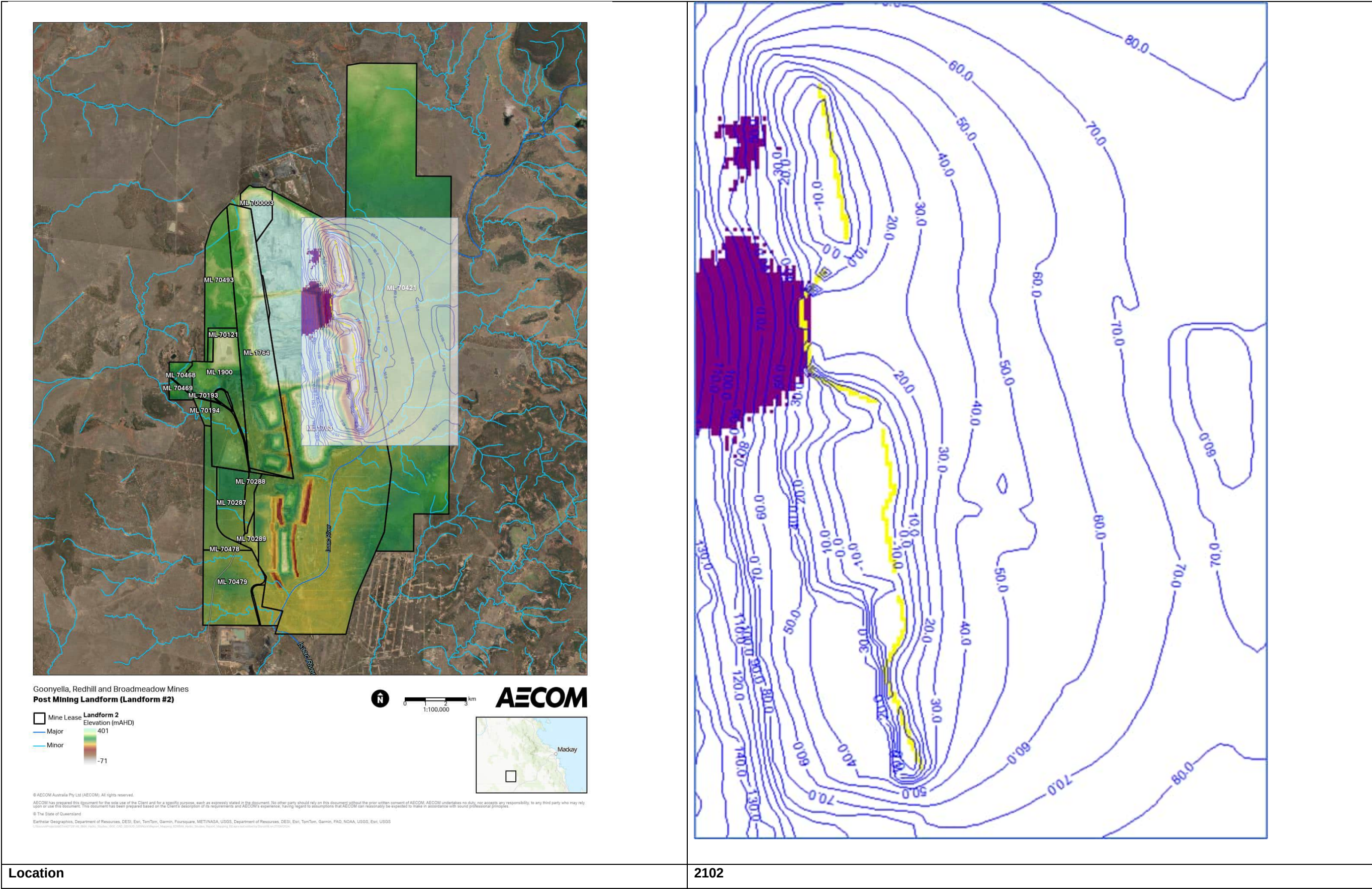
Figure 51 Groundwater flow contours for P4 years 2093, 2096, and 2102 – Goonyella Pit (GLS contours)



Yellow model cells depict the Goonyella residual void
Purple model cells are dry (unsaturated)



2096 (3-year water introduced 2094 to 2096)



Location

2102

15.7 Long-term assessment

Utilising particle tracking and the predicted groundwater elevations in the long-term, after 2199, the assessment of potential pit water migration within groundwater was conducted. The long-term assessment also considered potential migration from rehabilitated mine waste storage areas located across the model domain. Noting that RHM will utilise the GRB mine waste storage facilities during operations.

15.7.1 Particle tracking 2199 to 2299

As per Section 15.6 particles were included both within and immediately next to the residual voids as included in Figure 52. The particles, per year, were simulated within the predictive groundwater model to provide an indication of post-closure flow patterns.

The long term stabilised groundwater flow patterns in the GMS coal seam (in 2299) are included in Figure 52, which shows the Goonyella Pit (yellow model cells) acts as a groundwater “sink” in the long term. Particles included in and immediately adjacent to the Broadmeadow and Isaac pits plus particles within the Thiess, Ramp 32 East, and Ramp 32 South, were predicted to migrate over time. The travel times, in days, indicates that all particles will reach the Goonyella Pit within the 100 year (36500 days) particle tracking timeframe.

The Goonyella Pit influences localised flow within the Project area.

Particle tracking for the Goonyella Pit plus the predicted 2299 GLS groundwater elevation contours are included in Figure 53. Particles included in the model cells immediately adjacent to the Goonyella Pit final void indicate flow into the residual void.

The Goonyella Pit influences localised flow within the GLS at the Project.

15.7.2 Particle tracking for mine waste storage areas

To further assess the potential for water, associated with mine waste storage facilities, to migrate post-closure, particle tracking simulations were conducted.

The mine waste storage facilities and Goonyella and Riverside Mine Industrial Areas, which can act as potential sources of artificial recharge post closure, were included in the predictive groundwater model. The potential sources (identified to have been included in the final landform and will be rehabilitated) are included in Plate 41 (below), and include (refer to Figure 2) RS1 North and South tailings storage facility (TSF)

- GS1 North and South TSF
- Thiess TSF
- Riverside Rejects dump
- R32/Airstrip TSF
- Goonyella Mine Industrial Area (MIA)
- Riverside MIA.

Particles were included within each of these mine waste source areas in model layer 1, simulating possible seepage from these locations post-closure, for 100 years from 2199 to 2299. The resultant particle tracking indicates limited saturation in model layer 1 (purple model cells in Figure 54 are dry during the 2199 to 2299 simulation) resulting in migration from only the southern portion of GS1 TSF, the Riverside MIA, and the Riverside Rejects.

The 100 year particle migration is influenced by the Goonyella Pit; however, the possible migration will take over 100 years to reach the residual void.

Due to the limited saturation in model layer 1, which limits migration assessment, an evaluation of the depth-to-water below these mine waste storage facilities was conducted to evaluate the risk of artificial recharge from these facilities to the groundwater post-closure.

Figure 52 Long-term particle tracking for the residual voids except Goonyella Pit

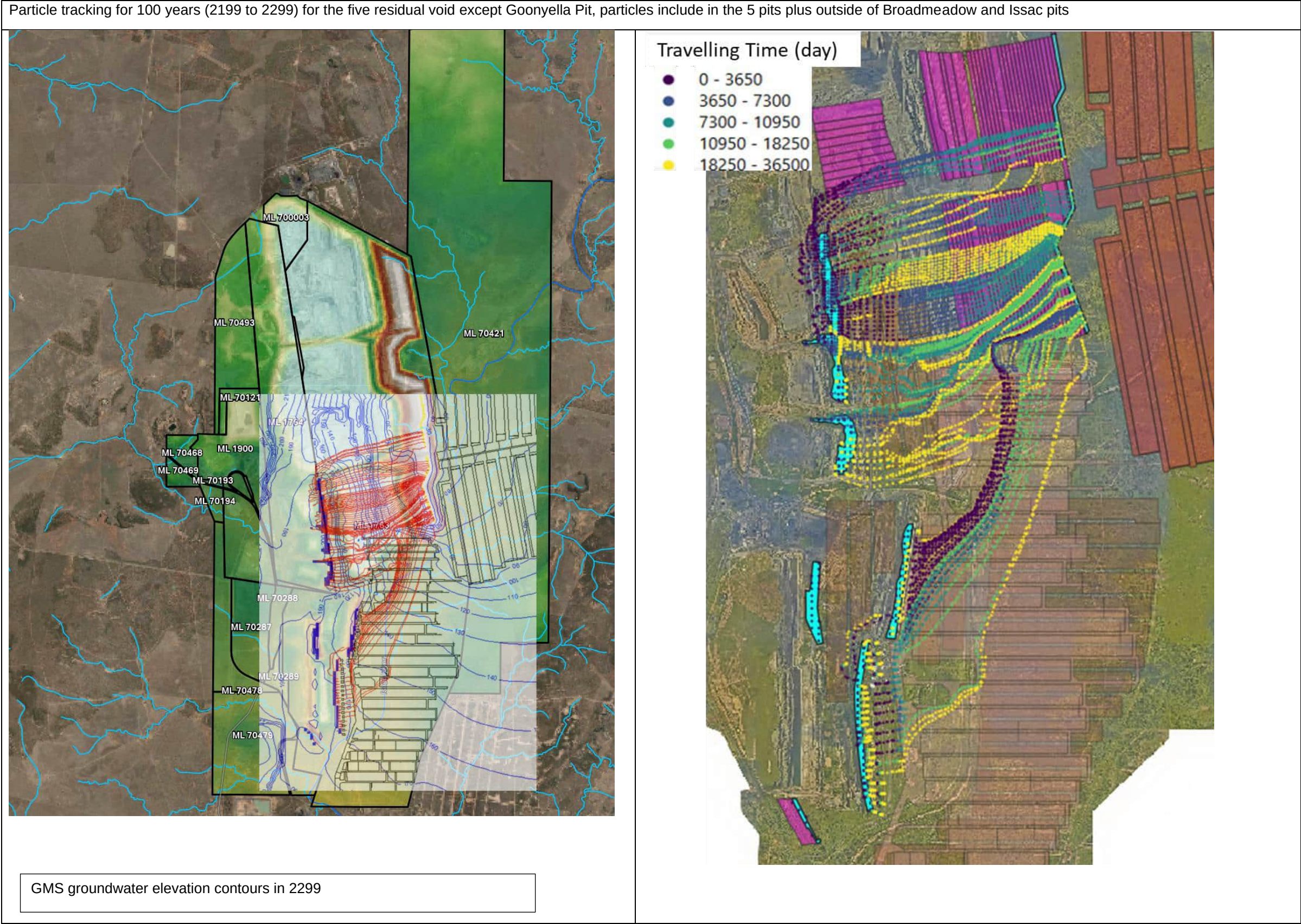
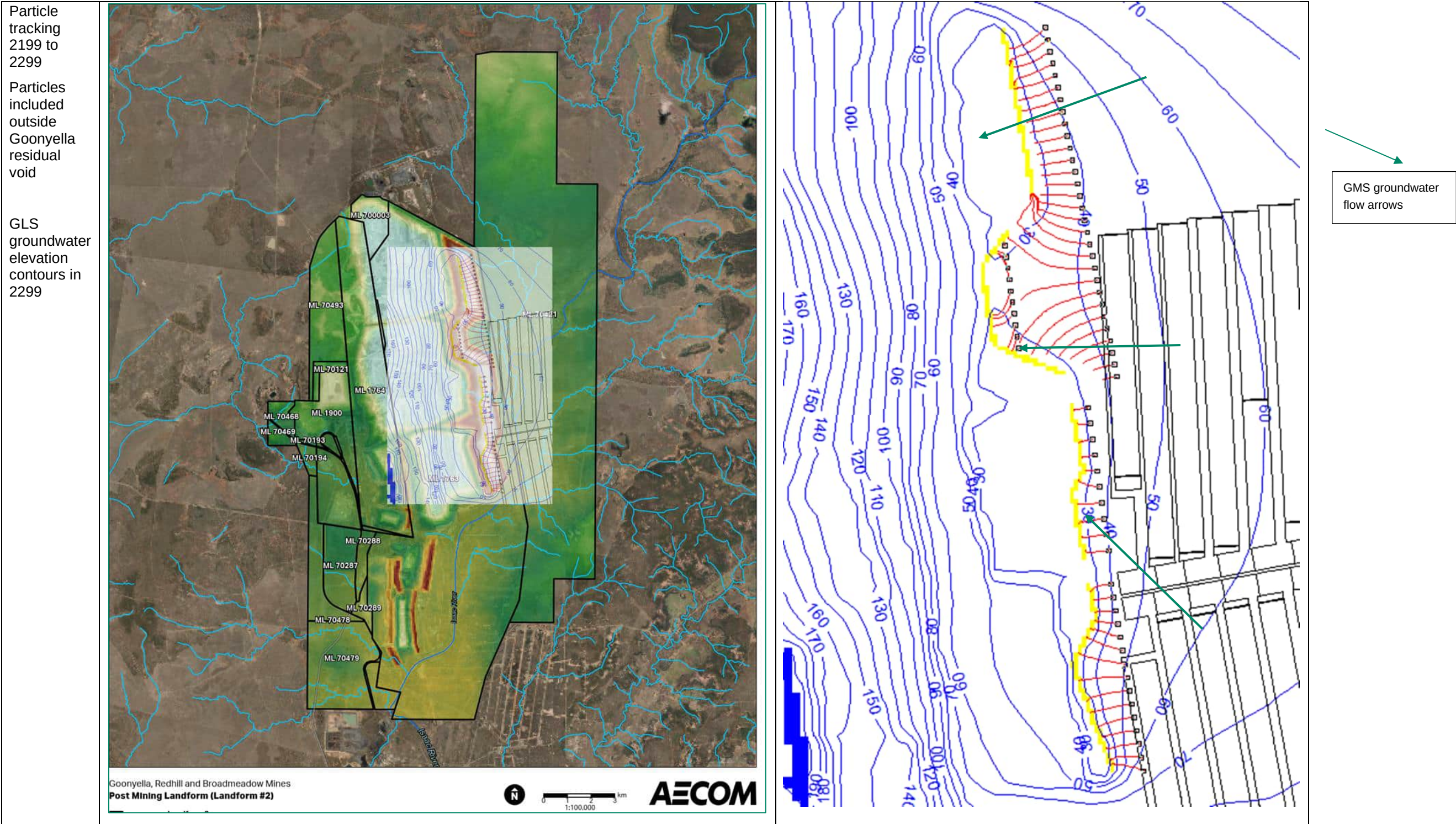


Figure 53 Long-term particle tracking for the Goonyella Pit residual void



It is noted in Figure 53 that particles introduced at RHM migrate towards the Goonyella residual void and localised GMS groundwater contours facilitate flow from RHM to the Goonyella residual void

Plate 41 TSFs, MIAs, and the Riverside Rejects locations

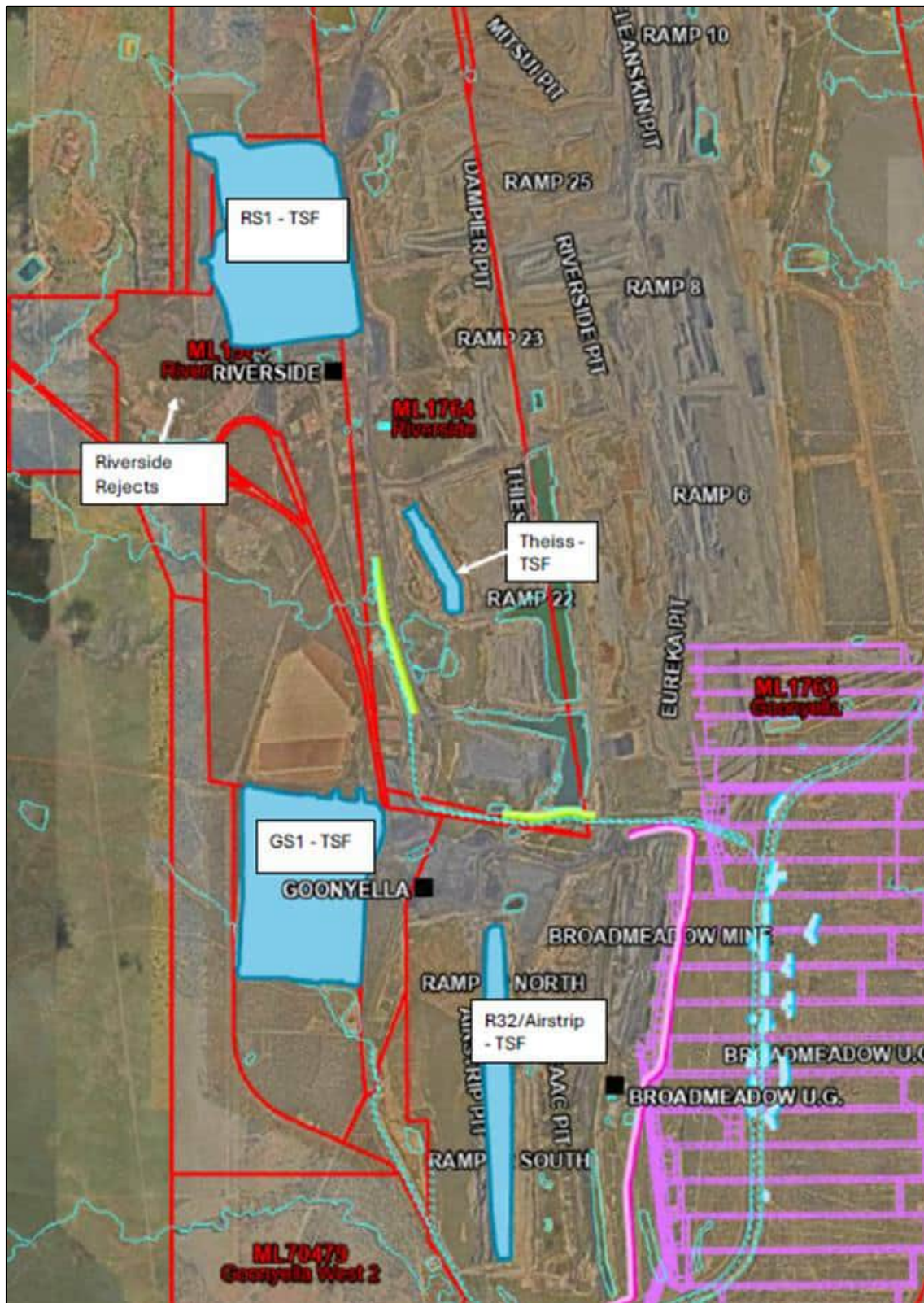
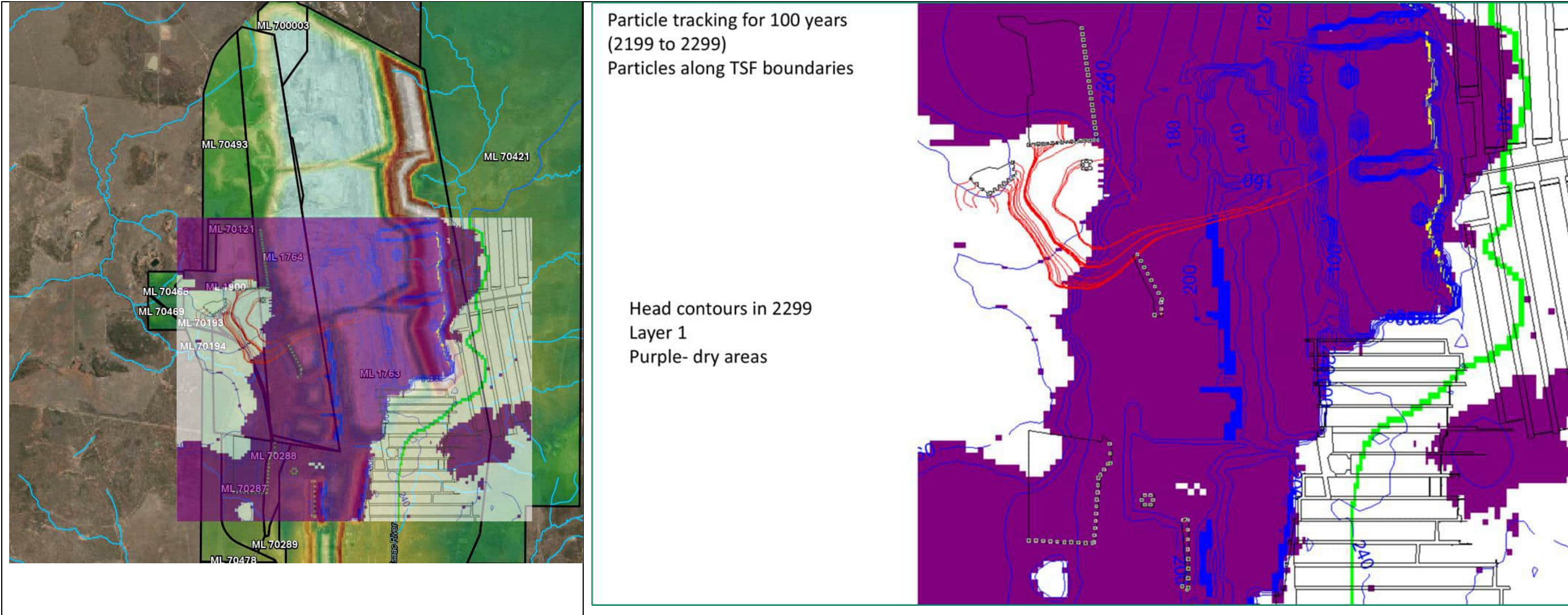


Figure 54 Particle tracking from mine waste storage facilities



Purple model cells in the surficial sediments (model layer 1) are dry
White model cells are saturated
Green model cells represent the Isaac River

Mine closure when all mining and decommissioning activities have ceased is recognised to be 2097. This is considered to include the rehabilitation of all mine waste storage facilities, included in the particle tracking simulation above. The particle tracking indicate migration across GRB from the former mine waste storage areas into Goonyella residual void. Particles are not predicted to migrate into RHM workings.

15.7.3 GMS long term saturation

The assessment of particle tracking and predictive groundwater elevations for the GMS indicate that the GMS would remain unsaturated in sections of the Project area post-closure. Groundwater elevations for the GMS after calibration (at the start of prediction phase P1), Figure 35, indicates the influence of historic Broadmeadow GMS underground mining. Water is introduced into the Broadmeadow underground workings between 2057 and 2060 (Section 15.2). An evaluation of groundwater contours for the GMS over time is included in Figure 55.

Figure 55 indicates the influence of RHM, the introduction of water into RHM, and the Goonyella Pit on the groundwater elevations and flow patterns in the GMS. The groundwater elevations and depth of GMS (bottom of coal seam elevations) allowed for the identification of saturated and unsaturated conditions of the GMS in the model. The purple model cells in Figure 55 indicate dry cells.

The northwest portion of the Broadmeadow GMS underground workings are identified to be unsaturated, after the introduction of water into the underground, over time due to the influence of the Goonyella Pit in this area.

The Broadmeadow underground workings are planned to be flooded with water to facilitate geotechnical stability. It is noted that mitigation and management of this portion of the Broadmeadow GMS workings may be required in the future subject to further geotechnical assessment.

The RHM (white model cells) will remain flooded. The GMS groundwater contours indicate flow from southwest (at the southern end of Broadmeadow GMS mine workings) to northeast (towards RHM workings), and then flow turns to towards the Goonyella residual void after P3.

The portion of the Project area presented in Figure 55 is as included below.

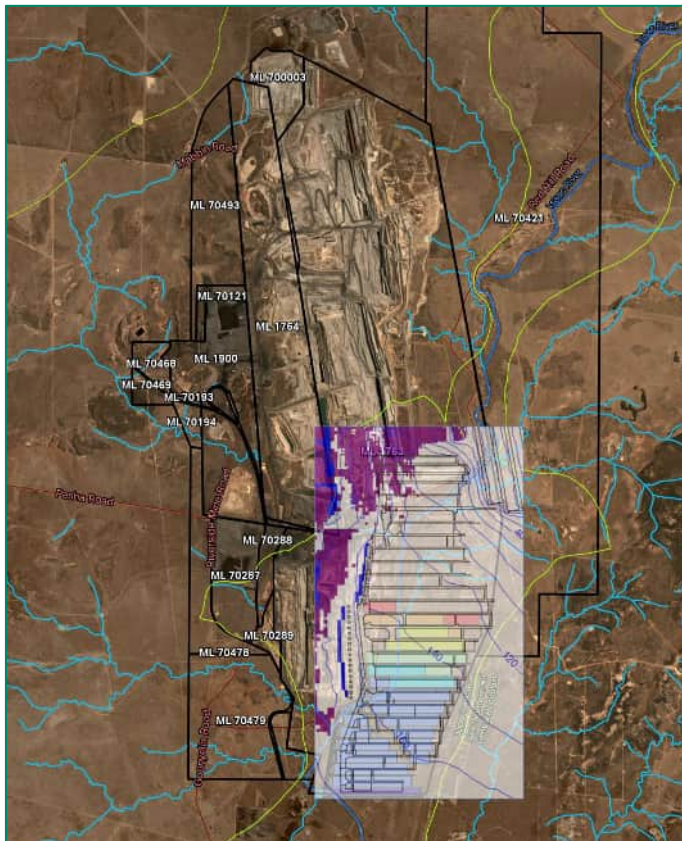
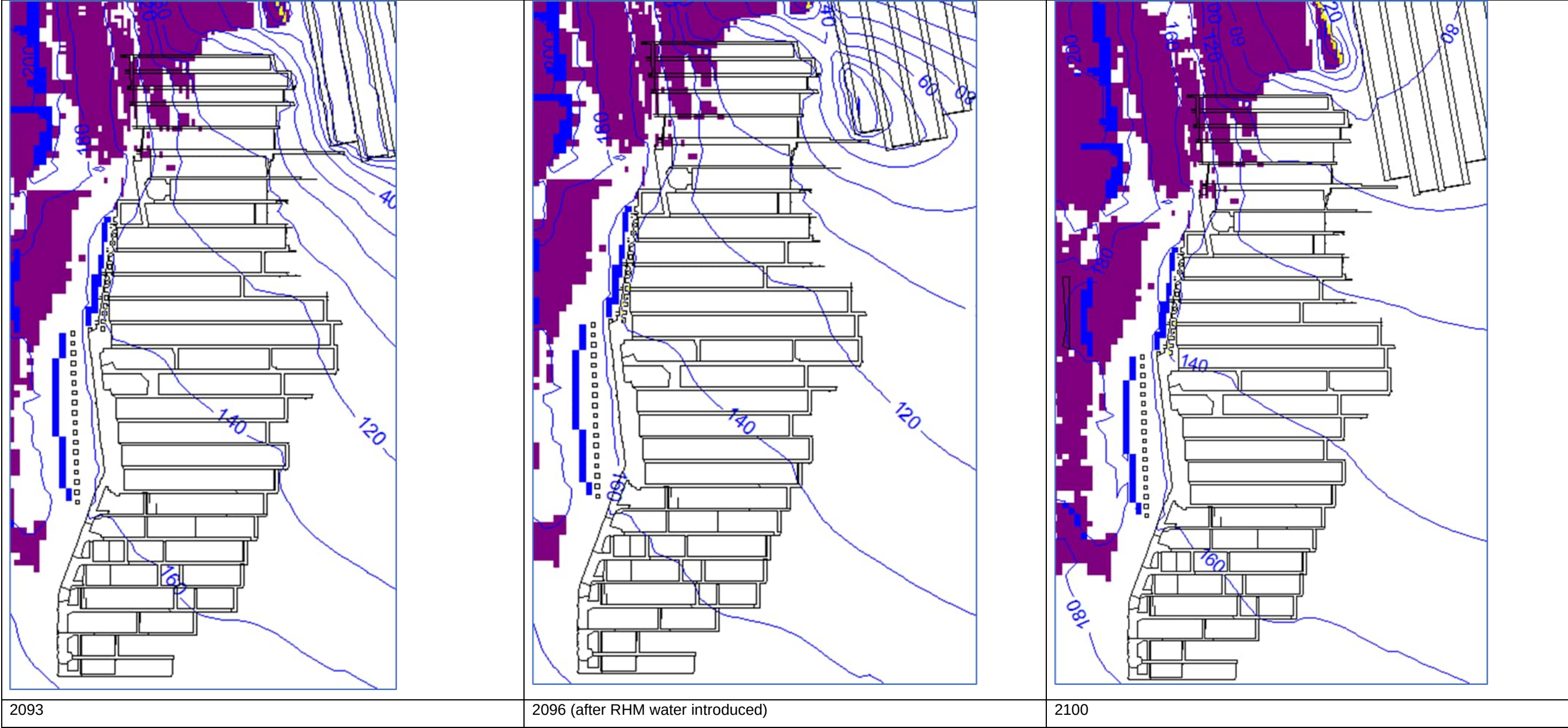
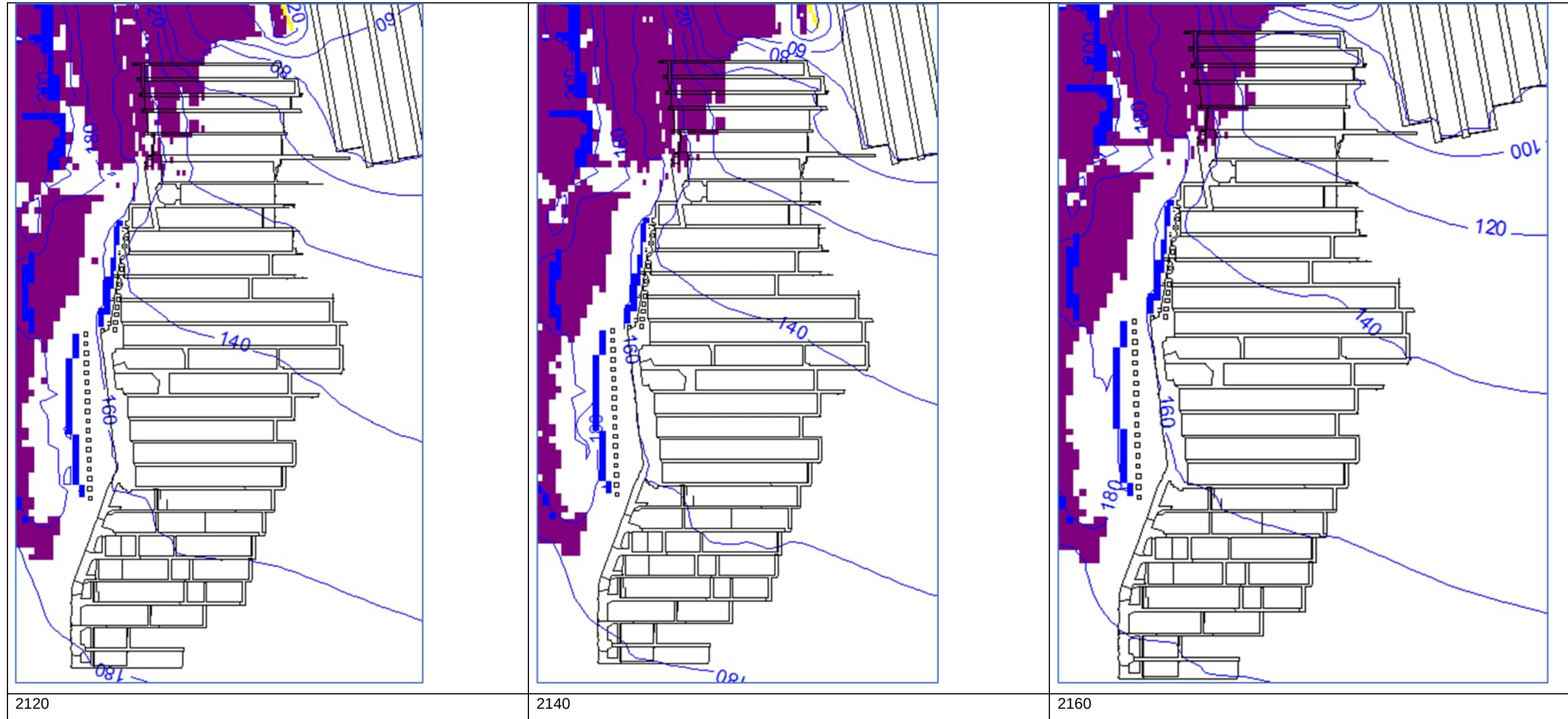
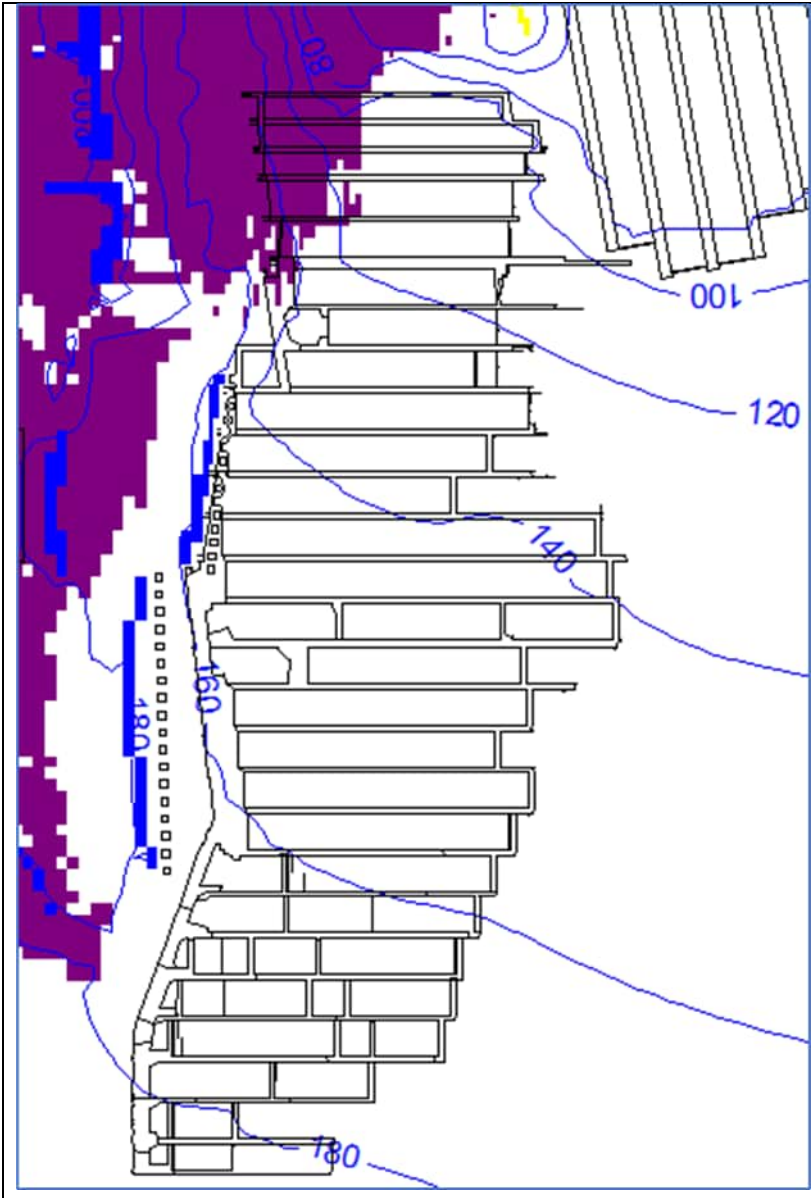


Figure 55 GMS saturated and unsaturated conditions over time

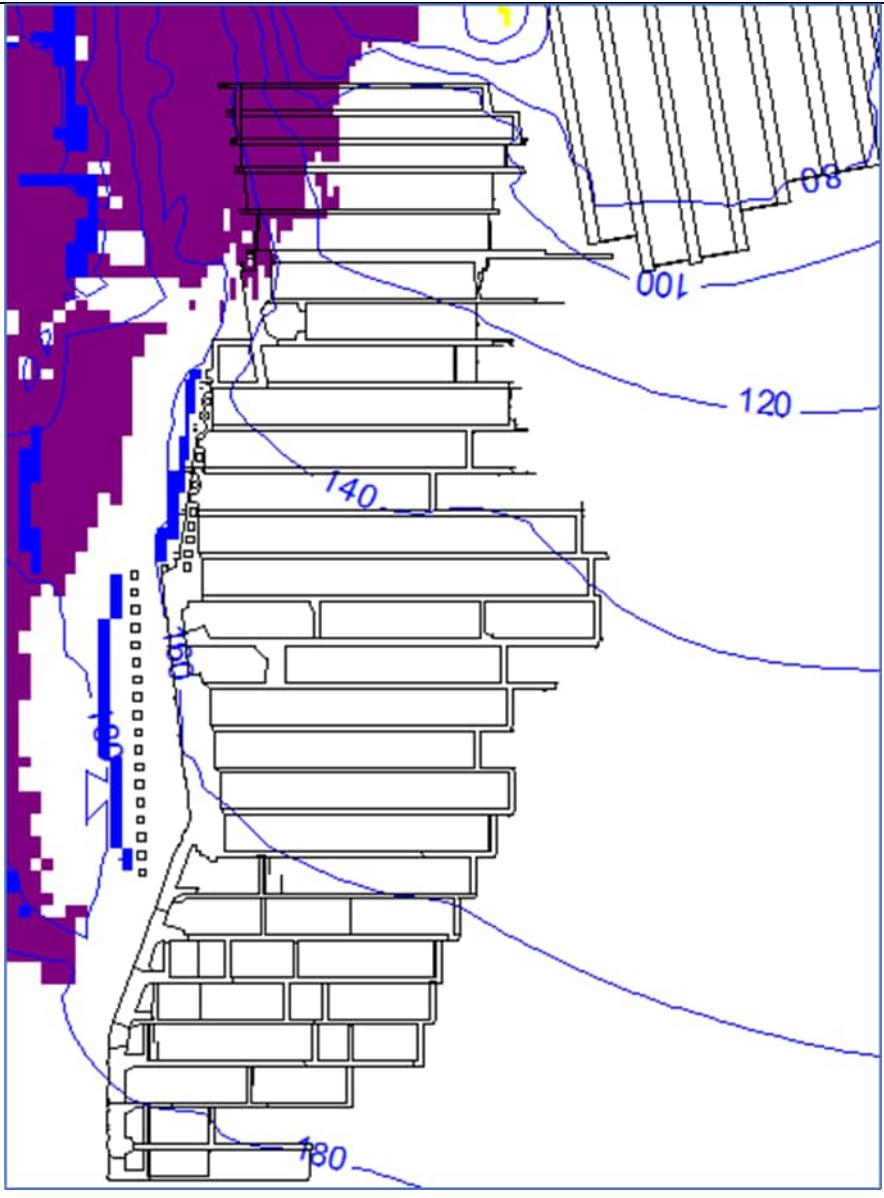


Purple model cells are dry
Yellow model cells are Goonyella residual void
Blue model cells are the other five residual voids
White model cells are saturated in the model

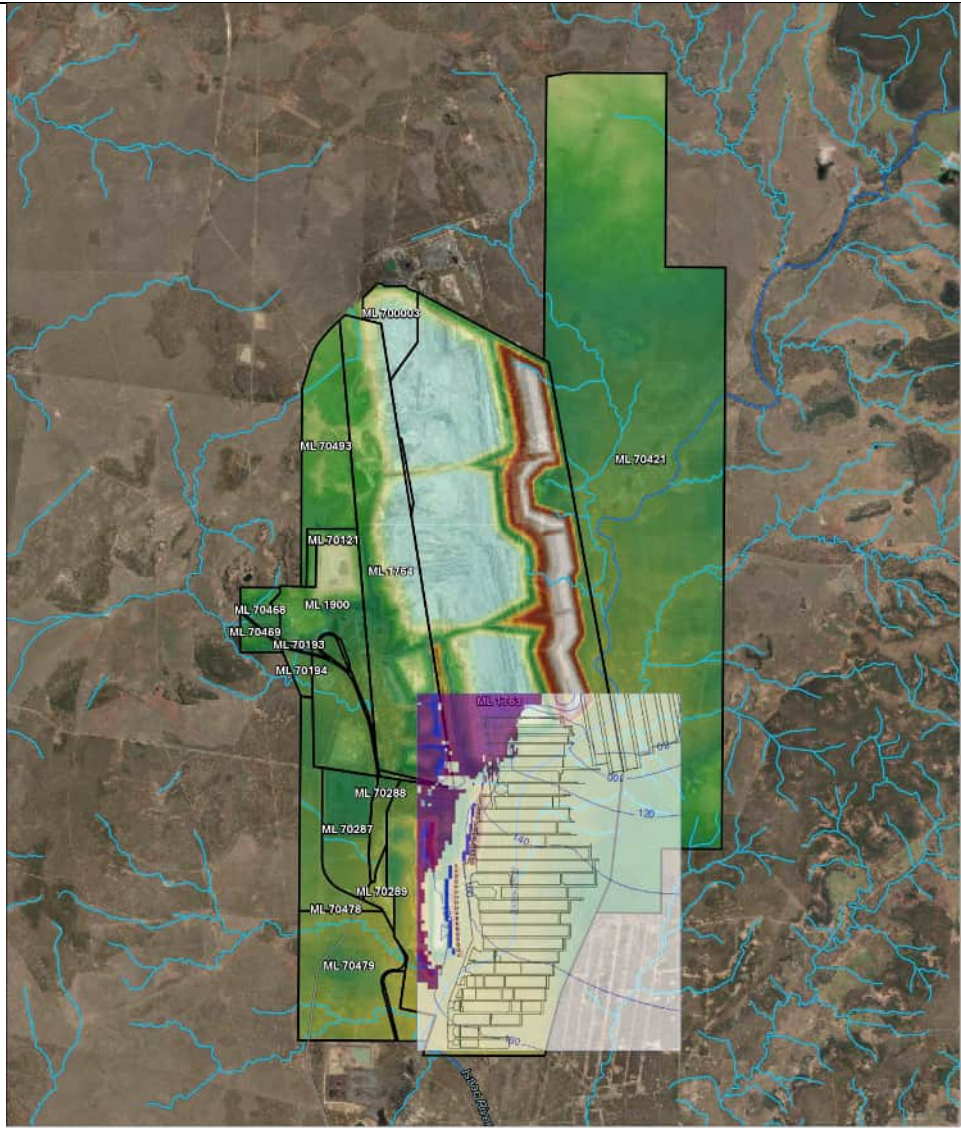




2180



2199



Goonyella, Redhill and Broadmeadow Mines
Post Mining Landform (Landform #2)



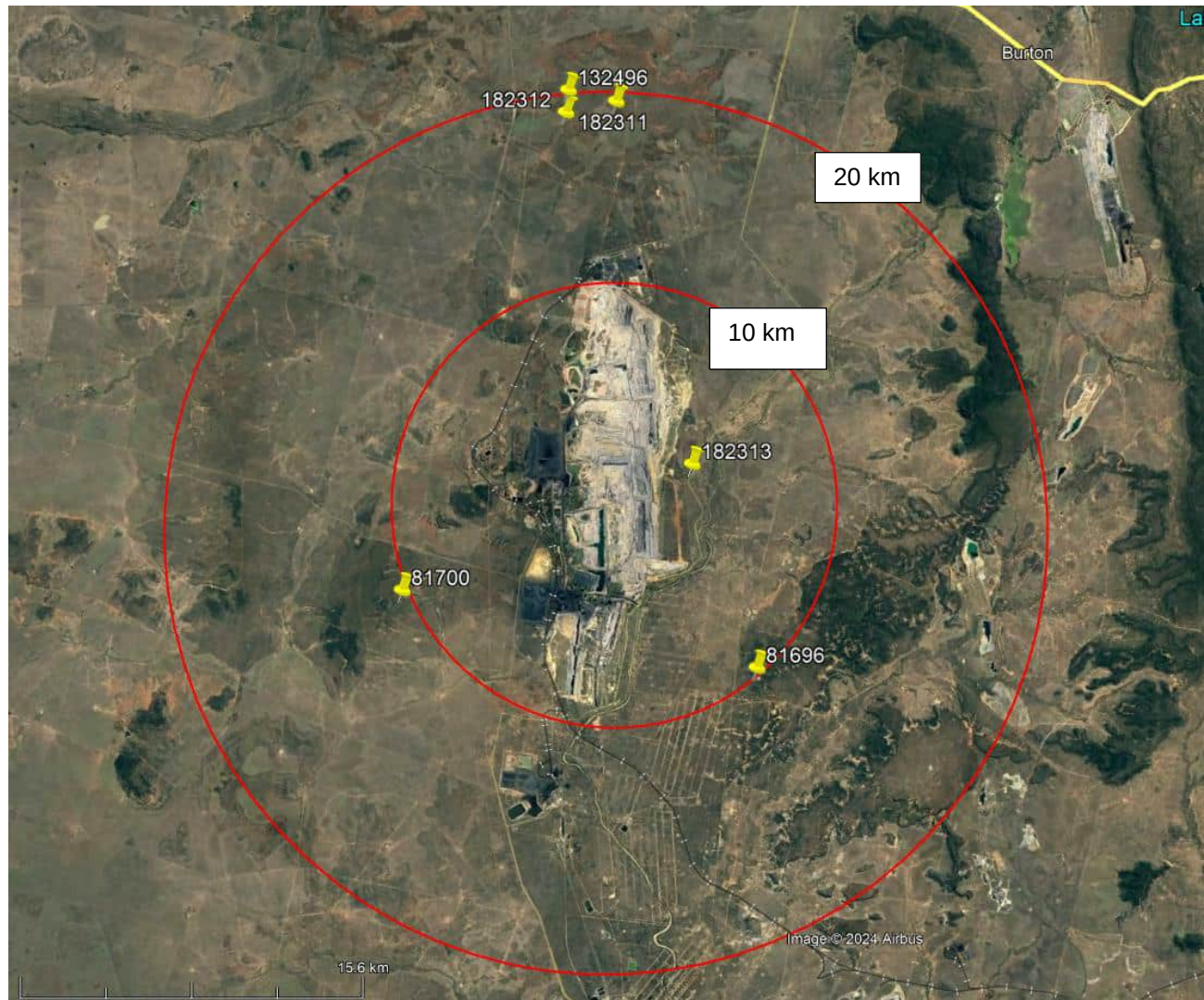
2199 reference

15.8 Potential Groundwater Level Impact to Receptors

15.8.1 Water supply bores

Six water supply bores were identified within the assessment of registered bores, as discussed in Section 9.1. The six water supply bores, as included in Table 14, were located up to 20 km from the existing GRB mining areas, as shown in Figure 56.

Figure 56 Water supply bores identified adjacent to GRB



Groundwater level hydrographs were compiled for each of these registered bores to assist in assessing the potential change in groundwater levels, due to approved mining and post-closure, overtime.

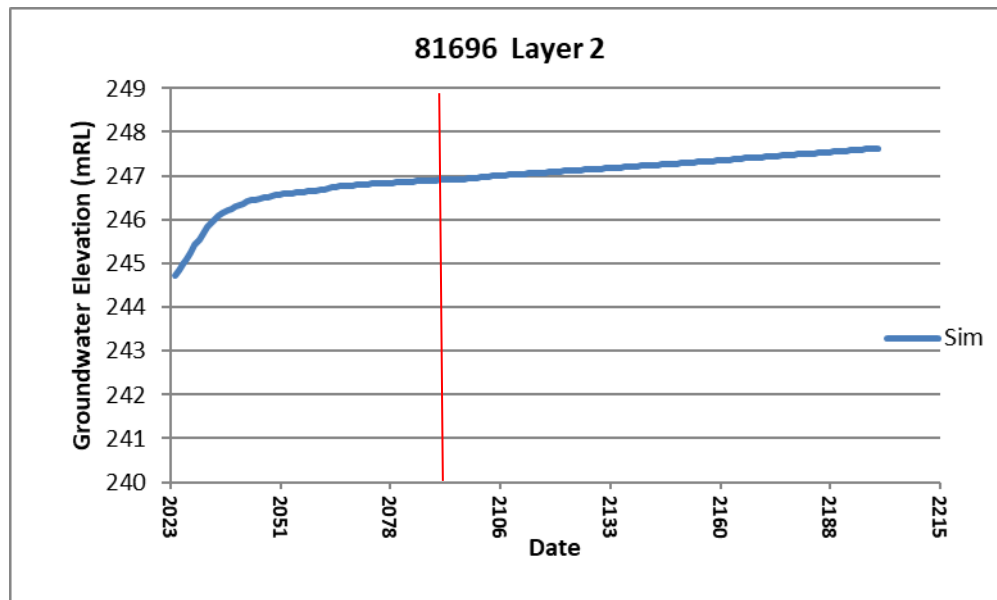
Three water supply bores, at or within 10 km from the current GRB mined areas, include:

- RN182313, Cleanskin Gully bore, which was drilled to 25.34 m, and based on depth intersects FCCM (model layer 2)
- RN81696, Skeleton Bore, which was drilled to 63.7 m in model layer 2
- RN81700, Harvey's Bore, has no data but assumed to be in model layer 2 (same as the other two water supply bores).

The water supply bores were included in the groundwater model domain and the groundwater levels were simulated during all four prediction phases (Section 15.2), from 2024 to 2199. The resultant hydrographs are discussed below.

The hydrographs include 2097 the date when mine closure is recognised, when all mining and decommissioning activities are complete.

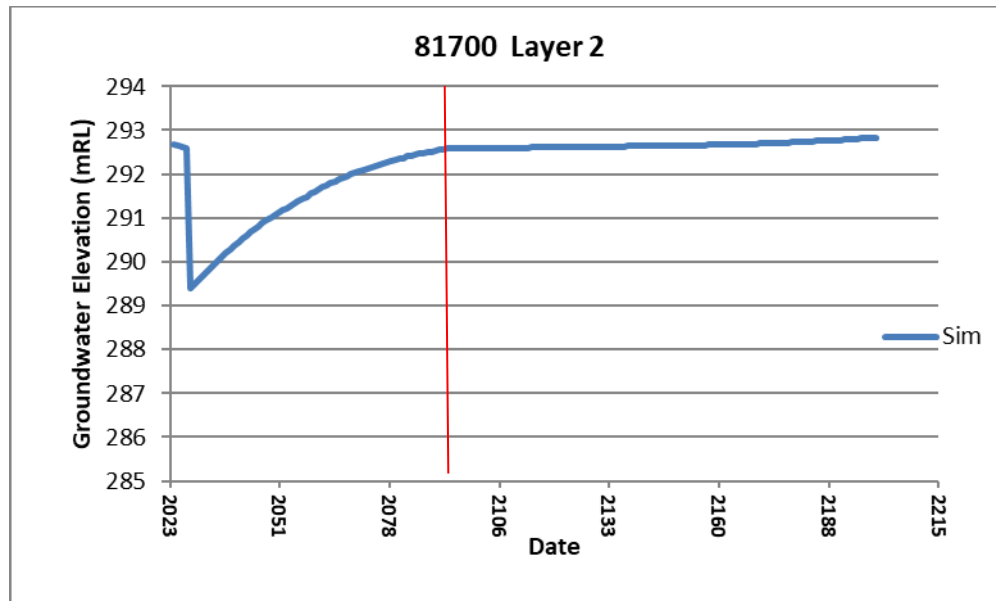
RN81696 Skeleton Bore



Sim – simulated groundwater level within the water supply bore

Red line – 2097 closure date

The bore, located some 10 km to the south west of GRB is recognised to recover over time, indicating no predicted alteration due to the Project during and post-closure in this location.

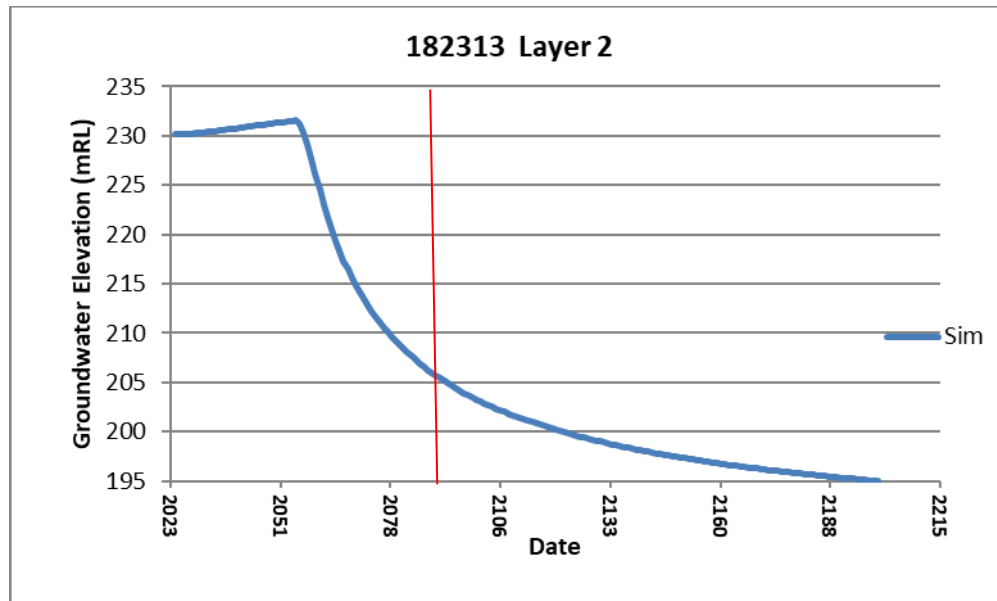
RN81700 Harvey's Bore

Sim – simulated groundwater level within the water supply bore

Red line – 2097 closure date

Note: Harvey's Bore is located to the west of the existing GRB mining footprint, on Back Creek Group sediments. The model layers 2 to 13 in this portion of the model domain are dummy layers as required in the MODFLOW model. The surficial sediments and Tertiary are 10 m thick in the model to the west of the sub-cropping Permian coal bearing units. This bore is assumed, based on the other water supply bores, to be deeper than 10 m and thus included in the underlying model layer.

The groundwater drawdown for RN81700 is predicted at the start of the prediction period P1 (2024 – 2056), which includes the Broadmeadow underground mining. This change in groundwater level possibly relates to matching calibration levels for the Back Creek Group rather than mine related drawdown (i.e., the mine dewatering activities are not predicted to impact on Back Creek Group sediments to the west). The groundwater level then recovers back to 2024 (start of P1) groundwater elevations.

RN182313 Cleanskin Gully Bore

Sim – simulated groundwater level within the water supply bore

Red line – 2097 closure date

This bore, down dip and in proximity to the residual Goonyella Pit void, is predicted to be dewatered overtime and remain dewatered post-closure. This bore is located in proximity to the Goonyella residual void high wall on BMA operated area. Therefore, it is reasonably assumed not to be used for supply purposes.

A drawdown of some 35 m will, based on the bore depth of 25.34 m, become dry with time. It is considered that the approved mining activities will result in the dewatering of the bore and has been assessed and managed under approval conditions.

15.8.1.1 Remaining water supply bores

Based on the limited impact of the mining post-closure at 10 km from the Project, the three registered bores, 182311, 182312, and 132496, are located some 20 km from the existing GRB mining areas and thus are sufficiently far from the mining activities to not be impacted.

These water supply bores are located outside the active model domain (Plate 16) (i.e., these bores are beyond the northern model boundary, which is based on the Isaac River catchment).

15.8.2 GDEs

The mapped potential GDEs (aquatic and terrestrial) are included in Figure 20. The mapping indicates low potential terrestrial GDEs adjacent to the Isaac River with the river channel itself identified as having high potential aquatic GDEs. Mine water storages across the GRB are mapped as high and moderate potential GDEs. It is noted that these storages, including the RS and GS TSFs (Plate 41) will be rehabilitated at closure. As per Section 9.2 it was noted that the potential aquatic GDEs, mapped in Figure 20, included areas containing tailings dams, mine water storages, and mining voids. Thus, the mapping is recognised to identify potential GDEs only.

Groundwater elevations derived during the groundwater model at the end of 2023 (Q1 2024) are included in Figure 57. These groundwater levels and flow patterns were representative of the influence of approved mining activities within the Project area. The modelling identified where saturated sediments, which can provide groundwater for GDEs, have been dewatered due to approved mining activities.

The extent of groundwater drawdown in the surficial sediments (model layer 1) as discussed in Section 15.5.1, is identified to be limited to the proximity of the mine workings. This is due to:

- The discontinuous nature of the surficial sediments
- The thin saturated thickness of the surficial cover
- The discontinuous nature of saturated sediments
- The restricted aquifer hydraulic properties.

Groundwater elevation contours from north (upstream) to south (downstream) along the Isaac River (green model cells) do not indicate any drawdown influence in 2024 (start of prediction periods in the groundwater model).

The mapped potential GDEs, a portion of Figure 20, is included in Figure 58. This figure includes the mapped GDEs within the mine footprint. Groundwater drawdown, compared to the initial groundwater elevations in model layer 1 in 2023/2024, is included in Figure 57.

The post-closure change in groundwater compared to current (2024) conditions resultant from approved mining, indicates:

- Zero (0) change along the Isaac River (green model cells)
- Drawdown immediately adjacent to the Goonyella residual void post-closure is not predicted to extend to the Isaac River
- Marked reduction in extent of drawdown around the closed mine workings due to decommissioning activities, introduction of water, and recovery of groundwater levels, which reduce the extent of drawdown.

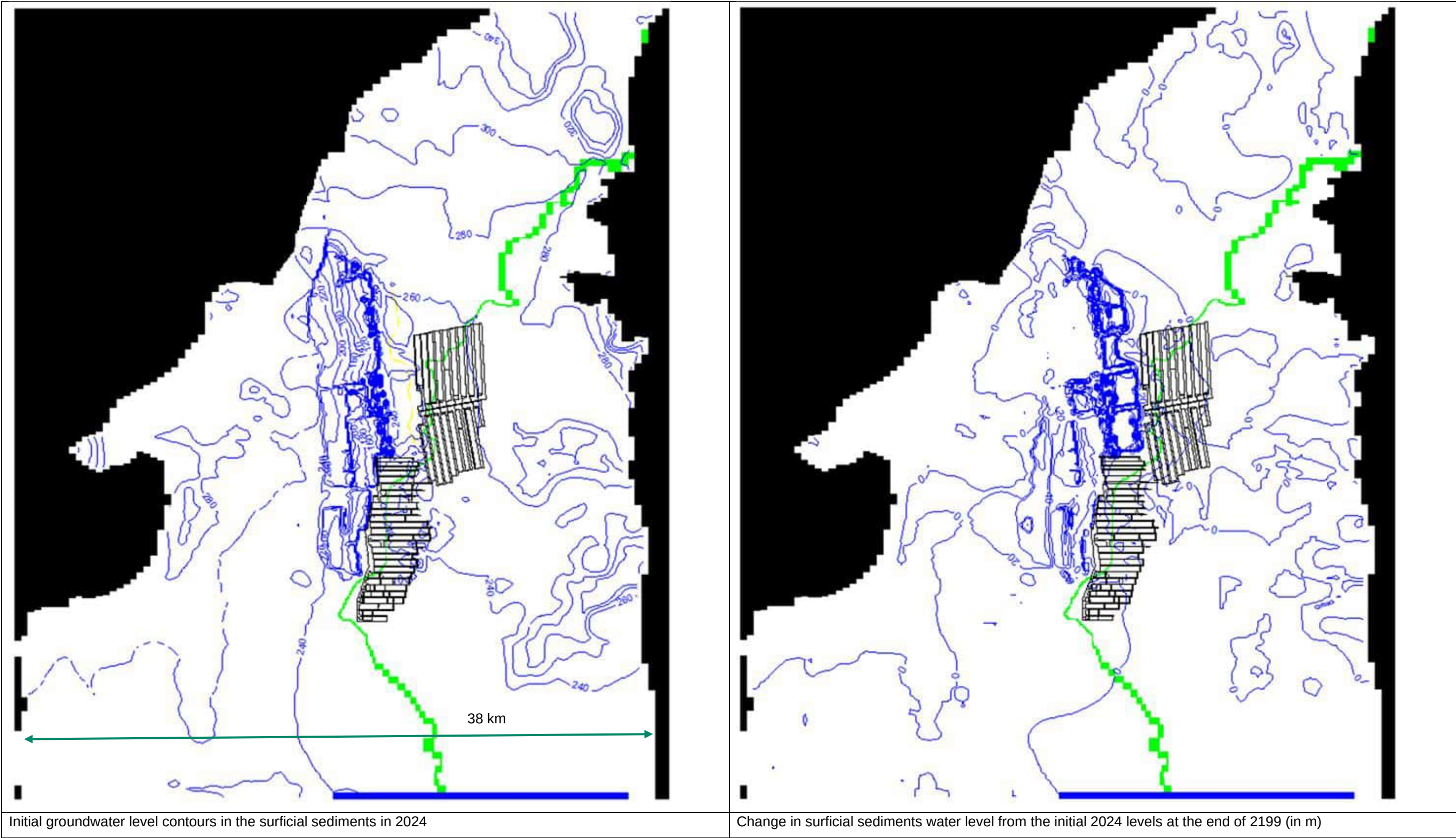
The post-closure groundwater conditions are not predicted to impact on the Isaac River GDEs and have reduced impact to potential GDEs compared to mining operations

Hypothetical water level observation points were included in the predictive model, model layer 1, along the Isaac River and at potential high potential aquatic GDEs, to aid in the assessment of water level change. The hypothetical observation points, GDE1 to GDE4, are included on Figure 58.

The hydrographs included in Plate 42 indicate:

- Stable or increasing groundwater elevation at these locations post-closure indicate no predicted impacts to the potential aquatic GDEs
- Limited natural fluctuation in groundwater levels over time (narrow range of groundwater levels)
- Water level recovery at GDE3 relates to initial water level derived during 2024 calibration correcting during the prediction periods in response to mining activities.

Figure 57 Water level change from the 2024 model layer 1 groundwater elevations post-closure



Green model cells are the Isaac River
Yellow model cells are the Goonyella residual void

Figure 58 Mapped GDEs within the Model Layer 1

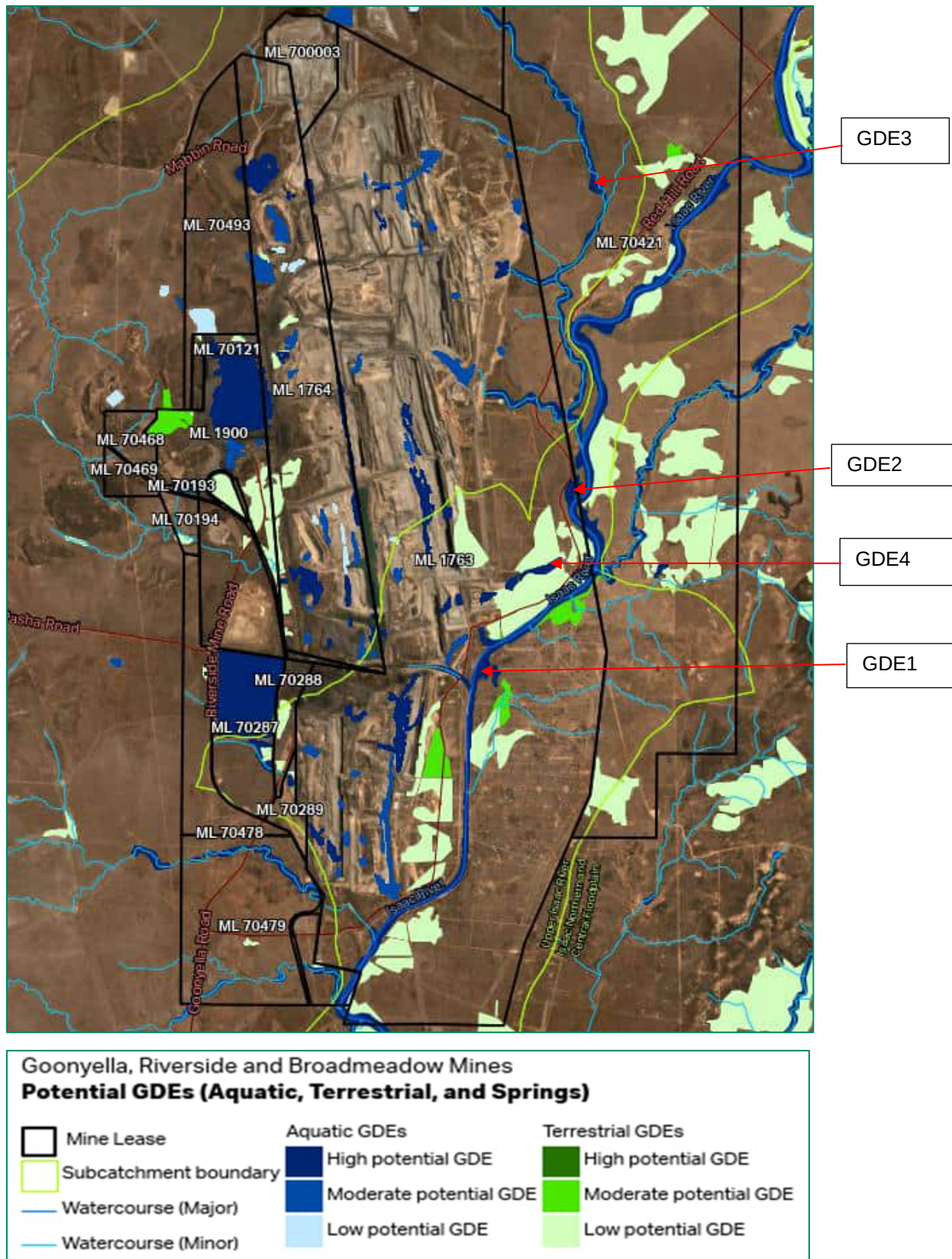
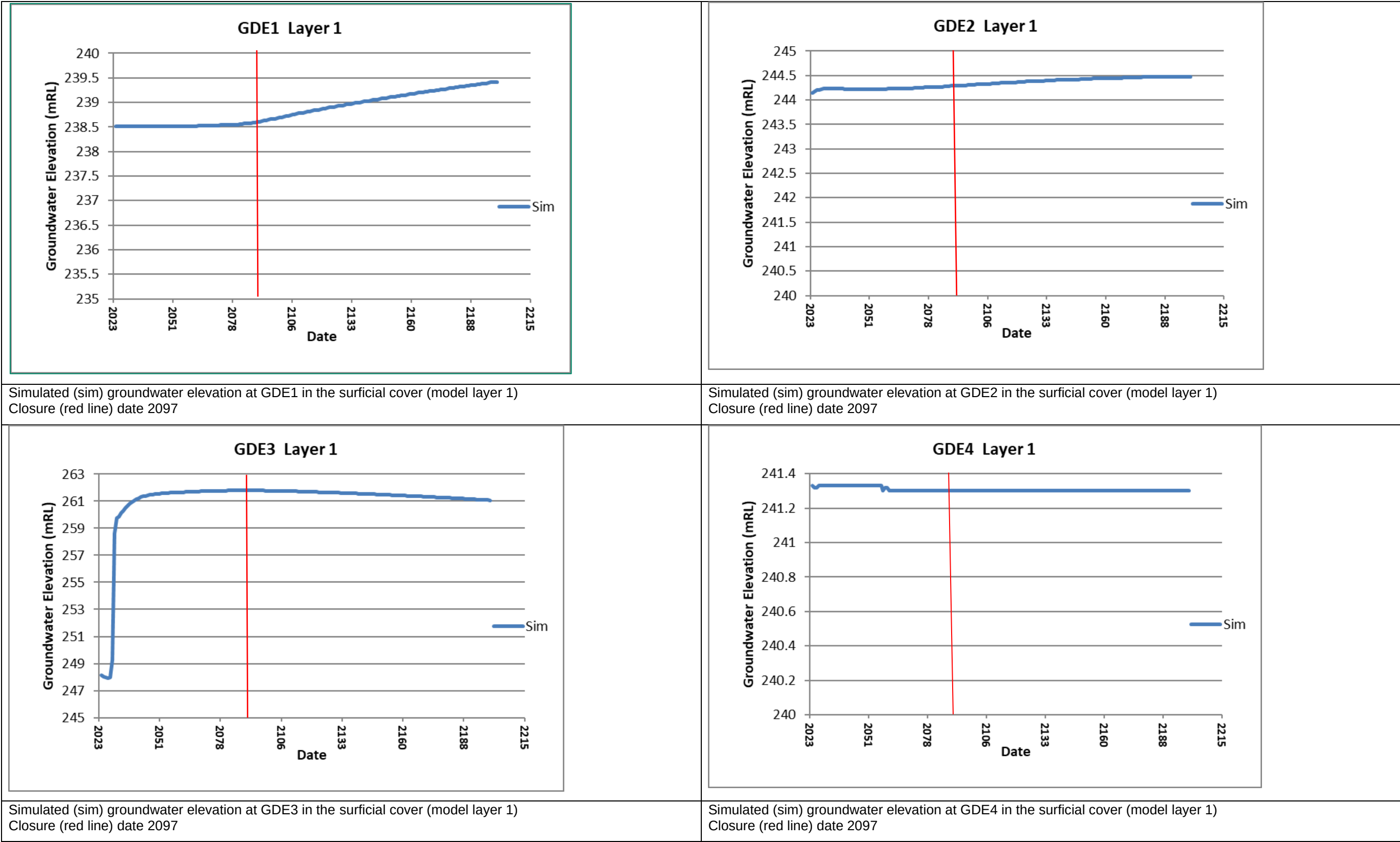


Plate 42 Hydrographs of groundwater elevation at high potential aquatic GDEs



16.0 Uncertainty analysis

16.1 Prediction uncertainty

Groundwater models are simplifications of complex natural systems and are inherently subject to uncertainty. Prediction uncertainty in groundwater modelling arises from various sources, including uncertainties in model conceptualization and parameter estimation. These uncertainties can significantly impact the reliability of model predictions and, consequently, the decision-making processes that rely on these predictions.

The conceptual model represents the understanding of the aquifer system, including its hydrogeological framework, flow processes, and interactions with surface water. Simplifications and assumptions made during the conceptualization phase can introduce uncertainty. However, the effects of alternative conceptualizations on the calibrated model were not explored in this study because the alternatives were considered limited. The current model has been built based on the best available information, including geological and hydrological data, which were deemed sufficient to represent the system conceptually.

Parameter uncertainty is a critical aspect of groundwater modelling that can significantly influence model predictions. Parameters such as hydraulic conductivity, porosity, and recharge rates are often estimated from limited field data, leading to inherent uncertainties. The spatial and temporal variability of these parameters further adds to the complexity. Given the inherent nature of parameter uncertainty, it is essential to incorporate this uncertainty into the model predictions and quantify the potential range of these predictions.

16.2 Approach to parameter uncertainty analysis

This section describes the methodology used to analyse parameter uncertainty in the groundwater model, employing PEST++ in conjunction with the Iterative Ensemble Smoother (IES) algorithm. This approach aligns with the Australian IESC guidelines for robust uncertainty assessment.

This approach provides a comprehensive analysis of parameter uncertainty by estimating posterior parameter distributions that yield an acceptable fit to the historical observations under the Bayesian framework. This method allows for the incorporation of prior knowledge and observational data to refine parameter estimates iteratively. During the iterative process, it employs ensemble-based sampling methods, similar to Monte Carlo simulations, to explore the parameter space and estimate parameter uncertainty. By generating multiple realizations of the model with different parameter combinations, it can assess the sensitivity of model predictions to parameter variations.

This process provides insights into quantifying the range of possible parameter values and assessing the uncertainty of model predictions. The results of this analysis can be used to inform decision-making processes, guide further data collection efforts, and improve the overall reliability of the groundwater model.

16.3 Ingress variation

The model calibration process, utilizing PEST++ IES, yielded multiple model realizations, each representing a unique set of parameter values that achieved a satisfactory fit to the historical observations. The goodness-of-fit for each realization was assessed using the standardized root mean squared error (SRMS), with all realizations achieving values below 10%. This indicates that the calibrated models are capable of replicating the observed data within a reasonable margin of error, providing confidence in the parameter values and the resulting predictions.

These accepted model realizations were then employed to explore the potential range of groundwater ingress into six mine pits: Broadmeadow, Issac, Thiess, R32 East, R32 South, and Goonyella. The ensemble of model predictions generated from these realizations provides a distribution of predicted ingress values for each pit. To interpret the probabilistic nature of these predictions, percentiles were calculated for each pit in every stress period (year) following the guidelines outlined in the Australian

IESC (2018) report. These percentiles translate the predicted ingress values into a likelihood of exceedance:

- <10th percentile indicates it is very likely the outcome is larger than this value
- 10th – 33rd indicates it is likely that the outcome is larger than this value
- 33rd - 67th indicate it is as likely as not that the outcome is larger or smaller than this value
- 67th - 90th indicates it is unlikely that the outcome is larger than this value
- > 90th percentile indicates it is very unlikely the outcome is larger than this value.

16.3.1 Groundwater contribution

Water balance modelling was conducted to predict pit water levels over time, the predictive groundwater modelling allowed for the estimate of groundwater contribution as detailed in Section 15.4. The groundwater contribution, compared to the surface water runoff inputs (derived from residual void water balance modelling Rev D, Section 15.4.1), was conducted based on the mean data compiled for the last 20 years. These statistics, allowing for runoff from different catchments and landcover, plus pit size (direct rainfall) is included in Table 24.

The data indicates the groundwater contribution into the mine pits has historically been less than 20% of the total ingress into the pits.

The contribution for the end of water balance modelling (31 December 2199), using the results of the coupled surface water and groundwater water balance modelling provided an estimate of groundwater contribution in 2199, as included in Table 25.

The contributions, after adopting the Landform #2.3, reduces surface water contribution. This results in the major contributor to the water balance is the groundwater ingress.

The daily water balance data in Table 25 indicate evaporation at each residual void is orders of magnitude higher than the total ingress during post-closure (end of 2199). This indicates that, allowing for different climate conditions and ingress uncertainty, the influx contributions to the residual voids are unlikely to exceed the evaporation outflux.

The surface water contributions over time are climate (seasonal) related and are markedly higher than the evaporation rate (on a daily) basis. This, plus the depth of the residual voids (shade), allows for the development of residual void water levels and not dry residual voids.

Table 24 GRB mine pit water balance data – mean for last 20 years

Mean for last 20 years	Goonyella	Broadmeadow	Isaac	R32South	R32East	Thiess
Pit Inflow (ML/day)	0.17	0.011	0.005	0.005	0.007	0.018
Natural inflow (ML/day)	0.005	0	0	0	0	0
Rehab Inflow (ML/day)	0.049	0.008	0.012	0.001	0.005	0.045
Direct Rainfall (ML/day)	0.147	0.008	0.007	0.003	0.008	0.016
Groundwater inflow (ML/day)	0.178	0.002	0	0.003	0.008	0
Groundwater outflow (ML/day)	0	0	0.002	0	0	0.0215
Evaporation Actual (ML/day)	0.53	0.029	0.022	0.012	0.029	0.058
Sum (ML/day)	1.08	0.06	0.049	0.024	0.058	0.158
%GW contribution (of influx)	32.5	8.5	0.06	25	29	0

Table 25 Residual void water balance data – 31 December 2199

End of P4	Goonyella	Broadmeadow	Isaac	R32South	R32East	Thiess
Pit Inflow (ML/day)	0.0287	0.0019	0.0009	0.0008	0.0012	0.0031
Natural inflow (ML/day)	0.0002	0	0	0	0	0
Rehab Inflow (ML/day)	0.0048	0.0008	0.0011	0.0001	0.0005	0.0043
Direct Rainfall (ML/day)	0.4119	0.0164	0.0223	0.0075	0.0200	0.0192
Groundwater inflow (ML/day)	3.3354	0.0474	0	0.0411	0.1647	0
Groundwater outflow (ML/day)	0	0	0.0594	0	0	0.5242
Evaporation Actual (ML/day)	15.0441	0.9299	0.6100	0.3639	0.8996	1.7333
Sum (ML/day)	3.7809	0.0664	0.0243	0.0495	0.1865	0.0266
%GW contribution (of influx)	88	71	0	83	88	0

The contributions, after adopting the Landform #2.3 at GRB, reduces surface water contribution. This results in the major contributor to the water balance is the groundwater ingress. The ingress contribution indicate that four of the residual voids will function as groundwater sinks. The Isaac and Thiess residual voids, with no groundwater ingress, function as sources, as recognised in Figure 50.

The daily water balance data in Table 25 indicate evaporation at each residual void is orders of magnitude higher than the total ingress during post-closure (end of 2199). This indicates that, allowing for different climate conditions and ingress uncertainty, the influx contributions to the residual voids are unlikely to exceed the evaporation outflux.

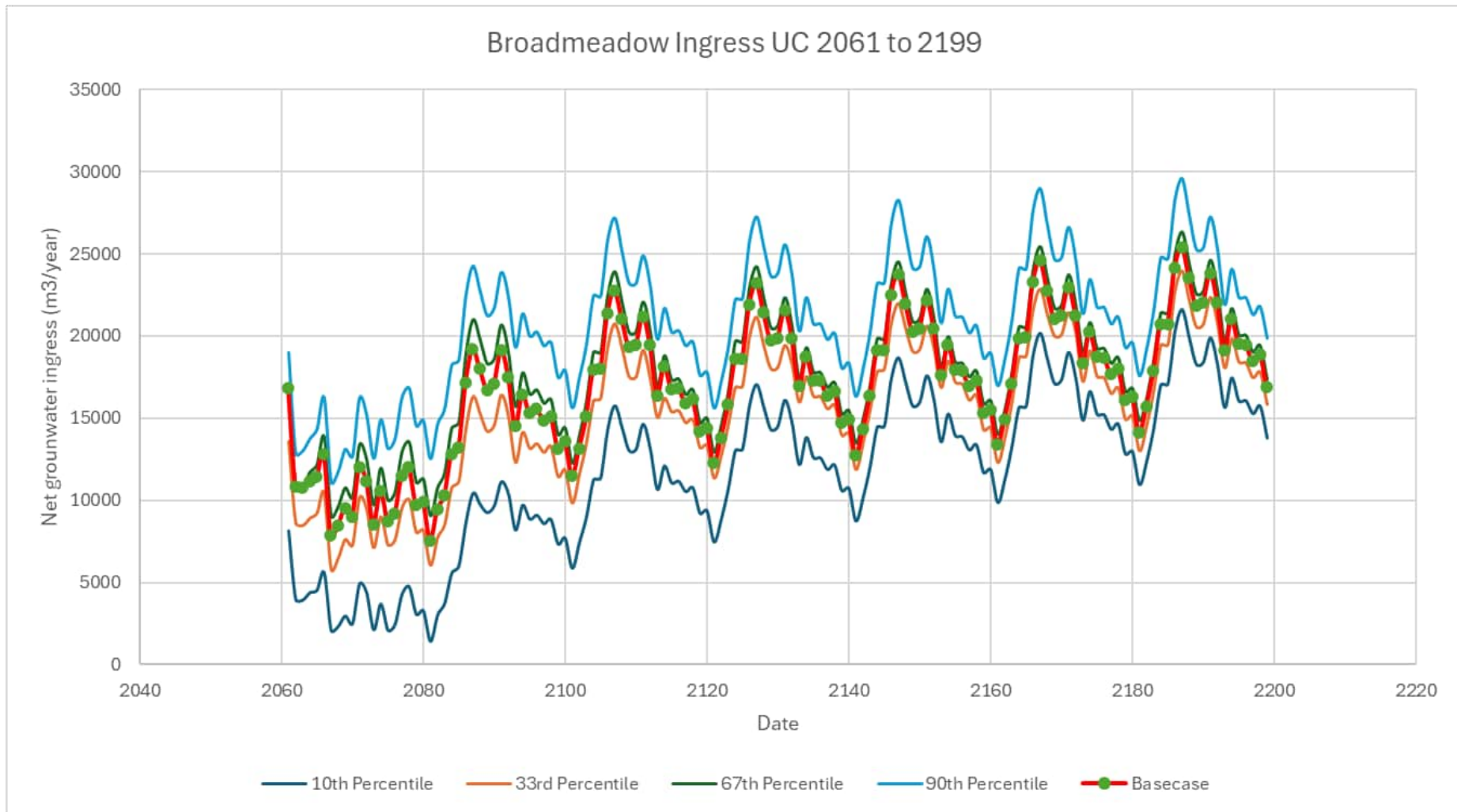
16.3.2 Broadmeadow Pit

Adopting the uncertainty approach as described above in Section 16.0 a range of ingress estimates were derived through the generation of multiple realizations of the model with different parameter combinations (while the model remains within the acceptable calibration criteria). These percentiles of ingress estimates across the stress periods for Broadmeadow Pit, as included in the model, are included in Plate 43.

The base case (set of model parameters) ingress predictions fall between the 10th percentile (very likely the outcome is larger than this value) and the 90th percentile (very unlikely the outcome is larger than this value), and matches well between the narrow band of estimates derived by the 33rd and 67th percentiles. This narrow band is included in Plate 43.

The ingress estimates, leading to the estimate of the Broadmeadow Pit water level is considered suitable for input into the water balance modelling, as the base case allowed for an estimate that (between 33rd and the 67th percentiles) is not likely to be larger or smaller than these ingress estimate values.

Plate 43 Uncertainty graph for Broadmeadow Pit



16.3.3 Isaac Pit

Groundwater is predicted to flow out from Isaac Pit during mining, decommissioning, and post-closure, as included in Plate 44, as evident from the base case estimates using the parameters adopted in the predictive model.

The multiple realizations of the model using different parameter combinations indicated the predictions were not sensitive to the parameter changes for Isaac Pit, as evident in the narrow band of estimates (considering the 33rd and 67th percentiles).

The base case and 90th percentile are similar indicating that the groundwater outflow from the pit is likely to be lower than included in the water balance model for the Isaac Pit water level predictions.

16.3.4 Thiess Pit

Similar to the Isaac Pit, groundwater is predicted to flow out from Thiess Pit during mining, decommissioning, and post-closure, as included in Plate 44, as evident from the base case estimates using the parameters adopted in the predictive model.

The multiple realizations of the model using different parameter combinations indicated the predictions allowed for the determination of a narrow band of estimates (all indicating groundwater loss post-closure).

The base case (set of model parameters) ingress predictions is similar to the 33rd percentile results, which indicates the groundwater loss from the pit is likely to be less than these estimates (noting these are negative values).

Based on the statistics it is likely that the net ingress (loss) from Thiess Pit would be between the 33rd and 67th percentiles, which is not a marked difference.

Plate 44 Uncertainty graph for Isaac Pit

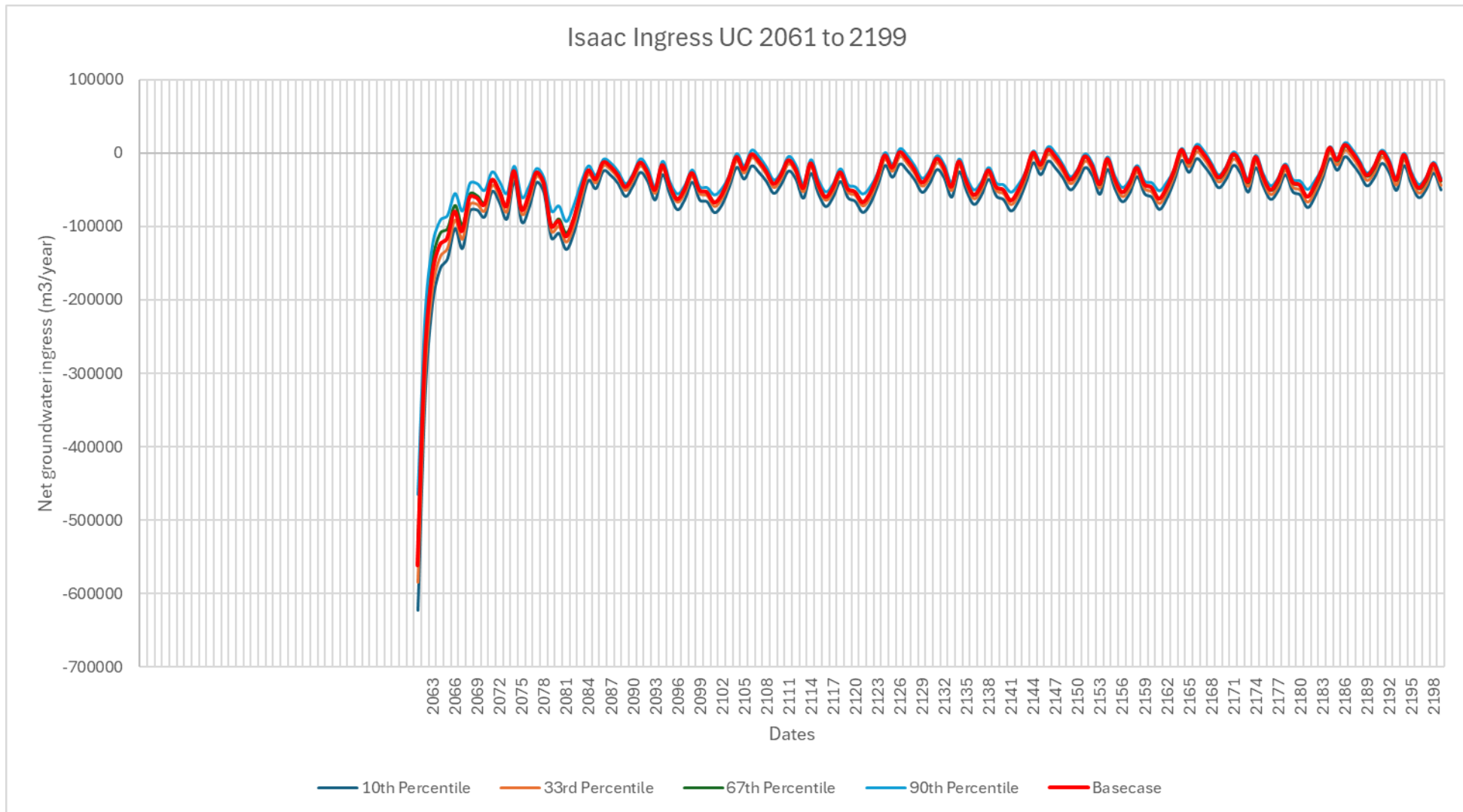
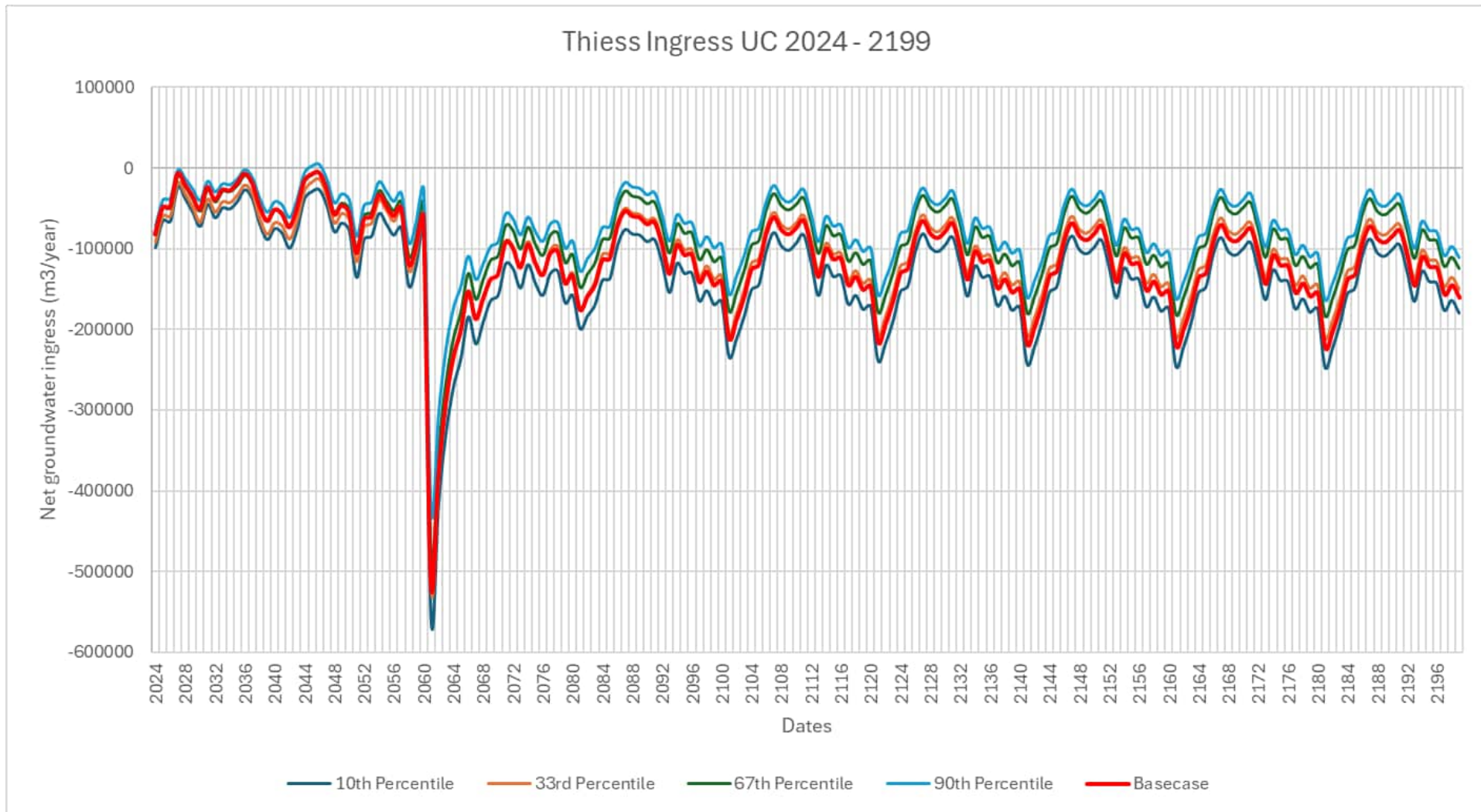


Plate 45 Uncertainty graph for Thiess Pit



16.3.5 R32 East Pit

A range of ingress estimates were derived through the generation of multiple realizations of the model with different parameter combinations for Ramp 32 East. These percentiles of ingress estimates, across the stress periods for Ramp 32 East Pit, are included in Plate 46.

The base case (set of model parameters) ingress predictions fall between the 67th percentile and the 90th percentile (very unlikely the outcome is larger than this value). This indicates that the groundwater ingress to the pit is likely to be lower than included in the water balance model for the Ramp 32 East Pit water level predictions.

16.3.6 R32 South Pit

A range of ingress estimates were derived through the generation of multiple realizations of the model with different parameter combinations for Ramp 32 South. These percentiles of ingress estimates, across the stress periods for Ramp 32 South Pit, are included in Plate 47.

The base case ingress predictions match well with the 67th percentile results, which indicates that the estimates are likely not to be larger or smaller than these estimates.

Plate 46 Uncertainty graph for R32 East Pit

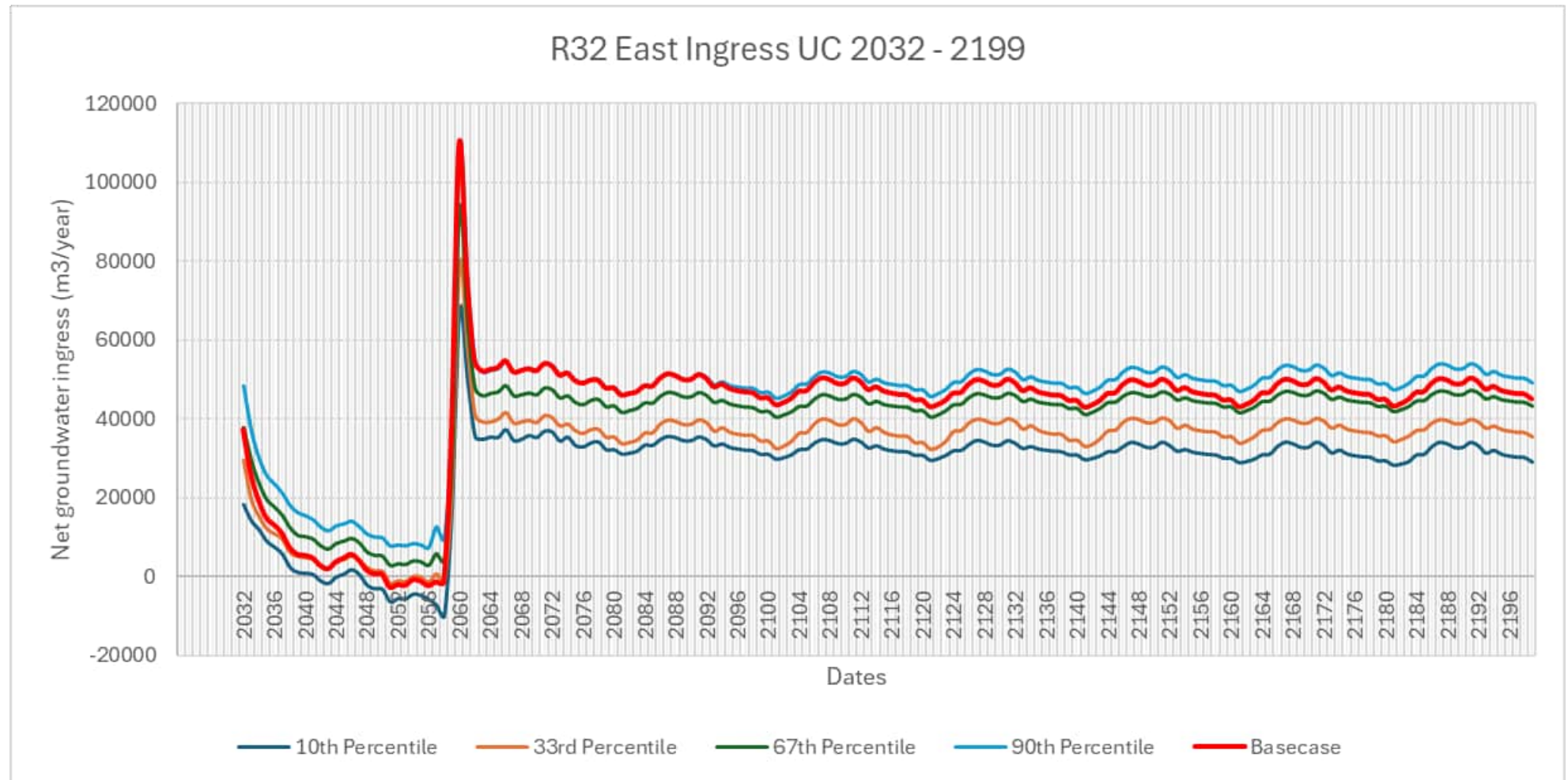
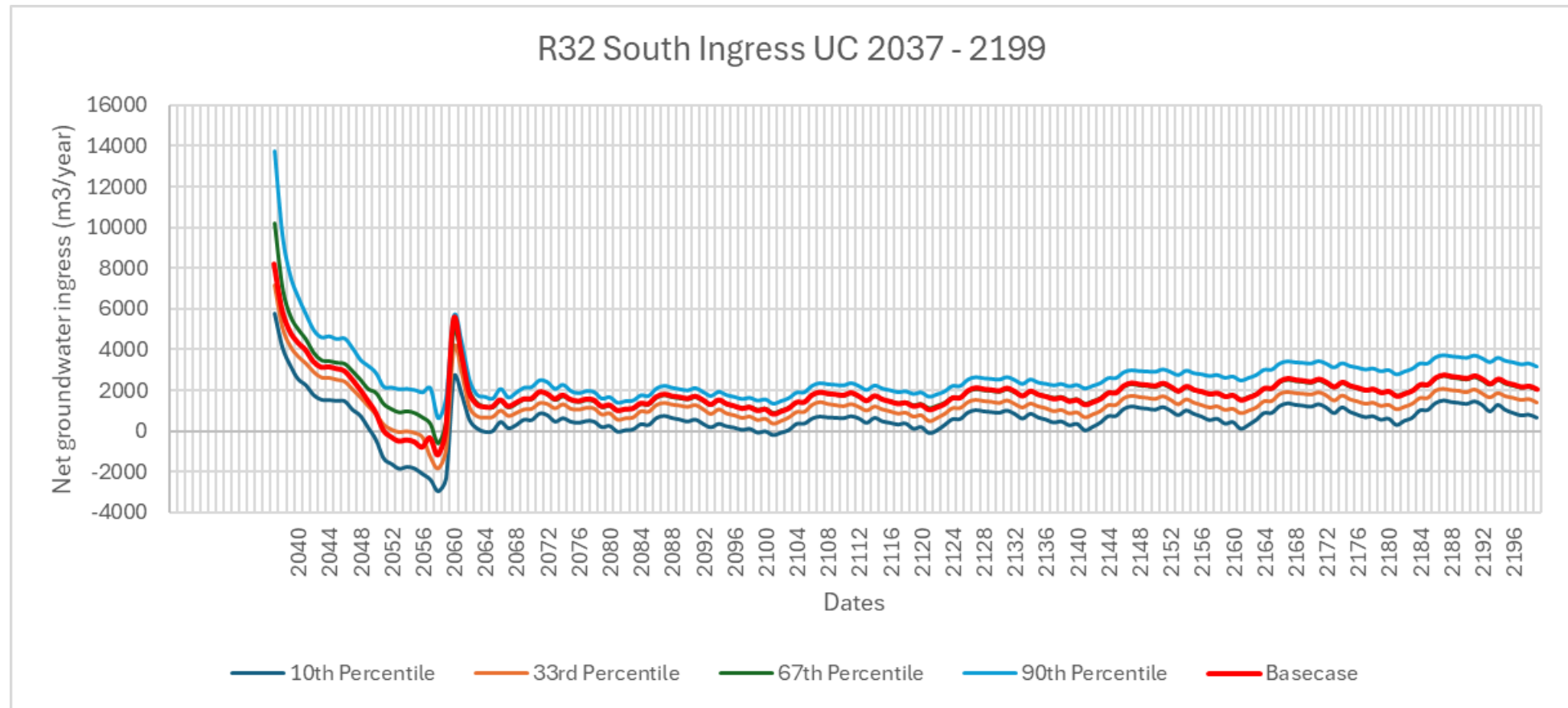


Plate 47 Uncertainty graph for R32 South Pit



16.3.7 Goonyella Pit

The uncertainty approach allowing for the quantifying of a range of possible parameter values and assessing the uncertainty of model predictions, was conducted for the Goonyella Pit. The range of groundwater ingress, in m³/year, for the 50 realisations are presented as percentiles in Plate 48.

The base case parameter set included in the predictive modelling input into the Goonyella Pit water level modelling is recognised as conservative, where the base case is very similar to the 90th percentile of the uncertainty realisations after 2144 (see below). This indicates that the groundwater ingress volumes used in estimating the pit water level is unlikely to be larger than this value.

The base case model predictions, comprising the majority influx contribution to the residual void water balance (Section 16.3.1), is within the higher predictions from the uncertainty modelling. This implies that the pit water level may be lower than currently predicted. This indicates that the Goonyella Pit is not likely to NOT act as a groundwater sink and has negligible risk of overtopping or decant in the long term.

Goonyella residual void acting as a sink in perpetuity results in localised groundwater flow patterns across RHM towards the residual void. This groundwater flow minimises the potential for flooded RHM mine workings water to migrate off lease. Figure 53 indicates the long term groundwater contours and flow patterns in the GMS at RHM, which indicates flow towards the Goonyella residual void.

16.3.8 Ingress comments

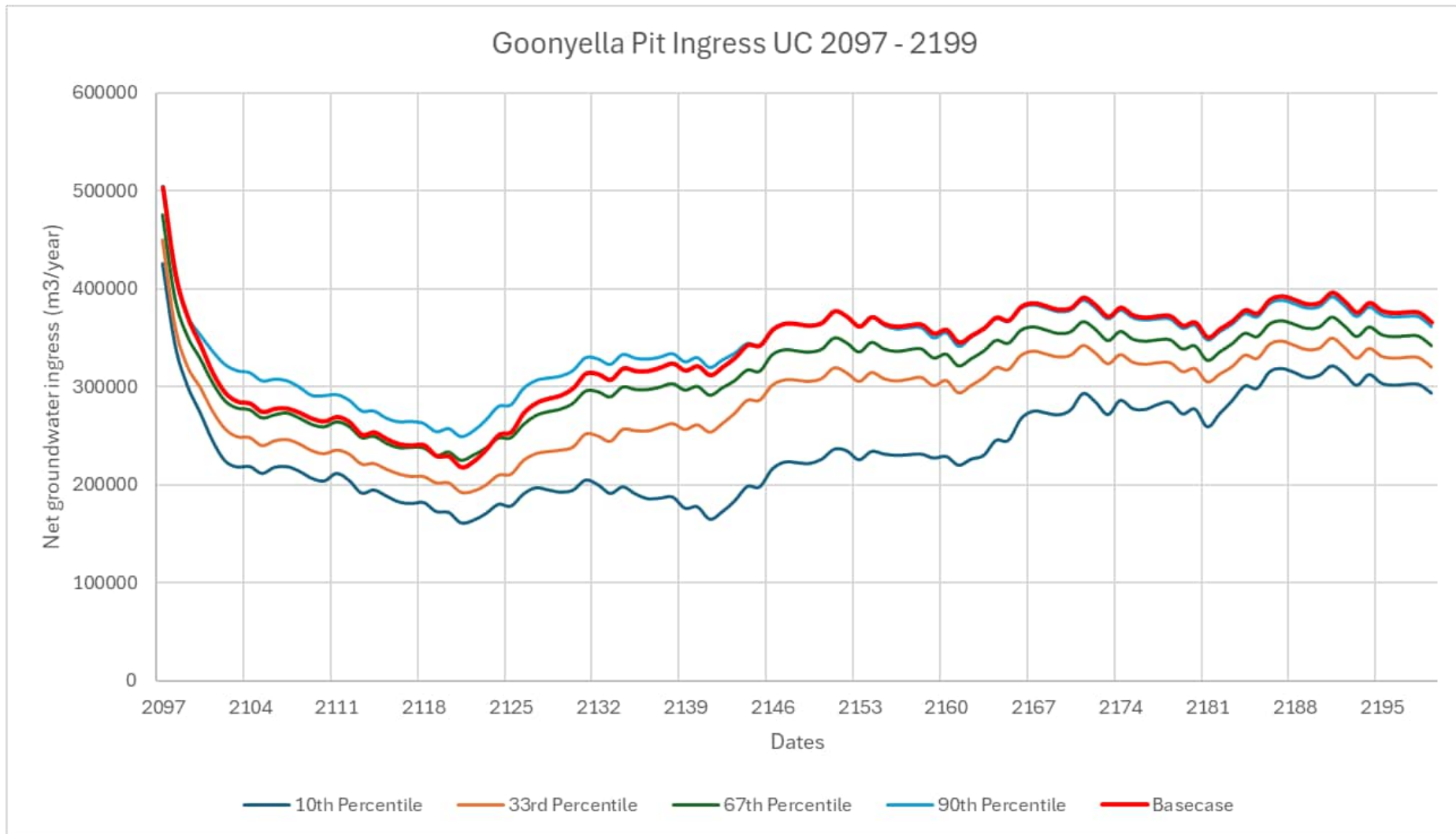
The base case parameters adopted in the groundwater model, allowing for groundwater ingress (or outflow) for the residual void water balance modelling, when considering the uncertainty analysis results allows for confidence in the predictions of pit water levels across the Project.

The dominant evaporation, orders of magnitude higher than the total influx estimates even when considering the upper groundwater (majority contribution) ingress estimates from the uncertainty analysis, indicate that the residual voids recognised to function as groundwater sinks will continue to do so.

The predictions of groundwater ingress into Goonyella residual void, within the higher predictions resulting from the uncertainty analysis parameter combinations, allows for confidence that the pit water level will be deep, some 20 mAHD (> 100 m deeper than other pit water levels) as detailed in Section 15.4.2.6. This deep groundwater sink influences long term groundwater flow patterns and prevents residual void and possible mine waste seepage water migration away from the Project as well as water from the flooded underground workings.

The influence of the Goonyella residual void indicates there is no need for future (pit) water reduction requirements.

Plate 48 Uncertainty graph for Goonyella Pit



17.0 Conceptual Site Model – Post-Closure

17.1 Post-closure conceptual model

A RHM conceptual model of the post-closure groundwater conditions, on completion of all GRB and RHM mining activities, rehabilitation, decommissioning, introduction of water into the underground workings, and recovery of groundwater levels to pseudo-steady conditions is included in Figure 59.

This conceptualisation is based on the end of mining HCM discussed in Section 11.0 (for Goonyella Pit open cut and RHM underground workings) and the post-mining groundwater modelling presented in Section 13.0.

17.2 Assessment

There is no evidence from a groundwater perspective that the final landform #2.3 to be adopted at GRB, which is hydraulically connected to RHM, is unsuitable for the closure from a hydrogeological perspective. This assessment is based on an evaluation of the groundwater regimes long term using predictive groundwater modelling.

The hydrogeological assessment identified the following key features:

- Residual void water level predictions, using the groundwater flux, for the Goonyella residual void, stabilises markedly below the post-closure recovered groundwater elevations for all directly impacted hydrostratigraphic units, including the RHM flooded workings water levels.
This groundwater sink effectively limits any potential poor quality water migrating away from the Project (Section 15.6 and 15.7).
- Residual groundwater drawdown within the MCM target coal seams as caused by the approved mining operations, with ongoing evaporative discharge from the residual voids, resulting in continued inwards hydraulic flow gradients in the coal measures to three of the six residual voids (Section 15.7).
- The Goonyella residual void is predicted to capture any seepage from mine waste and spoil / backfill areas, as well as from RHM workings, as evident in the particle tracking simulations (Section 15.7.2).
- The Goonyella residual void is predicted to influence groundwater levels within the Broadmeadow underground workings, where after water is introduced the (recovered) groundwater levels within the are predicted to decrease marginally.
- Little to no additional impact on surficial aquifers including the Isaac River alluvium caused by the GRB final landform plus RHM decommissioning and closure activities (15.5.1 and 15.8.2).
- Little to no impact on environmental (GDEs) receptors caused by the GRB final landform (Section 15.8).
- The continuous removal of groundwater in perpetuity from the Goonyella residual void indicates that groundwater levels in proximity to the residual void will not recover to pre-mining conditions.
- A single water supply bore, in proximity to the Goonyella Pit, will become dry as a result of approved mining. No anthropogenic receptors are identified to be impacted post-closure (Section 15.8.1).
- Goonyella residual void acting as a sink in perpetuity results in localised groundwater flow patterns across RHM towards the residual void. This groundwater flow minimises the potential for flooded RHM mine workings water to migrate off lease. Figure 53 indicates the long term groundwater contours and flow patterns in the GMS at RHM, which indicates flow towards the Goonyella residual void.

17.3 Source-Pathway-Receptor Analysis

A graphical representation of the CSM in source-pathway-receptor (SPR) format, with particular focus on the post-mining period, is presented as Figure 60.

The groundwater assessment for the PRC Plan does not identify a complete exposure pathways from the sources to water supply bores and ecological receptors, where:

- The Isaac River alluvium is not affected by drawdown and recharged from losing streams.
- The only water source bore identified to be affected is in proximity to the Goonyella Pit highwall. This bore will be impacted by approved mining and is therefore not predicted to be impacted due to mine closure.

Figure 59 Post-closure conceptual model for the Goonyella Pit and RHM underground workings

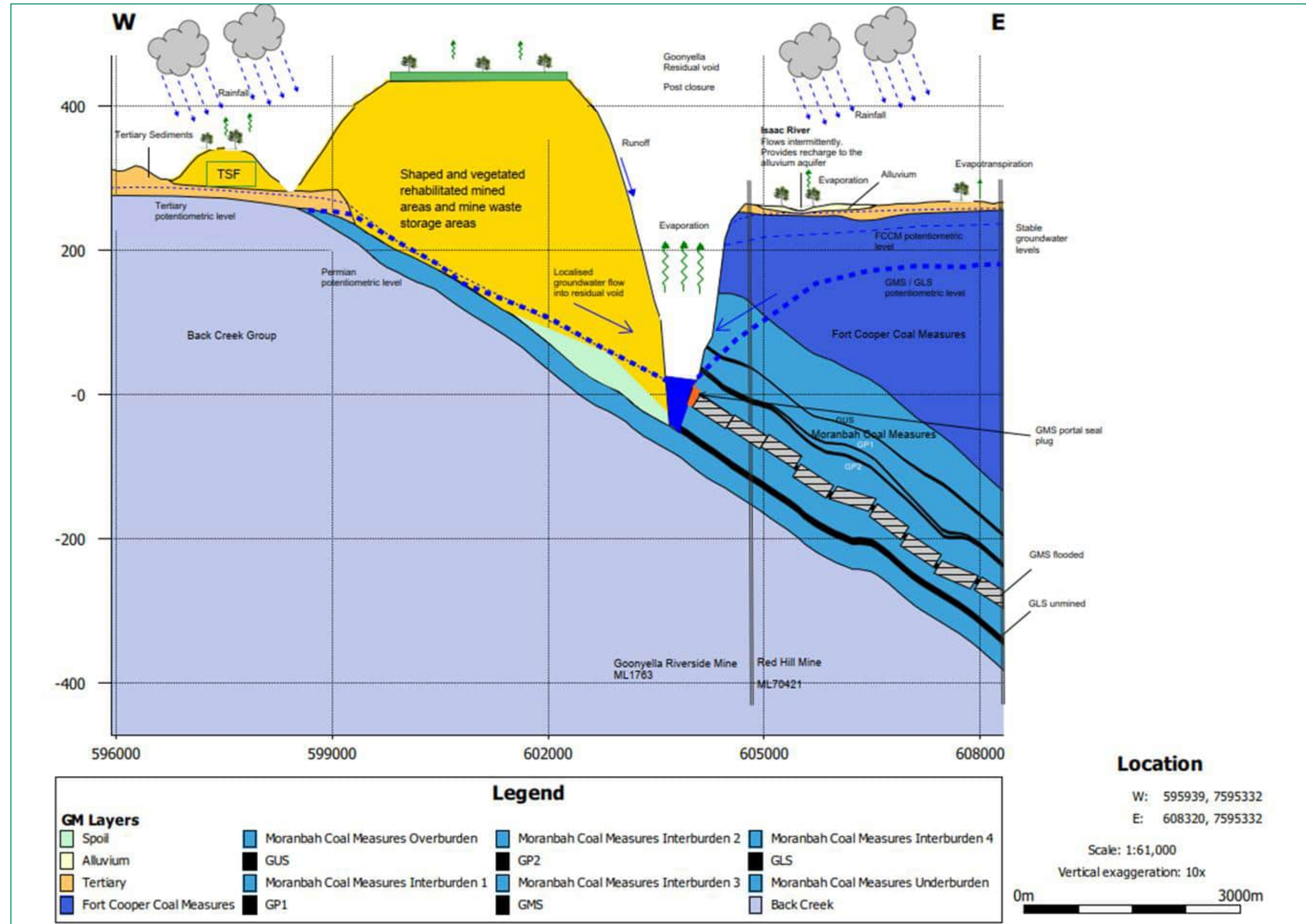


Figure 60 Source-Pathway-Receptor pathways post-closure

	Primary Sources		Secondary Sources		Transport Mechanisms		Exposure Pathways		Exposed Population
X	Residual Voids	X	Mine altered groundwater	X	Groundwater transport	X	Groundwater extraction		Water supply
X	Spoil / backfill areas					X	GDEs use		Industrial
X	MIA						Baseflow to surface water		Agricultural
X	TSF & Reject dumps								Ecological
X	Mine water storage		Surface water						
		X	Impacted soil, sediment	X	Leaching				

X - Potential

□ - Not applicable

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Appendix A

Red Hill Mining Groundwater Modelling



Report

Red Hill Mining Lease EIS

Groundwater Impact Assessment

24 SEPTEMBER 2013

Prepared for
BM Alliance Coal Operations Pty Ltd

42627136

URS

Project Manager:

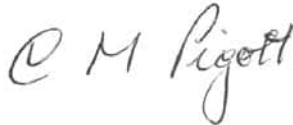


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**Date: 24 September 2013
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Status: Final**

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Abbreviations

Abbreviation	Description
AHD	Australian Height Datum
BBCGP	Bowen Basin Coal Growth Project
BMA	BHP Billiton Mitsubishi Alliance
BoM	Bureau of Meteorology
BRM	Broadmeadow underground mine
CHPP	coal handling and preparation plant
CSG	coal seam gas
DERM	Department of Environment and Resource Management
DSDIP	Department of State Development, Infrastructure and Planning
EIS	environmental impact statement
EPP (Water)	<i>Environmental Protection (Water) Policy 2009</i>
GDE	groundwater dependant ecosystems
GLS	Goonyella Lower Seam
GMA	groundwater management area
GMS	Goonyella Middle Seam
GPR	Ground Penetrating Radar
GRB	Goonyella Riverside and Broadmeadow
GRM	Goonyella Riverside Mine
GUS	Goonyella Upper Seam
IDAS	Integrated Development Assessment System
IMG	incidental mine gas
K	hydraulic conductivity
Kh	hydraulic conductivity – horizontal
Kv	hydraulic conductivity – vertical
LOM	life of mine
m	metre
MIA	mine industrial area
ML	mining lease
MLA	mining lease application
MR Act	<i>Mineral Resources Act 1989</i>
NRM	Department of Natural Resources and Mines
RHM	Red Hill Mine
RMSE	root-mean-square error
SP Act	<i>Sustainable Planning Act 2009</i>
STRM data	digital elevation data
TDS	total dissolved solids
ToR	Terms of Reference
URS	URS Australia Pty Ltd
VWP	Vibrating Wire Piezometers
Water Act	<i>Water Act 2000</i>
WQG	Water Quality Guidelines
WQO	Water Quality Objectives

Abbreviations

Unit	Description
°C	degrees Celsius
%	per cent
GL	gigalitres
L/s	litres per second
m ³ /t	cubic metres per tonne
m/day	metres per day
mbgl	metres below ground level
mg/L	milligrams per litre
µS/cm	microSiemens per centimetre

Introduction

The Red Hill Mining Lease is located adjacent to the existing Goonyella, Riverside and Broadmeadow (GRB) mine complex in the Bowen Basin, approximately 30 kilometres north of Moranbah and 220 kilometres south-west by road from Mackay, Queensland (refer **Figure 1-1**).

BHP Billiton Mitsubishi Alliance (BMA), through its joint venture manager, BM Alliance Coal Operations Pty Ltd, proposes to convert the existing Red Hill Mining Lease Application (MLA) 70421 to enable the continuation of existing mining operations associated with the GRB mine complex. Specifically, the mining lease conversion will allow for:

- An extension of three longwall panels (14, 15 and 16) of the existing Broadmeadow underground mine (BRM).
- A future incremental expansion option of the existing Goonyella Riverside Mine (GRM).
- A future Red Hill Mine (RHM) underground expansion option located to the east of the GRM.

The three project elements described above are collectively referred to as 'the project'. Further detail on each project component is as follows:

- The extension of BRM longwall panels 14, 15, and 16 into MLA70421. Key aspects include:
 - No new mining infrastructure is proposed other than infrastructure required for drainage of incidental mine gas (IMG) to enable safe and efficient mining.
 - Management of waste and water produced from drainage of IMG will be integrated with the existing BRM waste and water management systems.
 - The mining of the BRM panel extensions is to sustain existing production rates of the BRM mine and will extend the life of mine by approximately one year.
 - The existing BRM workforce will complete all work associated with the extensions.
- The incremental expansion of the GRM. Key aspects include:
 - underground mining associated with the RHM underground expansion option to target the GMS on mine lease (ML) 1763;
 - a new mine industrial area (MIA);
 - a CHPP adjacent to the Riverside MIA on MLA1764 and ML1900 – the Red Hill CHPP will consist of up to three 1,200 tonne per hour modules;
 - construction of a drift for mine access;
 - a conveyor system linking RHM to the Red Hill CHPP;
 - associated coal handling infrastructure and stockpiles;
 - a new conveyor linking product coal stockpiles to a new rail load-out facility located on ML1900; and
 - means for providing flood protection to the mine access and MIA, potentially requiring a levee along the west bank of the Isaac River.
- A potential new Red Hill underground mine expansion option to the east of the GRB mine complex, to target the GMS on MLA 70421. Key aspects include:
 - the proposed mine layout consists of a main drive extending approximately west to east with longwall panels ranging to the north and south;
 - a network of bores and associated surface infrastructure over the underground mine footprint for mine gas pre-drainage (IMG) and management of goaf methane drainage to enable the safe extraction of coal;
 - a ventilation system for the underground workings;

1 Introduction

- a bridge across the Isaac River for all-weather access. This will be located above the main headings, and will also provide a crossing point for other mine related infrastructure including water pipelines and power supply;
- a new accommodation village (Red Hill accommodation village) for the up to 100 per cent remote construction and operational workforces with capacity for up to 3,000 workers; and
- potential production capacity of 14 million tonnes per annum of high quality hard coking coal over a life of 20 to 25 years.

URS Australia Pty Ltd (URS) was commissioned by BMA to conduct a groundwater investigation and impact assessment as part of the project Environmental Impact Statement (EIS). For the purposes of this report, the area within the EIS study boundary is called the 'EIS study area'. The groundwater study, however, covered a larger area and this is defined as the 'survey area'. Refer to **Figure 1-1** which shows both boundaries.

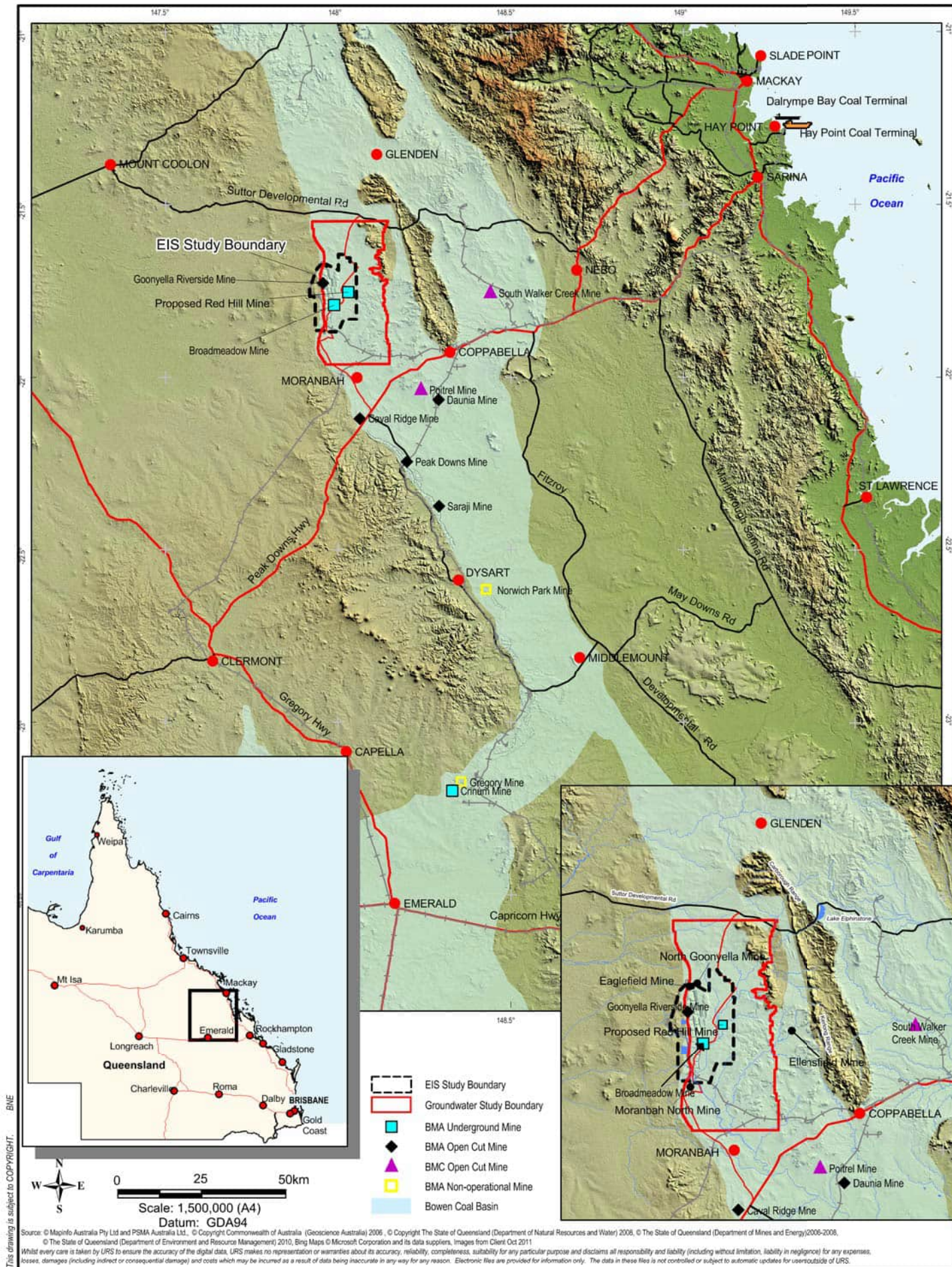
This standalone technical report provides details of an assessment of potential groundwater impacts associated with the proposed project, and includes recommended mitigation measures and monitoring protocols.

1.1 Scope of Work

The scope of work for the groundwater investigation was based on the terms of reference (ToR) for the project (Coordinator-General 2013).

The objective of this study was to assess the potential impacts of the proposed underground coal mining activities on the hydrogeological regime and, where necessary, identify measures for mitigation and/or monitoring of impacts as specified in the ToR. To achieve this objective, the scope of work included:

- A review of hydrogeological and geological data existing in the public domain, including reports and records held by the Department of Natural Resources and Mines (NRM) and maps published by the Geological Survey of Queensland.
- A review of exploration and monitoring bore data and groundwater reports provided by BMA.
- A review of hydrogeological data held on the NRM Groundwater Database for existing water bores in the area.
- Field investigations comprising groundwater sampling and aquifer parameter (variable head) tests.
- Survey of existing groundwater facilities (bores, wells) within the BMA properties and in neighbouring properties.
- An assessment and analysis of all available hydrogeological data through the development of a conceptual hydrogeological model and predictive hydrogeological modelling.
- Preparation of a report detailing the potential impacts of the proposed development on the groundwater regime.



BHP Billiton Mitsubishi Alliance

RED HILL MINING LEASE GROUNDWATER IMPACT ASSESSMENT

SURVEY AREA LOCALITY

URS

GROUNDWATER

File No: 42627136-g-2095c.wor

Drawn: VH

Approved: CT

Date: 26-11-2013

Figure: 1-1



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Legislative Framework and Requirements

A summary of the relevant policies, guidelines and legislation relevant to the project are outlined in **Table 2-1**.

Table 2-1 Summary of Relevant Policies, Guidelines and Legislation to the Project Area

Policy, Guidelines, or Legislation	Description	Relevance to the Project – Groundwater Impact Assessment
<i>Environmental Protection Act 1994 (EP Act)</i>	The objective of the EP Act is to protect the Queensland environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (Queensland Government 2012). Subordinate to this act is the Environmental Protection Regulation 2008, which provides for the effective administration and enforcement of the objectives and provisions of the EP Act.	All persons must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practical measures to prevent or minimise the harm (Section 319 of the Act). This general duty to the environment requires the implementation of proactive measures to prevent environmental degradation and act in accordance with the precautionary principle. This requirement is underpinned by the impact assessment and mitigation process in this study.
<i>Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)</i>	The purpose of the Act is to provide for the protection of matters of national environmental significance (MNES), including groundwater dependant ecosystems (GDEs) and MNES species that rely on springs. Since June 2013, Queensland is a signatory to the Council of Australian Governments National Partnership Agreement on Coal Seam Gas and Large Coal Mining Development (NPA). The NPA requires CSG or large coal mining development proposals undergoing environmental impact assessment that are likely to have a significant impact on water resources to be referred to an Independent Expert Scientific Committee (IESC).	The project is considered under the EPBC Act, as the EPBC Act is triggered for assessment of MNES. For groundwater this would be for assessment of impacts to mound springs or significant species habitat from drawdown. Regarding the EPBC Act, the depth of groundwater limits any potential use by listed or threatened species and migratory birds. Any potential changes in groundwater levels as a result of mine dewatering are therefore not considered to impact on listed or threatened species and migratory birds. After consultation between The Department of Environment and BMA this project is to include a summary report for the IESC as per the water resource trigger detailed in the NPA.
<i>Water Act 2000 (Water Act)</i>	The purpose of the Act is to provide for the sustainable management and efficient use of water and other resources, a regulatory framework for providing water services and the establishment and operation of water authorities. Water resource plans have been developed to define the availability and allocation of water and to ensure the sustainable management of water in Queensland. The objectives of the water resource plans are to balance the needs of humans and the environment in a sustainable manner.	Water use and the obligations, processes, and framework for coal mining in relation to groundwater monitoring, reporting, impact assessment and management of impacts on other water users including 'make good' agreements is regulated under the Act.

2 Legislative Framework and Requirements

Policy, Guidelines, or Legislation	Description	Relevance to the Project – Groundwater Impact Assessment
<i>The Water Supply (Safety and Reliability) Act 2008</i>	The purpose of the Act is to provide for the safety and reliability of water supply in Queensland. The Act sets out requirements for Environmental Management Plans and obligations in relation to the potential to impact on drinking water supplies.	The Project is automatically captured by this process for injection, direct supply or discharge of water, however; an exemption can be applied for.
Environmental Protection (Water) Policy 2009 (EPP (Water))	The purpose of the Policy is to achieve the objectives of the EP Act in relation to Queensland waters while allowing for ecologically sustainable development.	The environmental values are to be enhanced or protected (Section 6 of the Act). The relevant environmental values vary depending on the ecological value of the water, level of disturbance and intended use of the water. The management controls/ mitigation measures in this study were prepared to meet the requirements of this policy.
<i>Sustainable Planning Act 2009</i>	The purpose of the Act is to regulate the development of infrastructure outside petroleum tenures.	The Project is located within the Isaac Connors Groundwater Management Area (GMA) where any works for taking or interfering with water for purposes other than stock or domestic use (other than small diameter groundwater monitoring bores) are assessable activities and require a development permit.
Water Resource (Fitzroy Basin) Plan 2011	The Water Resource (Fitzroy Basin) Plan 2011 provides for the allocation and management of water in the Fitzroy Basin and the subordinate legislation under the Water Act.	Tenements in the northern portion of the Project area are located within the declared Isaac Connors GMA, as defined under Chapter 2, Section 7, Schedule 3, Schedule 4, and Schedule 7 of the Fitzroy Basin WRP 2011. Any long-term water take or interference from groundwater sources requires authorisation by way of a licence.

2.1 Water Act 2000

2.1.1 General

The *Water Act 2000* (Water Act) vests all rights to the use, flow and control of groundwater, overland flow water and water in watercourses, lakes, springs and dams in the State and provides a comprehensive planning and management regime for all vested water resources in Queensland.

Chapter 2 of the Water Act (allocation and sustainable management) seeks to advance sustainable management and efficient use of water and other resources by establishing a system for the planning, allocation and use of water in accordance with the principles of ecologically sustainable development.

Part 6 of Chapter 2 deals with the process of the allocation of licences or permits for the taking of or interfering with water. This includes groundwater. Land owners and other approved entities, including an applicant for, or the holder of, a mineral development licence or mining lease under the *Mineral*

2 Legislative Framework and Requirements

Resources Act 1989 (MR Act), may apply for a licence or permit to take or interfere with groundwater. This application process includes a public notification requirement, and requires that the chief executive consider information about the effects of interfering with the water on natural ecosystems and the physical integrity of the aquifers, among other considerations.

The Water Act also deals with the 'make good' obligations of an entity such as the holder of a mineral development licence or mining lease under the MR Act to the owner of a pre-existing Water Act bore.

2.1.2 Water Resource (Fitzroy Basin) Plan 2011

Water Resource Plans provide for the allocation and management of water in Queensland and are subordinate legislation under the Water Act. The Water Resource (Fitzroy Basin) Plan 2011 includes groundwater, in part due to the significant increase in the demand for groundwater resources in recent years, driven mainly by mining in the Isaac-Connors system. There is a risk that groundwater resources in this catchment may be over committed (DERM 2009).

The survey area is located within the declared Isaac Connors Groundwater Management Area (GMA), as defined under Section 6, Schedule 3 and Schedule 4 of the Water Resource (Fitzroy Basin) Plan 2011. Within the declared management area, water licenses and/or development permits are not required for stock or domestic bores, and NRM also generally exclude groundwater monitoring bores from the requirement for development permits.

Other groundwater-related activities, such as drilling of test pumping bores, and undertaking pumping tests, requires authorisation (by way of permits) from NRM, as well as a development permit (operational works) to allow drilling and construction of water bores. Any long-term water take or interference (whether actively via bores or passively via drainage to and dewatering of mine workings) from groundwater sources requires authorisation by way of a licence. The project will require a water licence for groundwater interfered with as a result of IMG drainage and mine dewatering activities.

2.2 Sustainable Planning Act 2009

The *Sustainable Planning Act 2009* (SP Act) provides the mechanism (via the Integrated Development Assessment System (IDAS)) through which assessment of a proposed development is undertaken, and under which a development permit is granted.

Within the declared Isaac Connors GMA any works for taking or interfering with water for purposes other than stock or domestic use are assessable activities and will require a development permit. Works that are for stock and domestic purpose are self-assessable development and do not require a development permit but must conform to the relevant self-assessable development code. NRM currently allows small diameter groundwater monitoring bores to be constructed without a development permit.

2.3 Environmental Protection (Water) Policy 2009

The Environmental Protection (Water) Policy 2009 (EPP (Water)) serves to protect Queensland's waters while allowing for ecologically sustainable development. This purpose is achieved within a framework that includes:

- Identifying environmental values for aquatic ecosystems and for human uses (e.g. water for drinking, farm supply, agriculture, industry and recreational use).

2 Legislative Framework and Requirements

- Determining water quality guidelines (WQGs) and water quality objectives (WQOs) to enhance or protect the environmental values.

The location of the proposed project is within the Isaac River sub-Basin of the Fitzroy Basin, as described in Schedule 1 of the EPP (Water). The scheduled environmental values for groundwater to be enhanced or protected in the area are the following qualities:

- biological integrity of aquatic ecosystems;
- suitability for recreational use (primary recreation);
- suitability for minimal treatment before supply as drinking water;
- suitability for use in primary industries (irrigation, farm supply, stock water); and
- cultural and spiritual values.

As discussed further in **Section 6.4**, the beneficial use of groundwater for some of these human uses within the EIS study area is limited to cases where salinity is suitably low and metal/metalloid concentrations are below guideline levels. Groundwater suitability for these anthropogenic uses therefore need to be assessed on a case-by-case basis, and in some cases it is interpreted that groundwater would have no practical use.

Review of Available Information

This groundwater assessment is based on a desktop review of available information and additional data collected on-site between March and June 2011. Previous groundwater studies undertaken within the survey area (as defined in **Section 4**) and the additional data collected during the compilation of this EIS have been used to describe the existing groundwater resources and thus allow for the assessment of the project on the current groundwater status.

The description of existing hydrogeological conditions within the survey area is based on the following available information:

- historical reports and groundwater monitoring data held by BMA for the GRB mine complex;
- data collected by BMA from the exploration drilling conducted for the GRB mine complex and the RHM;
- regional and local aeromagnetic geophysical surveys;
- environmental impact studies conducted for other coal mines in the area (**Figure 1-1**), including:
 - Anglo Coal (Grosvenor) Pty Ltd – Grosvenor Project, located 3 kilometres north of Moranbah and south of Moranbah North Mine (JBT Consulting 2010);
 - Peabody (Bowen) Pty Ltd – Eaglefield Expansion Project, located 36 kilometres north of Moranbah and immediately north of Goonyella Riverside Mine (GRM) (METServe 2010); and
 - Ellensfield Coal Management Pty Ltd – Ellensfield Coal Mine Project, located 35 kilometres north-east of Moranbah (AGE 2008);
- Geological Survey of Queensland Mount Coolon 1:250,000 Geological Map (Sheet SF55-7) and Bowen Basin Digital Geology;
- a search of the NRM groundwater and licensing database for registered bores located within a 10 kilometre radius of the site (conducted on 13 September 2011);
- a survey of existing groundwater facilities (bores, wells) within the EIS study boundary and neighbouring properties;
- Underground Water Impact Report (Arrow Energy 2011); and
- additional groundwater data collected on-site by URS for baseline studies between March and June 2011.

Previous hydrogeological investigations undertaken at GRB mine complex have focussed on assessing potential inflows to pits and underground workings and the establishment of boxcut or pit dewatering bores for mine design and production purposes. In each case, monitoring and dewatering bores have been constructed in the coal seams targeted for mining rather than overlying or underlying lithological units. Thus the hydrogeological work conducted previously on the site has covered:

- an assessment of Tertiary (units) permeability for a proposed boxcut at GRM (Thatcher 1976);
- an assessment and design of dewatering requirements for the Cleanskin Pit boxcut extension in the Goonyella Lower Seam (GLS) and double bench mining (Coffey & Partners 1987a, 1987b);
- a geotechnical assessment of slope stability for mining of the GLS beneath the existing Goonyella Middle Seam (GMS) pit at Ramp 13 (BHP Engineering 1993);
- hydraulic testing of the Goonyella Upper Seam (GUS) and GMS accompanied by numerical modelling of the GMS for the then proposed Goonyella No2 Mine (Rust PPK 1996; IESA 1996);
- installation of monitoring bores, numerical modelling of inflows for feasibility and tender purposes for the BRM (AGE 1998a, 1998b, 2000, 2002; BMA 2003);

3 Review of Available Information

- construction of monitoring bores, numerical modelling and installation/operation of depressurisation bores for the initial Airstrip pit boxcut and subsequent southerly extension of the pit (IESA 2001a, 2001b; AGE 2004a); and
- installation of monitoring bores and numerical modelling for the proposed double bench mining at Ramp 8 (AGE 2004b).

Physical Setting

The EIS study area is located within the upper sub-catchment of the Isaac River, which lies within the northern part of the Fitzroy River Basin (**Figure 1-1**).

4.1 Topography and Drainage

The upper Isaac River sub-catchment containing the EIS study area is bordered by the Peak Range to the southwest, Denham Range to the northwest, and the Broadsound and Connors Ranges to the east and northeast, respectively (**Figure 1-1**). Drainage gradients in the Isaac River sub-catchment are generally low across the central part of the sub-catchment and high around the margins, with elevations varying from a maximum of over 700 metres in the Connors Range down to approximately 90 metres at the junction with the Mackenzie River (Pearce & Hansen 2006). The central part of the sub-catchment is essentially flat lying where change in relief is typically less than 60 metres (SKM 2009).

The EIS study area is located within a broad valley through which the Isaac River flows, generally in a southerly direction. The northern portion of the EIS study area is formed by a low broad ridge that defines the northern extent of the Isaac River catchment. The low hills located to the east of the Isaac River near the GRB mine complex are undulating with a well-developed system of drainage lines.

The topography of the Isaac River valley near the EIS study area varies from approximately 250 metres AHD elevation along the Isaac River in the east of the EIS study area to approximately 325 metres AHD elevation along portions of the Denham Range that define the western edge of the valley. The relatively steep slopes associated with the Denham Range contrast with the extensive flat areas across the base of the river corridor, where gradients are generally less than 1v:100h.

There are five main ephemeral creeks within the EIS study area: Goonyella Creek, Eureka Creek, Fisher Creek, Platypus Creek, and 12 Mile Gully. These are tributaries of the Isaac River.

4.2 Climate

The climate of the Isaac River sub-catchment is predominantly dry tropical with hot summers and mild winters. Average maximum daily temperatures range from approximately 24°C in June-July to 34°C in December-January, whilst average minimum daily temperatures vary from approximately 10°C in July to 22°C in January-February for the Moranbah area (Bureau of Meteorology (BoM) monitoring station 034038). Rainfall is highly variable, both spatially and temporally across the sub-catchment. In the Moranbah area, the mean annual rainfall is approximately 600 millimetres (**Chart 4-1**). Rainfall is summer dominant with approximately 70 per cent of annual rainfall falling during months of the wet season from November to March (**Chart 4-2**). Average monthly evaporation consistently exceeds average rainfall over all months. However episodic, high intensity rainfall events do occur related to monsoonal troughs and cyclones, resulting in excess rainfall above evaporation at a frequency of eight per cent, with a duration between events ranging from approximately one to six years (SKM 2009). It is considered that infiltration of rainfall and subsequent groundwater recharge may be most likely to occur during high intensity rainfall events.

4 Physical Setting

Chart 4-1 Total Yearly Rainfall at the Moranbah Monitoring Station (BoM station no: 034038)

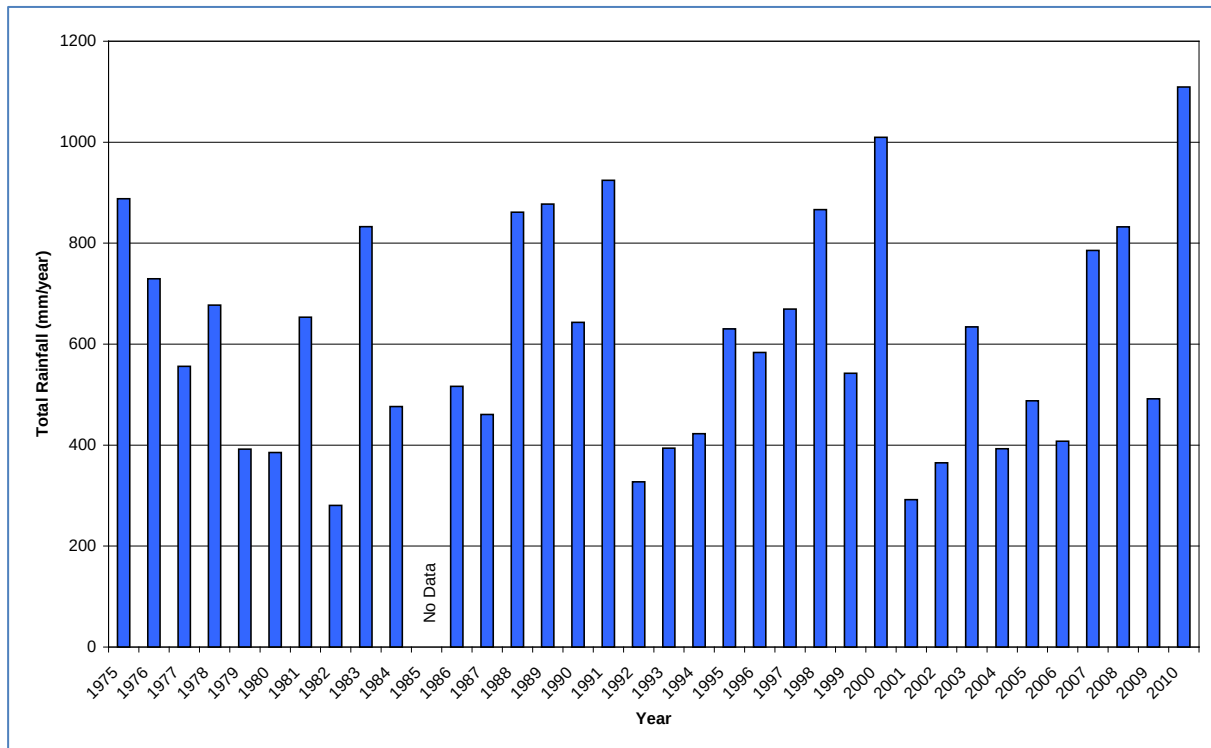
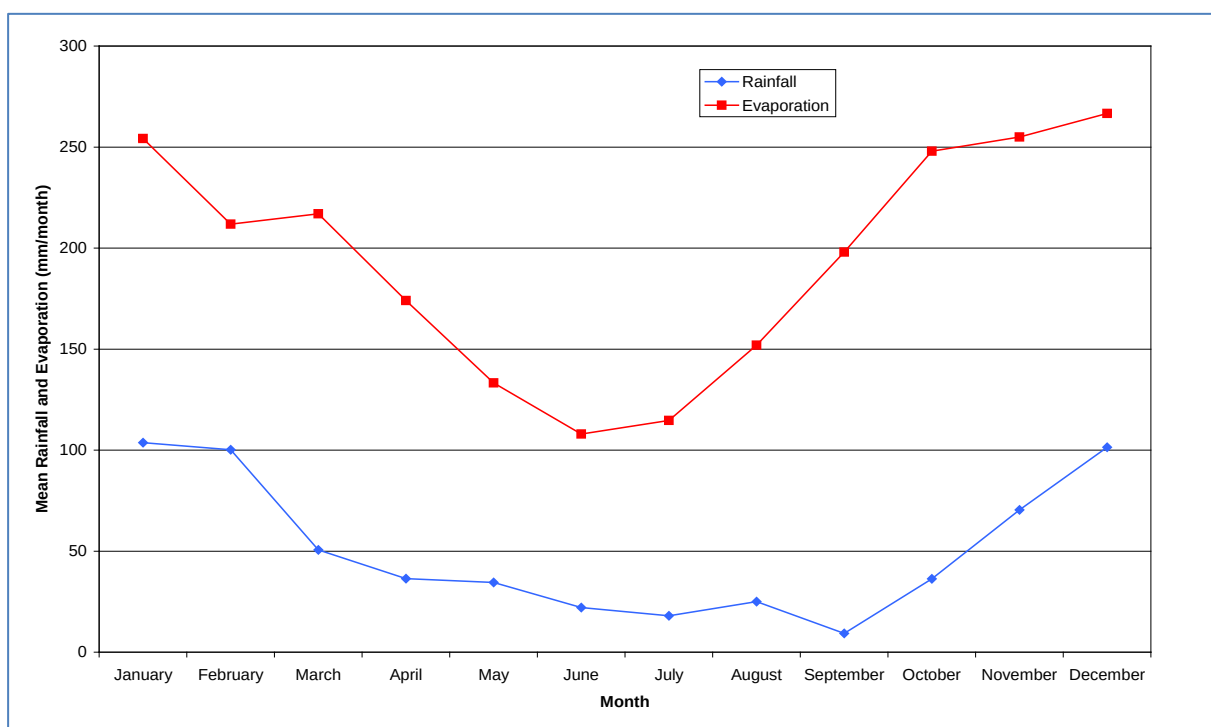


Chart 4-2 Mean Monthly Rainfall and Evaporation at the Moranbah Monitoring Station (BoM station no: 034038, 1986 to 2010)



4 Physical Setting

4.3 Land Use

Since European settlement, the Isaac River sub-catchment has been extensively used for agriculture. SKM (2009) reported that approximately 90 per cent of land within the sub-catchment was dedicated to grazing (predominantly beef cattle) of relatively natural (limited clearing) environments. Dryland cropping and coal mining are the other significant land uses in the sub-catchment, the latter primarily focussed in the western part of the sub-catchment.

Coal mining is undertaken to the north and south of the EIS study area, with North Goonyella underground and open cut mine (Eaglefield Pit) operated by Peabody Energy to the north and the Moranbah North underground coal mine operated by Anglo American Coal to the south.

The existing GRM is an open cut operation producing hard coking coal while the BRM is an underground, punch longwall mine and has been developed in an existing highwall of the open cut operation.

The RHM footprint has previously been cleared for cattle grazing. However, small patches of remnant bushland and scrub remain, particularly along riparian corridors. The local agricultural industry is partially dependent on groundwater for stock watering; the remaining water requirements are met by surface water supplies. Groundwater is primarily extracted from the coal seam aquifers and sandstone units of the Bowen Basin or alluvium associated with the main rivers. Increasing demand on groundwater from both agriculture and mining has led to these groundwater systems being regulated in the Water Resource (Fitzroy Basin) Plan 2011.

Geological Setting

5.1 Regional Geology

The geological Bowen Basin is an elongated, north-south trending basin which extends from east-central Queensland to northern New South Wales. The basin covers an area of approximately 200,000 square kilometres, and is exposed over 600 kilometres from Collinsville in the north to Rolleston in the south. It contains a sedimentary sequence of Permo-Triassic clastics, which attain a maximum thickness of 9,000 metres in the depo-centre of the Taroom Trough.

The Bowen Basin is divided into a number of tectonic units comprising north/north-west – south/south-east trending platforms or shelves, separated by sedimentary troughs. The major structural unit surrounding the EIS study area is the Collinsville Shelf, underlain at shallow depths (one to two kilometres) by the Clermont Stable Block which bounds the northern Bowen Basin to the west. The Collinsville Shelf was a stable tectonic environment and is characterised by a monoclinial accumulation of sediments, which dip gently (two to eight degrees) and thicken to the east. Folding is gentle and mostly related to drag on thrust faults at the eastern margin of the basin limb. The boundary between the Collinsville Shelf and the adjoining major axis of deposition, the Nebo Synclinorium of the Taroom Trough, is marked by a major thrust fault termed the Burton Range Thrust Fault, which is located approximately 10 kilometres east of the EIS study area. This scarcity of regional significant structures or fault zones distinguishes the Collinsville Shelf sediments from the tightly folded and intruded sediments of the Nebo Synclinorium.

Regionally, the stratigraphic sequence is summarised as follows: the Permo-Triassic sediments of the Bowen Basin are overlain by a veneer of unconsolidated Quaternary alluvium and colluvium, poorly consolidated Tertiary sediments of the Tertiary Suttor Formation and, in places, remnants of Tertiary basalt flows.

5.2 Local Geology and Stratigraphy

A summary of the stratigraphy from the survey area is presented in **Table 5-1** and the local geology is shown in **Figure 5-1**.

The marine influenced Early to Middle Permian Back Creek Group is the oldest Bowen Basin succession observed in the survey area. This is conformably overlain by the Late Permian Blackwater Group, which contains the coal seams of economic interest to BMA. Following deposition of the Blackwater Group, fluviolacustrine deposition led to the deposition of the Triassic Mimosa Group. Tertiary volcanic deposits composed mostly of basaltic lava flows overlie the Bowen Basin successions. These Tertiary volcanics occur as isolated exposures in the north of the survey area. Extensive Quaternary alluvial deposits are associated with the Isaac River system.

5 Geological Setting

Table 5-1 Stratigraphy of the Survey Area

Period	Stratigraphic Unit			Description	Max. Thickness (m)	Presence in Survey Area	
Quaternary	Alluvium			Clay, silts, sand, gravel, floodplain alluvium	37 m in survey area	Confined to present day stream alignments and palaeochannels	
Tertiary	Basalt			Olivine basalt flows	35 m in survey area	Isolated patches in north of survey area	
	Suttor Formation			Clay, silts, sand, gravel, colluvial and residual deposits, fluvial and lacustrine deposits	80 m in survey area	Most extensive in the mine areas and to the east	
Triassic	Early	Mimosa Group	Rewan Formation	Green lithic sandstone, pebble conglomerate, red and green mudstone	Unknown in survey area	Small area within the north east	
Permian	Late	Blackwater Group	Rangal Coal Measures	Sandstone, siltstone, mudstone, coal, tuff, sandstone	100 m	Outcrops or subcrops in the majority of the survey area	
			Fort Cooper Coal Measures	Burngrove Formation	Mudstone, siltstone, sandstone, coal, tuff		400 m
				Fair Hill Formation	Labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal		
			Moranbah Coal Measures	Quartzose to sublabile, locally argillacoues sandstone, siltstone, mudstone, carbonaceous mudstone and coal	250 m		
	Early to Middle	Back Creek Group			Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite	Unknown in survey area	Outcrops west of mines and extends under mined areas to the east
Carboniferous	Early	Drummond Basin Succession	Mount Rankin Formation	White and grey siltstone and fine sandstone, minor medium to very coarse grained sandstone, chert, granule to pebble conglomerate, rare tuff, ignimbrite and dacite/andesite	Unknown in survey area	Outcrops west of the survey area and is inferred to form basement under the Bowen Basin in the mine areas	
Devonian	Late	Silver Hills Volcanics		Rhyolite, dacite, rhyolitic ignimbrite, volcanoclastic sediments, sinter, minor sandstone and siltstone			
Proterozoic	Anakie Metamorphic Group			Siltstone, fine sandstone, phyllite, schist, commonly cleaved and multiply deformed			

5 Geological Setting

5.2.1 Basement Geology (Proterozoic-Carboniferous)

The nature and age of the crust beneath the Bowen Basin in the survey area is inferred from exposed rocks outside the basin and a deep seismic survey conducted by Geoscience Australia. Exploration drilling to date has not penetrated the basin succession away from its immediate margins.

Units that are exposed to the west of the Bowen Basin and that appear to continue underneath the survey area are the Proterozoic Anakie Metamorphic Group, Devonian Silver Hills Volcanics, and units of the Carboniferous Drummond Basin succession.

5.2.2 Back Creek Group

The Back Creek Group consists of Permian marine sediments, unconformable on the underlying basement. In the survey area, this unconformity is of low relief on a regional scale. The Back Creek Group is comprised of quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite. It is poorly exposed in and to the west of the EIS study area, and dips to the east below the Blackwater Group.

5.2.3 Blackwater Group

The Permian Blackwater Group contains, from oldest to youngest, the Moranbah Coal Measures, Fort Cooper Coal Measures, and Rangal Coal Measures.

The boundary between the Back Creek and Blackwater Groups is conformable and locally transitional. Due to the time involved in the gradual regression resulting in the deposition of the non-marine Blackwater Group, the boundary is diachronous, and the stratigraphy is complicated by facies changes and by changes in provenance of units.

Moranbah Coal Measures

The Moranbah Coal Measures outcrop or subcrop in the west and centre of the EIS study area, where they are mined in the GRM open cut pits.

The Moranbah Coal Measures were deposited in a predominantly fluvial flood plain environment. The lithology of the Moranbah Coal Measures is generally characterised by interbedded fine-grained lithic sandstone, siltstone, mudstone, claystone, and coal. The Moranbah Coal Measures show regular grading of lithological sequences from sandstone to siltstone and mudstone to coal, then tending back to sandstone, typical of depositional flood plain / river systems. The Moranbah Coal Measures are characterised by several laterally persistent thick coal seams interspersed with several thin minor seams, which split and coalesce. The three main seams are the GUS, GMS, and GLS. The GMS is the target seam for the proposed RHM.

Fort Cooper Coal Measures

The Late Permian Fort Cooper Coal Measures conformably overlie the Moranbah Coal Measures, and outcrop or subcrop in the centre to the east of the EIS study area. The Fort Cooper Coal Measures consist of lithic sandstone, siltstone, mudstone, coal, and tuffaceous sediments. A number of coal seams are contained within the Fort Cooper Coal Measures. These coal seams are typically highly banded with claystone, mudstone and siltstone and hence are non-commercial. The lower boundary of the Fort Cooper Coal Measures is taken as the base of a thick and widespread sequence of interbedded dull and stony coal, carbonaceous mudstone and tuff. This unit, referred to as the Fair

5 Geological Setting

Hill Seam, ranges in thickness up to approximately 25 metres and lies approximately 60 to 70 metres above the GUS.

Rangal Coal Measures

The Rangal Coal Measures comprise light grey, cross-bedded, fine to medium grained sandstone, grey siltstone, mudstone, and coal seams. Cemented sections are common in the sandstone. The transition between the Fort Cooper Coal Measures and the Rangal Coal Measures is generally clearly marked by the Yarrabee Tuff, a basin-wide marker bed comprising weak, brown tuffaceous claystone.

5.2.4 Mimosa Group

The Permian sediments are unconformably overlain by the Triassic Rewan Formation. The Permian-Triassic boundary marks the change from the carbonaceous sediments of the coal measures to the non-carbonaceous mainly green, fine to medium grained, micaceous, lithic, labile, sandstone and red, brown, green and locally mottled mudstone.

5.2.5 Cainozoic Cover

The Permian and Triassic formations are mantled by an irregular cover of poorly consolidated Cainozoic sedimentary strata and both fresh and weathered basalt. The Cainozoic cover is up to 110 metres thick in parts towards the north of the survey area, where infilled deeply incised Tertiary palaeochannels.

Tertiary Formations

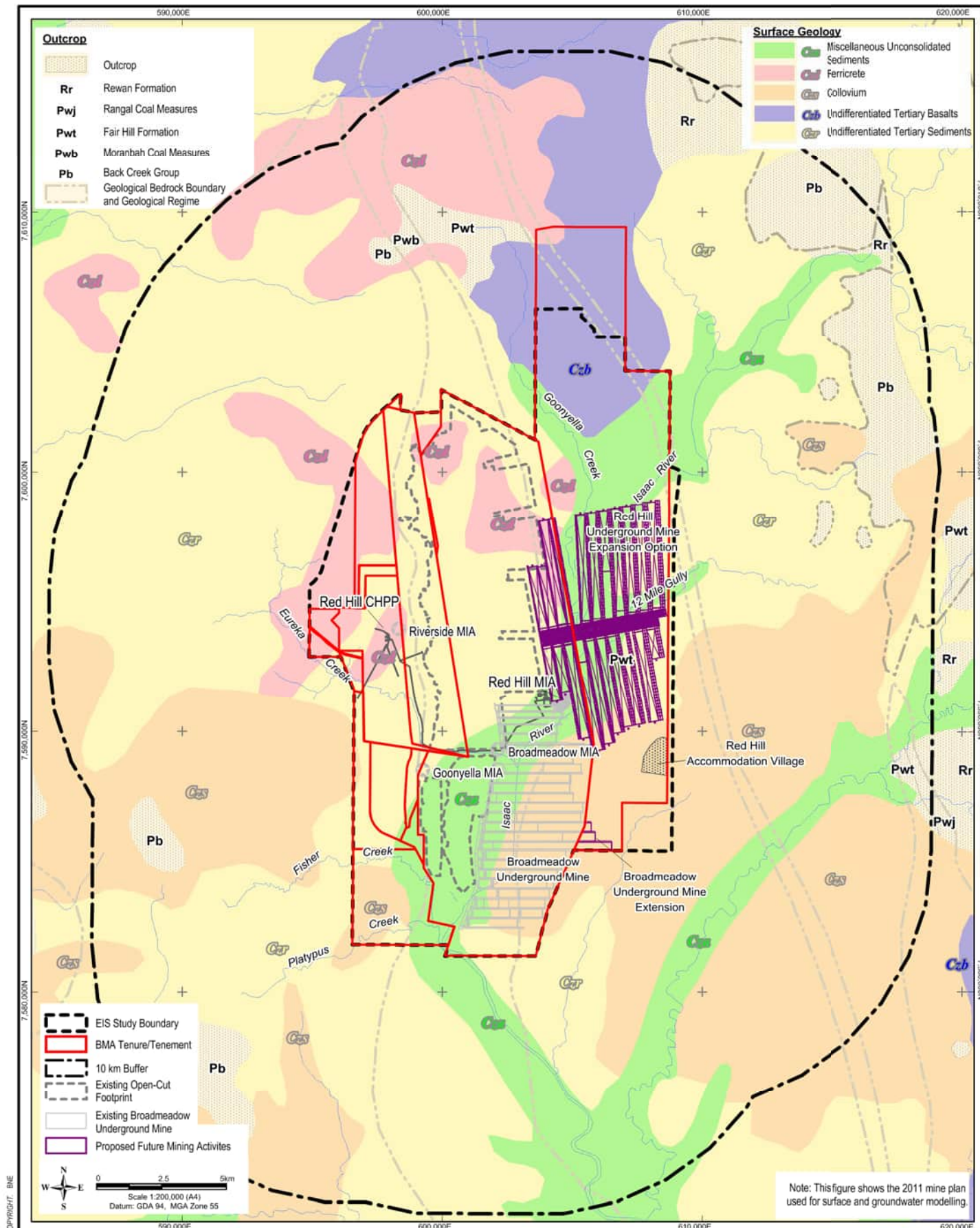
The mid-Tertiary Suttor Formation and its equivalents occur throughout the region, though outcrop is not continuous, and much of the Tertiary sequence is concealed by younger alluvium and colluvium. These strata consist of basalt, clay, silt, sand, weakly cemented sandstones, lignite and laterites. The Tertiary silts and clays are densely compacted and hard. Lag deposits of sand and gravel are found directly on the Tertiary/Permian unconformity.

The basalt appears to fill channels cut into the Tertiary sediments or into the Permian rocks. The basalts are deeply weathered and ferruginised in most places, but the thicker flows are fresher in their lower parts. Previous studies have reported basalt units range in thickness up to a maximum of 35 metres in palaeochannels in the GRM (Davies 1983).

A single major period of deep weathering has been identified for the region (Hutton *et al.* 1998). The weathering period was responsible for the strongly mottled and leached profiles on the Suttor Formation and its equivalents, and the basalts and older rocks. The associated duricrusts are generally cemented by clay minerals and silica.

Quaternary Formations

The Quaternary to Recent alluvial sediments consist of sand, gravel, clay and silt of varying content that have been unconformably deposited in an eroded, valley-fill environment associated with the creeks and drainage channels in the EIS study area. The alluvial deposits are thin, linear, irregular and lensoid in nature.



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RED HILL MINING LEASE GROUNDWATER IMPACT ASSESSMENT

SURFACE GEOLOGY OF THE SURVEY AREA

URS

GROUNDWATER

File No: 42627136-g-2096.wor

Drawn: VH

Approved: CT

Date: 24-06-2013

Figure: 5-1

Rev.A

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Hydrogeological Regime

6.1 Groundwater Occurrence

An aquifer is defined as a groundwater bearing formation sufficiently permeable to transmit and yield water in useable quantities. The groundwater regime in the survey area is considered to include:

- Quaternary alluvial aquifers associated with the creeks and Isaac River;
- Tertiary sediment aquifers;
- Tertiary basalt aquifers; and
- Permian-Triassic sedimentary fractured rock aquifers.

The EIS study area is located within the declared Isaac Connors GMA, as defined under Section 6, Schedule 3 and Schedule 4 of the Water Resource (Fitzroy Basin) Plan 2011. Within the Isaac Connors GMA, aquifers in the Quaternary alluvium are known as the Isaac Connors Groundwater Unit 1, with all other aquifers grouped together as the Isaac Connors Groundwater Unit 2. The alluvium associated with the Isaac River in the survey area is defined as the Isaac Connors Alluvium groundwater sub-area of the Isaac Connors GMA. Groundwater supply is not considered to be a major water source in the groundwater survey area. Based on a review of available data, the beneficial use of groundwater in the survey area is considered to be low due to low sustainable yields and poor groundwater quality.

The occurrence and continuity of the above mentioned aquifers will be highly dependent on the spatial distribution of the corresponding geological units in the area. The conceptual model of the groundwater regime in the survey area is presented in **Figure 6-1**.

6.1.1 Quaternary Alluvial Aquifers

Distribution

Quaternary alluvial deposits in the survey area occur predominantly within the Isaac River floodplains as shown in **Figure 6-2**. Along the Isaac River these deposits consist of clay, sandy clay, and sands and gravels with varying proportions of clay, to a depth of up to 37 metres, as observed for monitoring wells GW01 and 43840. Investigations in the Isaac River at the Moranbah North mine (located immediately south of the EIS study area) indicated that the thickness of bed sands in the Isaac River was two to three metres (JBT Consulting 2010). The alluvium associated with Eureka Creek consists of approximately nine metres of silty sand and poorly sorted sand and gravel at monitoring well GW08, with no alluvium present at GW07.

The sand and gravel deposits are recognised within the creek beds with the overbank deposits being silty and clayey with minor sand. In the upper catchments of the smaller creeks rock bars are evident. Sand and gravel deposits tend to build up behind the rock bars.

Groundwater Occurrence, Recharge and Flow

Potential for usable groundwater resources exists within the more permeable sand and gravel dominant sections of the alluvium, and represents an unconfined to semi-confined aquifer. However, drilling in the survey area alluvium indicates variable saturated thickness and does not form a consistent interconnected aquifer. The alluvial aquifer is classed as a porous media aquifer where groundwater occurs within the voids between individual grain particles. The volume of groundwater associated with the alluvium depends on the interconnection of permeable units, saturated thickness,

6 Hydrogeological Regime

and the ability to store groundwater, i.e. effective storage allowing for baseflow to creeks and rivers during the dry season.

The alluvial aquifers are considered to be strongly linked (recharged during flow events) to surface water (SKM 2009). The Isaac River and creeks within the EIS study area are ephemeral and recharge of the alluvium is by:

- recharge from surface water flow or flooding (losing stream); and
- surface infiltration of direct rainfall and overland flow, where alluvium is exposed and no substantial clay barriers occur in the shallow sub-surface.

Available hydrologic data suggests that water infiltrates / drains to the base of the alluvium relatively quickly after rainfall events where more permeable units are at surface. This saturation is sporadic, producing semi-permanent, localised, thin, aquifers.

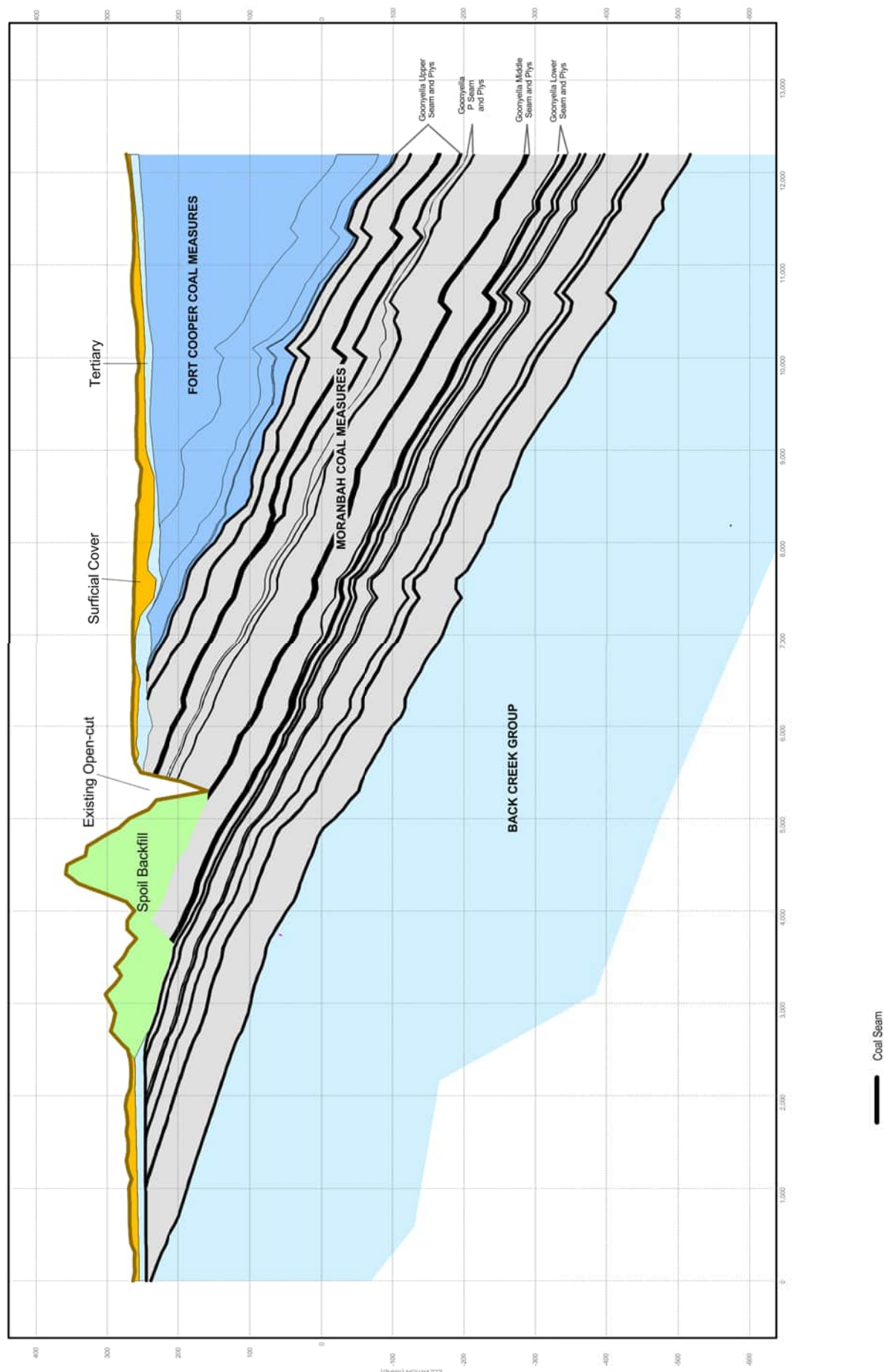
Groundwater discharge from the alluvium occurs through:

- evapotranspiration from vegetation growing in the creek beds and along the banks;
- short duration baseflow from the permeable sands and gravels within the alluvium material; and
- infiltration and recharge to the underlying older formations where the creeks cross more permeable zones within these units.

During a ground penetrating radar (GPR) survey of the Isaac River at Moranbah North mine, accessible during the dry season, it was noted that all test pits dug for the GPR survey within the bed sands were dry, or only damp in the base layer. This indicates that the Isaac River alluvium has limited effective storage, provides only limited volumes of baseflow, and does not contain groundwater all year round. Limited groundwater resources may, however, occur in the deeper and relatively narrow parts of the channel.

Due to the generally shallow saturated thickness and the lack of continuity of the more permeable gravel and sand sections, the Quaternary alluvium is not considered a significant aquifer as it has limited sustainable yield. However, during periods of creek or river flow, the alluvium may become fully saturated and discharge to sub-cropping coal seams or other underlying aquifers. Drilling on site indicates that, where groundwater does occur, depth to groundwater in the Quaternary alluvium was approximately 11 to 13 metres below ground level (mbgl). The groundwater level in the alluvium, measured in a study by Thatcher (1976), was about 20 metres above the piezometric (confined) water level in the coal at the same location. These groundwater levels indicate a marked separation between the perched alluvium groundwater level and the piezometric levels associated with the deeper coal seam aquifer groundwater. It is, thus, unlikely that changes in groundwater levels in the coal would significantly impact on the perched water table associated with the alluvium.

Owing to the paucity of data for the Quaternary alluvium, limited information exists regarding groundwater flow, however regionally, groundwater flow within the aquifer is expected to follow topography and drainage patterns.



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RED HILL MINING LEASE GROUNDWATER IMPACT STATEMENT

TYPICAL GEOLOGICAL CROSS SECTION



GROUNDWATER

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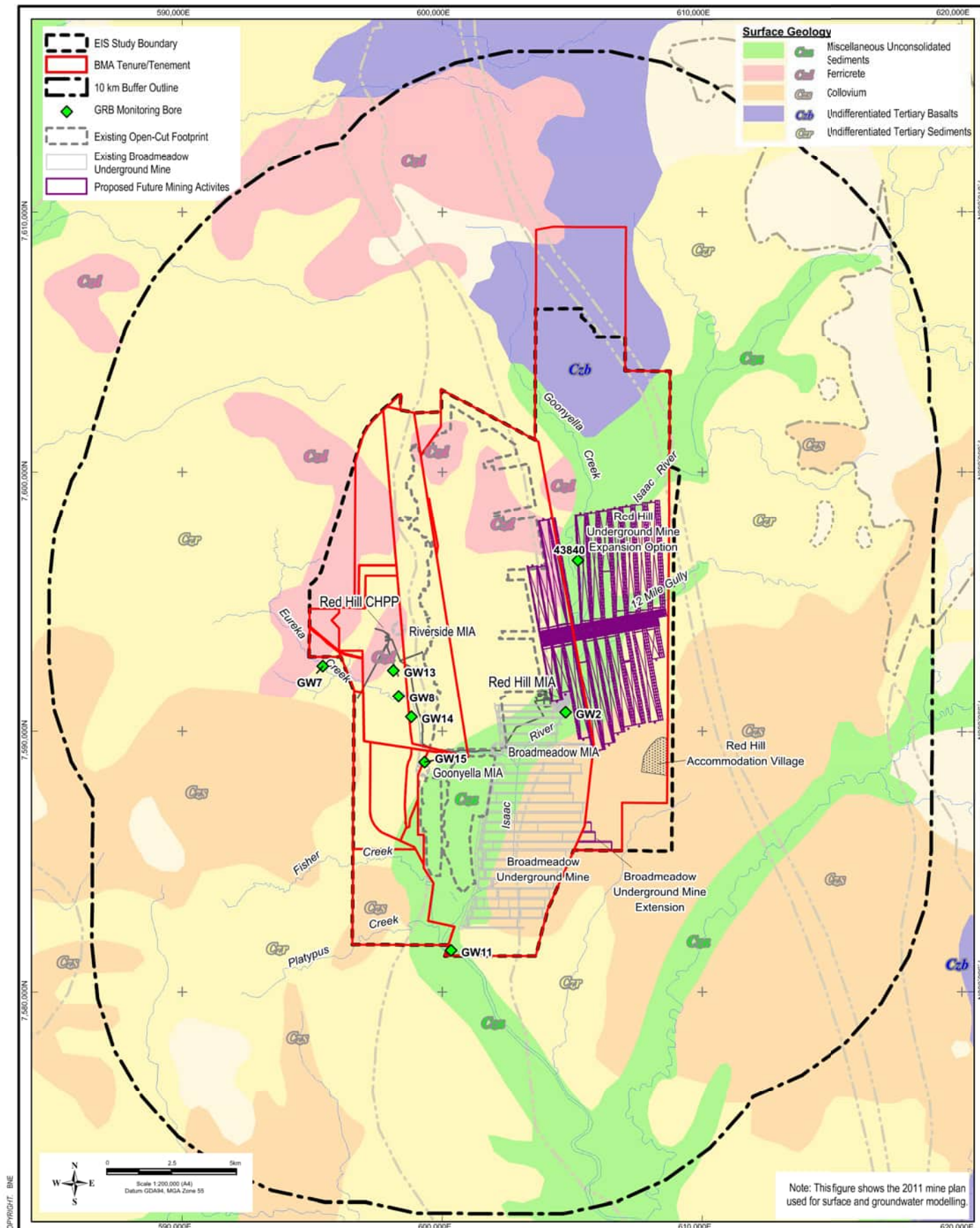
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Figure: 6-1

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RED HILL MINING LEASE GROUNDWATER IMPACT ASSESSMENT

QUATERNARY AND TERTIARY FORMATIONS WITHIN AND SURROUNDING THE EIS STUDY AREA

URS

GROUNDWATER

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6 Hydrogeological Regime

Hydraulic Parameters and Yield

Aquifer hydraulic properties of Quaternary alluvium material (Isaac River bed sands) and flood plain deposits were obtained from investigations undertaken at Moranbah North mine (JBT Consulting 2010). These hydrogeological investigations determined that permeability of the alluvium ranged from 8.9 to 45.4 metres per day (for some investigation sites water dissipated so rapidly that measurements could not be taken, indicating permeability higher than this range). These investigations also found that the Quaternary flood deposits (river bank sediments) were generally finer grained than the bed sands, and returned permeability values between 0.01 and 10 metres per day. This testing indicated that the river bank sediments were less permeable than the bed sands, and would be regarded as being of low to moderate permeability, compared to the higher permeability of the bed sands. Onsite, hydraulic testing of the Quaternary alluvium associated with the Eureka Creek at GW08 provided a hydraulic conductivity of 0.001 metres per day, typical for silty clay.

Even though the permeability of some areas of the Quaternary alluvial aquifers are high, the alluvium is not regionally extensive (continuous) and does not maintain a significant saturated thickness and hence is considered ephemeral in nature. Accordingly, groundwater extraction at high rates would not be sustainable in the long term (i.e. limited sustainable yields due to limited volumes held in storage).

6.1.2 Tertiary Sediment Aquifers

Distribution

The distribution of the Tertiary sediments is shown in **Figure 6–2**. The undifferentiated Tertiary sediments and Sutor Formation occurs extensively throughout the survey area, though outcrop is not always continuous, and much of the Tertiary sequence is concealed by younger alluvium and colluvium.

The Tertiary sediments generally consist of lenses of palaeochannel gravels and sands separated by sandy silts, sandy clays and clays. A review of the borehole logs within the RHM footprint showed the Tertiary sediments vary in thickness up to approximately 80 metres with a typical thickness of up to 15 metres. The thickness and extent of these Tertiary sediments are variable and for the most part, groundwater resources are limited and typically have poor quality. These Tertiary sediments have limited groundwater environmental values.

Groundwater Occurrence, Recharge and Flow

Potential for groundwater exists within the more permeable sand and gravel sections of the Tertiary sediments, and represents an unconfined to confined aquifer depending on location, degree of weathering, the nature of the overlying alluvium, and clay content.

Variable permeability within the Tertiary sediment, resulting in different pore pressures, has resulted in occurrences of pit wall instability. However, due to the limited storage the Tertiary sediment aquifers dewater with time. Dry open cut mining (at the GRB mine complex) indicates that this is not an ongoing problem and that these units readily dewater.

Recharge processes in the Tertiary sediment aquifers are via:

- direct infiltration of rainfall and overland flow where Tertiary sediments outcrop and no substantial clay barriers exist in the subsurface; and
- overlying Quaternary alluvial aquifers.

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Primary discharge mechanisms in the Tertiary sediment aquifers are likely to be:

- through flow into adjacent or underlying aquifers (outcropping or sub-cropping coal seams); evapotranspiration; and
- groundwater extraction.

The depth to groundwater in monitoring wells on-site in the Tertiary sediment aquifer is typically less than 15 mbgl (IESA 2001a).

Hydraulic Parameters and Yield

Most of the clean sand and gravel lenses in the Tertiary sediments are permeable but are of limited lateral and vertical extent. Thus the volume of groundwater stored and the ability to transmit groundwater depends on the particle size of the material and the saturated thickness of the sediments. A review of bore logs within the RHM footprint showed that the Tertiary sediments are dominated by low permeability clays and sandy clays with isolated areas of loose more permeable sand. The interpreted hydraulic conductivity value of 6.6×10^{-4} metres per day obtained from the variable (falling) head test for monitoring well GYTD7 during investigations for the Airstrip Pit Boxcut (IESA 2001a) is very low, indicating predominantly clay intersected within this bore. No other site specific testing of hydraulic properties has been undertaken on the shallow Tertiary sediments. Installation of monitoring bores (GW1 to GW15) showed that the Tertiary sediments, where intersected, comprise predominantly of clays, containing only very minor sand lenses, and intersected little or no groundwater. Data from exploration drilling also indicates that these sediments are often dry, and occurrence of groundwater in these sediments is sparse. However, where the sediment is coarse in composition, the unit may have localised zones of enhanced hydraulic conductivity.

6.1.3 Tertiary Basalt Aquifers

Distribution

An aeromagnetic geophysical survey has been undertaken over the Bowen Basin (GSQ 2004). The resultant magnetic data indicates that Tertiary basalt exists as small discontinuous remnants to the south and in the west of the EIS study area, with a larger continuous unit to the north (**Figure 6-2**). No basalt is mapped within the footprint of the RHM.

Groundwater Occurrence, Recharge and Flow

For the majority of exploration boreholes that intersected basalt, the basalt is logged as highly to extremely weathered, clayey and dry. The distribution of less-weathered, fractured and vesicular water-bearing basalt is variable. The Tertiary basalt aquifers are classed as a secondary porosity aquifer and are expected to represent unconfined to confined aquifers depending on location. Groundwater is principally stored and transmitted in the fractures, joints and other discontinuities within the rock mass.

The depth of the basalt, and the generally clayey nature of the weathered upper basalt and the Tertiary sediments associated with the basalt, indicate that the recharge is low. Groundwater recharge in this aquifer occurs from:

- infiltration of rainfall in rock outcrop areas where no substantial clay barriers exist in the shallow subsurface; and

6 Hydrogeological Regime

- vertical seepage or through flow from overlying or adjacent alluvial or tertiary sediment aquifers.

Primary discharge mechanisms in the Tertiary basalt aquifers are likely to be:

- down gradient Tertiary basalt outcrop areas;
- through flow into adjacent or underlying aquifers (outcropping or sub-cropping coal seams); evapotranspiration; and
- groundwater extraction.

Depth to groundwater in the Tertiary basalt aquifers have historically been measured at between 23 and 34 mbgl (AGE 2004b).

Hydraulic Parameters and Yield

The nature of the Tertiary basalt, and hence its permeability and porosity, is highly variable, depending on the degree of weathering and the intensity and interconnectedness of jointing and/or fracturing. Where the basalt is less weathered and more fractured or vesicular, the unit may have local zones of moderate to high hydraulic conductivity. Hydraulic testing at Moranbah North mine (JBT Consulting 2010) indicated the Tertiary basalt to be moderately permeable with hydraulic conductivity values ranging from one to four metres per day and storage coefficient between 1×10^{-2} and 1×10^{-4} . Onsite, interpreted hydraulic conductivity values of 1.21 and 0.48 metres per day were obtained from the variable head test for monitoring wells 45314 and 45319, respectively during investigations for the groundwater depressurisation assessment of the southern extension of the Airstrip Pit (AGE 2004a) located in the southwest of the EIS study area. The drilling program undertaken as part of this Airstrip Pit groundwater study showed that the Tertiary basalt appears to be highly heterogeneous and discontinuous locally. In the area of the Airstrip Pit, the basalt intersected during drilling was generally not water-bearing; however for the few holes that did intersect measurable groundwater flows, airlift yields were at most 1.25 litres per second (L/s).

6.1.4 Permian-Triassic Strata Aquifers

Distribution

The Permian-Triassic formations constitute the two dominant Permian formations, which are the Blackwater Group and the Back Creek Group as well as the Triassic Rewan Formation as shown in **Figure 6-3** and described in **Table 5-1**.

As with the rest of the Bowen Basin, the coal seams are the main aquifers within the Permian sequences, with the overburden and interburden rocks in most mines being described as essentially impervious to groundwater movement (AGE 2008). Within the EIS study area, the GLS, GMS and GUS coal seams constitute the most extensive aquifers. These seams have been removed in the majority of the western extent of the EIS study area through open cut mining. The Triassic Rewan Formation strata occur only in the very north-east of the EIS study area.

Groundwater Occurrence, Recharge and Flow

The coal seam aquifers are confined above and below by very low permeability geological formations and movement of water through the aquifer (transmissivity) is likely to be through the more permeable (cleats) coal rather than the confining units. The confining units also have very low vertical hydraulic conductivity (leakance), such that very slow, as is the rate at which water flows into the aquifer

6 Hydrogeological Regime

(recharge) is limited. Groundwater occurs within the coal seam cleats and fissures and within open fractures that intersect the seams. Other sediments in the coal overburden and interburden sequence are relatively impermeable (either due to high clay content or significant cementing) and form aquitards. The Permian and Triassic strata may, therefore, be categorised into the following hydrogeological units:

- hydrogeologically 'tight' and hence very low yielding to essentially dry claystone, mudstone, sandstone, siltstone and shale that comprise the majority of the strata;
- low to moderately permeable coal seams which are the prime water bearing strata within the Permian sequence; and
- localised fracture or fault systems which are open and have not been infilled by clay/carbonate deposition.

Groundwater recharge in this aquifer occurs from:

- infiltration of rainfall and overland flow in outcrop and sub-crop areas;
- downward seepage or through flow from overlying or adjacent alluvial or tertiary aquifers where no significant clay barriers exist; and
- leakage between aquifers by faulting and other structural discontinuities in overburden and interburden sediments.

Primary discharge mechanisms in the Permian-Triassic strata aquifers are likely to be:

- downgradient Permian-Triassic strata outcrop areas;
- through flow into adjacent (outcropping or sub-cropping coal seams) or seepage into underlying aquifers (via structural discontinuities); and
- groundwater extraction (IMG and other mine dewatering activities).

Groundwater levels in the Permian formations have been measured for hydrogeological investigations assessing potential inflows to pits and underground workings and the establishment of boxcut or pit dewatering bores for mine design and production purposes, as discussed in **Section 3**. There are 41 groundwater level measurements from 32 bores installed in the Permian formations over the period from 1995 to 2009, however many of these bores have been destroyed during mining. Consequently, there are no long term hydrographs of groundwater levels available, and the groundwater level information is not evenly spatially distributed.

Evidence from piezometric observations for the coal seam aquifers during these previous investigations suggests the groundwater levels were slightly different for each seam, with the GUS seam being one to two metres higher than the GMS seam, and the GLS seam being up to 14 metres lower than the GMS seam at the same location. This variation in hydraulic heads between coal seams indicates the aquitard nature of the interburden and the limited potential for induced flow. The phreatic surface varied from 15 to 50 mbgl. Prior to development of the GRB mine complex operations, groundwater flow direction in the coal seam aquifers appears to have been from the north and west to the south and east across the site. This flow direction is consistent with recharge to the coal seams occurring at the subcrops in the west of the site and discharge occurring downgradient in the Isaac River subcatchment in the Bowen Basin. The current groundwater flow pattern has been altered locally with groundwater flow towards the existing mine pits and underground workings due to mine dewatering and depressurisation. Groundwater modelling (AGE 2002) and groundwater level measurements indicate that groundwater levels are affected by mining induced drawdown up to 2.7 kilometres from the mine workings.

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The occurrence of groundwater in the interburden is limited. Aquifers in the interburden are discontinuous with heterogeneous hydraulic properties creating isolated, lens-like aquifers. Due to the heterogeneity and discontinuity of the interburden aquifers within the Permian strata, the groundwater flow direction cannot be determined on a regional scale for these aquifers.

No data exist on the seasonal fluctuations of groundwater level within the Permian-Triassic aquifers. However, due to the depth and confined nature of these aquifers, they are expected to show a subdued response to recharge or discharge.

Hydraulic Parameters and Yield

Interpreted hydraulic conductivity values determined for the Moranbah Coal Measures in the EIS study area are presented in **Table 6-1**. The aquifer testing results indicate that the cleats and joints in the coal are less open with depth, with a corresponding decrease in permeability. WDS (2011) conducted an engineering study for coal seam degassing required prior to mining of the RHM, using data derived from packer testing in 31 seam/site combinations in the Moranbah and Fort Cooper Coal Measures. This study found that:

- with increasing depth, effective stress increases and permeability decreases;
- with increasing ash (mineral matter), rock stress and effective stress increases and permeability decreases; and
- with increasing gas content to the east, primary permeability decreases.

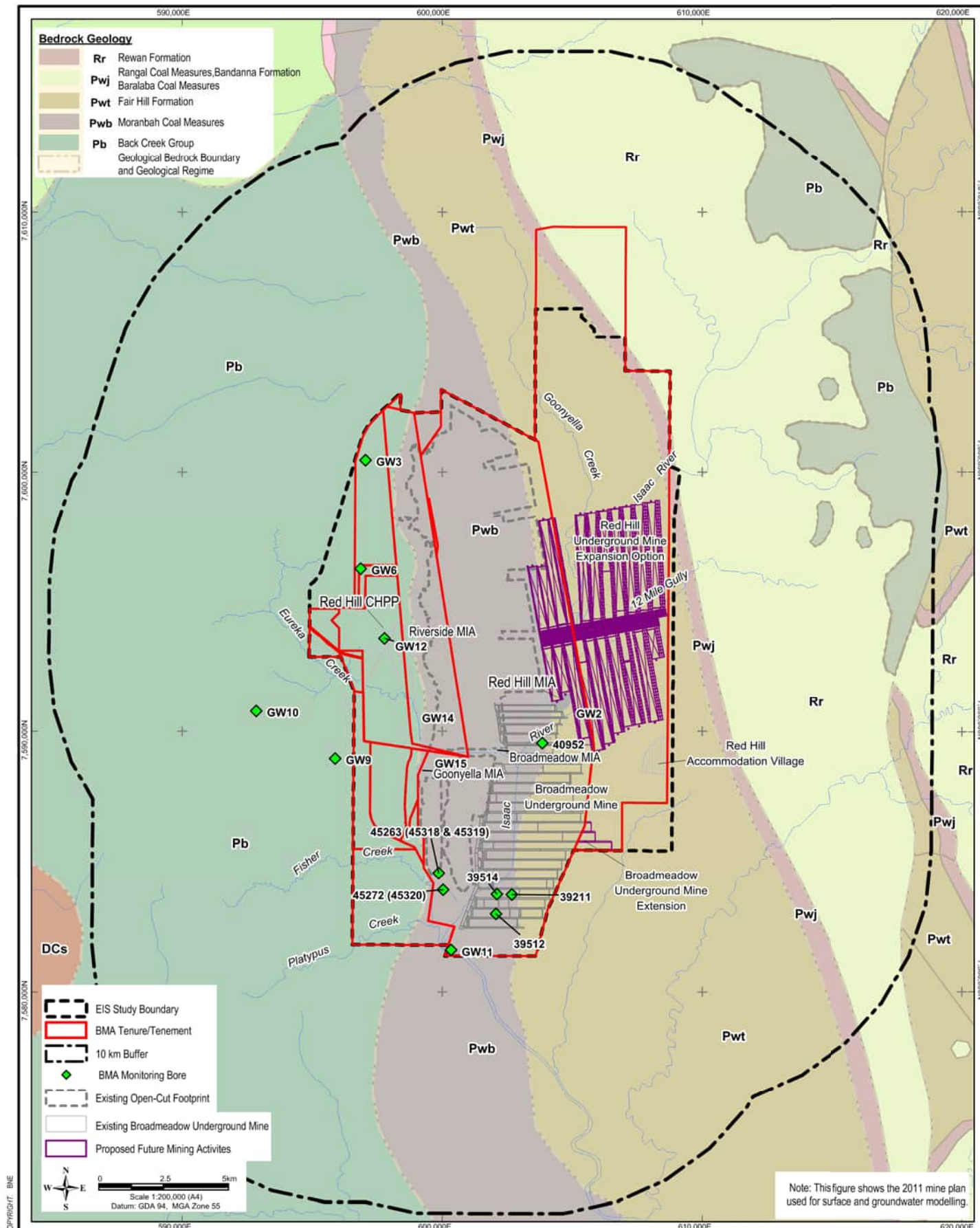
A relationship was determined for permeability variation with depth, ash, and gas content as part of this study. This relationship is:

- $\text{Permeability (mD}^1) = -0.00548 \times \text{Depth (metres)} - 0.2549 \times \text{Gas Content at 15 per cent ash} + 4.045688$.
- It applies to the GUS, GMS and GLS seams for depths of 132 to 593 metres, Gas Content at 15 per cent ash of 0.2 to 13.7 cubic metres per tonne (m^3/t).

Interpreted hydraulic conductivity values determined for the Back Creek Group during investigations as part of the EIS were between 0.002 and 0.1 metres per day.

Hydraulic testing of the interburden units (AGE 2004b) and of drill core undertaken for this EIS revealed highly variable hydraulic conductivity from moderately pervious to highly impervious. This is evidence that the Permian formations are heterogeneous, having discrete zones of higher permeability over short distances and the very low hydraulic conductivity in the majority of the interburden and overburden isolate more conductive parts associated with the fracture/fault systems.

¹ millidarcys an empirical unit of permeability



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RED HILL MINING LEASE GROUNDWATER IMPACT ASSESSMENT

PERMIAN AND TRIASSIC FORMATIONS WITHIN AND SURROUNDING THE EIS STUDY AREA



GROUNDWATER

Figure: 6-3

File No: 42627136-g-2098.wor

Drawn: VH

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Table 6-1 Interpreted Hydraulic Conductivity of Permian Strata Aquifers

Area of Investigation	Permian Strata Investigated	Method of Determination	Hydraulic Conductivity (m/day)
Goonyella No2 (Rust PPK 1996)	GMS	Pumping test	0.003 to 0.034
	GMS	Packer test	0.009 to 0.085
Airstrip Boxcut (IESA 2001a)	GLS	Falling head slug test	0.06 to 0.47
Goonyella Longwall Development (AGE 2002)	GMS	Calibration of groundwater numerical model	0.0009 to 0.1
Airstrip South Boxcut (AGE 2004a)	GLS	Falling head slug test	0.06 to 0.80
		Calibration of groundwater numerical model	0.82
Ramp 8 (AGE 2004b)	GLS	Shut in pressure test	0.10
		Falling head slug test	0.01 to 0.03
	Interburden	Falling head slug test	2E-05 to 0.33
EIS study area	Interburden	Constant head core test	Horizontal 2E-06 to 3E-05 Vertical 9E-07 to 9E-05

A review of the BMA exploration bore database was undertaken to assess airlift yields recorded during drilling. An airlift yield is the rate at which groundwater is removed from a bore during drilling with an air flushed drilling method, and is an estimate of the potential yield of a bore. Of the 659 exploration bores in the RHM area identified with recorded yield data, 440 bores (67 per cent) were identified as no recordable yield (i.e. dry), and 174 (26 per cent) had airlift yields of less than 0.5 L/s. Airlift yields recorded during drilling of the exploration bores are summarised in **Chart 6-1**. Many of the exploration bores that did not have recorded airlift yields in the exploration database may have been dry, thus the above histogram may overestimate the yield from the Permian strata. The length of time for which the airlifting was conducted was not available, therefore the sustainability of these yields is not known. The airlift yields generally decrease with airlift depth as shown in **Chart 6-2** confirming permeability decreases with depth as a response to fractures being less open at depth.

6 Hydrogeological Regime

Chart 6-1 Histogram of Airlift Yields of Exploration Bores

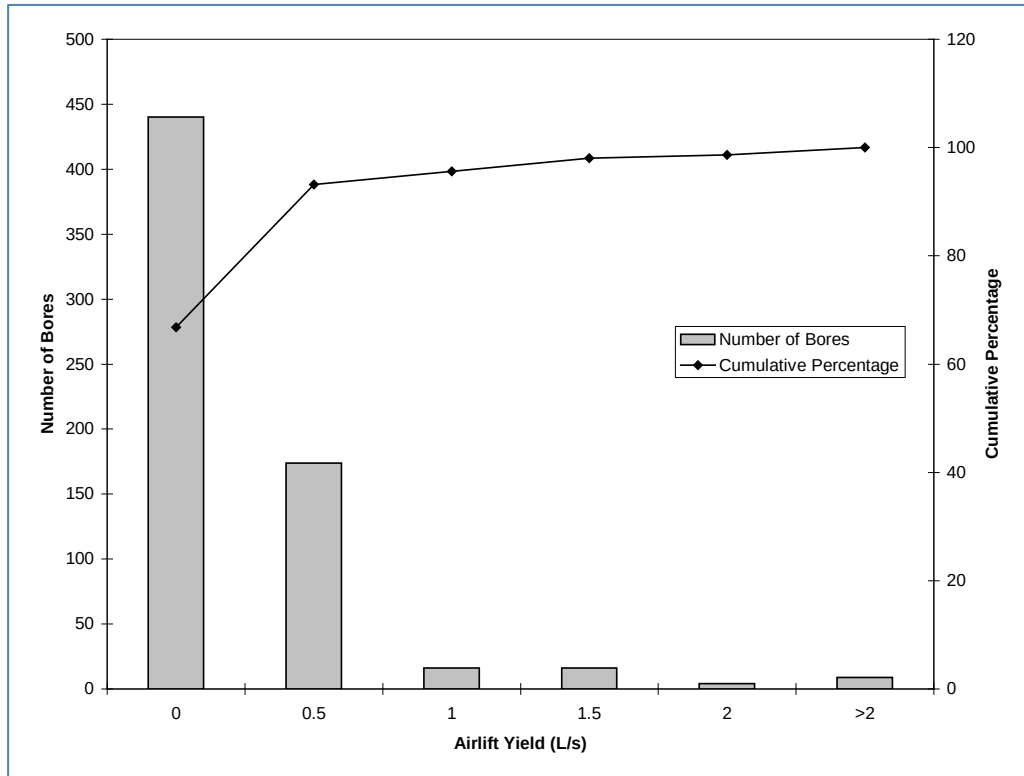
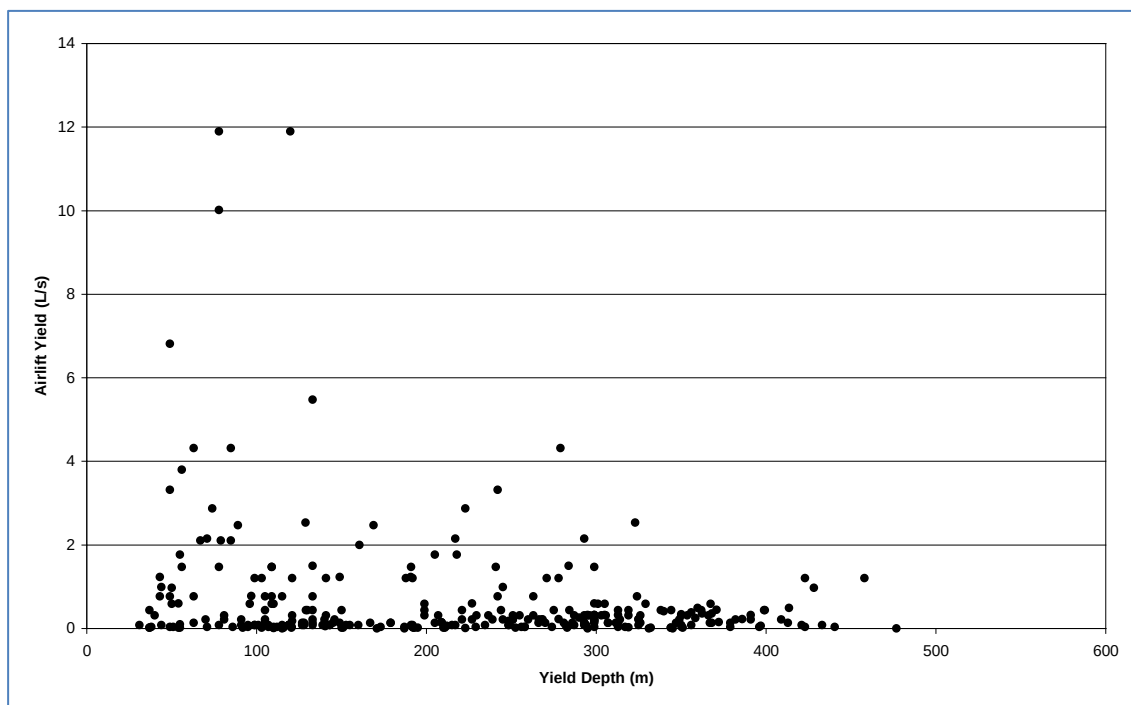


Chart 6-2 Airlift Yield and Airlift Depth for Exploration Bores



6 Hydrogeological Regime

6.2 Groundwater Quality

Groundwater samples were collected for chemical analysis from piezometers installed around the site during previous site investigations and for this EIS study.

The physico-chemical results obtained during groundwater sampling within the EIS study area for the period 2001 to 2010, which have been summarised and presented in **Table 6-2**, indicate the groundwater chemistry is typically neutral to weakly alkaline (pH) for all formations. The Tertiary and Permian formations have variable salinity (measured as electrical conductivity), ranging from brackish to saline, while the groundwater quality within the alluvium is fresh.

It should be noted that the depth of the aquifer and its distance from the area of recharge are likely to influence the result at a given sample point, as salinity is highly variable, and appears to increase with depth and the distance from the area of recharge. Based on ANZECC/ARMCANZ (2000) guideline values, the groundwater may be suitable for livestock drinking water and irrigation of salt tolerant crops. However, the low yield typical of the aquifers would preclude use for large-scale irrigation.

Median groundwater salinity values were greater than the 50th percentile WQO nominated in the (Water) for groundwaters in the Isaac River Sub-basin (zone 34, which covers part of the survey area). The limited dataset does, however, indicate that groundwater results cover a wide range for each unit (due to depth, distance from recharge, and age of water). The lower end of the range results are within the WQO.

Results of the analyses of groundwater samples between 1998 and 2011 from monitoring bores installed on site are shown in **Table 6-3**. The Permian Moranbah Coal Measures and Back Creek Group has moderate to high salinity principally due to elevated levels of sodium and chloride ions. The Back Creek Group groundwater contains a relatively higher proportion of sulphate due to marine influence during deposition compared to the Moranbah Coal Measures. The groundwater from the Quaternary alluvium is dominated by sodium and bicarbonate ions, and has a lower salinity than the groundwater of the Permian formations.

Major ion concentrations for alluvial groundwater are less than the EPP (Water) 50th percentile water quality objectives for shallow (<30 metre depth) groundwater, while the maximum concentration of zinc recorded is above the ANZECC/ARMCANZ (2000) water quality guideline for aquatic ecosystems.

The median concentration of sodium for groundwater from the Moranbah Coal Measures is just less than the EPP (Water) 50th percentile water quality objective for deep (>30 metre depth) groundwater, while the median concentrations of chloride and bicarbonate are above the respective water quality objectives. The median concentration of manganese is also above the relevant water quality objective, while the median concentrations of nutrients (nitrate and nitrite, total phosphorous) and some dissolved metals (chromium, copper and zinc) are also above the ANZECC/ARMCANZ (2000) water quality guideline for aquatic ecosystems.

The median concentration of all major ions for groundwater from the Back Creek Group are greater than the EPP (Water) 50th percentile water quality objective for deep (>30 metre depth) groundwater. The median concentration of manganese and iron are also above the relevant water quality objective, while the median concentrations of nutrients (nitrate and nitrite, total phosphorous) and some dissolved metals (boron, cadmium, chromium, copper, nickel, selenium and zinc) are above the ANZECC/ARMCANZ (2000) water quality guideline for aquatic ecosystems.

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Table 6-2 Physico-Chemical Results for Aquifers in the EIS Study Area (2110-2010)

Aquifer	Number of Samples	Electrical Conductivity (µS/cm)		pH	
		Range	Median	Range	Median
Quaternary Alluvium	2	521-561		6.88-7.55	
Tertiary Basalt	3	2,670-15,384	13,100	8.19-8.67	8.38
Tertiary Sediment	1	5,060		9.30	
Permian Interburden	6	7,030-18,800	12,805	7.38-8.38	8.06
GMS	5	2,450-16,127	9,110	6.65-7.90	7.12
GLS	30	387-31,300	24,050	2.71-8.76	7.99
Back Creek Group	3	4,530-24,030	22,660	5.98-6.79	6.74
Undifferentiated from airlift sampling during exploration drilling	75	100-30,000	12,593	6.89-9.18	7.68
ANZECC/ARMCANZ (2000) upper limits ¹ - irrigation - livestock – cattle		2,900-5,200 8,300-16,700 ²			
EPP (Water) ³ – 50 th percentile - shallow groundwater (<30 m) - deep groundwater (>30 m)		2,150 6,100		7.75 7.80	

1 – ANZECC/ARMCANZ (2000) Water Quality Guidelines for livestock drinking water (cattle) and irrigation of salt tolerant crops

2 – Electrical Conductivity value based on TDS value for livestock (EC [µS/cm] = 1.67 × TDS [mg/L])

3 – EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34.

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Table 6-3 Summary of Water Chemistry for Representative Bores On-Site between 1998 and 2011

Parameter	Guidelines					Moranbah Coal Measures				Back Creek Group				Quaternary Alluvium			
	EPP(Water) – 50 th Percentile, Shallow (<30 m depth) ¹	EPP(Water) – 50 th Percentile, Deep (>30 m depth) ¹	ANZECC/ ARMCANZ (2000) and QWQG (2006) - Freshwater Ecosystems ²	ANZECC/ ARMCANZ (2000) - Livestock Drinking Water ³	NHMRC (2011) - Human Drinking Water ⁴	Count ⁵	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count ⁵	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count ⁵	Min (mg/L)	Med (mg/L)	Max (mg/L)
Major Ions																	
Sodium	747	1,100	ne	ne	30 ⁶	13	40	1096	3560	3	824	3470	4400	2	40	-	94
Calcium	84	145	ne	1,000	ne	13	<0.01	49	469	3	34	214	422	2	13	-	39
Magnesium	108	115	ne	ne	ne	13	<0.01	25	570	3	86	542	805	2	7	-	20
Potassium	ne	ne	ne	ne	ne	13	1.4	6	28	3	29	35	38	2	3	-	3
Chloride	1,309	1,900	ne	ne	ne	13	64	2024	7510	3	1390	7000	9750	2	10	-	71
Bicarbonate	536	330	ne	ne	ne	13	85	497	5656	3	10	417	774	2	180	-	293
Sulphate	140	138	ne	1,000	200 ⁶	13	0.2	4	626	3	223	692	763	2	6	-	26
Fluoride	0.28	0.155	ne	2	1.5	11	<0.1	0.2	1.2					2	0.2	-	0.4
Nutrients																	
Nitrite + Nitrate as N	0.95	2.15	0.015	ne	ne	13	0.02	0.2	0.9	3	0.05	0.09	0.33	2	0.125	-	0.315
Total Phosphorus as P	ne	ne	0.03	ne	ne	13	0.03	0.5	5.08	3	0.78	1.49	1.56	2	0.47	-	0.75
Metals (Dissolved)																	
Aluminium	ne	ne	0.055	5	ne	13	<0.01	<0.01	0.1	3	0.04	0.05	0.05	2	0.05	-	<0.1
Antimony	ne	ne	ne	ne	0.003	2	0.004	-	0.007	3	<0.001	0.004	0.004	-	-	-	-

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Parameter	Guidelines					Moranbah Coal Measures				Back Creek Group				Quaternary Alluvium			
	EPP(Water) – 50 th Percentile, Shallow (<30 m depth) ¹	EPP(Water) – 50 th Percentile, Deep (>30 m depth) ¹	ANZECC/ ARMCANZ (2000) and QWQG (2006) - Freshwater Ecosystems ²	ANZECC/ ARMCANZ (2000) - Livestock Drinking Water ³	NHMRC (2011) - Human Drinking Water ⁴	Count ⁵	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count ⁵	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count ⁵	Min (mg/L)	Med (mg/L)	Max (mg/L)
Arsenic	ne	ne	0.013	0.5	0.01	7	<0.001	0.002	0.024	3	0.001	0.008	0.013	2	<0.001	-	<0.01
Barium	ne	ne	ne	ne	2	2	0.168	-	0.313	3	0.046	0.095	0.107	-	-	-	-
Beryllium	ne	ne	ne	ne	0.06	2	<0.001	-	<0.001	3	<0.001	<0.001	0.001	-	-	-	-
Boron	ne	ne	0.37	5	4	7	<0.1	0.26	0.6	3	1.51	1.82	3.32	2	<0.1	-	0.1
Cadmium	ne	ne	0.0002	0.01	0.002	7	<0.0001	0.0002	0.005	3	0.0002	0.0005	0.0006	2	0.0002	-	<0.005
Chromium	ne	ne	0.001	1	0.05	7	<0.001	0.002	0.01	3	0.002	0.003	0.004	2	0.002	-	<0.01
Cobalt	ne	ne	ne	1	ne	7	<0.001	0.003	0.01	3	0.018	0.02	0.08	2	<0.001	-	<0.01
Copper	0.01	0.03	0.0014	1	2	7	<0.001	0.002	0.01	3	0.001	0.002	0.004	2	<0.001	-	<0.01
Gallium	ne	ne	ne	ne	ne	2	<0.001	-	<0.001	3	<0.001	<0.001	<0.001	-	-	-	-
Iron	0.03	0.05	ne	ne	ne	13	<0.01	<0.05	1.2	3	<0.05	0.12	1.94	2	<0.05	-	<0.05
Lead	ne	ne	0.0034	0.1	0.01	7	<0.001	0.001	0.01	3	<0.001	<0.001	<0.001	2	<0.001	-	<0.01
Lithium	ne	ne	ne	ne	ne	2	0.041	-	0.136	3	0.206	0.276	0.41	-	-	-	-
Manganese	0.01	0.05	1.9	ne	0.5	13	0.002	0.18	1.23	3	0.958	0.991	1.07	2	0.037	-	0.16
Mercury	ne	ne	0.00006	0.002	0.001	2	<0.0001	-	<0.0001	3	<0.0001	<0.0001	<0.0001	-	-	-	-
Molybdenum	ne	ne	ne	0.15	0.05	7	<0.001	0.01	0.021	3	<0.001	0.002	0.003	2	<0.001	-	<0.01

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Parameter	Guidelines					Moranbah Coal Measures				Back Creek Group				Quaternary Alluvium			
	EPP(Water) – 50 th Percentile, Shallow (<30 m depth) ¹	EPP(Water) – 50 th Percentile, Deep (>30 m depth) ¹	ANZECC/ARMCANZ (2000) and QWQG (2006) - Freshwater Ecosystems ²	ANZECC/ARMCANZ (2000) - Livestock Drinking Water ³	NHMRC (2011) - Human Drinking Water ⁴	Count ⁵	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count ⁵	Min (mg/L)	Med (mg/L)	Max (mg/L)	Count ⁵	Min (mg/L)	Med (mg/L)	Max (mg/L)
															1		
Nickel	ne	ne	0.011	1	0.02	2	0.002	-	0.033	3	0.009	0.028	0.131	-	-	-	-
Selenium	ne	ne	0.005	0.02	0.01	7	<0.01	<0.01	0.05	3	<0.01	0.01	0.03	2	<0.01	-	<0.01
Strontium	ne	ne	ne	ne	ne	2	1.75	-	3.86	3	0.675	8.52	10.7	-	-	-	-
Thorium	ne	ne	ne	ne	ne	2	<0.001	-	<0.001	3	<0.001	<0.001	<0.001	-	-	-	-
Titanium	ne	ne	ne	ne	ne	2	<0.01	-	<0.01	3	<0.01	<0.01	<0.01	-	-	-	-
Uranium	ne	ne	ne	0.2	0.017	2	0.002	-	0.005	3	<0.001	0.002	0.003	-	-	-	-
Vanadium	ne	ne	ne	ne	ne	2	<0.01	-	<0.01	3	<0.01	<0.01	<0.01	-	-	-	-
Zinc	0.015	0.025	0.008	20	ne	7	<0.01	0.013	0.13	3	0.05	0.054	0.174	2	0.008	-	0.02

1 – EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for Zone 34 groundwater

2 – ANZECC/ARMCANZ (2000) and QWQG (2006) trigger values for moderately disturbed upland stream freshwater ecosystems

3 – ANZECC/ARMCANZ (2000) guidelines for livestock watering of beef cattle

4 – NHMRC (2011) health based guidelines for drinking water

5 – Number of samples

6 – EPP (Water) Isaac River Sub-basin Environmental Values and Water Quality Objectives for drinking water

ne – No guideline value established

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6.3 Groundwater Use

The survey area is located within the declared Isaac Connors Groundwater Management Area, as defined under Section 6, Schedule 3 and Schedule 4 of the Water Resources (Fitzroy Basin) Plan 2011. Within the declared management area, water licenses and/or development permits are not required for stock or domestic bores, and NRM also generally excludes groundwater monitoring bores from the requirement for development permits. In Queensland, all wells deeper than six metres, including monitoring wells, must be constructed by, or under the supervision of, a licensed water bore driller who has the correct endorsements on their licence for the type of activity being performed. It is a requirement of the Water Act that a licensed water bore driller submit the records of the drilling and installation of a water well to NRM within 30 days of completion of the well. These records are entered in the NRM database.

From a search of the NRM groundwater database, 31 bores are registered within 10 kilometres of the EIS study area boundary, as shown on **Figure 6-4**. Of the 31 bores, 27 have been installed for private use, and four have been installed by NRM for groundwater monitoring and assessment (three of which have been abandoned and destroyed). Of the 27 bores installed for private use, 16 were installed for coal seam gas (CSG) exploration in the Moranbah or Fort Cooper Coal Measures, with four of the seven other private bores in these formations being abandoned and destroyed. No stratigraphic or casing description information has been included in the NRM database for the three remaining non-CSG bores and accordingly it is not certain from which aquifer these bores extract groundwater. No information exists in the database on the normal pumping rates of these bores, or the drawdown that occurs during pumping. The current use of the bores is not specified in the NRM database, however typical groundwater use in the area is expected to be for stock watering owing to the variable salinity levels and generally low yields. No dewatering for CSG extraction is currently undertaken within the EIS study area, however CSG exploration has been undertaken in the area and producing CSG wells are located to the south east of the project.

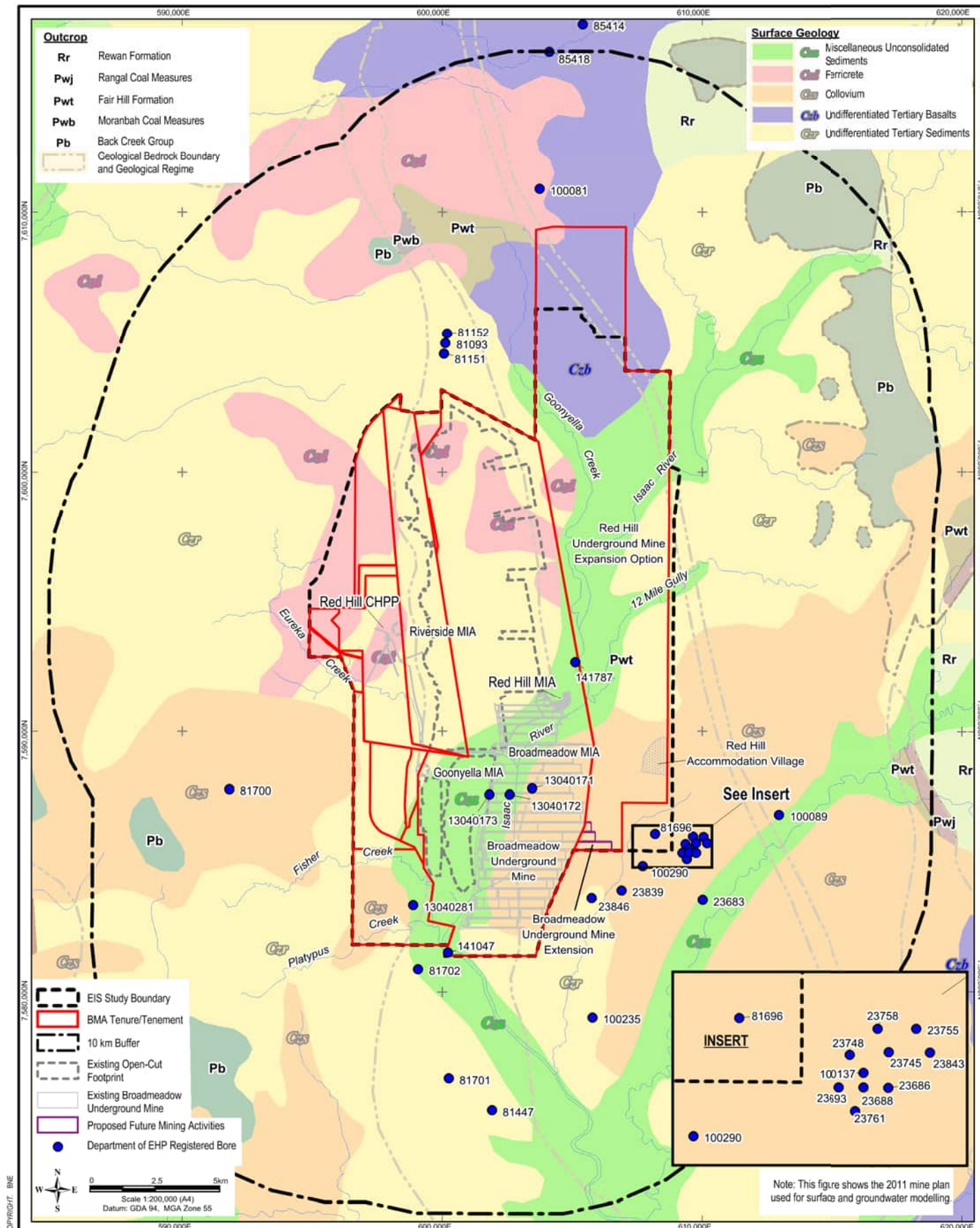
A groundwater bore census was conducted within and on properties surrounding the EIS study area boundary to collect information on groundwater bores installed before registration was a requirement, and additional information on bores registered in the NRM database. Four bores were recorded during the census, two on 'Denham Park' and two on 'Broadmeadow'. The location of these bores is shown on **Figure 6-4** and summary of bore details are provided in **Table 6-4**. The bores on 'Denham Park' intersect the basalt aquifers to the northwest of the EIS study area, however, the basalt does not extend into the project's infrastructure or mine areas and so these bores are unlikely to be impacted by it. The bores on 'Broadmeadow' are considered to be constructed into the base of Tertiary (basal sand/sandstone) or the top of the Permian formations. These bores are generally used for stock watering, with one (Tex's bore on Denham Park) also used for house hold supply during drought.

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Table 6-4 Summary of Information Collected During Bore Census

Property	Bore Name	Drilled Depth (mbgl)	Depth to Water (mbgl)	Water Use	Pumping Rate (L/s)	Landholder Description of Water Quality
Denham Park	Tex's Bore	118.9	34.13	Domestic and stock watering in drought	4.5	
Denham Park	Old Mill Bore	117.1	90.66	Stock watering	1.9	
Broadmeadow	Skeleton Bore (NRM Registration 81696)	63.7	28.41	Stock watering when required	1.3	'Good'
Broadmeadow	Cleanskin Gully	25.34	14.02	Stock watering when required	2.6	'Good'

There have been groundwater dewatering bores on site at GRB in the past for the establishment of GRM boxcuts, however these were not replaced when they were mined out because groundwater inflow to the open cut pits is limited once mining is established. Due to the large surface area of the open cut pits and the significant excess of evaporation over rainfall in the area, groundwater which seeps from the coal seams in the open pits mostly evaporates, with limited amounts collected in sumps and pumped to the mine water system for reuse. Groundwater is not actively dewatered in advance of mining in the BRM, with seepage collected in sumps and pumped to the surface into the existing mine water system for reuse. Total groundwater contribution rates to the mine water system are not monitored as these are at low levels.



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RED HILL MINING LEASE GROUNDWATER IMPACT ASSESSMENT

LOCATION OF NRM REGISTERED BORES AND BORE CENSUS



GROUNDWATER

Figure: **6-4**

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6.4 Assessment of Groundwater Environmental Values

The location of the proposed project is within the Isaac River sub-basin of the Fitzroy Basin as described in Schedule 1 of the EPP (Water). The scheduled environmental values for groundwater to be enhanced or protected in the area are the following qualities:

- biological integrity of aquatic ecosystems;
- suitability for recreational use (primary recreation);
- suitability for minimal treatment before supply as drinking water;
- suitability for use in primary industries (irrigation, farm supply, stock water); and
- cultural and spiritual values.

The existing groundwater environment, within the groundwater survey area, has been assessed against these environmental values.

Biological Integrity of a Pristine or Modified Aquatic Ecosystem

The local area within and around the RHM footprint has been cleared for agriculture, predominantly beef cattle grazing, as well as for coal mining purposes. These farming and mining practices modify the landscape, affecting the volume and rate of rainfall runoff, the flow characteristics of the creeks, and the recharge to groundwater. As such, the aquatic ecosystems of the area have been modified.

Groundwater dependant ecosystems (GDE) are ecosystems which have their species composition and natural ecological processes determined in part by groundwater. The groundwater parameters that sustain GDEs are flow rate, level, and quality, with dependence potentially being a function of one or all of these factors.

The water level measurements undertaken as part of the EIS indicate that the water table within all aquifers on site is generally greater than 10 mbgl, although the depth to water within the bed sands (ephemeral aquifer) in watercourses is less than this when saturated. These depths to groundwater, and the lack of permanent springs in the area, indicate that GDEs are not likely to exist in the vicinity of the site. This was confirmed in the Red Hill Mining Lease EIS Section 9. The vegetation species and regional soil/geology types suggest that the level of groundwater dependence is likely to be relatively low (riparian vegetation communities are considered as opportunistically groundwater dependent) and vegetation is likely to be able to satisfy plant water requirements using retained soil moisture. Water available to ecosystems may include a mix of groundwater with soil water (unsaturated zone) and surface water. Sampling for stygofauna was undertaken as part of the ecology study for the project (refer to Appendix K3 of the Red Hill Mining Lease EIS). No stygofauna were found in any of the accessible groundwater bores on site.

In addition the depth of groundwater limits any potential use by listed or threatened species and migratory birds. Any potential changes in groundwater levels as a result of mine dewatering are therefore not considered to impact on listed or threatened species and migratory birds.

Although groundwater investigations indicate very low potential for groundwater resources to be physically available to support GDEs, the groundwater analytical results, as presented in **Table 6-3**, have been assessed against the EPP (Water) (for Zone 34, which includes the Moranbah area), ANZECC/ARMCANZ (2000), and Queensland (DERM 2009) water quality guidelines (for the protection of moderately disturbed freshwater ecosystems, central region, upland streams). This allows consideration of whether the groundwater resources in the area are of a sufficient quality to provide environmental value to possible GDEs via flow into surface water bodies.

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The assessment of groundwater quality using these surface water guideline values has an inherent level of conservatism due to the assumptions made regarding the behaviour, fate and transport of the analytes detected in groundwater and the subsequent effects in the surface water ecosystem. The existing groundwater quality concentrations are above the water quality guidelines for freshwater ecosystems for some dissolved metals and nutrients, and the median concentrations of most of the major ions are above the 50th percentile WQO for the Isaac River sub-basin for the deeper groundwater (Back Creek Group and Moranbah Coal Measures). These existing exceedences indicate that even if the deeper groundwater was physically available to support GDEs, it has low environmental value for sustaining the biological integrity of aquatic ecosystems. Shallow groundwater in the alluvium may, however, sustain aquatic ecosystems as flow to GDEs or surface water bodies although shallow aquifers are ephemeral, only existing for short periods after recharge.

Suitability for recreational use (primary recreation)

This category of environmental value is considered not applicable to groundwater *in-situ*. There are also no registered groundwater springs in the area that could be considered for recreational use. Groundwater seepage from the alluvium into water courses can provide short duration baseflow into rivers and creeks immediately after heavy rains or flooding, however, after larger flood events suitability of these waters for recreation may be limited by other factors.

Suitability for Minimal Treatment before Supply as Drinking Water (raw water)

The groundwater analytical results, as presented in **Table 6-3**, have been assessed against the Australian drinking water guidelines (NHMRC 2011) to consider the potential health effects of drinking minimally treated groundwater. The EPP (Water) also give a drinking water guideline of 30 milligrams per litre (mg/L) for sodium and 200 mg/L for sulphate. The groundwater quality from the monitoring wells indicates that, in general, the groundwater is unsuitable for human consumption. This is due to elevated concentrations of sodium, sulphate and several dissolved metals (antimony, arsenic, manganese, nickel and selenium) in some of the groundwater samples collected from the Permian formations. Generally the groundwater samples contain elevated levels of salinity (>1,000 mg/L), which are above the guideline for aesthetics based on the groundwater having an unsatisfactory taste.

Groundwater resources within the survey area would require significant treatment before it could be utilised for drinking. The only local groundwater that may be suitable for human consumption is that which comes from the alluvium associated with the Isaac River. However, concentrations of sodium have been recorded at levels above the EPP (Water) limit of 30 mg/L. It is noted that the concentrations of sodium are less than the Australian drinking water guidelines (NHMRC 2011) limit of 180 mg/L.

The availability of reticulated mains water, rain water tank supplies, and the generally low yield and poor quality of the groundwater bores in the area, are also factors that preclude the usage and potential for usage of the groundwater as a drinking water source.

Suitability for Primary Industry Use

Groundwater quality results presented in **Table 6-2** and **Table 6-3** suggest that groundwater within the study area is generally suitable for stock watering for beef cattle. The higher salinities of the Back Creek Group and Blackwater Group aquifers would potentially result in loss of production and decline

6 Hydrogeological Regime

in animal condition and health as salinity concentrations are > 5,000 mg/L. The groundwater in some of the Permian formations has levels of selenium that are slightly elevated above the guideline values.

Although groundwater quality is generally acceptable for stock watering, the generally low sustainable yield of the water bores in all aquifers in the area and the salinity of groundwater in the Back Creek Group and Blackwater Group precludes the usage and potential for usage of the groundwater as a source of irrigation water.

Maintenance of Cultural and Spiritual Values

There are no registered groundwater springs or seeps that supply surface water bodies in the survey area. No springs are known to have significant Aboriginal and/or non-indigenous cultural heritage associations.

Shallow groundwater (in the alluvium), however, may sustain baseflow in the Isaac River for short periods after heavy rains or flooding, although shallow aquifers are ephemeral, only existing for short periods after recharge. The Aboriginal cultural heritage values of that section of the Isaac River within the EIS study area are discussed in the Red Hill Mining Lease EIS Section 16.

Numerical Modelling

To assess the potential impacts of the proposed project and associated infrastructure on the regional groundwater regime, predictive groundwater modelling was undertaken. The objectives of the predictive modelling were to:

- estimate groundwater extraction (passive seepage and active dewatering for IMG control) over the mine life;
- predict the zone of influence of dewatering and the level and rate of drawdown at specific locations;
- identify areas of potential risk where groundwater impact mitigation/control measures may be necessary; and
- predict the impact of mine dewatering on groundwater discharges and other groundwater users.

7.1 Available data

To assist in constructing and calibrating the necessary numerical integrated model, the following information was considered:

- the EIS study area, comprises the proposed RHM, Broadmeadow extension, and includes GRB mine complex (approved mining operations);
- the Permian strata dips at between two and eight degrees to the east;
- the final underground mine depth will be approximately 500 metres;
- the geology within the area comprises Quaternary alluvial, Tertiary sediments, and Permian-Triassic formations with coal measures;
- mining of the GRB mine complex continues at currently approved rates with completion of BRM in 2030 and GRM in 2068;
- mining sequences for existing mines and RHM provided by BMA (mine plan dated October 2011);
- no major faults or intrusions are located within the RHM footprint;
- bore logs and hydrogeological data from monitoring bores and the BMA exploration database across the site;
- shape files for the topography, alluvium, tertiary, and coal seams; and
- climate data.

7.2 Model Approach

URS utilised the MODHMS (Hydrogeologic Inc., USA) groundwater modelling package to construct the required groundwater model. MODHMS is based on the standard MODFLOW groundwater modelling code. The MODFLOW code was developed by the United States Geological Survey (McDonald and Harbaugh 1984) for three-dimensional, finite-difference, modular, groundwater flow modelling. The MODFLOW code is the most widely used code for groundwater modelling and is currently considered an industry standard. MODHMS incorporates additional computational modules to enhance the simulation capabilities and robustness. MODHMS was selected as it allowed for:

- the modelling of variable saturation conditions, allowing for unsaturated and saturated conditions thus avoiding dry-cell problems;
- coupled flow and mass transport simulations (if required);
- the inclusion of discrete features, such as the backfill area of open cuts; and
- integrated groundwater and surface water modelling (if required).

A pseudo-steady state model was constructed based on the available data and represented current groundwater flow conditions due to the existing GRB mine complex dewatering. The outcome of this

7 Numerical Modelling

modelling of the existing approved GRB mine complex impacts (drawdown extent) was used as initial conditions for the transient model, which undertook predictive scenarios for RHM. The modelling approach comprised the following:

- Simulations of dewatering cones and extent at the end of mining (both for the currently approved GRB mine complex, and the proposed RHM).
- Groundwater extraction volumes with time to simulate IMG depressurisation and mine dewatering.

7.3 Model Conceptualisation

Every numerical groundwater model has as its foundation a conceptual model. The conceptual model is an understanding of how the groundwater system operates and is an idealised and simplified representation of the natural system.

The conceptual groundwater model of the groundwater survey area was developed based on geological and topographical maps, geological information from coal exploration bores drilled across the GRB mine complex and RHM footprint areas, geological modelling developed by BMA, results from previous hydrogeological investigations in the Bowen Basin, and relevant data from hydrogeological and gas drainage studies conducted by BMA.

The conceptual model area encompasses the upper units of the Back Creek Group, the Blackwater Group, and the overlying units of the Bowen Basin on the Collinsville Shelf and is bounded by:

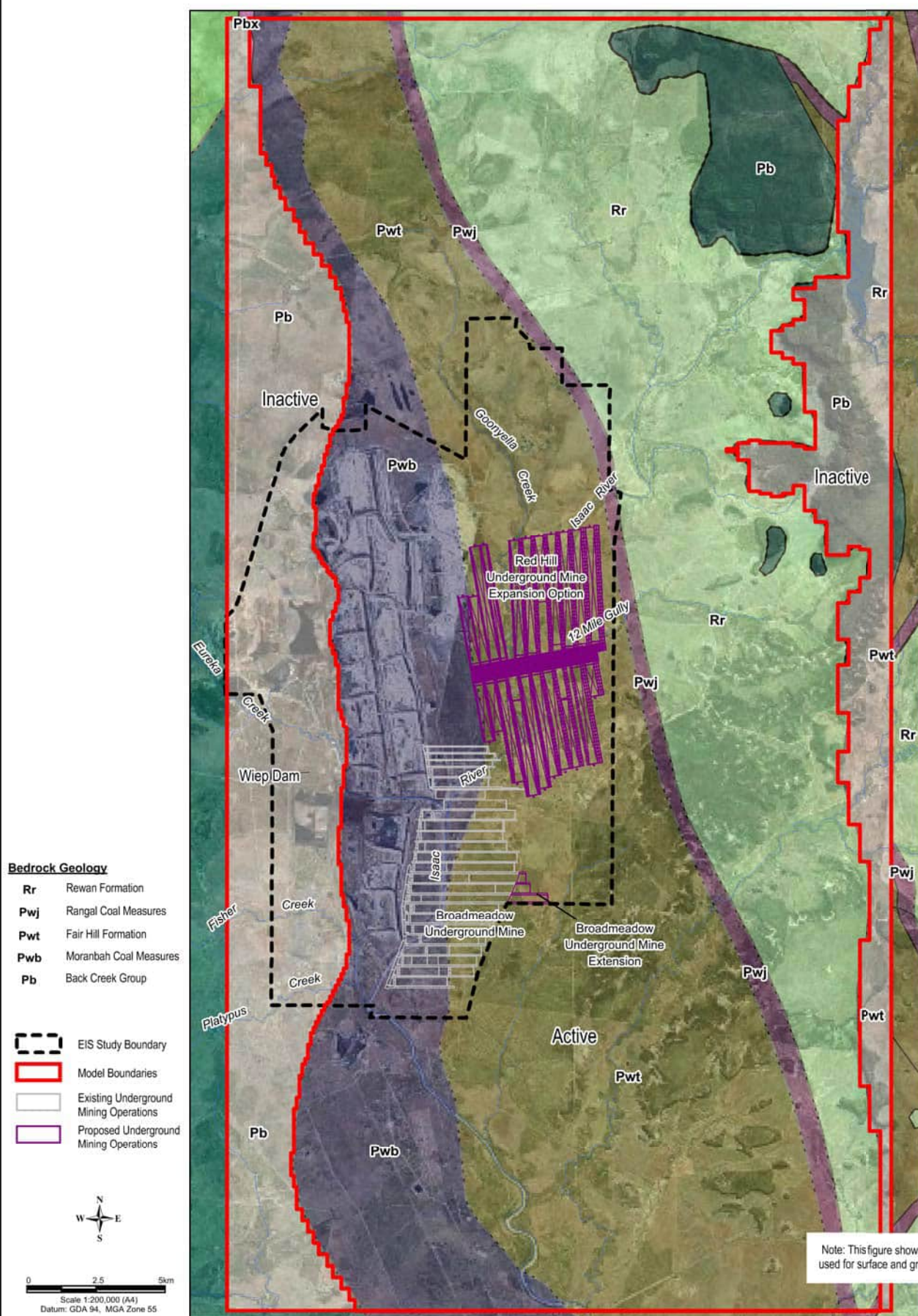
- the outcrop/subcrop of the Back Creek Group to the west of the mine;
- a system of thrust faults approximately 10 kilometres to the east of the proposed RHM that offset the Moranbah Coal Measures; and
- an arbitrary distance of approximately 25 kilometres to the north and south of the RHM that was judged to be beyond the influence of potential mine dewatering (**Figure 7-1**).

7.3.1 Model Extent and Grid

The regional groundwater model was constructed across an area of 24 by 46 kilometres as shown in **Figure 7-1**, with the EIS study area situated towards the western extent of the model based on boundary conditions.

The model was constructed with a refined grid of 100 by 100 metres for the mining area and with grid spacing of 400 by 400 metres outside the EIS study area, as shown in **Figure 7-2**. The finite difference model comprised:

- a model area of 1,104 square kilometres;
- 316 rows and 156 columns; and
- 667,522 active cells for a seventeen-layer model.



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RED HILL MINING LEASE GROUNDWATER IMPACT ASSESSMENT

NUMERICAL MODEL EXTENT



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NUMERICAL MODEL GRID



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Figure: 7-2

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7 Numerical Modelling

7.3.2 Boundary Conditions

Model boundaries were based on available information and data limitations. The boundaries include:

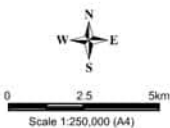
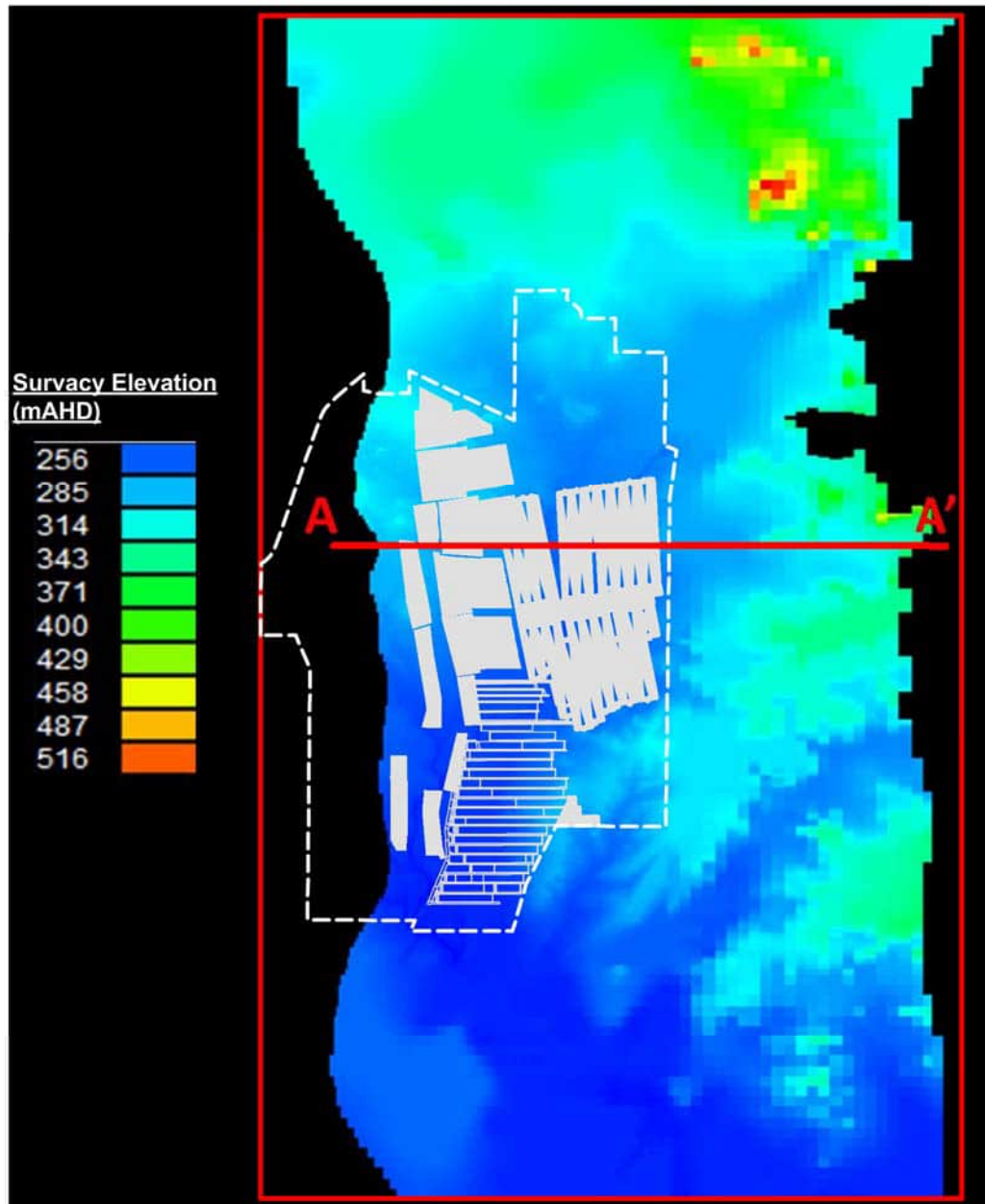
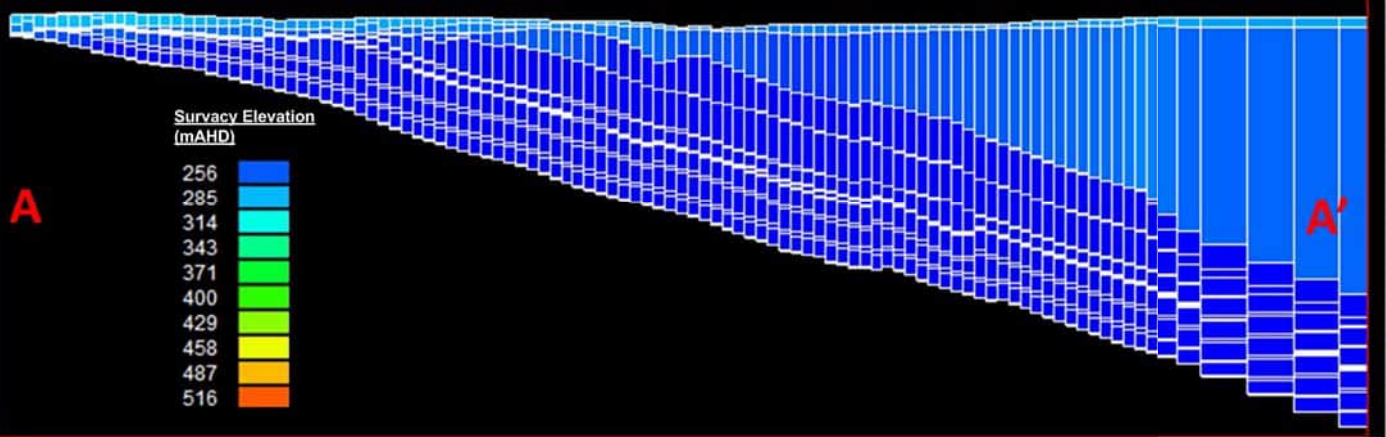
- **Top inflow boundary** comprising recharge and evaporation. Available precipitation and evaporation data was reviewed / verified;
- **Horizontal inflow boundary** based on groundwater level data, which is used to determine the model's east, west, north, and south boundary conditions. Geological log data and groundwater level information was used to set up representative prescribed head boundaries, sufficiently far from the RHM footprint for the southern and northern boundaries. Since few head observations were available near the boundaries, topographic elevations were used as reference elevations relative to groundwater levels. It was assumed that groundwater levels were 35 mbgl for the northern boundary and were 20 mbgl for the southern boundary based on average depth to groundwater from available observations across the survey area. No flow boundaries were ascribed to the western boundary at the outcrop/subcrop of the Back Creek Group, and to the eastern boundary defined as the Burton Fault, which has offset the Blackwater Group; and
- **Bottom inflow boundary** considered below the site. Model bottom elevations were determined from floor and roof elevation data in the geological model supplied by BMA. The no-flow boundary was assumed sufficiently far below the base of any mining (GMS and GLS) elevation based on available geological data.

7.3.3 Model Layers

Publicly available digital elevation data (STRM data) with a 90 by 90 metre grid spacing was used to represent the ground surface in the model outside of the refined area (400 metre grid area in **Figure 7-2**), and BMA topographical data was used to represent the ground surface within the refined area (100 metre grid in **Figure 7-2**). The model layer elevations in the refined-grid area were generated based on the BMA geological model; while the layer elevations outside the refined area were extrapolated based on available data (Bowen Basin digital geology, Bowen Basin regional contouring of the top of the Moranbah Coal Measures on 50 metre intervals, and coal seam gas well logs) and assumptions. These data sets were used to create layer elevations throughout the model domain.

Seventeen layers, representing the different lithological units across the survey area, were included in the model (**Table 7-1**). **Figure 7-3** presents a west-east cross-section through the centre of the model, illustrating the model layers (pre-mining).

It is important to note that faults can act as both conduits for groundwater flow, or in the case of coal seams, barriers to flow. The eastern boundary of the model is along the Burton Fault, where the Moranbah Coal Measures are significantly offset, and is considered a no flow boundary. Within the groundwater survey area, the Moranbah Coal Measures have undergone some minor to moderate faulting that may interrupt the continuity of the aquifer and act as boundaries to groundwater flow. In the model domain, the coal seams are simplified to allow continuous groundwater flow and to tie in with the interpolated levels beyond the EIS study area where data is limited. The effect of this simplification was to remove barriers to groundwater flow, which effectively extends the predicted drawdowns and increases groundwater inflows to the workings. The model is therefore considered to be conservative and would likely to be a 'worst case scenario'.



EIS Study Boundary



Open-Cut and Underground Mining Operations

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.

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RED HILL MINING LEASE GROUNDWATER IMPACT ASSESSMENT

SITE TOPOGRAPHY AND CROSS-SECTION THROUGH NUMERICAL MODEL SHOWING MODEL LAYERS



GROUNDWATER

Figure: **7-3**



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7 Numerical Modelling

Table 7-1 Numerical Model Layers

Model Layer	Unit
1 (top)	Tertiary, alluvium
2	Fort Cooper Coal Measures –
3	Fort Cooper Coal Measures FC1
4	Fort Cooper Coal Measures – Interburden
5	Fort Cooper Coal Measures FC2
6	Moranbah Coal Measures – Overburden
7	Moranbah Coal Measures - GUS
8	Moranbah Coal Measures – Interburden
9	Moranbah Coal Measures – Goonyella 'P' Seam GP1
10	Moranbah Coal Measures – Interburden
11	Moranbah Coal Measures – Goonyella 'P' Seam GP2
12	Moranbah Coal Measures – Interburden
13	Moranbah Coal Measures – GMS
14	Moranbah Coal Measures – Interburden
15	Moranbah Coal Measures –GLS
16	Moranbah Coal Measures – Underburden
17 (bottom)	Back Creek Group

7.3.4 Rainfall Recharge

Recorded site specific data, from the Moranbah weather station, is available for the period 1972 to 2011. However, for an extended period (120 years) of rainfall data, a statistical analysis of climate data from surrounding weather stations was compiled based on the Data Drill system. The rainfall and evaporation data for the period between 1889 and 2011 indicates an average 546.5 millimetre annual rainfall, and 2,093.8 millimetre annual evaporation rate.

Through a review of available data (AGE 2008; METServe 2010), recharge rates would be less than one per cent of mean annual average rainfall, and evapotranspiration was not considered due to the depth to groundwater observed for the deep aquifers.

7.3.5 Hydraulic Parameters

Probable ranges of hydraulic conductivity (K) and storativity values, as displayed in **Figure 7-2**, were derived from hydraulic test results (as described in **Section 6**) and literature values where onsite data was not available.

7 Numerical Modelling

Table 7-2 Ranges of Hydraulic Conductivity (K) and Storativity Values for Each Numerical Model Layer

Layer	K(horizontal) (m/day)		K(vertical) (m/day)		Storage Coefficient		Specific Yield (/m)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1	1.0E-02	1.0E+01	1.0E-03	5.0E-01	1.0E-06	1.0E-04	5.0E-02	2.0E-01
2	1.0E-04	1.0E-01	1.0E-05	1.0E-03	1.0E-06	1.0E-04	1.0E-02	1.0E-01
3	1.0E-04	1.0E-01	1.0E-05	1.0E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
4	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
5	1.0E-04	1.0E-01	1.0E-05	1.0E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
6	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
7	1.0E-05	2.5E-02	1.0E-06	2.5E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
8	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
9	1.0E-05	2.5E-02	1.0E-06	2.5E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
10	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
11	1.0E-05	2.5E-02	1.0E-06	2.5E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
12	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
13	1.0E-05	2.5E-02	1.0E-06	2.5E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
14	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
15	1.0E-05	2.5E-02	1.0E-06	2.5E-03	1.0E-06	1.0E-04	5.0E-03	5.0E-02
16	1.0E-05	5.0E-02	1.0E-06	1.0E-04	1.0E-06	1.0E-04	1.0E-02	1.0E-01
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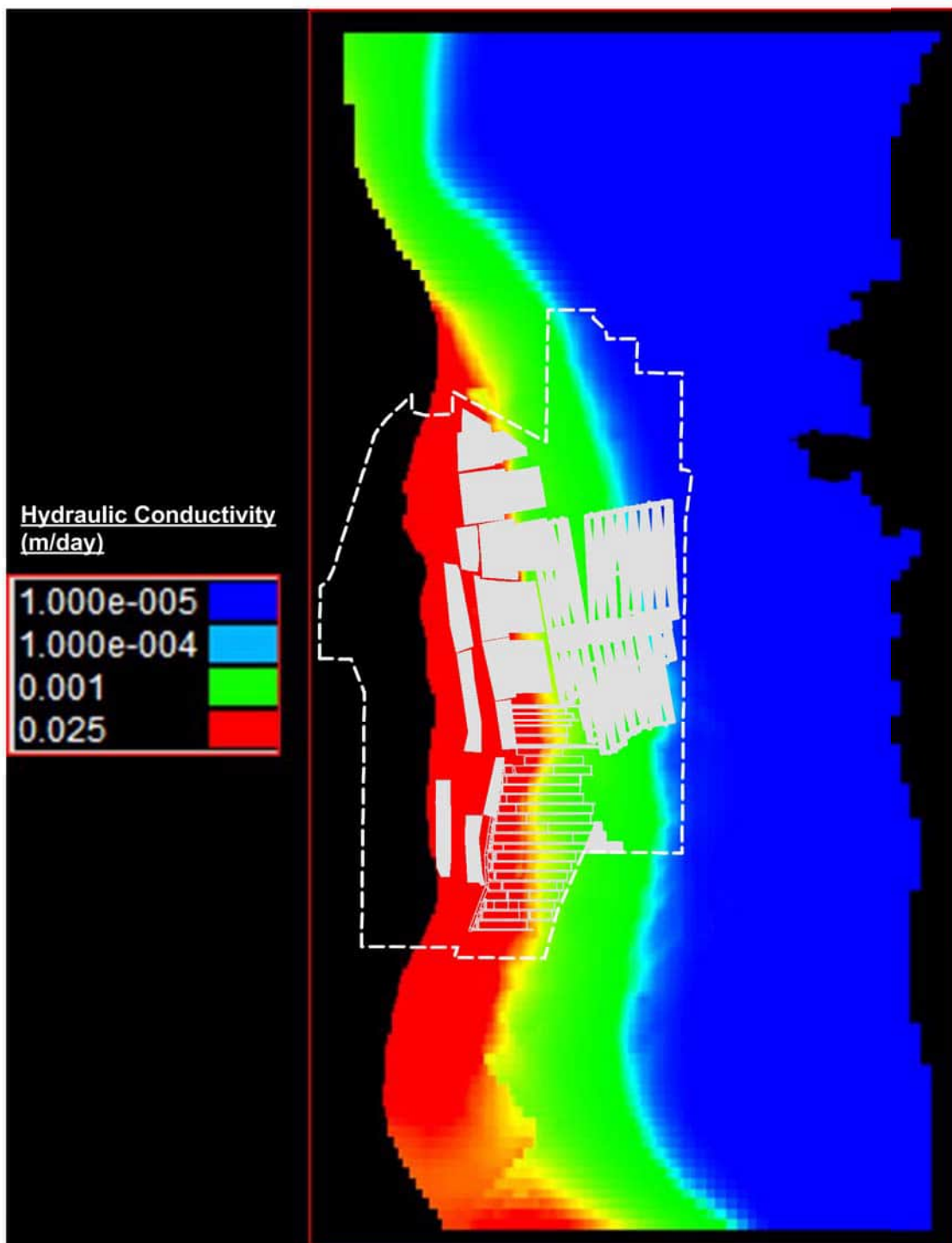
Parameterization

Following the principle of parsimony, model parameterization was kept as simple as possible while accounting for the system processes and characteristics that are evident in observations and important to predictions. For the numerical model, hydraulic conductivity (K) values were assigned as homogeneous values to the layers, except for the layers representing the Moranbah Coal Measure coal seams (layers 7, 9, 11, 13 and 15) to which a K distribution, allowing for the recognised permeability decrease with depth, was ascribed. This K distribution was based on the WDS (2011) study for coal seam gas depressurisation prior to mining. A regression formula from this study was derived as follows:

$$\text{Permeability (m/day)} = 233.52 \times e^{(-0.016 \times \text{depth})}$$

Where depth is below land surface (metres)

Based on the regression formula horizontal K distributions were derived for the coal seam layers, within constraints of the K values not being higher than 0.025 metres per day and not lower than 1×10^{-5} metres per day (derived from filed data and literature values). The horizontal K distribution for the GMS (layer 13 in the numerical model), the target coal seam for mining in the proposed RHM, is shown in **Figure 7-4**. The vertical K distributions within these layers follows the same distributions as the horizontal K distribution but with values one order of magnitude lower (typical modelling assumption where limited data available).



0 2.5 5km
Scale 1:250,000 (A4)



EIS Study Boundary



Open-Cut and Underground Mining Operations

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.

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RED HILL MINING LEASE GROUNDWATER IMPACT ASSESSMENT

HORIZONTAL K DISTRIBUTION FOR GMS (LAYER 13) OF NUMERICAL MODEL

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Figure: 7-4

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7 Numerical Modelling

As well as the K distribution for the five Moranbah Coal Measures coal seam layers, four horizontal and vertical K parameters were assigned to the remaining model layers as listed in **Table 7-3**, with the vertical parameters defined based on the ratio of K_h/K_v and tied to the horizontal parameters during the calibration.

Table 7-3 Relationship of Hydraulic Conductivity between Each Layer in the Numerical Model

Model Layer	Unit	K (horizontal) Parameter	K (vertical) Parameter
1	Tertiary, alluvium	K_1	K_{z1}
2	overburden	K_2	K_{z2}
3	FC1	K_3	K_{z3}
4	interburden	K_4	K_{z4}
5	FC2	K_3	K_{z3}
6	interburden	K_4	K_{z4}
7	GUS	K distribution	K distribution x 0.1
8	interburden	K_4	K_{z4}
9	GP1	K distribution	K distribution x 0.1
10	interburden	K_4	K_{z4}
11	GP2	K distribution	K distribution x 0.1
12	interburden	K_4	K_{z4}
13	GMS	K distribution	K distribution x 0.1
14	interburden	K_4	K_{z4}
15	GLS	K distribution	K distribution x 0.1
16	interburden	K_4	K_{z4}
17	Base	K_4	K_{z4}

7.3.6 Simulation of Mine Dewatering using Drains

In order to assess the potential zone of influence created around RHM due to mine dewatering, the MODHMS drain package was utilised. Using drains involved the setting of a reference (drain target) elevation (base of the target coal seam) and a conductance (leakage) term.

The bottom elevations of the drains were set at the base of the GMS coal seam to be mined. Groundwater levels in the model were compared to the elevation of the bottom of the drain in each model cell and when the groundwater level is above the bottom of the drain water was removed from the model domain at a rate determined by the head difference and the drain hydraulic conductance. The drains were activated according to the proposed mine plan (schedule and progression). Drain conductance was set at a high rate to ensure the groundwater level was lowered to the drain level (to simulate dry workings as required for mine safety).

This approach was adopted for the environmental impact assessment in order to estimate the total volume of groundwater to be removed during an estimated 25 year life of mine (LOM), and assess the resultant drawdown cone at the end of mine life.

7 Numerical Modelling

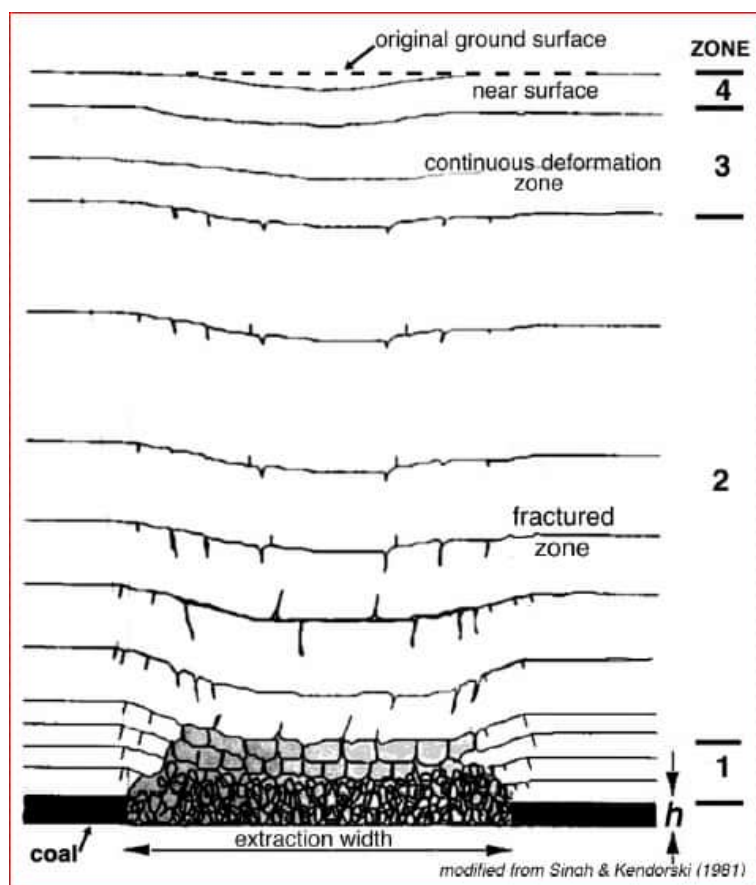
7.3.7 Simulation of Mine Dewatering considering Goaf Alteration

To further estimate mine impacts and estimates of groundwater ingress over the LOM, consideration and simulation of aquifer alteration (due to longwall mining (goaf)) was given.

As longwall mining progresses, goaf develops due to roof collapse in the mining retreat, resulting in a progressively upward collapse of the overburden and where propagation to surface, subsidence. The subsidence profile is divided into four distinct zones (Singh and Kendorski 1981) as shown in **Drawing 7-1**. In zone 1, the depth of strata directly affected by roof caving is 2 to 10 times the thickness of the mined out coal (up to six metres in the RHM area). In zone 2, the fractured zone, partial fracturing of strata occurs from 10 to 24 times the thickness of the mined out coal. In zone 3, the continuous deformation zone, buckling of strata occurs from 24 to 64 times the thickness of the mined out coal. The caved and fractured zones (zone 1 and 2) alter the natural groundwater flow system and can potentially introduce significant vertical leakage through fractures. The highest vertical leakage would occur in the caved zone (zone 1, 2 to 10 times the thickness of mined out coal), therefore it was envisaged that the range of zone 1 would be within the interburden between the GMS and GUS, which is layer 12 in the numerical model.

It was assumed (for groundwater modelling purposes) that goafing fully develops a year after the mine extraction.

Drawing 7-1 Typical Subsidence Profile (from Winters and Capo 2004)



7 Numerical Modelling

7.3.7.1 Mine Dewatering Scenarios

Two approaches of estimating the additional groundwater inflow due to the development of goaf were adopted and compared.

The first approach was based on using the time-variant properties capabilities of MODHMS (2010) by assuming that vertical and horizontal K values were increased 10 times from the original values for the goaf area within layers 12 and 13, with this increase in K for these model layers remaining over the model run.

The second approach was based on using the drain package in MODFLOW to approximate additional inflows by adding drain cells to the goaf areas within model layers 12 and 13. Note that the drain conductance was determined through several trial runs and was estimated to be within the range of 0.1 to 1 rather than a large value used for freely drained cells.

7.4 Model Calibration

7.4.1 Calibration Data

Model calibration was to groundwater level data collected by BMA over time within the survey area and groundwater level information collected from the Eaglefield Expansion Project EIS (METServe 2010). Most of the observation locations had only one measurement record. Regional groundwater level data in this area were not available from the NRM registered bore database.

As mining commenced with the Goonyella mine in the 1970s and has been ongoing since that time, it is envisaged that significant groundwater level changes in the survey area would already have occurred due to mine dewatering. As mining pits progress and new mining areas were created over time, areas and impacts of dewatering would also vary with time. As time series groundwater level data were not available and historic records of dewatering rates and locations were not readily available, transient calibration of the model was not possible. Instead, a pseudo steady-state condition was calibrated, considering the length of mining in the area (40 years), in order to establish an initial condition for predictive simulations. This was done to assess the potential impacts of the project on groundwater already altered by approved mining.

7.4.2 Calibration Approach

Model calibration is a process of refining the model's depiction of the hydrogeological framework, aquifer hydraulic properties, and boundary conditions until a desired correspondence is achieved between the model simulated and measured field data. The end result of the model calibration process is a potential optimal set of parameter values and boundary conditions that minimise the discrepancy between simulated and observed data.

The major calibration target of the model was groundwater level data with constraints of reasonable ranges of hydraulic conductivity and other parameters (e.g. recharge). Transient calibration was not conducted due to limited available data.

The parameter estimation program PEST (Doherty 2008) along with detailed parameter output verification was used to calibrate the parameters of the regional groundwater flow model. PEST implements a nonlinear least-squares regression method to estimate model parameters by minimising the sum of squared weighted residuals of groundwater levels.

7 Numerical Modelling

The calibration process was assessed against the Murray-Darling Basin Commission Groundwater Flow Modelling Guideline (Aquaterra 2000).

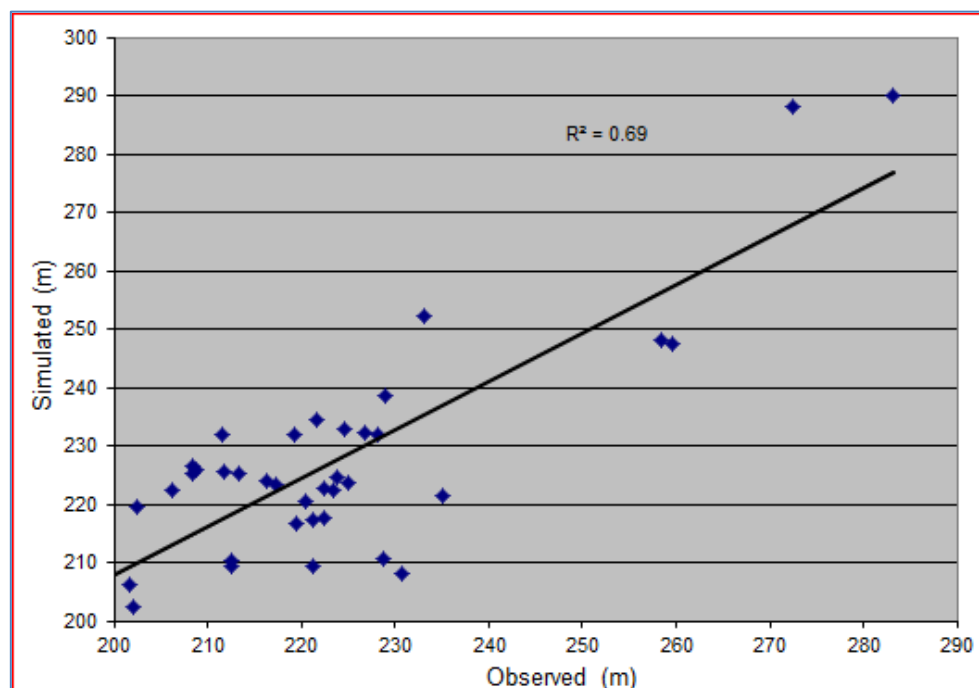
7.4.3 Calibration Assessment

The pseudo steady-state calibration aimed at representing an average state of groundwater levels. A total of 39 groundwater measurements from different monitoring points were used for the calibration process.

Parameter values of hydraulic conductivities, recharge, and drain conductance were estimated through PEST. Hydraulic conductivities were constrained by upper and lower limits and the spatial distribution as discussed in **Section 7.3.5**, while recharge rate was a single value for the model area.

The difference between the modelled and observed (measured) groundwater levels was the preferred indicator of model simulation error. A scatter plot of modelled versus observed groundwater levels is shown in **Chart 7-1** for steady-state calibration.

Chart 7-1 Modelled Versus Observed Head Values for Steady-State Calibration



Root-mean-square error (RMSE) was selected to evaluate the performance of the model calibration based on groundwater levels. Good agreements between modelled results and field measurements usually have RMSE less than 10 per cent of the difference between the observed maximum and minimum potentiometric heads within the model area. The RMSE for the steady-state calibration was 11.6 metres, which is 13.2 per cent of the approximate 87.7 metre range of groundwater levels.

Table 7-4 shows the calibration statistics for the steady-state calibration. These calibration statistics indicate that the model calibration is reasonable based on the parameter constraints (within site specific ranges) and data availability (impacted by mining).

7 Numerical Modelling

The 39 calibration head targets covered the period 1996 to 2009, with many of the measurements undertaken within discrete time intervals (e.g. eight groundwater bore levels were recorded on 12 October 1998). As discussed in **Section 7.4.1**, there are no pre-mining groundwater level data, and available groundwater level data would be largely impacted by mine dewatering. Since the pseudo steady-state model only reflects the existing mining conditions, close 'point-to-point' matching throughout the historic records was not possible, resulting in high residuals. Instead, the pseudo steady-state calibration was inclined to provide a regional flow pattern, which could be used as initial conditions for the predictive simulations.

Table 7-4 Calibration Statistics for Numerical Model Steady-State Calibration

Calibration Statistics	Steady-State Calibration (39 observations)
Mean Error (m)	-4.1
RMSE (m)	11.57
Standard Deviation (m)	10.97
Head Range (m)	87.73
Mean Error %	-4.6%
RMSE %	13.2%
Standard Deviation %	12.5%
R ²	0.69

The groundwater levels determined from the steady state simulation were contoured to provide an indication of groundwater level variations across the model domain. **Figure 7-5** presents the simulated pseudo steady state groundwater head distribution in the GMS. The calibrated parameters, which were then used for the predictive modelling, are presented in **Table 7-5**. Note that the K distribution for the Moranbah Coal Measure coal seams was adopted from the WDS regression formula (WDS 2011) without further calibration, as it is envisaged that these distributions include the best information available.

Table 7-5 Summary of Calibrated Parameters for Numerical Model

Model Layer	Unit	K (horizontal) (m/day)	K (vertical) (m/day)
1	Tertiary, alluvium	0.49	0.049
2	overburden	1.00E-03	1.00E-04
3	FC1	1.00E-03	1.00E-04
4	interburden	1.08E-04	1.08E-05
5	FC2	1.00E-03	1.00E-04
6	interburden	1.08E-04	1.08E-05
7	GUS	Distribution*	Distribution* x 0.1
8	interburden	1.08E-04	1.08E-05
9	GP1	Distribution*	Distribution* x 0.1
10	interburden	1.08E-04	1.08E-05
11	GP2	Distribution*	Distribution* x 0.1
12	interburden	1.08E-04	1.08E-05

7 Numerical Modelling

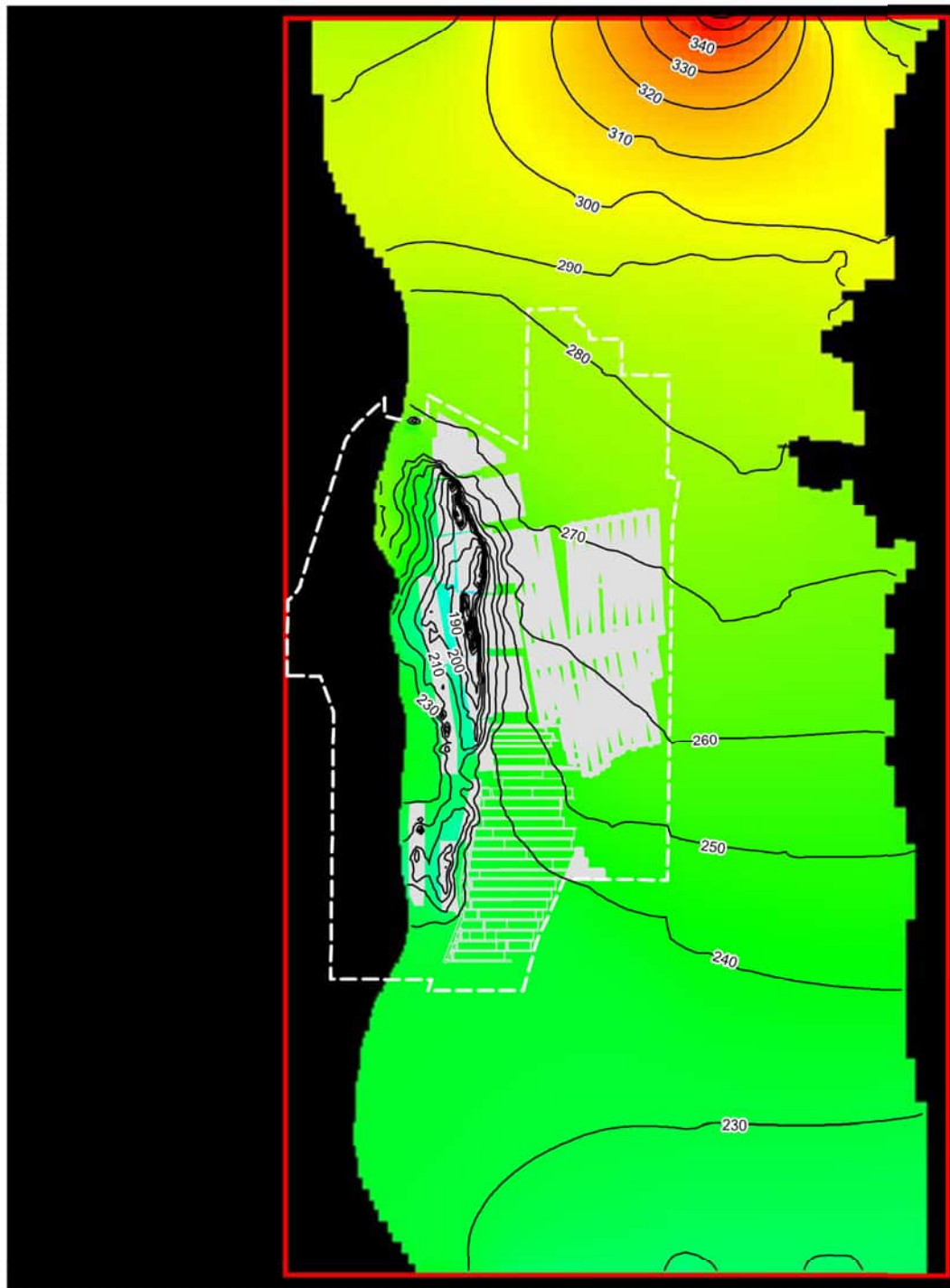
Model Layer	Unit	K (horizontal) (m/day)	K (vertical) (m/day)
13	GMS	Distribution*	Distribution* x 0.1
14	interburden	1.08E-04	1.08E-05
15	GLS	Distribution*	Distribution* x 0.1
16	interburden	1.08E-04	1.08E-05
17	Base	1.08E-04	1.08E-05
Recharge		1.00E-07 m/day	

* K distribution derived from the WDS regression formula- $233.52 \cdot \text{EXP}(-0.016 \cdot X \text{ depth})$

7.4.3.1 Comments on Model Calibration

The model calibration statistical results indicate a moderate agreement between the field measured groundwater levels or assumed steady-state water levels (as discussed in **Section 7.4.1**) and the model simulated levels. This is due to the following:

1. There are no pre-mining groundwater levels to calibrate against, and since the mining is an ongoing process, there was no steady-state condition that really existed. The available measurements in the historical records are impacted by historic mine dewatering. Higher residuals (field vs. model) at certain points were expected as dewatering can easily cause drawdown to be more than 50 metres.
2. Consideration of reducing residuals, to within a desirable range, was given, i.e. using a zonation or the pilot point approach to calibration. This approach was recognised, however, to result in an over-calibrated model, i.e. calibrated to noise or dewatering effects. As historic mine dewatering extraction rates were unavailable it was not possible to accurately incorporate this (mine dewatering) stress into the modelled system during pseudo steady-state calibration. Instead, the rule of parameter parsimony was adopted. The best data available was the approach of K values varying with depth using the regression formula. Thus the main purpose of calibration was to capture the regional groundwater flow trend rather than “point-to-point” matching.
3. The purpose of the calibration was to obtain an acceptable starting condition that represented the regional trend for the predictive simulation and reasonable parameter ranges.
4. Consideration of uncertainty was given as, trying to calibrate too closely to observed heads was likely to result in calibration to dewatering impacts and no actual aquifer conditions. This would have resulted in the model comprising a wide range of hydraulic conductivity, both spatial and with depth, which is not considered to match site conditions. The only way of verifying reliability of the model was to conduct uncertainty analysis for the predictive model, which is discussed in **Section 7.5.3**.



Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.



0 2.5 5km
Scale



EIS Study Boundary



Open-Cut and Underground Mining Operations



— 230 — Groundwater Elevation Contour (mAHD)

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RED HILL MINING LEASE GROUNDWATER IMPACT ASSESSMENT

MODELLLED EXISTING GROUNDWATER HEAD DISTRIBUTION IN THE GMS



GROUNDWATER

File No: 42627136-g-2104.wor

Drawn: VH

Approved: CT

Date: 24-06-2013

Figure: 7-5

Rev.A

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7 Numerical Modelling

7.4.4 Model Limitations

The groundwater flow model was a simplification of a real system, so it is subject to limitations. Limitations result from the simplification of the conceptual model upon which the numerical model is based, the grid scale, the inaccuracies of measurement data, and the incomplete knowledge of the spatial variability of input parameters.

There are no pre-mining groundwater levels available, and since mining has been ongoing since the 1970's, there was no steady-state condition to calibrate against. Thus the available groundwater level measurements in the historical records are impacted by historic mine dewatering; however, dewatering rates are also unavailable so the model could not be developed with a transient calibration. Therefore, the rule of parameter parsimony was adopted.

The best data available is the hydraulic conductivity values from aquifer tests, core tests, and the spatial distribution with depth identified by WDS (2011). The groundwater model was thus calibrated to capture the regional groundwater flow trend identified from groundwater levels with the objective of obtaining an acceptable starting condition that represented the regional trend for the predictive simulation and reasonable parameter ranges. Verification of reliability of the model was conducted by undertaking uncertainty analysis for the predictive model.

7.5 Predictive Simulations

After the steady state model was calibrated to the available data, the model was then converted to transient flow conditions to undertake the predictive scenarios for impact assessment. Predictive simulation was conducted for the ongoing GRM, BRM (including the extension into MLA70421), and proposed RHM for the active period of mining for the total complex (until 2068, the expected end of mining at GRM). Calibrated model parameters were used for the predictive simulation, and the modelling drain package was used for simulating open-cut and underground mining, approved and proposed.

The calibrated hydraulic conductivity values in **Table 7-5** were used for the predictive simulation; while the storativity values were adopted from literature and hydraulic tests as transient calibration was not possible with the available data. The model parameters used during the simulations are presented in **Table 7-6**.

7 Numerical Modelling

Table 7-6 Summary of Numerical Model Parameters Used in the Predictive Simulation

Model Layer	Unit	K (horizontal) (m/day)	K (vertical) (m/day)	Storage Coefficient	Specific Yield
1	Tertiary, alluvium	0.49	0.049	1.00E-05	0.1
2	overburden	1.00E-03	1.00E-04	1.00E-05	3.00E-02
3	FC1	1.00E-03	1.00E-04	1.00E-05	1.00E-02
4	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
5	FC2	1.00E-03	1.00E-04	1.00E-05	1.00E-02
6	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
7	GUS	Distribution*	Distribution* x 0.1	1.00E-05	1.00E-02
8	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
9	GP1	Distribution*	Distribution* x 0.1	1.00E-05	1.00E-02
10	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
11	GP2	Distribution*	Distribution* x 0.1	1.00E-05	1.00E-02
12	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
13	GMS	Distribution*	Distribution* x 0.1	1.00E-05	1.00E-02
14	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
15	GLS	Distribution*	Distribution* x 0.1	1.00E-05	1.00E-02
16	interburden	1.08E-04	1.08E-05	1.00E-05	3.00E-02
17	Base	1.08E-04	1.08E-05	1.00E-05	3.00E-02
Recharge		1.00E-07 m/day			

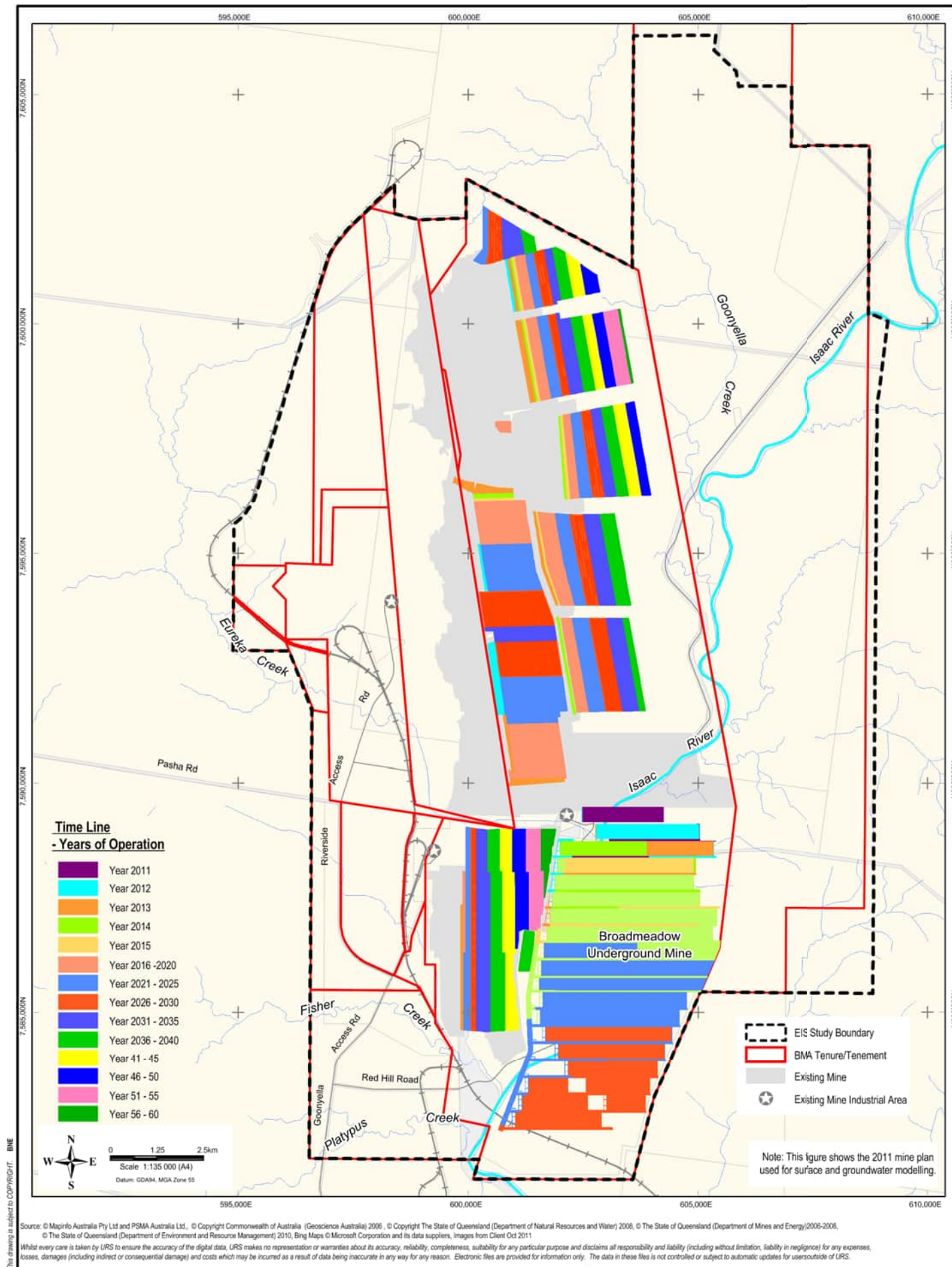
* K distribution derived from the WDS regression formula- $233.52 \cdot \text{EXP}(-0.016 \cdot \text{depth})$

7.5.1 Mine Progression Plans

Year-on-year mine plans for the existing GRM and BRM, as well as proposed mine plans for the RHM were simulated to assess the cumulative impacts of the proposed project. Several assumptions were made for the predictive simulation:

- Mining was assumed to progress on an annual time step as provided in the mine plans. Where the mine plans showed multi-year time steps, the mine plan was subdivided into equal (based on surface area) yearly time steps.
- Open-cut mining progress areas were assumed to be open for two years as backfilling occurs after mining.
- Underground mine areas will be maintained in a dewatered state for the life of each mine.
- Goafs were assumed to be formed in the year following mining (as discussed in **Section 7.3.7**).

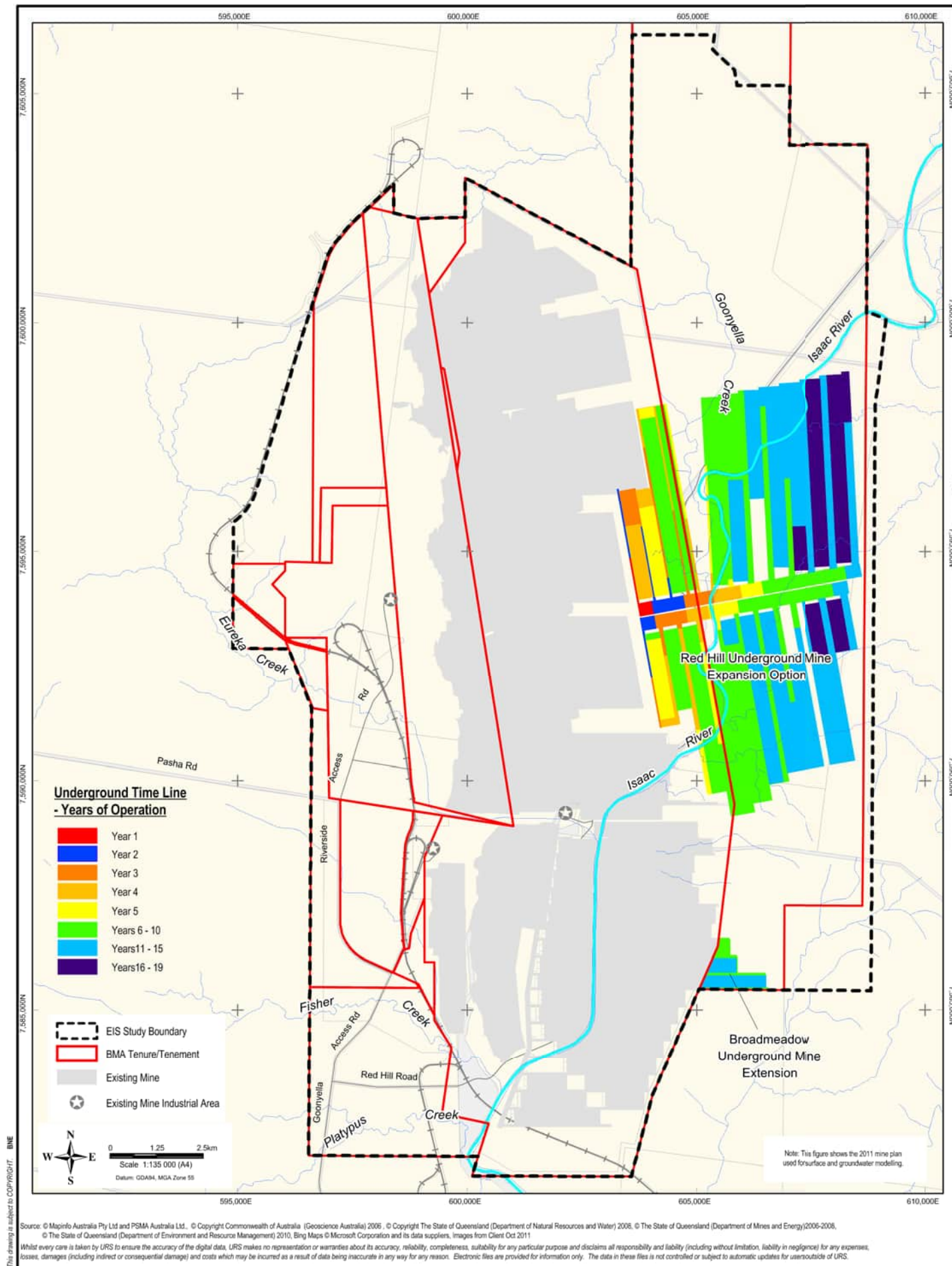
GRM and BRM progression plans were provided with yearly progression to 2068 and 2030, the end of mining for each respectively. The mining progression plans for the proposed RHM were provided with yearly progression for the first four years and then five-yearly progression for the remainder on the LOM. The mine progression for the approved GRB mine complex is shown in **Figure 7-6**. The mine progression for the proposed RHM including the Broadmeadow extension is shown in **Figure 7-7**.



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7 Numerical Modelling

7.5.2 Predicted Groundwater Drawdown and Inflow

Groundwater drawdown predictions were modelled on the October 2011 mine plan. A new mining sequence has since been developed for the RHM, Broadmeadow extension and the existing approved BRM. Further, both the BRM and the proposed Broadmeadow extension footprints have been revised. This has the potential to alter groundwater volumes and drawdown over the life of mine. However, the mine plan and revised schedule are indicative only and sequencing of production and annual production rates are dependent on a range of factors and likely to vary. Regardless of this, the changes are not anticipated to have a significant impact on modelling predictions.

In order to assess the potential impact of the project on groundwater, in addition (cumulative) to the impact of the existing approved GRB mine complex, predictive simulations were performed for two scenarios (with and without the project). Total drawdown contours for cumulative impact (approved GRB mine complex and the project) and for the impact caused by RHM beyond the approved baseline (additional drawdown due to the project calculated by the difference in predicted impact of the GRB mine complex by itself and with the project), for the Tertiary/Quaternary Formations (Layer 1) and for the GMS (the mined seam, Layer 13) are shown in **Figure 7-8** and **Figure 7-9** for 2040 (the modelled end of mining for the RHM) and **Figure 7-10** and **Figure 7-11** for 2068 (the end of mining at GRM) respectively.

Prediction of groundwater volumes to be removed, either through mine dewatering and / or active dewatering for IMG drainage, were estimated through the use of zone budgets in the MODHMS model simulation. Groundwater extraction with time for the two approaches to goaf simulation, use of time varying properties and use of drain cells, are shown in **Chart 7-2** and **Chart 7-3**. It is noted that the results of the two approaches are comparable.

Groundwater extraction is predicted to peak at approximately two gigalitres (GL) per year using the time varying properties approach, and 3.5 GL per year using the drain cell approach. Some of this predicted extraction will not be extracted by IMG drainage or seepage collection, but will be lost from the mine water balance as embodied water in extracted coal or evaporation through the mine ventilation system. Note that extraction from the underground mines stop at the completion of mining, but that groundwater would continue to flow into the mine void and goaf with a consequent lag in groundwater drawdown as this storage is filled.

7 Numerical Modelling

Chart 7-2 Estimated Total Groundwater Ingress Using Time Varying Properties

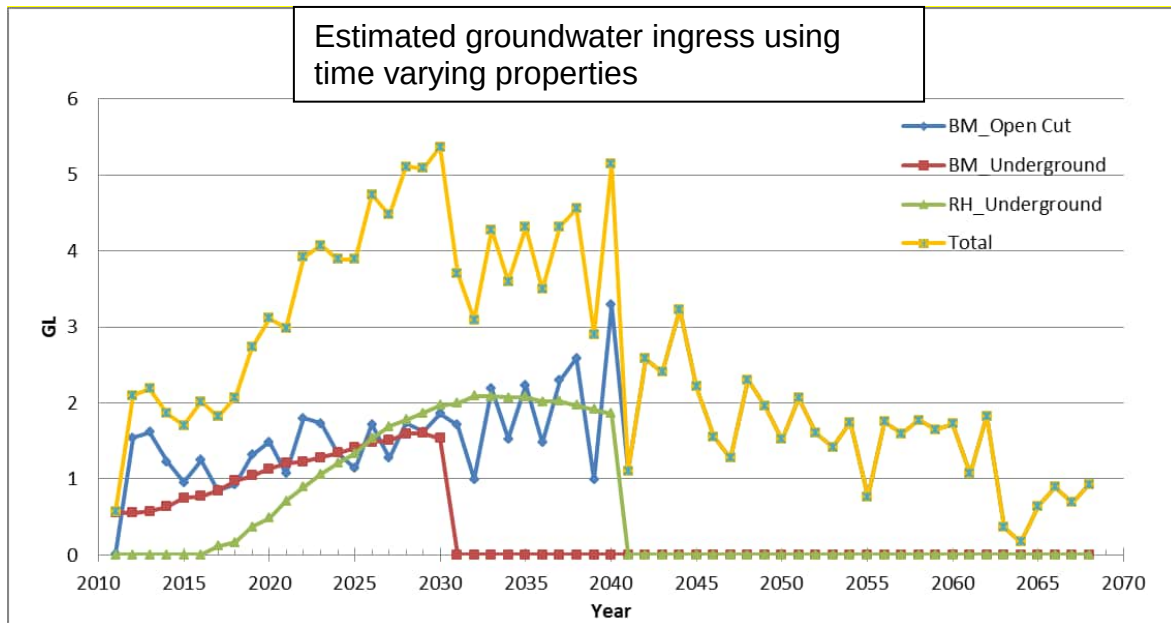
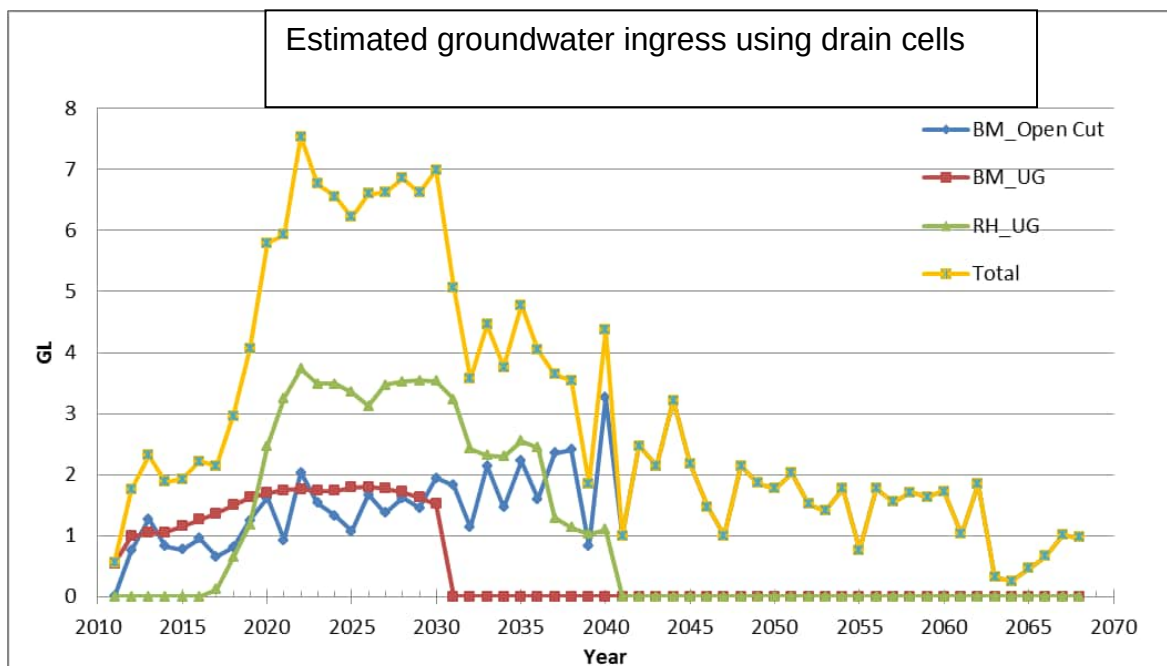
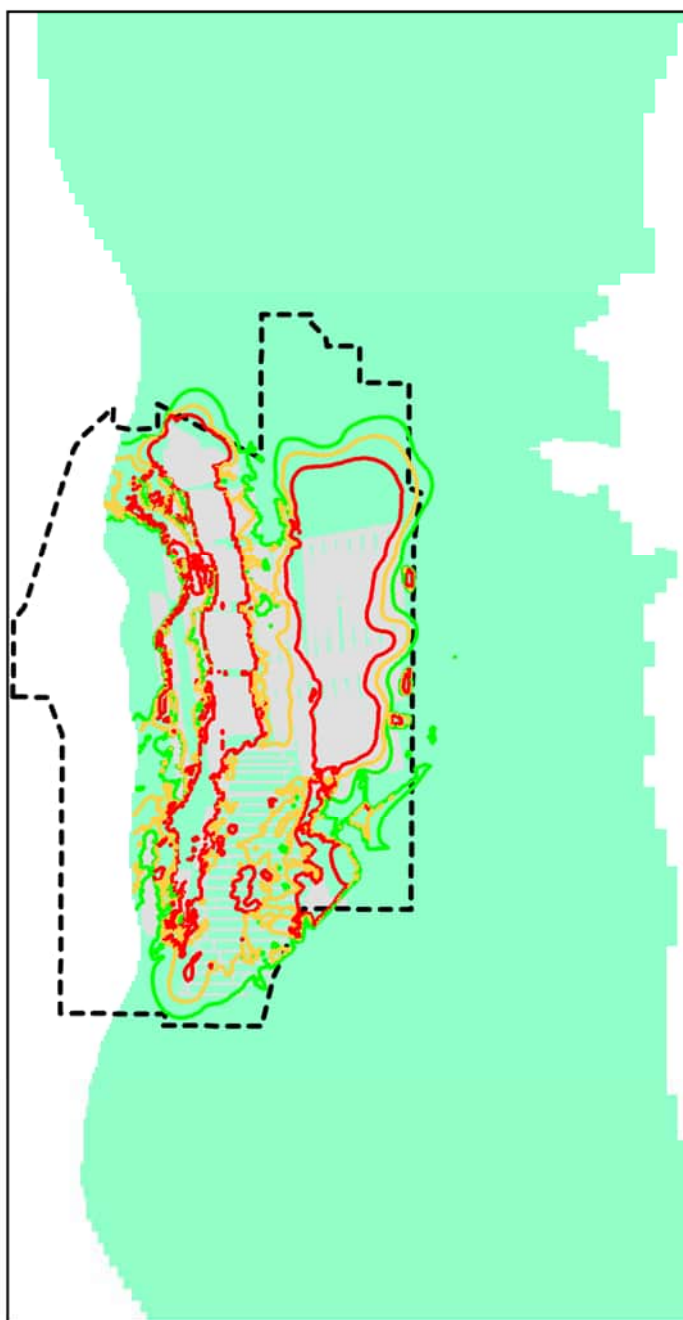


Chart 7-3 Estimated Total Groundwater Ingress Using Drain Cells



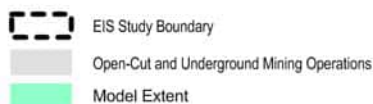
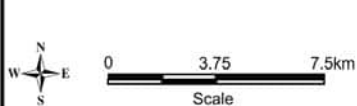


Drawdown modelled for Goonyella Riverside, Broadmeadow and proposed Red Hill Mine



Drawdown as a result of proposed Red Hill Mine

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.



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RED HILL MINING LEASE GROUNDWATER IMPACT ASSESSMENT

MODELLLED DRAWDOWN IN TERTIARY/QUATERNARY FORMATIONS AT END OF 2040

URS

GROUNDWATER

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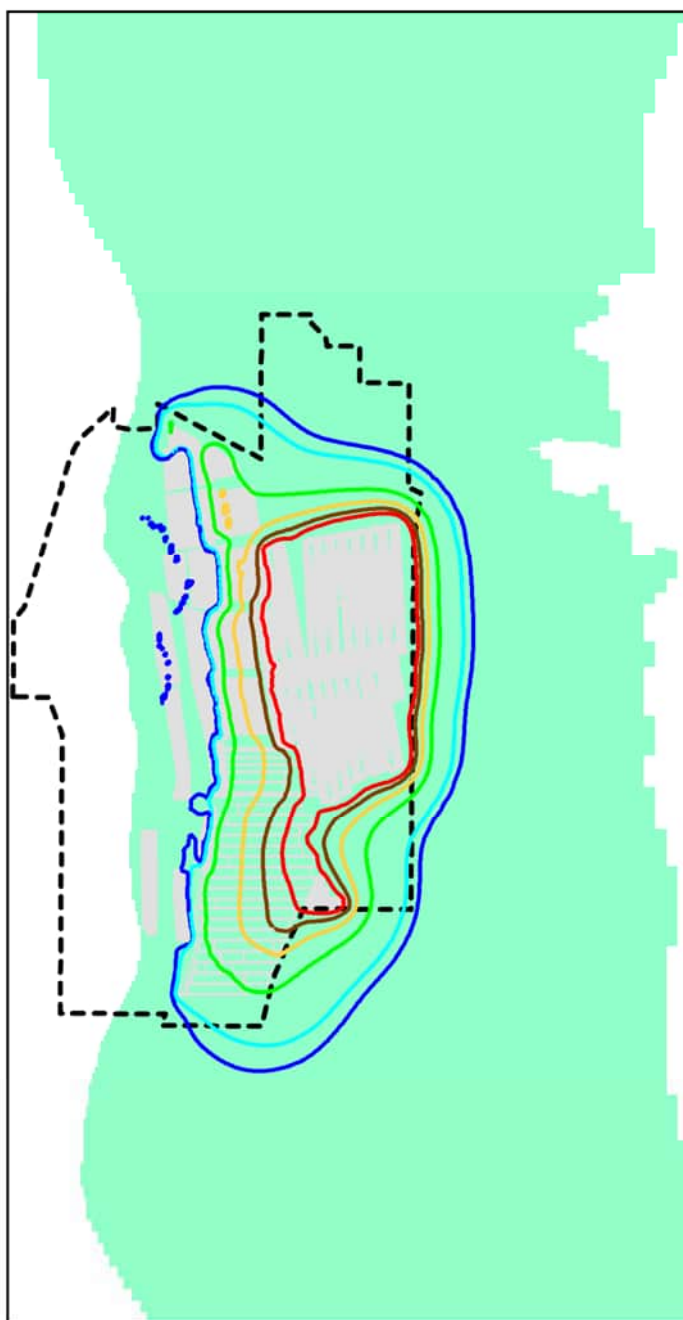
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Figure: 7-8

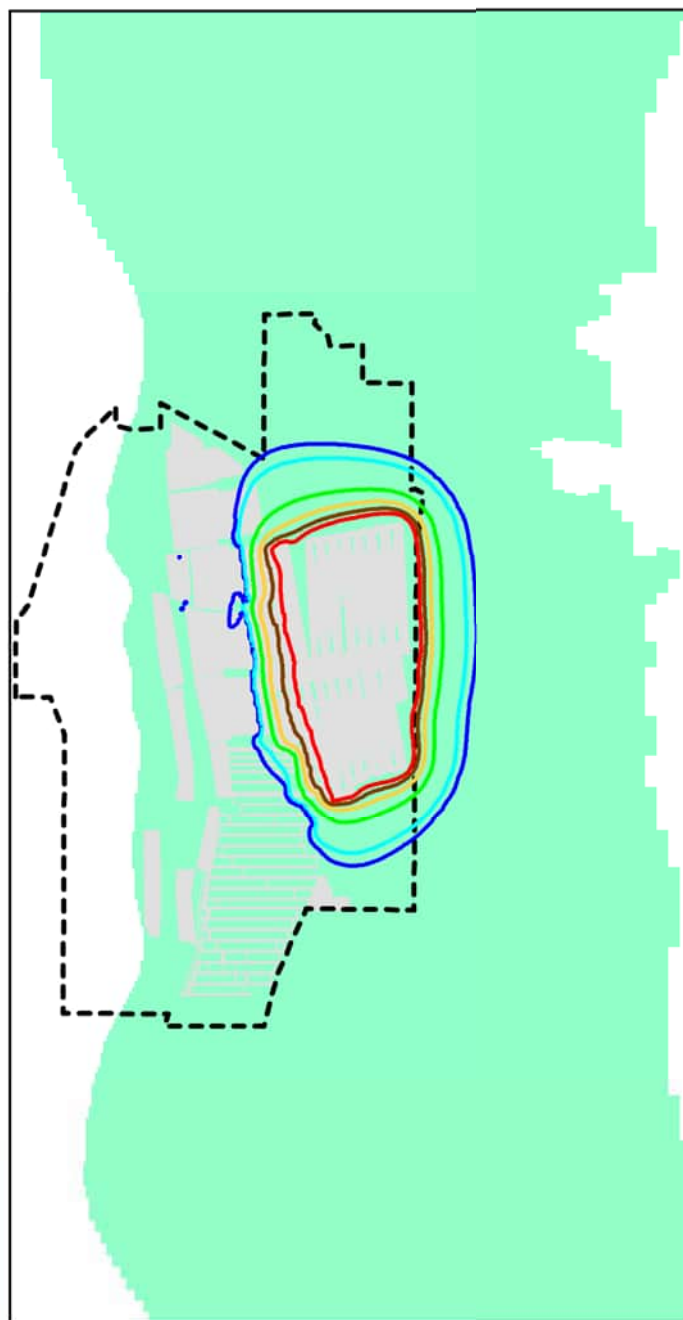
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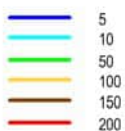


Drawdown modelled for Goonyella Riverside, Broadmeadow and proposed Red Hill Mine



Drawdown as a result of proposed Red Hill Mine

Drawdown (m)



EIS Study Boundary

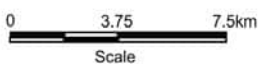


Open-Cut and Underground Mining Operations



Model Extent

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.



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RED HILL MINING LEASE GROUNDWATER IMPACT ASSESSMENT

MODELLED DRAWDOWN IN GMS AT END OF 2040



GROUNDWATER

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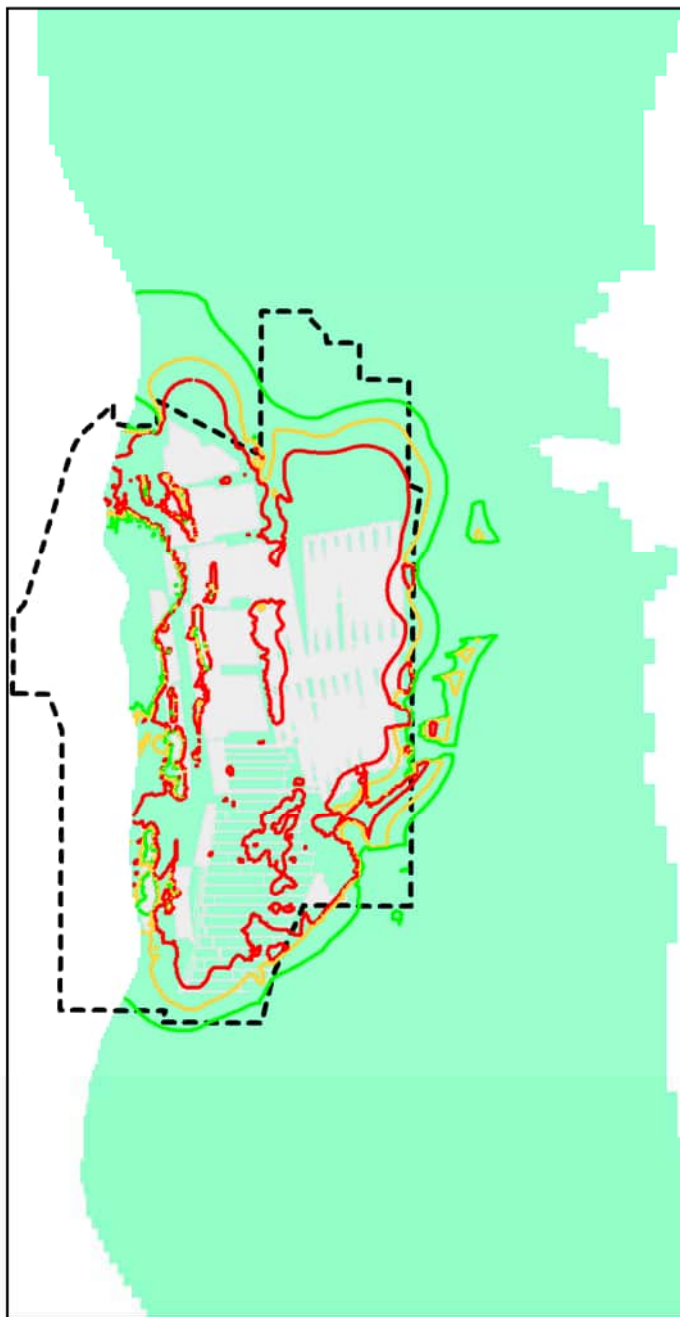
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Figure: 7-9

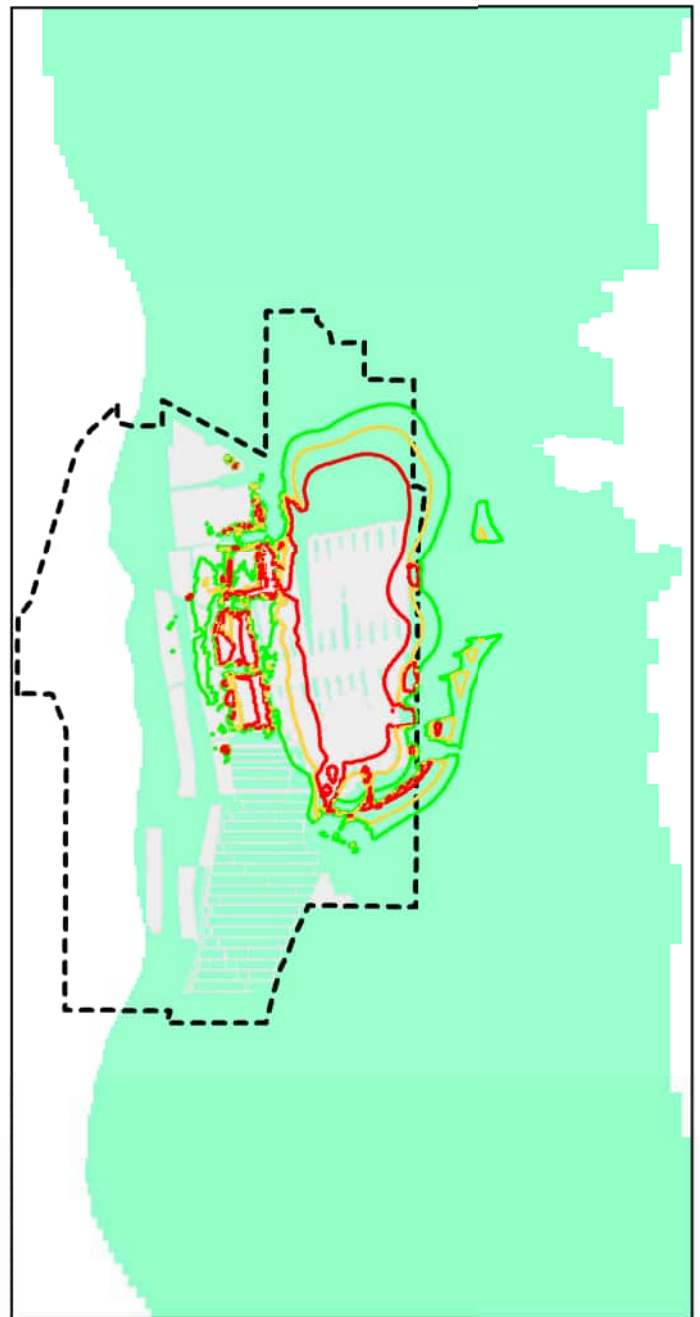
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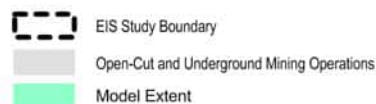
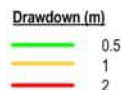
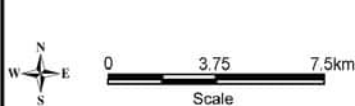


Drawdown modelled for Goonyella Riverside, Broadmeadow and proposed Red Hill Mine



Drawdown as a result of proposed Red Hill Mine

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.



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RED HILL MINING LEASE GROUNDWATER IMPACT ASSESSMENT

MODELLLED DRAWDOWN IN TERTIARY/QUATERNARY FORMATIONS AT END OF 2068

URS

GROUNDWATER

Figure: 7-10



File No: 42626730-g-2109b.wor

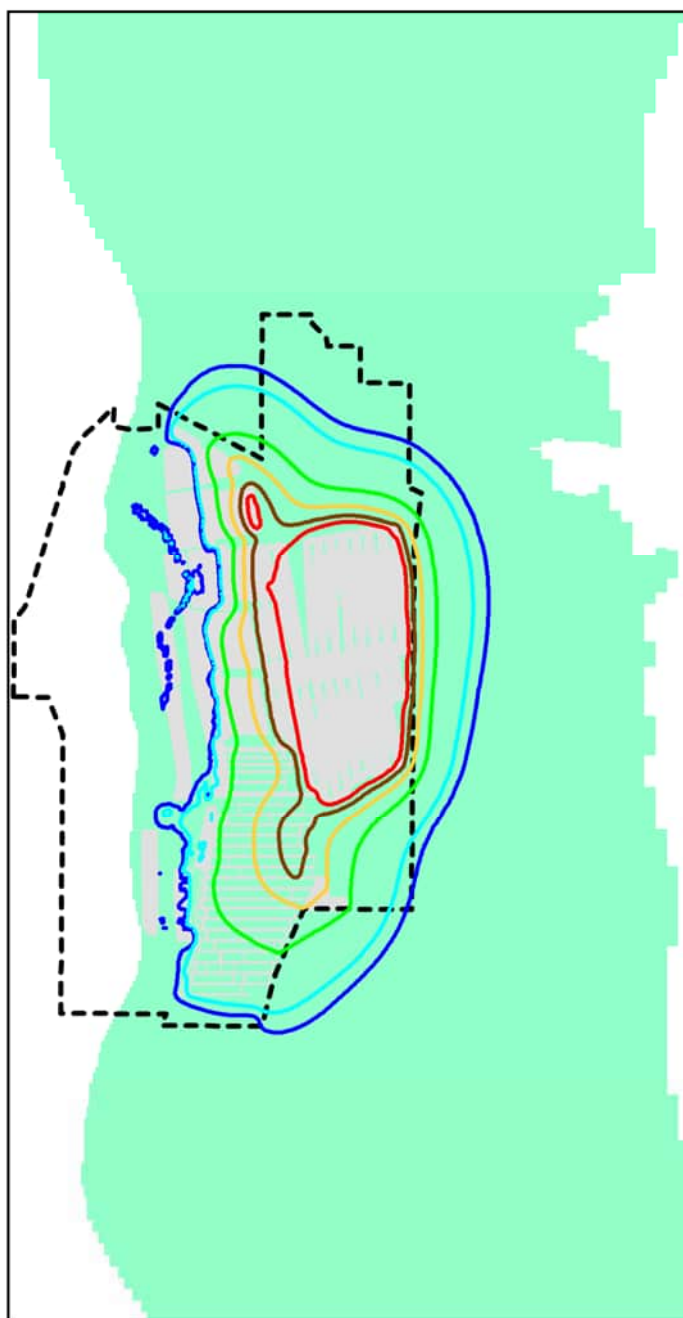
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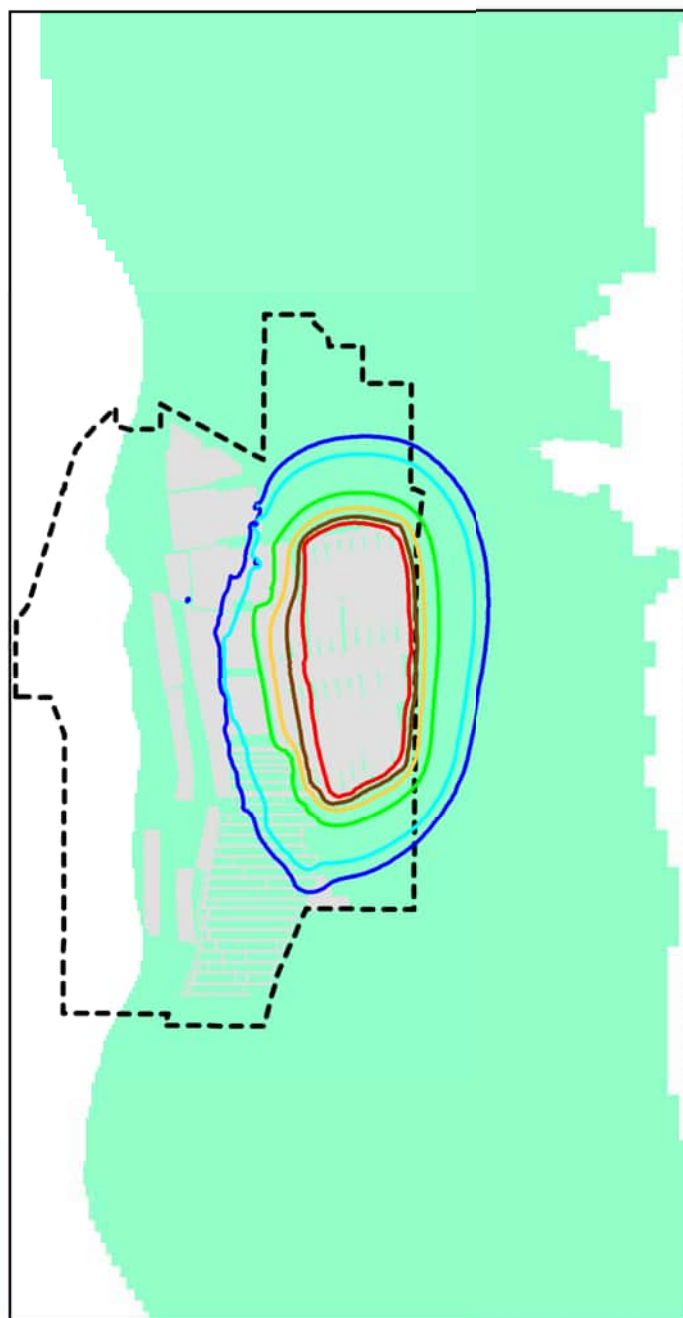
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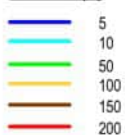
Drawdown modelled for Goonyella Riverside, Broadmeadow and proposed Red Hill Mine



Drawdown as a result of proposed Red Hill Mine

Note: This figure shows the 2011 mine plan used for surface and groundwater modelling.

Drawdown (m)



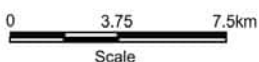
EIS Study Boundary



Open-Cut and Underground Mining Operations



Model Extent



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RED HILL MINING LEASE GROUNDWATER IMPACT ASSESSMENT

MODELLED DRAWDOWN IN GMS AT END OF 2068



GROUNDWATER

File No: 42627136-g-2110.wor

Drawn: VH

Approved: CT

Date: 24-06-2013

Figure: 7-11

Rev.A

A4



7 Numerical Modelling

7.5.3 Groundwater Ingress

Based on the model approach adopted to assess the potential impacts of mine dewatering, in terms of drawdown on the local and regional groundwater resources, conservative assumptions were included. This allowed for “worst-case” scenarios regarding potential impacts to be assessed.

The use of drains provided elevated groundwater ingress predictions, which were not suitable for inclusion in the mine water management assessment (Red Hill Mining Lease EIS Appendix I2), as this study requires a more realistic estimate of groundwater volumes for inclusion in the water balance.

The predictive model was revised to simulate year-on-year groundwater ingress volumes, considering impacts of longwall mining (goaf) resulting in the alteration of aquifers over time. The predictive model simulated cumulative dewatering of the GRM open cuts, the BRM, the Broadmeadow extension, and the RHM underground workings.

Table 7–7 presents the year-on-year volumes of groundwater associated with the proposed mine panels over the LOM for RHM and GRB mine complex mines. The estimates are predicted using the basecase set of aquifer parameters, determined during calibration. An estimated total groundwater volume of 35 GL will be removed during the RHM LOM (20 to 25 years).

The estimates for groundwater ingress into RHM range from 0.12 GL to 2,09 GL over the LOM. These data are shown in **Chart 7–2**.

Table 7-7 Groundwater Ingress Estimated for RHM (basecase) in cubic metres

Year	GRM	BRM	RHM	Total
2011	15,303	558,060	0	573,363
2012	1,542,580	554,985	0	2,097,565
2013	1,614,730	570,974	0	2,185,704
2014	1,227,470	633,868	0	1,861,338
2015	951,768	752,522	0	1,704,290
2016	1,244,380	771,574	0	2,015,954
2017	855,044	848,690	118,571	1,822,305
2018	930,070	977,918	165,444	2,073,432
2019	1,316,480	1,041,970	369,962	2,728,412
2020	1,488,760	1,134,290	487,836	3,110,886
2021	1,070,720	1,204,010	707,199	2,981,929
2022	1,796,650	1,226,570	891,687	3,914,907
2023	1,728,670	1,280,900	1,065,610	4,075,180
2024	1,342,020	1,342,580	1,205,810	3,890,410
2025	1,139,750	1,409,990	1,335,560	3,885,300
2026	1,716,190	1,488,220	1,533,330	4,737,740
2027	1,276,560	1,508,450	1,690,990	4,476,000
2028	1,740,780	1,591,900	1,777,100	5,109,780
2029	1,624,370	1,601,560	1,863,880	5,089,810
2030	1,859,850	1,533,980	1,969,540	5,363,370
2031	1,711,400	0	1,994,020	3,705,420

7 Numerical Modelling

Year	GRM	BRM	RHM	Total
2032	996,491	0	2,093,040	3,089,531
2033	2,187,430	0	2,087,220	4,274,650
2034	1,524,260	0	2,070,090	3,594,350
2035	2,234,130	0	2,079,210	4,313,340
2036	1,479,800	0	2,016,940	3,496,740
2037	2,294,810	0	2,022,040	4,316,850
2038	2,589,180	0	1,968,360	4,557,540
2039	986,844	0	1,911,950	2,898,794
2040	3,289,370	0	1,860,960	5,150,330
2041	1,107,730	0	0	1,107,730
2042	2,582,380	0	0	2,582,380
2043	2,404,440	0	0	2,404,440
2044	3,229,910	0	0	3,229,910
2045	2,216,570	0	0	2,216,570
2046	1,554,660	0	0	1,554,660
2047	1,274,060	0	0	1,274,060
2048	2,301,260	0	0	2,301,260
2049	1,963,800	0	0	1,963,800
2050	1,517,800	0	0	1,517,800
2051	2,064,960	0	0	2,064,960
2052	1,603,870	0	0	1,603,870
2053	1,418,090	0	0	1,418,090
2054	1,742,260	0	0	1,742,260
2055	763,412	0	0	763,412
2056	1,751,760	0	0	1,751,760
2057	1,597,000	0	0	1,597,000
2058	1,773,450	0	0	1,773,450
2059	1,647,270	0	0	1,647,270
2060	1,722,730	0	0	1,722,730
2061	1,067,610	0	0	1,067,610
2062	1,825,650	0	0	1,825,650
2063	363,198	0	0	363,198
2064	170,852	0	0	170,852
2065	640,507	0	0	640,507
2066	891,452	0	0	891,452
2067	686,828	0	0	686,828
2068	928,758	0	0	928,758

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For the purposes of establishing a mine water balance for RHM, it has been assumed that around 2,200 KL/day or 800 ML/year of water will be produced from gas extraction wells. Thus over 25 years of mining the volume of groundwater extracted from IMG will be ~ 20 GL and from mine dewatering ~ 15 GL.

Table 7–9 below provides an indication of the possible range of groundwater ingress estimates, based on model parameter sensitivity and uncertainty analysis. As noted above, this analysis is based on the 2011 indicative mine plan. However, the revised mine plan is not expected to result in significant changes to these conclusions.

7.5.4 Uncertainty Analysis

Prediction uncertainty arises mainly as a result of uncertainties in model conceptualisation and model parameters. The effects of alternative conceptualisations on the calibrated model were not explored in this study because the alternatives were considered very limited as the model has been built based on the best available information and understanding of the groundwater regime through site specific studies.

Parameter uncertainty was explored through varying selected parameters (one at a time) to examine the impacts on predicted groundwater drawdown or extraction. The base case model used was the calibrated predictive model using the time varying properties approach for goaf simulation. Uncertainty was assessed by conducting 12 additional model runs with varying parameters as shown in **Table 7–8**. The horizontal hydraulic conductivity (Kh) and vertical hydraulic conductivity (Kv) distributions were scaled up with factors of two and five and scaled down with factors of 0.5 and 0.2 for sensitivity runs one to four. The specific yield (Sy) for coal seams in the base case was 0.01 and was considered at the lower end, so only the effect of higher Sy was considered in sensitivity run five. The variation of Kh values for interburden was considered in sensitivity runs six and seven. Only scaling up of Kv for interburden was considered in sensitivity run eight as Kv of the base case was at the lower end. The variation of Kh and Kv values for overburden was considered in sensitivity runs nine to 12.

Table 7-8 Parameter Variations Used for Model Sensitivity Assessment as a Product of Calibrated Base Case Parameters Displayed in Table 7-5

Sensitivity Run	Unit	K (horizontal)	K (vertical)	Specific Yield
1	Moranbah Coal Measures seams (layers 7, 9, 11, 13, and 15)	Base case × 2	Base case	Base case
2	Moranbah Coal Measures seams (layers 7, 9, 11, 13, and 15)	Base case × 0.5	Base case × 1	Base case × 1
3	Moranbah Coal Measures seams (layers 7, 9, 11, 13, and 15)	Base case × 1	Base case × 5	Base case × 1
4	Moranbah Coal Measures seams (layers 7, 9, 11, 13, and 15)	Base case × 1	Base case × 0.2	Base case × 1
5	All coal seams (layers 3, 5, 7, 9, 11, 13, and 15)	Base case × 1	Base case × 1	Base case × 2
6	Interburden (layers 4, 6, 8, 10, 12, 14, and 16)	Base case × 2	Base case × 1	Base case × 1
7	Interburden (layers 4, 6, 8, 10, 12, 14, and 16)	Base case × 0.5	Base case × 1	Base case × 1

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Sensitivity Run	Unit	K (horizontal)	K (vertical)	Specific Yield
8	Interburden (layers 4, 6, 8, 10, 12, 14, and 16)	Base case × 1	Base case × 5	Base case × 1
9	Overburden	Base case × 2	Base case × 1	Base case × 1
10	Overburden	Base case × 0.5	Base case × 1	Base case × 1
11	Overburden	Base case × 1	Base case × 5	Base case × 1
12	Overburden	Base case × 1	Base case × 0.2	Base case × 1

Mean drawdown of in the Alluvium/Tertiary layer and the GMS at the end of year 2068 is presented in **Table 7–9** for the base case model and sensitivity runs. For the base case, the mean drawdown was 8.26 and 64 metres respectively. The largest mean drawdown of 12.96 metres for the Alluvium/Tertiary occurred in sensitivity run eight, in which Kv of the interburden increased five times, allowing more drawdown to propagate upwards.

Table 7-9 Mean Drawdown from Sensitivity Runs for Alluvium/Tertiary and Goonyella Middle Seam, 2068

Sensitivity Run	Alluvium, Tertiary Mean Drawdown (m)	GMS Mean Drawdown (m)
Base Case	8.26	64.00
1	8.25	59.45
2	8.34	71.02
3	8.28	65.13
4	8.26	56.36
5	8.33	67.56
6	8.01	57.28
7	8.48	65.58
8	12.96	56.34
9	8.40	66.97
10	8.11	62.06
11	7.06	61.94
12	8.10	61.93

Total groundwater inflow for RHM and for RHM and the GRB mine complex are presented in **Table 7-10** for the sensitivity analysis. The highest groundwater inflow occurred in sensitivity run eight, where groundwater inflow was two times higher than the base case for RHM and was almost double the base case for RHM and GRB mine complex. Sensitivity run eight had a higher Kv value for the interburden, which allowed more leakage to the GMS.

Through the analysis of parameter uncertainty, it was identified that uncertainty of Kv of the interburden between coal seams could have marked impacts on predictive groundwater drawdown and inflow because the chosen sensitivity value of Kv value of 5×10^{-5} m/day (five times the base case value) was still within the reasonable parameter range.

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Table 7-10 Total Groundwater Inflows for each Sensitivity Run at the end of Mining

Sensitivity Run	Red Hill Mine Total Inflow (GL)	Red Hill Mine and GRB Mine Complex Total Inflow (GL)
Base Case	35.3	146
1	35.1	142
2	33.4	138
3	35.2	140
4	30.9	135
5	37.1	147
6	34.5	139
7	33.8	139
8	75.5	214
9	34.1	139
10	34.1	140
11	34.1	138
12	34.0	139

Of particular note, the greatest uncertainty identified surrounds the vertical permeability of interburden and goaf aquifer parameters and therefore corresponding groundwater inflows as there is no known published data for post goaf aquifer parameters. The uncertainty in the model results can be reduced through the collection of inflow data. If significant divergence is observed between the measured and model predicted inflows, revisiting the model and specifically re-calibration of the model parameters against the measured inflow data will reduce the model uncertainty and gain better predictions for the future. It is also recommended that model refinement and predictions be rerun (at intervals no longer than three years during the LOM based on monitoring data compiled).

Potential Impact of Project on Groundwater Regime and Mitigation Measures

The impacts on groundwater from the development, operation, closure and post-closure of the project have been evaluated. Potential impact of the mine on the regional groundwater regime was assessed by predictive groundwater modelling. The groundwater model was developed to estimate groundwater extraction (passive seepage and active dewatering for gas control) over the mine life, project drawdown in aquifers, evaluate the zone of influence and direct and indirect impacts of dewatering, and evaluate the possible impact on other groundwater users. The groundwater model was constructed using the geological model, hydraulic parameters determined on site and from literature, and groundwater level information within the survey area.

Mining within the GRB mine complex area commenced after the granting of the original Goonyella mining lease (ML1763) in 1971 and the Riverside mining lease (ML1764) in 1978. While the main aquifers within the area are the coal seams, inflow from the exposed seams to the current GRM pit voids have not been significant. Dewatering in advance of mining is generally not required for the current open pit or underground workings.

The Goonyella North mine is located along the strike of the Moranbah Coal Measures immediately north of the EIS study area, with the Moranbah North mine located immediately south. Given the close proximity of these coal mines, this assessment considers the additional and, where possible, the cumulative impact of the project on the current (mine influenced) groundwater resources in the survey area.

8.1 Potential Impacts during Development and Operation

8.1.1 Potential Impacts on Regional Groundwater Levels

The project is within the declared Isaac Connors GMA; however, there are few groundwater users locally. From a search of the NRM groundwater database, seven bores are registered within 10 kilometres of the EIS study area boundary for water supply purposes. Other bores are present but these are either monitoring bores or coal seam gas exploration bores) as discussed in **Section 6.3**.

During the LOM, groundwater inflow from the aquifers to the underground mine workings or extraction as part of gas depressurisation can lead to increased drawdown of the potentiometric surface in the vicinity of the mine workings when compared to drawdown from the existing approved coal mines in the area.

8.1.1.1 Impacts on Permian Formation Aquifers

Dewatering resulting from IMG drainage and groundwater ingress into the mine workings will cause drawdown of groundwater levels as discussed in **Section 7.5.2** and presented in **Figure 7-9** and **Figure 7-11**. Resultant variations in the current groundwater levels, which have already been altered due to existing mine dewatering, were predicted.

Groundwater modelling was used to project drawdown caused by dewatering and IMG drainage of the proposed RHM. Predictive modelling indicates that drawdown of five metres (from pre-RHM mining levels) will occur to a distance of up to four kilometres from the proposed RHM footprint. The drawdown predictions were simulated for the target GMS, allowing for the prediction of the largest zone of influence at the end of mining.

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Groundwater drawdown will also occur in the units above the GMS due to induced flow towards the depressurised coal seam and the impact of the goaf resulting in increasing vertical permeability. The extent and degree of drawdown within the overlying units decreases with increasing distance above the dewatered seams.

The Goonyella North and Moranbah North mines are located along strike and also target the Moranbah Coal Measures to the north and south of RHM, respectively. The cumulative impact of these mines will be to superimpose the drawdown of each mine such that the Moranbah Coal Measures between the mines will be significantly dewatered. No groundwater users were identified between the mines.

Drawdown in bores of five metres or more is considered, in fractured rock aquifers, to have a material impact on bore yield. There are no identified groundwater supply bores within the predicted five metre drawdown zone. Thus no “at-risk” bores have been identified.

There are two production bores (Skeleton Bore (NRM Registration 81696), and Cleanskin Gully Bore) on the ‘Broadmeadow’ property are located outside the predicted five metre drawdown contours zone but still within the predicted cone of depression on the ‘Broadmeadow’ property (Skeleton Bore (NRM Registration 81696), and Cleanskin Gully Bore), as shown on **Figure 6–4**. While it is expected that users of these two bores will still have access to groundwater and not realise a marked change in supply it is recommended that monitoring be conducted to validate predictions.

Additional bores that may potentially be affected by mine dewatering and IMG drainage are the CSG bores. These bores are, however, designed to remove groundwater to allow gas extraction, and hence, mine-induced drawdown should not cause any impacts on these bores.

8.1.1.2 Impacts on Tertiary and Quaternary Aquifers

All creeks and the Isaac River within the EIS study area are ephemeral and there are no perennial water holes or groundwater dependant environments present, as discussed in **Section 6.4**. Under dry season conditions, groundwater does not contribute or have any hydraulic connection with surface water resources within these drainages. In exceptionally wet years it is possible that the Quaternary alluvium and shallow Tertiary aquifers may contribute some groundwater to the surface water system along water courses for a short duration after rain events.

Where excavations required for the surface infrastructure and mine access portals encounter Quaternary alluvium near creeks or the Isaac River and / or Tertiary sediments, groundwater inflow may occur (i.e. direct drainage impacts). The aquifers in these units are typically ephemeral are not considered significant aquifers. Due to the expected low hydraulic gradients (one to two metres) and low conductivity, the drawdown zone of influence, as a result of the direct impacts, is considered to only extend some 10 to 100 metres around excavations. This area around the excavations will remain dewatered, as recognised in the GRB mine complex open cut pits, as evaporation exceeds recharge.

The Quaternary alluvium associated with the Isaac River is considered, based on permeability and water quality, to be the most significant aquifer within the survey area, but is unlikely to be significantly impacted by groundwater drawdown as there are no major excavations to take place in close proximity to the Isaac River and limited hydraulic connection between the perched water tables in the alluvium and the confined coal seam aquifers (which will be depressurised and dewatered).

Although the numerical model indicates the potential for drawdown of over two metres in the Tertiary/Quaternary (as shown in **Figure 7–8**), this is not considered to occur in reality due to the

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ephemeral nature of the Cainozoic units. The model simulations assume fully saturated conditions in the Tertiary sediments and Quaternary alluvium and that these units are in hydraulic connection with the underlying confined aquifers. In reality due to the short periods over which the aquifers are actually, saturated, drawdown due to mining will be much less than predicted.

Subsidence is predicted to create cracking at surface (IMC 2011), the clay-rich nature of the Tertiary sediments, Quaternary alluvium, and weathered Permian will, however, self-heal. This will reduce the potential of leakage from surface to the mine workings. Observations at the adjacent BRM appear to confirm this.

All creeks and the Isaac River within the EIS study area are ephemeral and there are no perennial water holes or groundwater dependant ecosystems present, as discussed in **Section 6.4**. On this basis, impacts on groundwater dependent ecosystems are not expected.

Incidental mine gas drainage activities are not expected to impact on the Tertiary or Quaternary aquifers as the bores will be sealed where they intersect these aquifers.

8.1.2 Impacts on Groundwater Quality

The groundwater quality of the Permian strata is brackish to saline and not suitable for human consumption or irrigation, but has some use for stock water according to the limits set in ADWG (2004) and ANZECC/ARMCANZ (2000) water quality guidelines.

During mining operations, groundwater quality within aquifers surrounding the site is not expected to change from pre-mining conditions. This would be a result of all RHM water and waste storage facilities infrastructure being designed, constructed, and managed to ensure little or no potential of seepage. In the event that groundwater contamination did occur contaminant migration off site in the groundwater will not occur. This is expected as during degassing and mining operations, groundwater will be continually extracted from bores or sumps in the underground workings to ensure a safe working environment. This drainage of groundwater will create a depression in the potentiometric (groundwater) surface around the workings such that the net movement of groundwater is towards the workings during mine operation. This will prevent the movement of water that may have been impacted by mining from moving away from the mine operation area and into the surrounding aquifers. The resultant drawdown, changing groundwater flow patterns, effectively limits the potential for contaminant plumes to migrate off site via groundwater.

Groundwater quality away from the influence of the project will not deteriorate as these resources will continue to receive recharge via the same processes that occurred pre-mining.

Groundwater quality data (with respect to major anions and cations and dissolved metals) indicate that groundwater in the alluvial aquifers and basalt is of similar or better quality when compared to the coal seam aquifers of the Moranbah Coal Measures. Hence, any inadvertent mixing of groundwater (during and post mining) by induced downward movement from the upper to lower aquifers is unlikely to result in a deterioration of groundwater quality in the Permian aquifers.

Another potential source of contamination for groundwater is through contact with mine waste materials which may be acid forming or leach salt or metal contaminants to groundwater. A geochemical assessment of the coal and mine wastes (waste rock and tailings) was undertaken for the project (URS 2012a). The study indicates that the overburden (excavated for mine access) and rejects generated by the proposed mining and coal processing operation is predominantly

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geochemically benign. Any possible seepage and /or surface run-off is expected to be slightly alkaline and have low-to-moderate salinity following surface exposure. Overburden and reject materials are unlikely to generate acid given the lack of oxidisable sulphur content, excess acid neutralising capacity and existing alkaline pH of these materials. As the direction of groundwater flow will be towards the mine workings, the buffering capacity of the groundwater is expected to neutralise any oxidation products of the coal seams due to mine dewatering, and any potential for the development of acid mine drainage is low.

The expected water quality of overburden and coal reject materials (runoff and seepage) and the water quality of the coal seam aquifers indicate that groundwater seeping into the underground mine will require dilution or treatment to reduce the salinity prior to reuse. The acid-base classification of coal samples found that most coal samples were potentially acid forming, although the potential for acidification of groundwater in contact with exposed coal seams is expected to be relatively low. This is due to the low sulphur concentration of coal and the significantly greater proportion of pH-neutral material and in the roof and floor of the underground mine compared to coal.

The waste rock dumps, waste placement areas, CHPP and coal stockpiles are located over the relatively saline aquifers of the Permian formations (Moranbah Coal Measures or Back Creek Group), not the fresh water aquifers of the Isaac River Quaternary alluvium or Tertiary sediments. Thus any potential seepage or runoff is unlikely to result in a marked alteration to groundwater quality of the underlying Permian formations.

The quality of the groundwater in the shallow Cainozoic groundwater resources that may exist within the project footprint (i.e. Quaternary alluvium and Tertiary sediments) have the potential to be impacted by spills and seepage from the MIA, and waste disposal and fuel storage areas where these are in sufficient quantities to leach through the soils to groundwater. Any spills from these areas are typically localised and not regionally significant in terms of groundwater impacts. The risks of groundwater contamination from chemical or fuel spills will be minimised by storage and handling of fuels, oils and other chemicals in accordance with Australian standards and requirements of Material Safety Data Sheets. The design of storage and handling facilities will provide full containment, and procedures for immediate clean-up of spills will be available. These measures are standard practice or a legislated requirement at mine sites. Areas of hydrocarbon and chemical storage will have spill control measures in place and a regular inspection regime will be required in order to monitor activities that could potentially lead to contamination of groundwater. Any accidental spills will be assessed on a case-by-case basis and remediated, which may include excavation and disposal of any contaminated soil, in accordance with NRM requirements.

During mining, mobile and stationary machinery including excavators, cranes, trucks and other vehicles will be required. There is potential for hydrocarbon contamination of the soil associated with leaks or spills from this machinery (or fuel storage areas for the maintenance of machinery). Dissolved and free-phase hydrocarbon may impact on the shallow aquifers underlying and down-gradient of areas of fuel spillage.

During mine operation, groundwater quality within aquifers surrounding the mine areas will continue to be suitable for the same purposes applicable during the pre-mining period. The groundwater quality within the aquifers surrounding the EIS study area will be monitored to ensure no marked deterioration in groundwater is occurring as a result of the proposed mining activities.

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8.1.3 Additional Potential Impacts

8.1.3.1 *Reduced recharge*

Compression and/or sealing of the ground surface associated with the construction of roads and building foundations and IMG infrastructure is not expected to greatly alter the permeability of strata immediately beneath the site and, as such, will not markedly reduce rainfall recharge of the underlying aquifers. Works will be limited in the vicinity of the Isaac River, further limiting potential impacts on the Quaternary alluvial aquifer.

8.1.3.2 *Subsidence*

Underground mining using the thick seam mining method (longwall top coal caving) will result in subsidence of the overlying strata in the mined-out areas behind the longwall, with fracturing extending from the extraction horizon toward the surface. This caving and subsidence can cause fractures and joints in the overlying strata. AGE (2002) state that following the passage of longwall panels and stabilisation of subsidence, fracturing in the bulk of the strata will generally close up, allowing strata permeability to return to near to the pre-mining levels. Within the tensile zone above and adjacent to the longwall panels the vertical and horizontal strata permeability will be markedly and permanently altered due to sub-surface fracturing. The vertical extent of these fractures is dependent on numerous factors, such as mine design, geological conditions, surface topography, and the distance between the mine workings and the ground surface and in the RHM is predicted to extend up to 10 metres above the mine workings (IMC 2011).

8.1.3.3 *Gas removal*

To allow safe underground mining of the coal, degassing of the coal seams in advance of mining is required. Methods of degassing the coal are currently being developed for the project, and are likely to include installation of gas drainage wells (vertical or surface to in-seam). The drilling and installation of gas drainage wells has the potential to impact on groundwater (through water quality mixing, gas migration (pathways if not sealed correctly), and resulting in composite potentiometric heads) by creating potential pathways for leakage between formations.

Standard gas drainage well construction techniques, including fully cased and grouted wells and undertaking cement bond logs, will minimise the potential for inter-aquifer transfer through the bore. The IMG water production dam, where groundwater removed during the IMG drainage will be temporarily stored en-route to the mine water management system, will be fully lined with an impermeable lining, removing the potential for seepage to groundwater.

Permanent subsurface structures such as building foundations and road embankments can impede shallow groundwater flows and cause localised groundwater restrictions and waterlogging due to the build-up of pressure in the up-gradient area. The project does not require extensive subsurface structures in the vicinity of the Isaac River and associated alluvial aquifer. Detailed design will need to assess the need for engineering solutions such as pressure head relief.

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8.2 Potential Impacts Post Mining

The main features of the final landform after mining ceases will comprise partially to totally filled mine voids in the underground workings, and subsidence troughs on the surface.

As with the impacts during mining, the increased permeability and storage for groundwater in the goaf will remain after mining.

8.2.1 Impacts on Regional Groundwater Levels

The remnants of the mine void will collect and accumulate water from groundwater ingress through the walls and goaf of the final workings. There is also the potential for groundwater ingress to occur from surface through leakage down the ventilation shafts, the mine access drift, old exploration holes or abandoned bores. These pathways facilitate groundwater rebound post mining.

Typically, the mine workings will fill up and groundwater levels recover over time. The groundwater modelling, which does not take account of these leakage sources, indicates that a lag effect will persist after groundwater extraction is stopped, with residual drawdown in the GMS persisting until 2068. The groundwater system will re-adjust to the new (altered and enhanced) aquifer conditions surrounding and within the mined area. Groundwater levels and piezometric pressures within the regional aquifers will, over time, attain a new equilibrium level. This new equilibrium for the groundwater system will have a different potentiometric surface from that which was present pre-mining owing to the presence of the mined workings and the different hydrogeological parameters of the goaf.

A detailed study of groundwater level recovery within RHM has not been conducted as part of the EIS because the closure requirements for the GRM will have a significant impact on recharge to groundwater and the rate of groundwater recovery. Groundwater levels are expected to recover within RHM after closure during the period of continued operation of GRM (2040 to 2068), and further work will need to be undertaken throughout the GRM mine life to determine the hydrological regimes, and the expected water quality of the mine voids. It is considered that the groundwater levels will recover in RHM, over time, to the base of the GRB mine complex open pits. The GRB mine complex final voids will, based on size and climate conditions (evaporation exceeding rainfall), permanently alter groundwater flow patterns towards the GRB mine complex final voids.

8.2.2 Impacts on Groundwater Quality

A rise in the groundwater salinity within the RHM void may occur as a result of atmospheric weathering of the exposure of wall, roof and floor rock during mining. However as discussed in **Section 8.1.2**, any increase in groundwater salinity is expected to be minor compared to the natural salinity of the groundwater in the Permian formations. Current and previous geochemical analysis in the Moranbah Coal Measures lithology show that there is low acid generation potential, with the roof and floor strata having excess buffering capacity, thus there is a low risk that metals will be mobilised into the groundwater.

Post-mining water quality within all aquifers surrounding the EIS study area is expected to remain similar to pre-mining water quality.

8 Potential Impact of Project on Groundwater Regime and Mitigation Measures

8.3 Mitigation Measures for Potential Impacts

8.3.1 General Groundwater Monitoring Program

A network of groundwater monitoring bores were previously installed around the EIS study area as shown in **Figure 6-3**. Additional groundwater monitoring bores and vibrating wire piezometers (VWPs) were also installed by BMA in early 2012. Further groundwater monitoring bores are to be installed down-gradient of mine water and waste storage facilities with locations to be determined after finalisation of the site layout. Further monitoring will be undertaken prior to the commencement of mining of the RHM underground expansion option to enable the long term monitoring of groundwater levels and groundwater quality, as well as to provide data for updates of the groundwater model.

Routine monitoring during the mining operation will provide early warning of any variation in response of the groundwater system to that predicted. This will enable BMA to undertake mitigation measures to minimise impact on surrounding groundwater users and the environment, such as the implementation of make good measures. In addition, the groundwater monitoring will enable the identification of any cumulative groundwater level drawdown impacts as a consequence of other mining operations in the area.

The monitoring bores are required to be completed in accordance with the Minimum Construction Requirements for Water Bores in Australia (Land and Water Biodiversity Committee 2003), the Water Act and undertaken by a licensed water bore driller. They must be surveyed for elevation levels of ground surface and monitoring measurement point to allow future groundwater levels to be measured to a consistent, known, datum and allow groundwater sampling as required.

Groundwater level and quality monitoring will be undertaken regularly to enable the detection of seasonal fluctuations and any groundwater level or quality trends or impacts. In turn, the monitoring data (level and chemistry) will be entered into a BMA environmental monitoring database to enable a regular assessment and interrogation to evaluate potential groundwater impacts.

A groundwater monitoring network and program will be developed and implemented for the RHM underground expansion option to detect any marked change to ground water quality due to activities. This will be consistent with the current suitability of the groundwater for agricultural use (stock watering), limited domestic use, and any discharge to surface waters that may occur after significant wet weather events.

Prior to commencement of mining for the RHM underground expansion option, at least 12 groundwater monitoring events will be undertaken, evenly spread across wet and dry seasons for at least two years. The monitoring events will record:

- groundwater levels; and
- groundwater quality with analysis of the parameters: - pH, electrical conductivity (EC), total dissolved solids (TDS), major cations and anions, nutrients (total nitrogen, nitrous oxides, ammonia, phosphorous), selected dissolved metals (aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, and zinc), and total petroleum hydrocarbons (for bores monitoring potential fuel spill / seepage sources).

In addition, continuous groundwater level monitoring will be conducted across at least two wet and dry seasons using vibrating wire piezometers automatically recording water levels at regular intervals.

8 Potential Impact of Project on Groundwater Regime and Mitigation Measures

The background groundwater monitoring program will consist of 12 sampling events evenly spread over a two year period to determine background groundwater quality as far as practicable in order to determine groundwater contaminant and trigger limits for comparison to the EPP (Water) groundwater quality objectives for the Isaac River sub-catchment (zone 34) (as shown in **Table 6-3**)

On completion of monitoring, groundwater trigger levels, based on the 85th percentile value of groundwater quality results and groundwater contaminant limits based on the 99th percentile of groundwater quality results will be determined.

During mining operations, groundwater monitoring will continue, including:

- Monitored of groundwater levels in standpipe monitoring bores and VWP's.
- Groundwater quality sampling undertaken at least once very wet season and once every dry season with analysis of the parameters: - pH, EC, TDS, major cations and anions, nutrients, selected dissolved metals (aluminium, arsenic, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium and zinc), and total petroleum hydrocarbons (for bores monitoring potential seepage sources).
- Additional monitoring in one or more bores may be undertaken in the event of a significant spill of fuels or other contaminants with potential to cause groundwater contamination.
- Measurement of daily precipitation, evaporation, and gas drainage and mine dewatering volumes will be undertaken through operations.

Groundwater monitoring and sampling will be conducted by a suitably qualified and experienced professional in accordance with the current edition of the DERM Monitoring and Sampling Manual, or subsequent updated versions; and the AS/NZS 5667.11:1998 Australian/New Zealand Standard for water quality – sampling Part 11; guidance on sampling groundwater.

Monitoring data (level and chemistry) will be entered into a BMA environmental monitoring database to enable a regular assessment and interrogation to evaluate groundwater trends.

If groundwater quality results exceed trigger levels set out in the environmental authority, monitoring will be repeated within 60 days. If concentrations exceed trigger levels in the second sampling event then an investigation into cause, optimum response, and the potential for environmental harm must be conducted and mitigation measures developed and implemented to address the outcome of the investigation.

An annual review of the monitoring program will be conducted by a suitably qualified and experienced hydrogeologist. This annual review of the monitoring program will be conducted to evaluate the effectiveness of each monitoring location, to assess where new locations and modifications to the monitoring program may be needed, and to evaluate impacts that may be occurring. These data will, on a regular basis (no longer than three years), be used to validate model predictions.

Post-mining groundwater monitoring will be subject to detailed closure/relinquishment conditions. It is expected that during the operational phase of the project, the groundwater data collected for the region will be comprehensive enough to accurately predict the long term recovery of the aquifers. This will assist in the development and implementation of the closure strategy and the refinement of post-mining groundwater monitoring programs.

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8.3.2 Impacts on Nearby Groundwater Users

While groundwater model predictions do not indicate any significant impacts on adjacent groundwater users, should a detrimental impact on landholder groundwater supplies be detected, and shown to be related to the project operations, then BMA will seek to reach mutually agreeable arrangements with affected neighbouring groundwater users for the provision of alternate water supplies. To this end, BMA will update its groundwater census of bores on properties within the predicted drawdown cone prior to commencement of mining, and enter into make-good agreements with landholders specifying trigger levels and appropriate responses.

Regular groundwater monitoring will enable groundwater level drawdown to be identified prior to any impacts being experienced in surrounding landholder bores. In turn, alternative water supplies can be put in place before supplies from relevant existing landholder bores are adversely affected. Options for alternate supplies include:

- installations of new pumps capable of extracting groundwater from greater depth within existing bores;
- deepening of existing bores;
- installation of a new bore at another location on the property; and / or
- provision of piped water sourced from the mine (i.e. surplus water from the gas depressurisation program, depending on quality).

The specific arrangements for affected properties will be discussed with each relevant landholder with a view to reaching a mutually acceptable agreement.

8.3.3 Seepage from Stockpiles and Surface Water Control Structures

Good environmental practice requires that reasonable effort be made to minimise seepage from stockpiles and surface water control structures wherever this may affect the groundwater system. All mine water storages will be constructed in accordance with the NRM (2002) dam guidelines. These guidelines include requirements for management of seepage from mine water storages.

The surface water runoff collection system from the MIA and CHPP will be managed as a non-release system with water stormwater returned to the mine water management system. Raw and product coal stockpiles will be contained within hardstand or compacted areas and drainage will be directed to the mine water management system.

Early detection of significant seepage will enable management of any potential problems. Potential seepage from the project surface water management system (such as the IMG water production dam for gas drainage works) will be regularly assessed through the installation and monitoring of the monitoring bore network on-site, including down-gradient of all potential seepage sources. Management of surface water will include monitoring of water at selected locations for potential contaminants.

Installation of monitoring bores down-gradient of potential seepage sources is proposed to enable early detection of any leachate entering the shallow Quaternary alluvial or Tertiary sediment aquifers. The key indicator parameters of seepage will be monitored including (but not restricted to) standing water level, salinity (as TDS), dissolved metals, and major ions initially on a quarterly basis.

8 Potential Impact of Project on Groundwater Regime and Mitigation Measures

In the unlikely event of groundwater impact, mitigation strategies will include some or all of the following measures (depending on the specific requirements):

- investigation of water management system integrity;
- removal of contaminant source and repair / redesign of any water management structures as required;
- installation of and pumping from, groundwater interception wells; and / or
- installation of and pumping from groundwater interception trenches.

8.3.4 Hydrocarbon and Chemical Contamination

Areas of hydrocarbon and chemical storage and handling will be designed to contain spills and procedures will be in place to minimise likelihood of spills and provide a rapid response in the event that spills occur. Spill kits and spill clean-up training will be available on site.

Installation and monitoring of the monitoring bore network on site, including down-gradient of all potential spill areas, will enable early detection of any contaminated seepage.

Further information on the prevention and management of spills is provided in the Red Hill Mining Lease EIS Section 5.4.

8.3.5 Installation of Gas Drainage Bores

Any gas drainage wells will be designed and constructed in accordance with industry standards, with the goal of maintaining hydraulic isolation between discrete water-bearing formations, and will therefore inherently mitigate the risk of gas migration into overlying aquifers and/or releases at the surface. In addition, the integrity of the wellhead and casing will be monitored as part of normal operations.

8.3.6 Closure and Post Closure

There are no specific groundwater management requirements in relation to closure and post closure. If significant groundwater drawdown has occurred, groundwater levels may continue to be monitored to track recovery.

Glossary

ALLUVIUM - Sediments (clays, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on river beds, floodplains, and alluvial fans.

ALLUVIUM AQUIFER - A deposit of detrital material - mostly sediment - formed by river, stream and floodplain processes that store and transmit water in spaces between sediments grains. Stored water can be extracted and used.

ANISOTROPY - The condition under which one or more of the hydraulic properties of an aquifer vary according to the direction of flow.

AQUICLUDE - A low-permeability unit that forms either the upper or lower boundary of a groundwater flow system.

AQUITARD – These are geologic units that are of low permeability. Aquitards usually form a layer in a geologic sequence. They may contain water, but would not yield reasonable volumes of water to bores or wells. An example of an aquitard would be a saturated clay layer that is overlying a saturated sandy aquifer.

AQUIFER - A geological structure of formation or part thereof, permeated with water or capable of- (a) being permeated permanently or intermittently with water; and (b) transmitting water.

AQUIFER, CONFINED - An aquifer that is overlain and underlain by impervious layers. The water level in bores tapping confined aquifers rises within the bore to a level above the top of the aquifer, and may result in an artesian or sub artesian bore. Confined aquifers tend to occur in the central and deeper parts of the Basin.

AQUIFER, PERCHED - Perched Aquifers occur in the upper catchments. They sit over a thick layer of clayey weathered sediments and have no connection to the fractured rock aquifers beneath the clay. This lack of connection means that their ecosystems are highly dependent on rainfall runoff, lateral subflow, from unconsolidated sediments overlying the clay or upstream flow contributions. These systems are more sensitive to surface water changes. Development of surface water resources or disruptions to subsurface flow will have the greatest impact on flora and fauna in this setting.

AQUIFER, SEMICONFINED - An aquifer confined by a low-permeability layer that permits water to slowly flow through it. During pumping of the aquifer, recharge to the aquifer can occur across the confining layer. Also known as a leaky artesian or leaky confined aquifer.

AQUIFER TEST - A hydrological test performed on a well, aimed to increase the understanding of the aquifer properties, including any interference between wells, and to more accurately estimate the sustainable use of the water resource available for development from the well.

AQUIFER, UNCONFINED - An aquifer which has the water table as its upper surface which may be recharged directly by infiltration from the groundwater surface.

AUSTRALIAN HEIGHT DATUM (AHD) - The Australian height datum, adopted by the National Mapping Council of Australia, for referencing a level or height back to a standard base level.

BORE (WELL) - Any bore, well or excavation or any artificially constructed or improved underground cavity used or to be used for the purpose of—(a) the interception, collection, storage or extraction of groundwater; or (b) groundwater observation or the collection of data concerning groundwater; or (c) the drainage or desalination of any land; or (d) in the case of a bore that does not form part of a septic tank system, the disposal of any matter below the surface of the ground; or (e) the recharge of an

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aquifer— but does not include a bore that is used solely for purposes other than those specified in paragraphs (a), (b) and (d).

BOUNDARY CONDITIONS - Specified Head (or Fixed or Constant Head). Refer to Dirichlet Condition (also known as First Type Boundary). **Specified Flow.** Refer to Neumann Condition (also known as Second Type Boundary). **Head-dependent Flow.** Refer to Cauchy Condition (also known as Third Type Boundary).

CAUCHY CONDITION - Also known as Head-dependent Flow or Third Type Boundary Condition. A boundary condition for a groundwater model where the relationship between the head and the flow at a boundary is specified, and the model computes the groundwater flux for the head conditions applying.

CALIBRATION - Calibration of a model is the process where parameters in the model are fine tuned to get the best possible match between actual and modelled data over a defined period.

CALIBRATION, INITIAL CONDITIONS - The initial hydrologic conditions for a flow system that are represented by its aquifer head distribution at some particular time corresponding to the antecedent hydrologic conditions in that system. Initial conditions provide a starting point for transient simulations.

CALIBRATION, STEADY STATE - The calibration of a model to a set of hydrologic conditions that represent (approximately) an equilibrium condition, with no accounting for aquifer storage changes.

CALIBRATION, TRANSIENT - The calibration of a model to hydrologic conditions that vary dynamically with time, including consideration of aquifer storage changes in the mathematical model.

COMPLEXITY - The degree to which a model application resembles, or is designed to resemble, the physical hydrogeological system. A hierarchical classification of three main complexities in order of increasing complexity: Basic, Impact Assessment and Aquifer Simulator. Higher complexity models have a capability to provide for more complex simulations of hydrogeological process and/or address resource management issues more comprehensively. In this guide, the term complexity is used in preference to fidelity.

COMPLEXITY – Basic Model - With limited data availability and status of hydrogeological understanding, and possibly limited budgets, a Basic model could be suitable for preliminary quantitative assessment (rough calculations), or to guide a field program.

COMPLEXITY – Impact Assessment Model - More detailed assessments are possible with an Impact Assessment approach, which usually requires more data, better understanding, and greater resources for the study.

COMPLEXITY – Aquifer Simulator - An Aquifer Simulator is a high complexity representation of the groundwater system, suitable for predicting the response of a system to arbitrary changes in hydrogeological conditions.

CONCEPTUAL MODEL - A simplified and idealised representation (usually graphical) of the physical hydrogeologic setting and our hydrogeological understanding of the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes.

CONE OF DEPRESSION - The radial decline of potentiometric levels or underground water levels around a point of water extraction from an aquifer.

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DARCY'S LAW - An empirical equation developed to compute the quantity of water flowing through an aquifer. Usually expressed as $Q=kiA$, where Q =flow, k =hydraulic conductivity, l =hydraulic gradient, A =aquifer cross-sectional area.

DEWATERING - Removing underground water for construction or other activity. It is often used as a safety measure in mining below the water table or as a preliminary step to development in an area

DIRICHLET CONDITION - Also known as a Specified, Fixed or Constant Head Boundary, or Third Type Boundary Condition. A boundary condition for a groundwater model where the head is known and specified at the boundary of the flow field, and the model computes the associated groundwater flow.

DRAWDOWN - Refers to a lowering of the surface that represents the level to which water will rise in cased bores. Natural drawdown may occur due to seasonal climatic changes. Groundwater pumping may also result in seasonal and long-term drawdown.

EXTRACTION - In relation to any bore includes withdrawing, taking, using or permitting the withdrawing, taking or using of water from that bore.

EVAPOTRANSPIRATION - The sum of evaporation and transpiration.

FINITE-DIFFERENCE MODEL - A particular kind of numerical model based upon a rectangular grid that sets the boundaries of the model and the nodes where the model will be solved.

Gigalitre (GL) - A volumetric measure equal to one million kilolitres or one billion litres.

GROUNDWATER - (a) Water occurring naturally below ground level (whether in an aquifer or otherwise); or (b) water occurring at a place below ground that has been pumped, diverted or released to that place for the purpose of being stored there; but does not include water held in underground tanks, pipes or other works.

GROUNDWATER FLOW MODEL - An application of a mathematical model to represent a site-specific groundwater flow system.

GROUNDWATER-DEPENDENT ECOSYSTEMS (GDE) - Ecosystems which have their species composition and natural ecological processes wholly or partially determined by groundwater.

HETEROGENEOUS - A medium which consists of different (non-uniform) characteristics in different locations.

HOMOGENEOUS - A medium with identical (uniform) characteristics regardless of location.

HYDRAULIC CONDUCTANCE - A term which incorporates model geometry and hydraulic conductivity into a single value for simplification purposes. Controls rate of flow to or from a given model cell, river reach, etc.

HYDRAULIC CONDUCTIVITY - A measure of the ease of flow through a pore space or fractures. Hydraulic conductivity has units with dimensions of length per time (e.g. m/s, m/min, or m/d).

HYDRAULIC GRADIENT - Spatial variation in the effective elevation of water table and/or potentiometric level, which drives lateral flow of underground water.

HYDRAULICALLY LINKED - In relation to sub artesian water, means there is a direct connection between the sub artesian water and surface water to the extent that— (a) if the aquifer is full and surface water is removed, sub artesian water begins, within approximately 1 day, to flow to the

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surface, replacing the surface water removed; and (b) if the aquifer is not full, surface water begins, within approximately 1 day, to seep into the aquifer causing the water level in the aquifer to rise.

HYDROLOGIC EQUATION - An expression of the law of mass conservation for purposes of water budgets. It may be stated as inflow equals outflow plus or minus changes in storage.

INFILTRATION - The flow of water downward from the land surface into and through the upper soil layers.

ISOTROPY - The condition in which hydraulic properties of the aquifer are equal in all directions.

LEAKANCE - Controls vertical flow in a model between cells in adjacent layers. Equivalent to effective vertical hydraulic conductivity divided by the vertical distance between layer midpoints.

MODEL CALIBRATION - The process by which the independent variables (parameters) of a numerical model are adjusted, within realistic limits, to produce the best match between simulated and observed data (usually water-level values). This process involves refining the model representation of the hydrogeologic framework, hydraulic properties, and boundary conditions to achieve the desired degree of correspondence between the model simulations and observations of the groundwater flow system.

NEUMANN CONDITION - Also called a constant flux boundary. The boundary condition for a groundwater flow model where a flux across the boundary of the flow region is known and specified, and the model computes the associated aquifer head.

NON-UNIQUENESS - The principle that many different possible sets of model inputs can produce nearly identical computed aquifer head distributions for any given model.

NUMERICAL MODEL - Refers to a mathematical representation of a physical system intended to mimic the behaviour of a real system, allowing description about empirical data and prediction about untested states of the system.

OBSERVATION WELL - A non-pumping well used to observe the elevation of the water table or the potentiometric surface. An observation well is generally of larger diameter than a piezometer and typically is screened or slotted throughout the thickness of the aquifer.

PARSIMONY - A principle that states that the simplest explanation that explains the greatest number of observations is preferred to more complex explanations.

PIEZOMETER - A non-pumping well, generally of small diameter, that is used to measure the elevation of the water table or potentiometric surface. A piezometer generally has a short well screen through which water can enter.

PIEZOMETRIC SURFACE - Is a surface that represents the level to which groundwater will rise in cased bores intersecting confined aquifers.

POROSITY - The ratio of the aggregate volume of the spaces between grains or fractures in a rock, sediment or soil to its total volume, generally expressed as a percentage.

RECHARGE - Is the addition of water, usually by infiltration, to an aquifer.

RECHARGE BOUNDARY - An aquifer system boundary that adds water to the aquifer. Streams and lakes are typically recharge boundaries.

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RESIDUAL - The difference between the computed and observed value of a variable at a specific time and location.

SATURATED ZONE - The zone in which the voids in the rock or soil are filled with water at a pressure greater than atmospheric. The water table is the top of the saturated zone in an unconfined aquifer.

SEDIMENTARY AQUIFERS - These occur in consolidated sediments such as porous sandstones and conglomerates, in which water is stored in the intergranular pores, and limestone, in which water is stored in solution cavities and joints. These aquifers are generally located in sedimentary basins that are continuous over large areas and may be tens or hundreds of metres thick. In terms of quantity, they contain the largest groundwater resources.

SENSITIVITY ANALYSIS - The measurement of the uncertainty in a calibrated model as a function of uncertainty in estimates of aquifer parameters and boundary conditions.

SIMULATION - One complete execution of a groundwater modelling program, including input and output.

SPECIFIC CAPACITY - The ratio of the rate of discharge of water from the well to the drawdown of the water level in the well. Specific capacity should be described on the basis of the number of hours of pumping prior to the time the drawdown measurement is made. It will generally decrease with time as the drawdown increases.

SPECIFIC STORAGE - The amount of water per unit volume of a saturated formation that is expelled from storage due to compression of the mineral skeleton and the pore water.

SPECIFIC YIELD - The ratio of the volume of water that a given mass of saturated soil or rock will yield by gravity to the volume of that mass.

SPRING - A spring of water naturally rising to and flowing over the surface of land, but does not include the discharge of underground water directly into a watercourse, wetland, reservoir or other body of water.

STOCHASTIC - A description of a parameter or a process with random qualities. A stochastic parameter has a range of possible values, each with a defined probability. The outcome of a stochastic process is not known with certainty.

STORAGE COEFFICIENT (STORATIVITY) - Is the volume of water released or taken into storage per unit plan area of aquifer per unit change of head. It is a dimensionless value. In an unconfined aquifer, it is equal to specific yield.

SUB-ARTESIAN - Groundwater that does not rise above the surface of the ground when accessed by a bore and must be pumped to the surface.

TOPOGRAPHIC DIVIDE - The boundary between adjacent surface water boundaries. It is represented by a topographically high area.

TRANSMISSIVITY - Aquifer hydraulic parameter used to indicate the ease of groundwater flow through a metre width of aquifer section.

UNCERTAINTY ANALYSIS - The quantification of uncertainty in model results due to incomplete knowledge of model aquifer parameters, boundary conditions or stresses.

VADOSE ZONE - Also known as the zone of aeration and the unsaturated zone. The zone between the land surface and the water table. It includes the root zone, intermediate zone, and capillary fringe.

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The pore spaces contain water at less than atmospheric pressure, as well as air and other gases. Saturated bodies, such as perched groundwater, may exist in the unsaturated zone.

VERIFICATION - A test of the integrity of a model by checking if its predictions reasonably match the observations of a reserved data set, deliberately excluded from consideration during calibration.

WATER BUDGET - An evaluation of all the sources of supply and the corresponding discharges with respect to an aquifer or a drainage basin.

WATER TABLE - Is the upper surface of an unconfined aquifer.

YIELD, SAFE - The amount of naturally occurring groundwater that can be economically and legally withdrawn from an aquifer on a sustained basis without impairing the native groundwater quality or creating an undesirable effect such as environmental damage. It cannot exceed the increase in recharge or leakage from adjacent strata plus the reduction in discharge that is due to the decline in head caused by pumping.

YIELD, SUSTAINABLE - An accepted working definition of sustainable yield is (Kalaitzis et al, 1999): "Sustainable yield is that proportion of the long term average annual recharge which can be extracted each year without causing unacceptable impacts on groundwater users or the environment".

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Appendix B

Geotechnical Report

BMA**Estimating changes in hydraulic conductivity induced
by BMA longwall and pillar extraction mines.****BMA-11 Groundwater report****Date: 29/04/2024****R.W.Seedsman****RPEQ**

EXECUTIVE SUMMARY

As the PRCP process has evolved, it has become apparent that there is a need to provide hydraulic conductivity and porosity estimates of the ground impacted by longwall extraction.

This is a somewhat controversial environmental issue in the NSW coalfields with different opinions held by mining companies, consultants, regulators, and environmental groups. The NSW experiences are not directly transferable to the Bowen Basin as the Queensland mines are much shallower.

This report reviews the evolution of hydrogeological models related to longwall extraction and introduces a geotechnical model for overburden fracturing that can be used to estimate hydraulic conductivity and porosity.

Recommendations are made on how the model could be implemented in groundwater studies.

WORKING DRAFT
FOR INTERNAL BHP REVIEW

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WORKING DRAFT
FOR INTERNAL BHP REVIEW

1 INTRODUCTION

Longwall mining involves wide extraction faces such that the overburden progressively collapses – in fact progressive collapse is essential. One factor in the design of longwall mines has been the prevention of unacceptable large inflows of water into the workings. The recognised hazards included consideration of whether flow rates in access roadways present a hazard during evacuation of the work force, whether there is adequate pumping capacity to remove the water, or whether there is adequate storage volume down-dip.

It is important to note that there are relatively few cases in which the prediction of mine water inflow is critical. The empirical models appear to work well, although they were severely tested in the case of Crinum North and subsequently revised.

As the technology developments allowed wider extraction panels, concern has arisen about the possible impact longwalls may have on the gradual lowering of water tables in near-surface aquifers. The mining depths associated with these environmental impacts are much greater than those involved in the inflow hazard and there is no evidence that the outflows from the aquifers result in hazardous inflows to mines. In NSW the environmental issue relates to longwall extraction under water catchments and it was also a component of EIS studies into longwall mining in the Galilee Basin relative to the Great Artesian Basin.

Compared to NSW, the depths of the BMA mines are much less such that caving extends to the overburden collapses extends to the surface. The mine geometry is referred to as “supercritical” compared to the NSW cases which are “subcritical”. There has been relatively little attention paid to the hydrogeological conditions of supercritical geometries.

This document presents a brief outline of the evolution of hydrogeological models and makes recommendations on how they can be applied to the preparation of PRCP management plans.

2 AVAILABLE DATA AND OBSERVATIONS

Longwall mining results in fracturing of the rock mass as the overburden sequence collapses/caves into the void left by the extraction of the coal. This is an intrinsic part of the mining system. Observations of the results of the collapse are limited to the sides of the collapse at seam level and also the ground conditions if there has been subsequent mining in overlying seams. There have been examples where longwall caving has been exposed during subsequent surface mining of lower seams but any studies of these have not been presented in the public domain. The collapse of the overburden can extend to the surface and result in mining-induced subsidence which has been extensively studied.

2.1 Seam level

At seam level at Mandalong Mine in NSW, which is considered to be typical of most longwall mines, the majority of visible blocks in the collapsed volume (Figure 1) were smaller than 0.8m, with only one between 0.8 and 0.9m in size, and another with a mean size of around 1m (Seedsman et al, 2023).



Figure 1 Typical nature of caved material at seam level

2.2 Overmining

Evidence from multiseam mining when conducted in an ascending order is that the bedding layers and orientation are maintained despite the vertical subsidence they have experienced. Mark et al (2007) produced a prediction equation for successful multiseam mining which suggests mining can be conducted at about 10 m above the lower seam if there is acceptance of additional ground support, and at about 35 m above the lower seam without any additional ground support. The author has direct experience with overmining in Australia that is consistent with this prediction.

Mining at Cumnock Colliery in the Lower Pikes Gully seam 35 m above 2.8 m thick lower seam (Li and Cairns, 2000) identified a consistent feature referred to as a D zone (Figure 2). Within the zone, the strata were delaminated with some open vertical fractures with apertures of several millimetres; ribs had open joints and small vertical steps. It was found to be very predictable by extending lines at angles of $\alpha = 15^\circ$ (fracture angle) and $\beta = 35^\circ$ (full collapse angle) from the goaf edge. There was no noticeable fracturing/displacement above the majority of the mined-out underlying Liddel Seam. Chekan and Listak (1993) discuss the possible presence of a mining-induced shear zone present in a similar location.

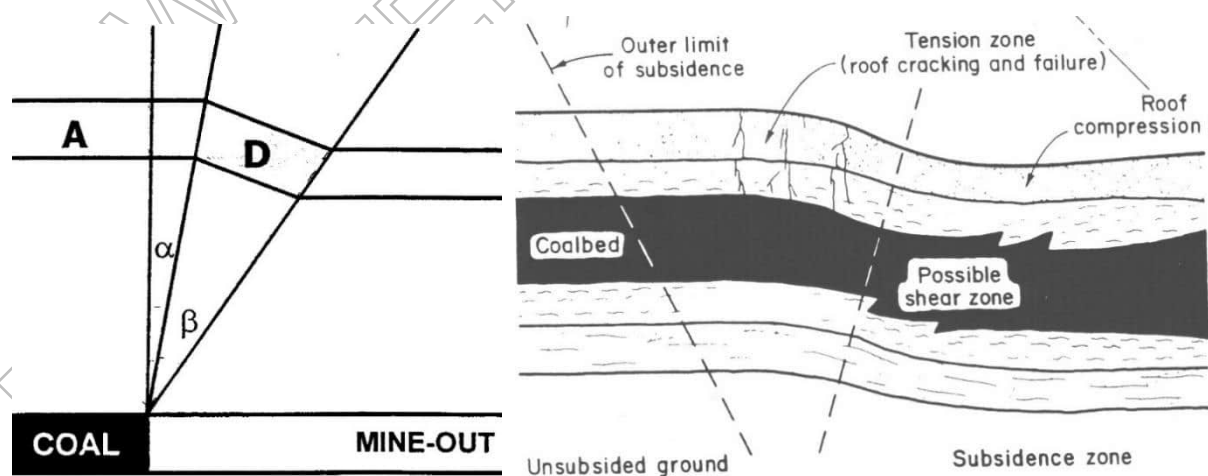


Figure 2 Mining conditions reported from overmining (left - Li and Cairns, 2000; right Chekan and Listak, 1993).

2.3 Physical models

Physical models published by Whittaker and Reddish (1989) indicate there is negligible disruption to the layering during collapse (as experienced in overmining), negligible dilation along the centreline of the collapsed rock mass, there is a void at the top of the collapse that is about half the extraction thickness, and there is some dilation to the sides of the extraction consistent with D zone concept discussed (Figure 3).

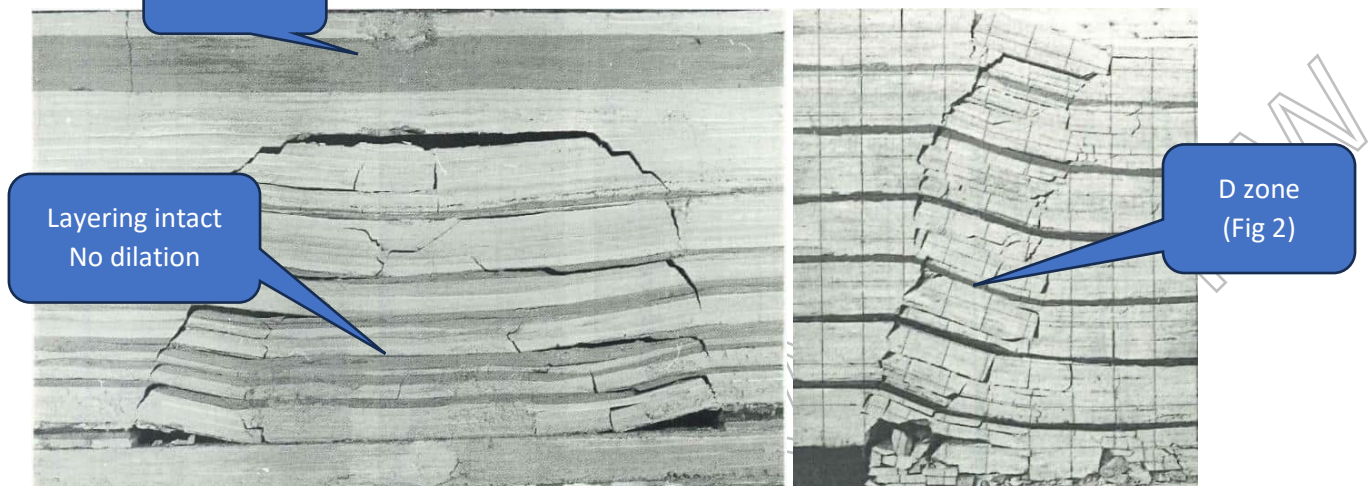


Figure 3 Physical models provide examples of collapse that are consistent with reported mining conditions.

Based on physical models such as Figure 3, identified continuous and discontinuous cracking with heights of A and B respectively, restricted to the sides of the cave. Discontinuous cracking reaches the surface when surface tensile strains are about 35 mm/m, and continuous cracking intersects the surface at 55 mm/m (Figure 4).

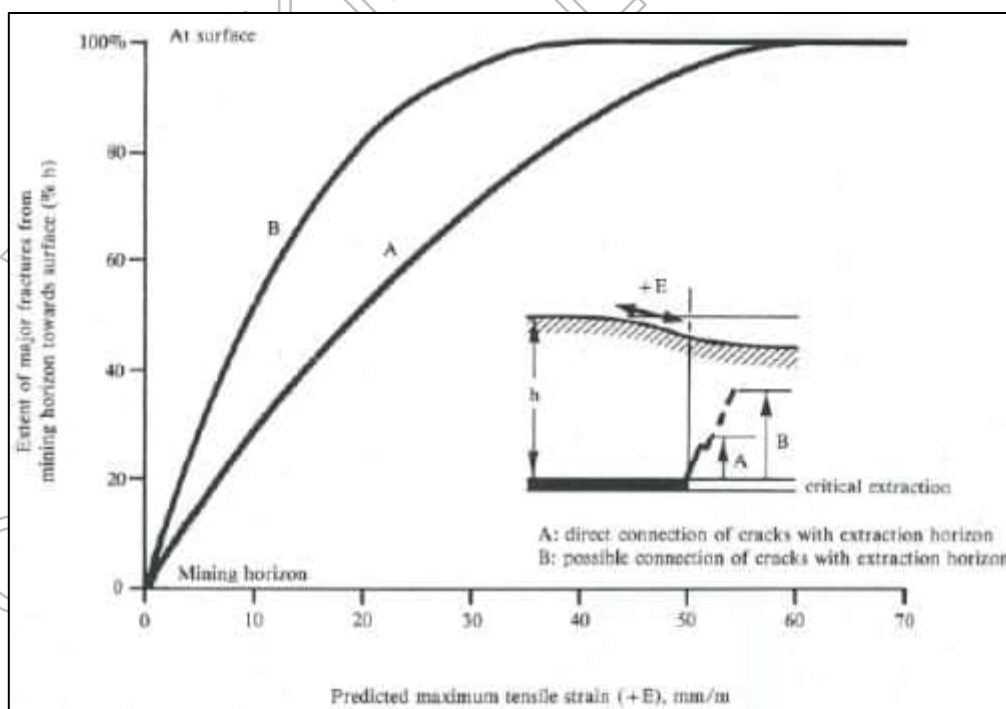


Figure 4 Zone A and Zone B fracturing in the Whittaker and Reddish model (note that the definition related to cracks at the edge of the extraction).

2.4 Surface subsidence

Surface subsidence data is typically presented in a normalised form with a smooth design line drawn to encompass most of the data (Figure 5). This can lead to the arguable interpretation that subsidence and hence overburden collapse is a smooth continuous process. An alternative interpretation of subsidence data invokes a step change between a subsidence/extraction thickness ratio of 0.2 to a S_{max}/T of 0.60 which also represents the change between subcritical to supercritical mine geometries. This step in the vertical movement would require that the underlying material has experienced little dilation between the layers as they collapsed – this is consistent with the overmining observations and also with physical models.

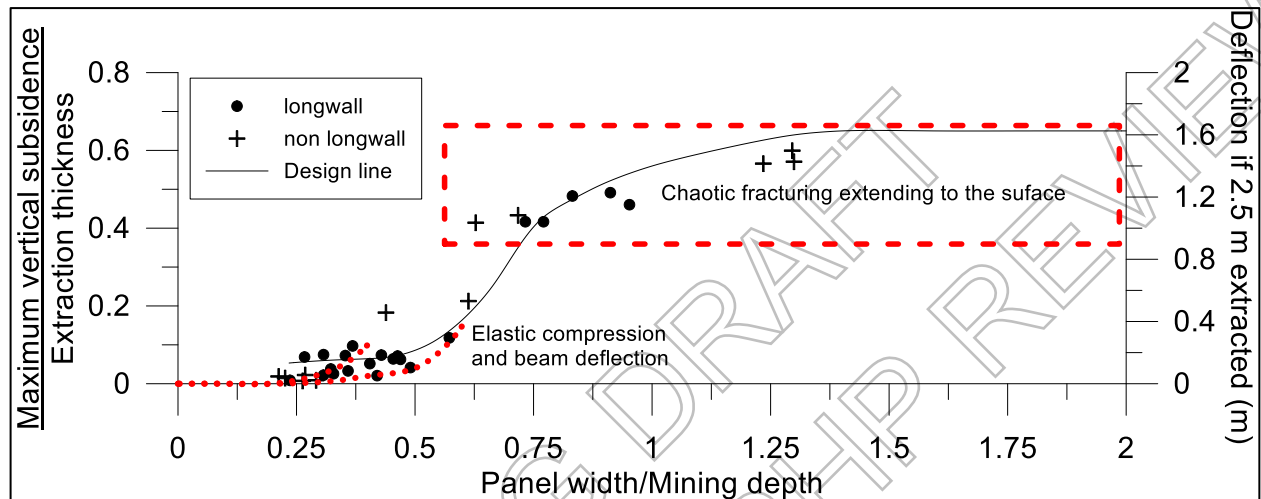


Figure 5 Alternative interpretation of surface subsidence data involving a step change in behaviour from beam deflection to chaotic fracturing.

3 MODELS FOR WATER INFLOWS

3.1 Kendorski models

Kendorski et al (1979) presented an assessment of the hazards of uncontrolled mine water inflows and this work was subsequently developed to produce one of the standard models for longwall collapse (Kendorski, 1993) which invokes four horizontal zones with their geometry defined as ratios of the extracted thickness (T). Other workers have used different terms for essentially the same zones. Progressing upwards from the mined coal seam, these zones are (Figure 6):

- Caved – the zone immediately above the mined coal, described as highly broken and chaotic with a thickness of between $2T$ to $10T$.
- Fractured – described as having layering intact but some fracturing associated with the collapse of the rock mass, with a thickness of between $24T$ to $30T$. Unacceptable flow into mine workings is possible through the fractured zone.
- Dilated – described as characterised by opening of the bedding but no collapse fracturing and with a thickness of up to $60T$. There is no increase in the vertical conductivity but there is an increase in horizontal conductivity.
- Constrained and Unaffected - where there is no bedding opening and no collapse fracturing.

Values for hydraulic conductivity were not provided.

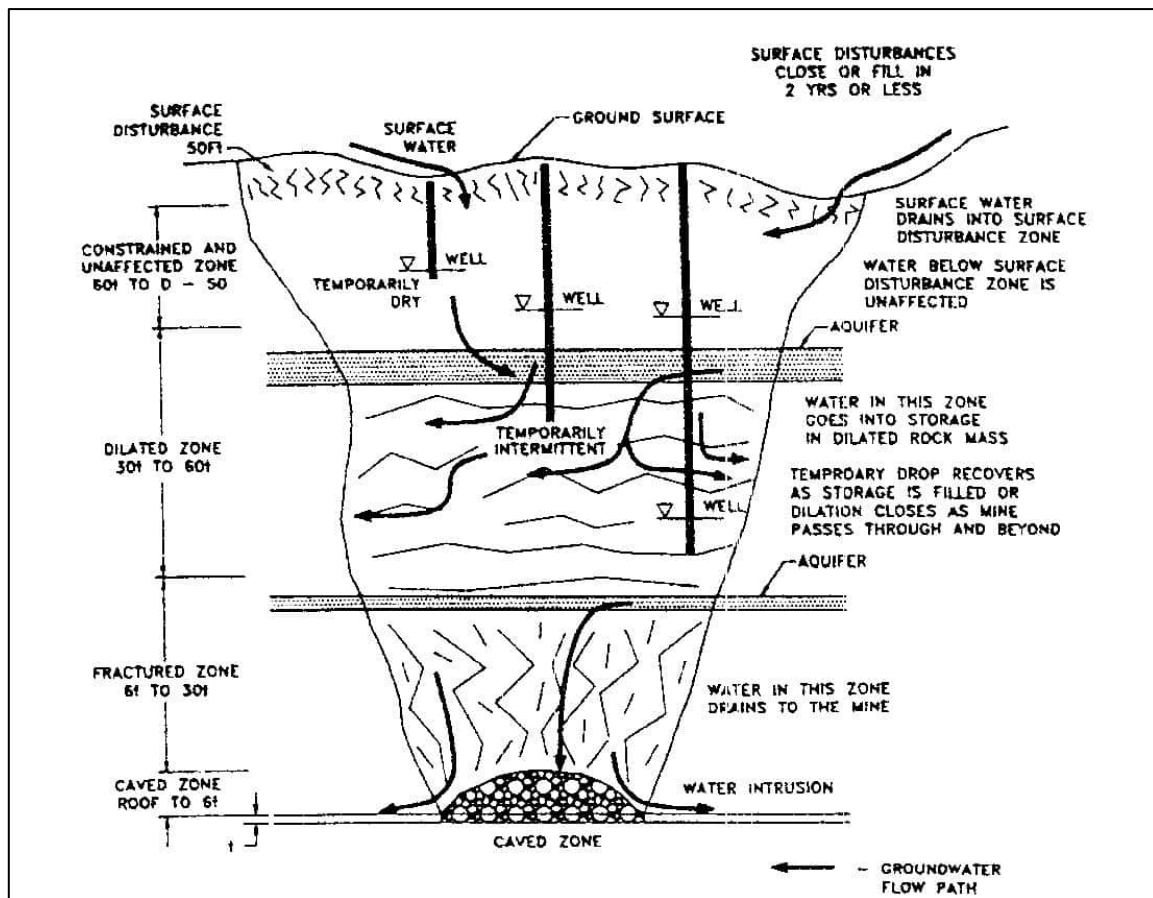


Figure 6 Kendorski 1993 inflow model

One difficulty with this model is that there is no reference to the width of the longwall extraction – recognising the rapid evolution of longwall mining in recent decades it is quite possible that the widths were in the order of 150 m. Another difficulty is the view that there is no increase in vertical conductivity in the dilated zone – perhaps this was in the context of hazardous mine water inflows and not meant to be an absolute statement.

3.2 Ditton and Merrick model

Ditton and Merrick (2014) developed equations to predict the heights based in panel width as well as extraction thickness specific to Australian mining conditions and geometries (Figure 7). They also extended the concept from rib-side cracking to zones across the full extraction to mirror the Kendorski model.

Zone A is referred to as the Continuous Fracture Zone, with continuous relating to connected fractures to the extraction level. The definition does not highlight the location of the continuous fractures being at the sides of the cave. For a 340 m wide face and 5 m extraction, the central prediction for Zone A only extends to the surface for depths less than 120 m (Figure 7).

Zone B is referred to as Discontinuous Fracture Zone. In a consulting report Ditton stated that: *“Overall the majority of the B Zone is considered to be a “constrained dilated” strata zone, with low connectivity potential to the mine workings. The B Zone therefore represents a sub-surface fracturing zone that causes only minor groundwater system disturbance.”* For a 340 m wide face,

Zone B is present at the surface for depths in excess of 120 m for the central prediction of Zone A or at depth in excess of 170 m for the upper bound prediction of Zone A.

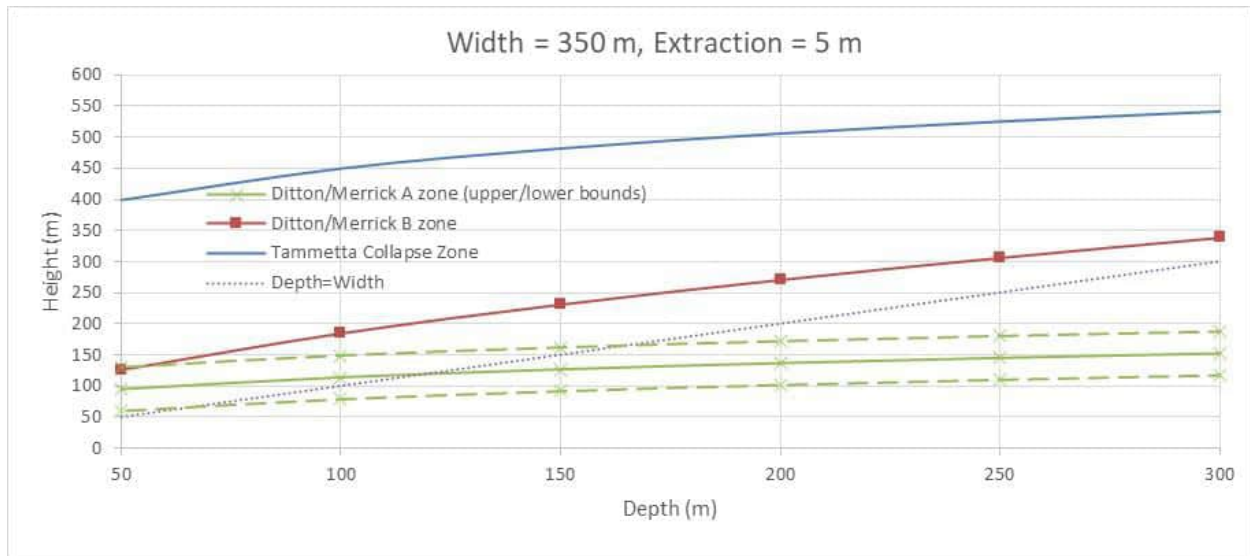


Figure 7 Ditton/Merrick and Tammetta zones

Specific hydraulic conductivity values are not given allocated to the A and B zones.

The application of the Ditton and Merrick method is assessed to be valid for the prediction of mine water inflows. Its application to environmental assessments has been questioned, probably in the context of what is “minor groundwater disturbance”. For a 340 m wide face, the prediction of Zone B conditions at depth in excess of 120m/170m may be at odds with the likely surface subsidence of about 3.5 m indicating chaotic collapse extending to the surface.

3.3 Strata Control Technology model

The ACARP report (SCT 2008) used the FLAC numerical program along with in-house developed FISH codes to examine mine water inflows. FLAC is a continuum code which, by definition, does not consider dilation of fractures. The method is reported to simulate rock failure and hence fracturing and then provide a fracture aperture with a width equal to the non-elastic deformation assuming 1 fracture per element in the model: these widths are then used to calculate conductivity using standard fracture flow equations. Details of the method, including the size of each element, have not been published and hence are not subject to peer review.

The upper diagram in Figure 8 presents an example of the predicted hydraulic conductivity and it is noted that the patterns of conductivity, which are a function of the fracturing, have little resemblance to the physical models. The fracture models are not consistent with the reported ground conditions during overmining.

SCT (2008) also includes a cross plot of mining depth, vertical subsidence and average overburden conductivity. This average conductivity value relates to the average over a vertical profile, presumably at the centreline of the extraction – how it relates to the conductivity in a horizontal plane is not provided noting that the minimum conductivity in a horizontal plane would control inflows from the surface.

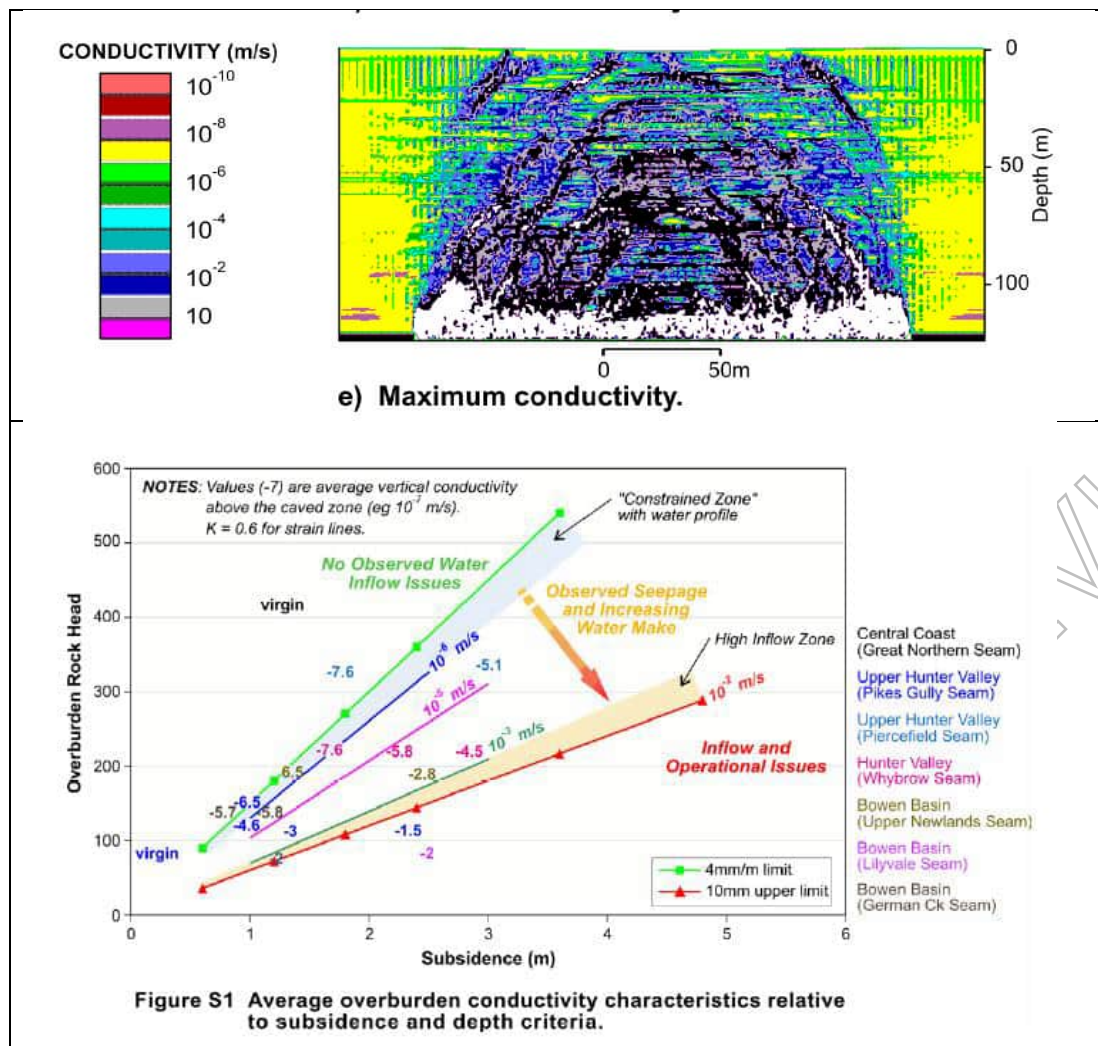


Figure 8 SCT model

4 MODELS FOR SHALLOW GROUNDWATER IMPACT

4.1 Tammetta model

Tammetta (2012) was primarily concerned with the impact of longwall on shallow ground water resources (Figure 9). His work was based on the interpretation of piezometer data to indicate the zone of complete groundwater drainage (unsaturated) which he refers to as the "Collapsed Zone". The maintenance of instrumentation, in particular cabling, is a challenge when differential movements in the caving overburden could be in the order of 1-2 m. The possibility of loss of signal due to cable breakage instead of a drop in the standing water level was not considered. We have concerns about the integrity of the data base that was utilised. The predictive equation for the height of a parabolic-shaped collapsed zone with complete drainage is independent of the overburden geology. The predicted height of his collapsed zone is significantly greater than that for Ditton/Merrick's Zone B (Figure 7) and in all cases implies connection to the surface for a 340 m wide longwall for all depths considered.

Tammetta (2013) provides empirical data on hydraulic conductivity from lugeon testing in boreholes. He presents data that indicate a 2 orders of magnitude increase down the panel centreline within the upper portion of the collapsed zone, and 1 order of magnitude above the collapse zone. There are no data for the lower portion of the collapsed zone but he extrapolates very high values.

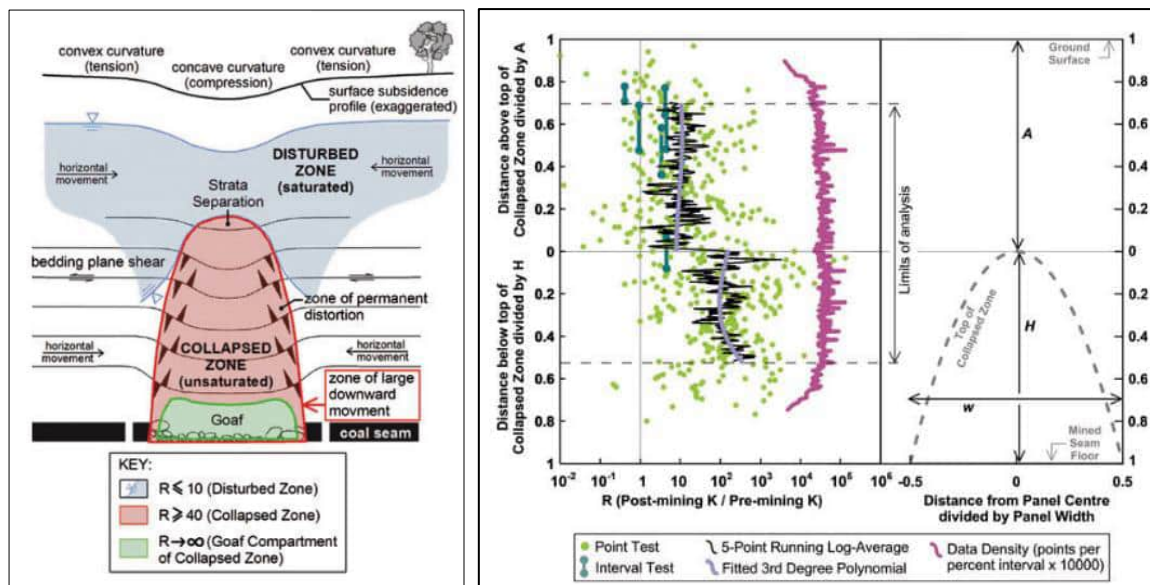


Figure 9 Tammetta's model for the extent and hydraulic conductivity in the Collapsed Zone.

The essential difference is that the Tammetta model allows the prediction of drainage path from the surface to the mine workings over a much greater range of depths compared to the Kendorski and Ditton/Merrick models. The hydraulic conductivity proposed by Tammetta is sufficient to impact shallow groundwater users but not present an inflow hazard to the underground mine.

The conceptual caving model presented in Galvin (2016) combines the Kendorski model with the zones limited by angles of draw with a derivative of the Tammetta collapsed zone within the fractured zone. Kendorski dilated zone is renamed as the constrained zone.

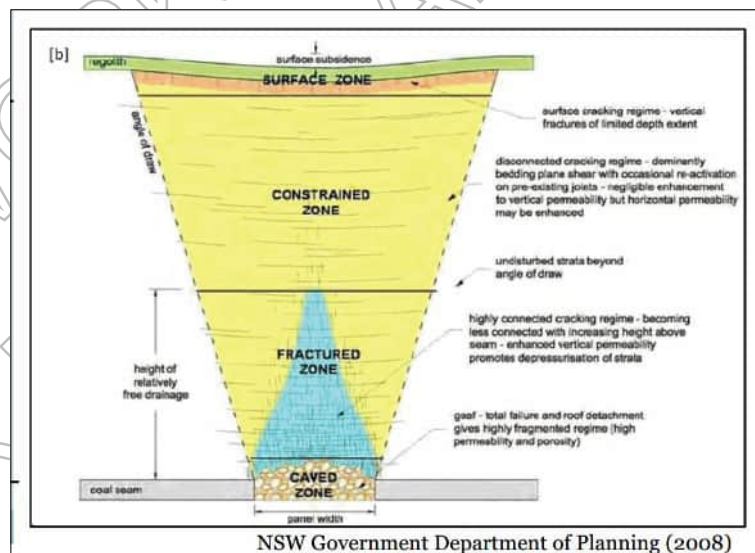


Figure 10 The Mackie conceptual model (Galvin, 2016)

4.2 CSIRO models

In a number of ACARP reports, CSIRO has developed a set of complex DEM (Discrete Element Method), PFC (Particle Flow Code) and finite element simulations to estimate hydraulic conductivity. DEM and PFC offer the possibility of specifically considering apertures which are then imported into

a finite element code to assess hydraulic conductivity. The resulting fracture models are similar to the SCT models (Figure 11) and hence inconsistent with the observed mining conditions and the physical models. The results are presented in terms of changes in the permeability (which is the same as changes in hydraulic conductivity) and show extreme variation – up to 5 orders of magnitude at some depths.

The same limitations for application to mine closure studies are present – not readily accessible, possibly not representative of actual mine conditions, and lack of precision in terms of predicted hydraulic conductivity.

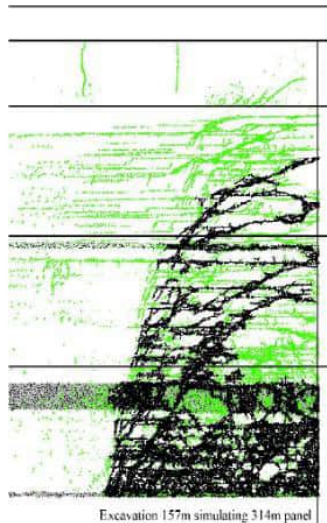


Figure 1 Fractures connected to mine work along the panel width with symmetry on the

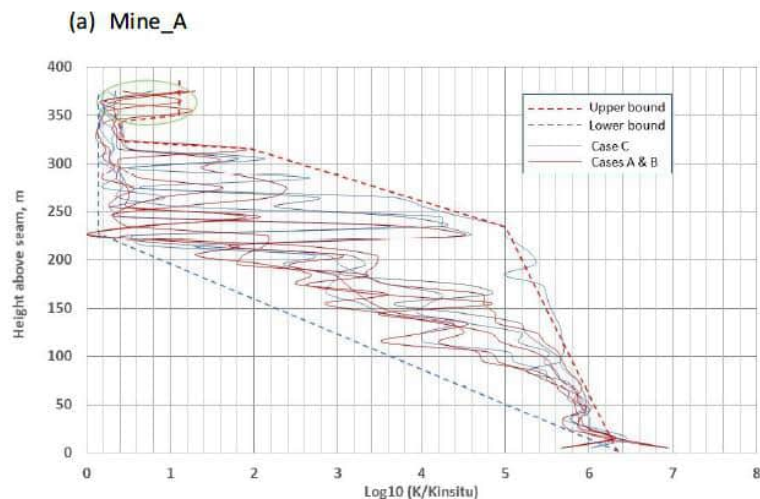


Figure S1 Estimated permeability changes for Mine_A; also plotted are proposed vertical permeability change curves.

Figure 11 CSIRO model

5 GEOTECHNICAL MODEL

5.1 Background

The previous 2 sections of this report outline some of the weaknesses of the available empirical models. In this context, the comment by Gavin (2017)¹

The authors of the five reports relevant to this summary document are consistent in their advice that neither the Tammetta equation nor the Ditton equation for the height of free drainage is robust because neither properly and adequately accounts for geology, the mechanics of rock behaviour and time dependent hydrogeology processes. This has implications for the construction and calibration of some numerical models which have found application to Dendrobium Mine and, hence, to the reliability of predictions based on these models. Models may need to be updated and rerun.

In the past 2 decades Crinum Mine conducted longwalling under a laterally extensive aquifer and as a result of intensive monitoring of ground levels and mine pump outs was able to supply key data to test the predictions of the available empirical models. An alternative model has been developed and reported in 3 peer-reviewed technical papers.

¹ Galvin and Associates Pty Ltd. 2017. Summary and explanation of height of fracturing issues at Dendrobium Mine. Report for NSW Department of Planning and Environment. Report No, 1716-11/1b.

5.2 Inflows to Crinum Mine

Seedsman (2019) analysed several years of mine pump-out data for a shallow longwall mine in the Bowen Basin (Crinum North) that was located under a columnar-jointed basalt aquifer that was recharged three times by rainfall (Figure 12).

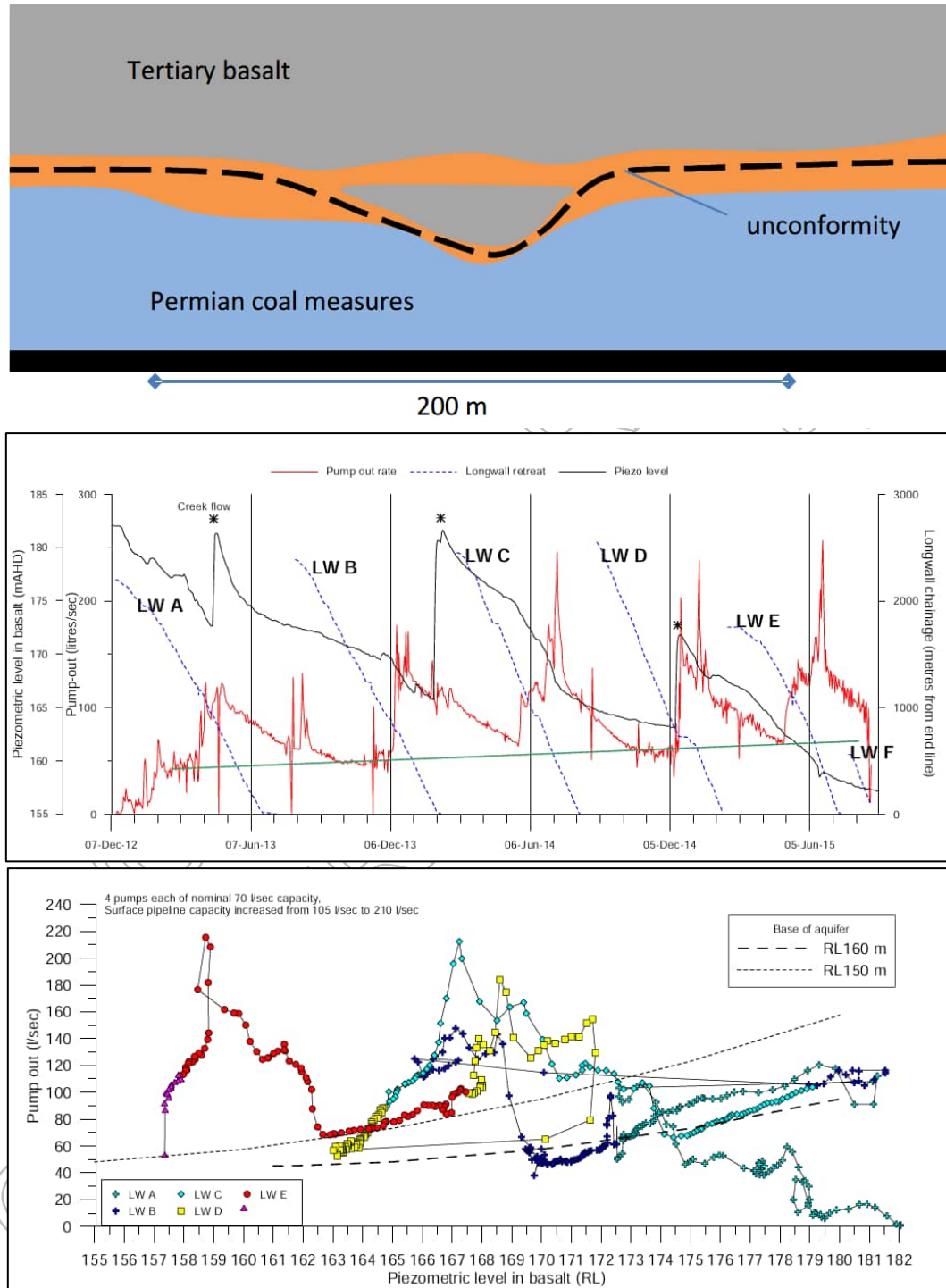


Figure 12 Crinum North: top is geological cross section at natural scale, middle are trends in pump out rates (black line), longwall retreat (dashed blue line), and groundwater level (black line), lower – cross plot of groundwater level and pumpout rate.

The pump-out rates did not increase with the progressive extraction of each longwall panel indicating that inflow was not related to cross-sectional area in a standard Darcian approach. Likewise, the peak pump-out rate did not correspond to the highest groundwater level. It was also noted that pump-outs were not required if the face was not moving, even when the basalt aquifer was recharged. Considering the data in the context of Darcy flow, it was concluded that the inflow paths had different cross-sectional areas and hydraulic conductivity to those in the empirical models.

The proposed explanation was that inflow to the mine was related to a fracture connection to the aquifer that progressed with the retreating longwall face (Figure 13)– this was called the Enhanced Conductivity Zone (ECZ). The explanation also included the possibility of the material at the base of the collapse softening in the presence of water and then consolidating with a consequent major reduction in hydraulic conductivity – this was called the Potential Consolidation Zone (PCZ).

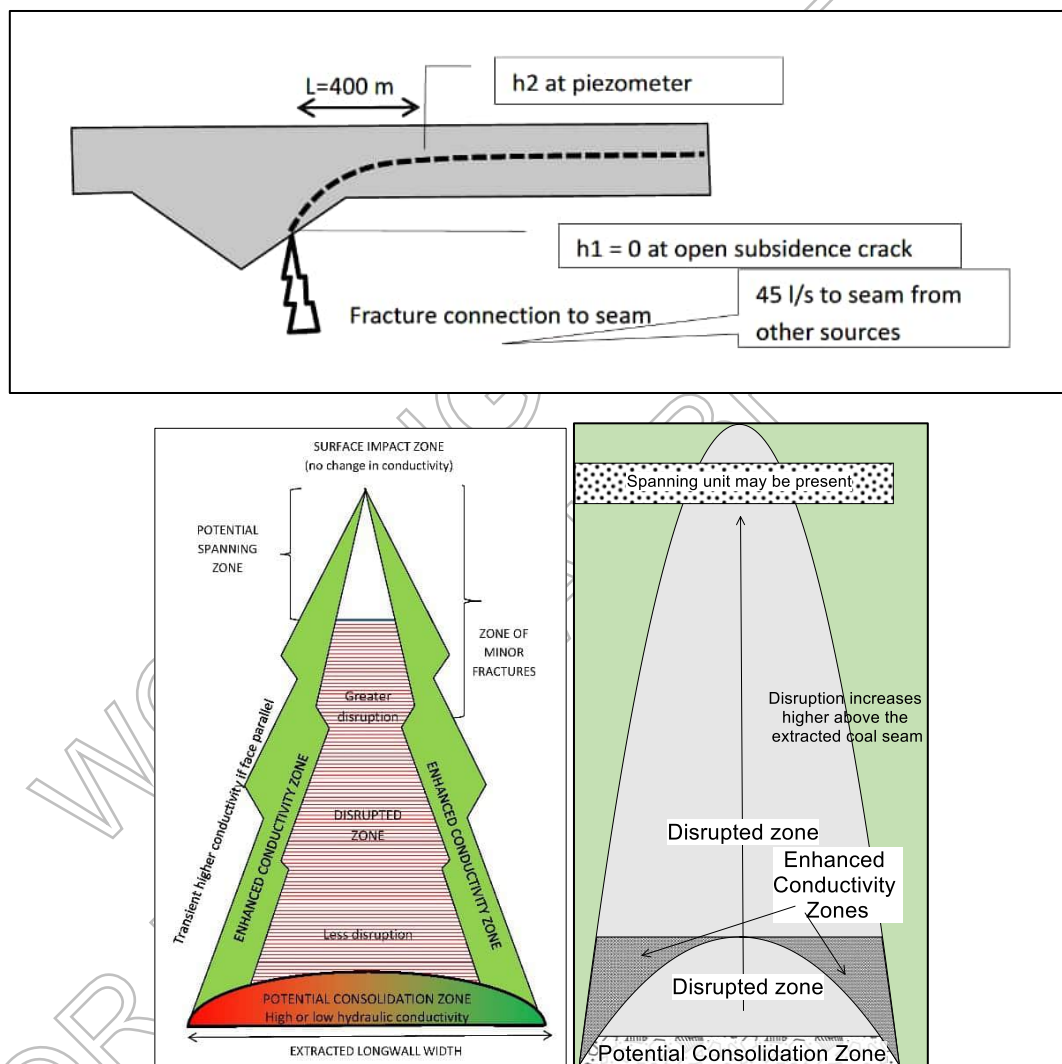


Figure 13 Evolution of the geotechnical model

5.3 Further development

These ideas were further developed in Seedsman (2021, 2023) with the following (Figure 13):

- The simple triangular-shape of the disrupted zone replaced by a parabolic shape following some numerical analysis of failure in bedding rock masses.

- The height of the disrupted zone is a function of the average thickness of the bedded units in the overburden. The default height is two times the extraction width which is equivalent to the panel geometry that represents the step from subcritical to supercritical (Figure 5).
- The ECZ geometry is based on the D zone angles (Figure 2, with overall shape defined by two parabolas. The ECZ is the locus for high inflows so its height should be similar to heights of Kendorski fractured zone or Zone A.
- It was suggested that the limit of spanning deformation would be in the order of 400 mm. A corollary of this was that if the surface subsidence developed between adjacent chain pillars was in excess of this amount then there would be a fracture connection – albeit possibly tortuous – between the surface and the underground workings.

In research examining the possible use of abandoned longwall mines as lower reservoirs for pumped hydroelectric schemes, Seedsman et al (2023) focussed on the likely hydraulic properties of the various zones. Hydraulic conductivity within the ECZ and Disrupted zone was estimated using a simple geometric model (Figure 14) for the increase in length along a given horizontal line because of downward movement and assuming a given spacing of fractures (be they joints or mining induced). The model assumes no dilation at the centreline above the PCZ. The dilation is equally distributed between the fractures and conductivity is calculated based on laminar fracture flow with smooth interfaces. The predicted conductivity is isotropic. The parameters for the PCZ were derived from large scale permeameter tests. Figure 15 presents the data for conductivity and porosity.

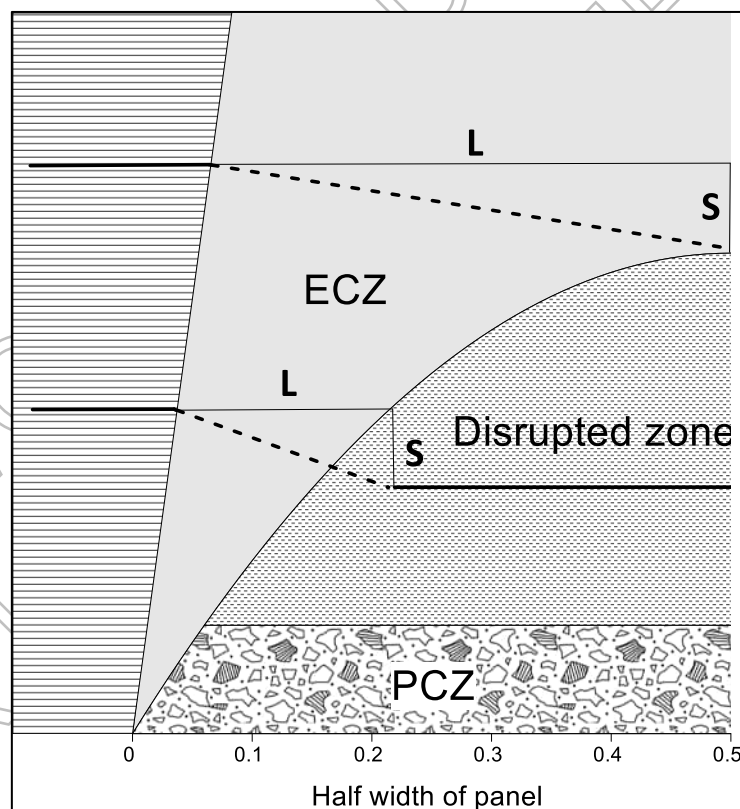


Figure 14 Basis of the geotechnical crack dilation model

The ECZ has conductivities in the order of 0.1-10 m/s with the higher values near the extraction. The values for the PCZ decrease progressively from the edge of the extraction in response to increasing consolidation associated by the progressive increase height of the goaf pile.

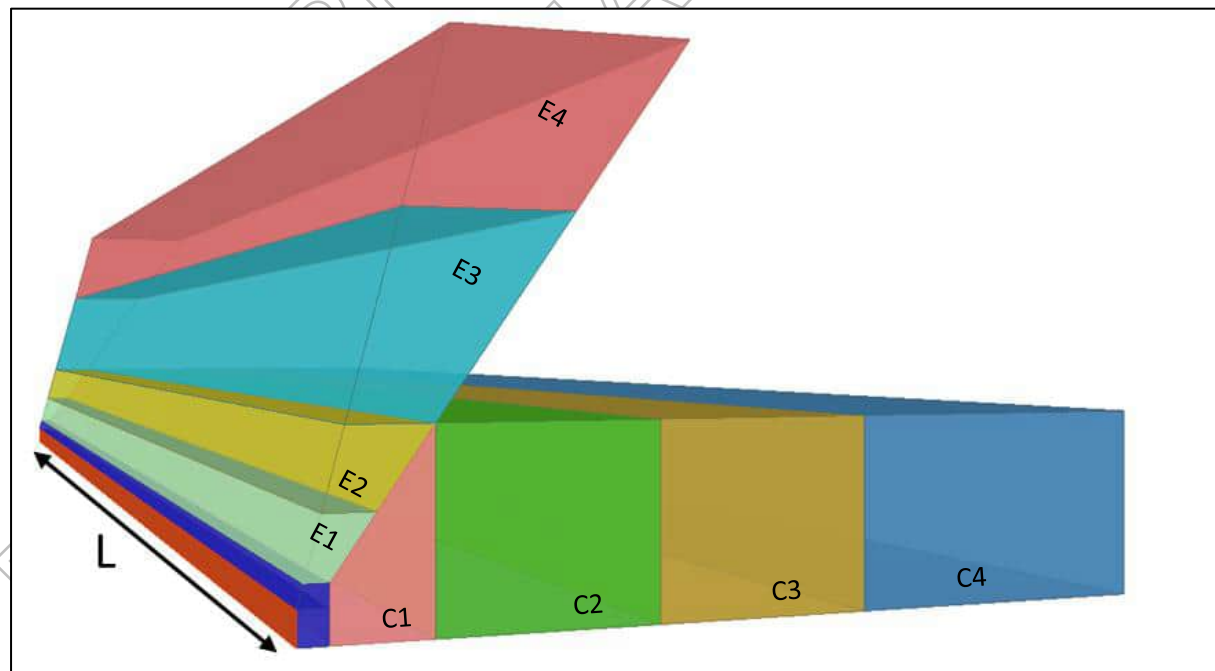
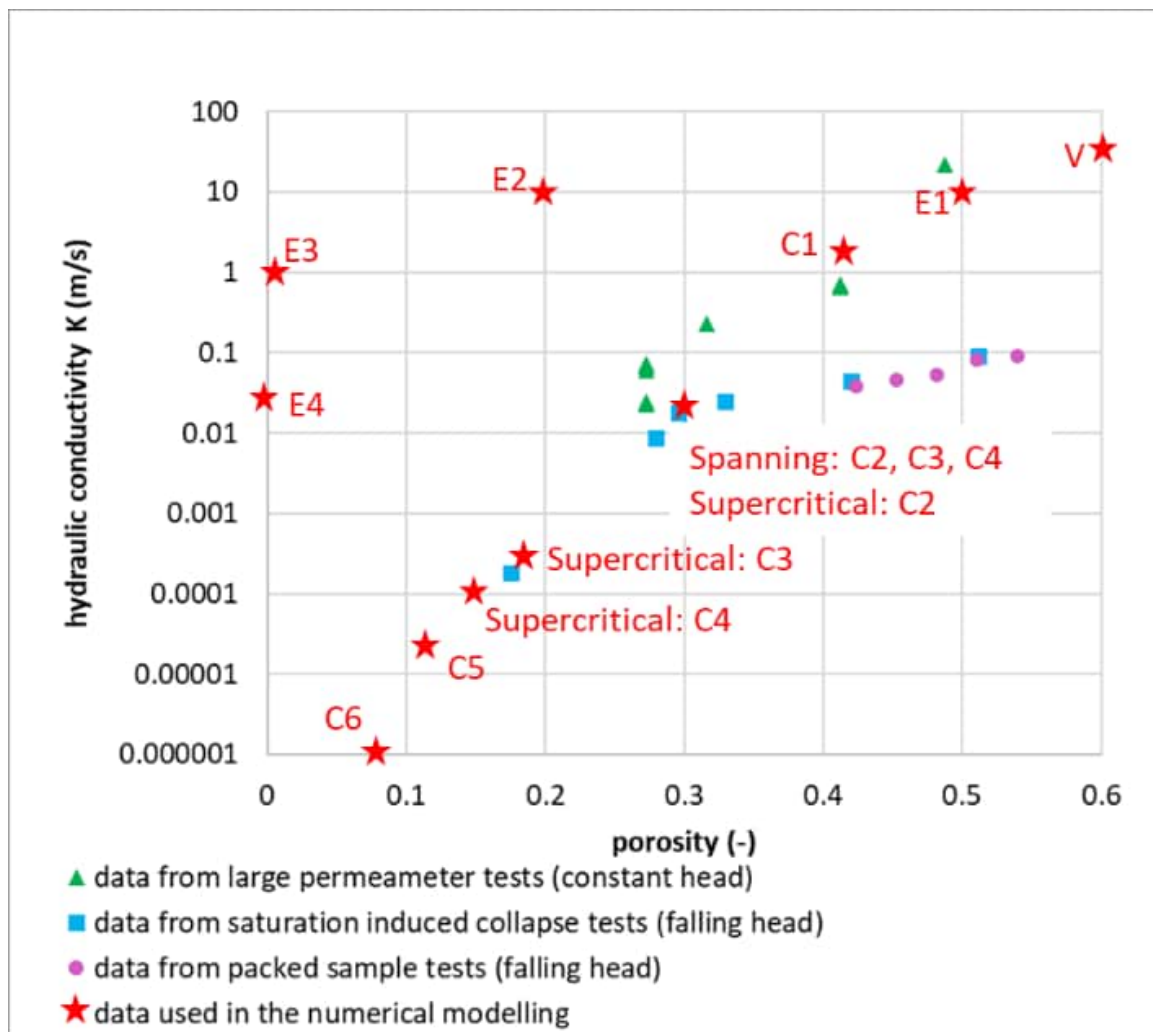


Figure 15 Estimates of the porosity and hydraulic conductivity of longwall goaf material (C1-C6 in the Potential Consolidation Zone, E1-E4 in the Enhanced Conductivity Zone, V is remnants of the initial access roadway).

6 PRCP PREDICTION

The Geotechnical model should be used as the basis for the prediction of hydraulic conductivity associated with the supercritical longwall geometry of BMA's longwall operations. It is important to note that there is no validation of the method available and it is difficult to imagine how it could be done as we are dealing with a large volume. Mine inflows are not useful in this context as they are most likely related to the ECZ and not the larger Disrupted zone and there is the problem of the low conductivity in the PCZ.

The only rock mass property used in the geotechnical model is the spacing of the joints – the rock mass is assumed to be a dilated fractured volume of rigid blocks. The geotechnical model is applicable to the Permian and Tertiary sequences but does not include the possible role of Quaternary and Recent alluvials at the surface.

The input variables to the geotechnical model are:

- Maximum vertical subsidence, or more precisely the difference in the maximum subsidence at /near the panel centreline relative to the subsidence above the chain pillars.
 - The extraction width.
 - The spacing of the cracks – these may be mining-induced or the natural geological joints.
- This is a highly uncertain parameter and its selection will require substantial judgement.

Output from the geotechnical Model includes the conductivity changes up to twice the excavation width – it can be sliced at any actual mining depth.

An example is presented in Figure 16 which also includes a sensitivity study on the choice of fracture spacing.

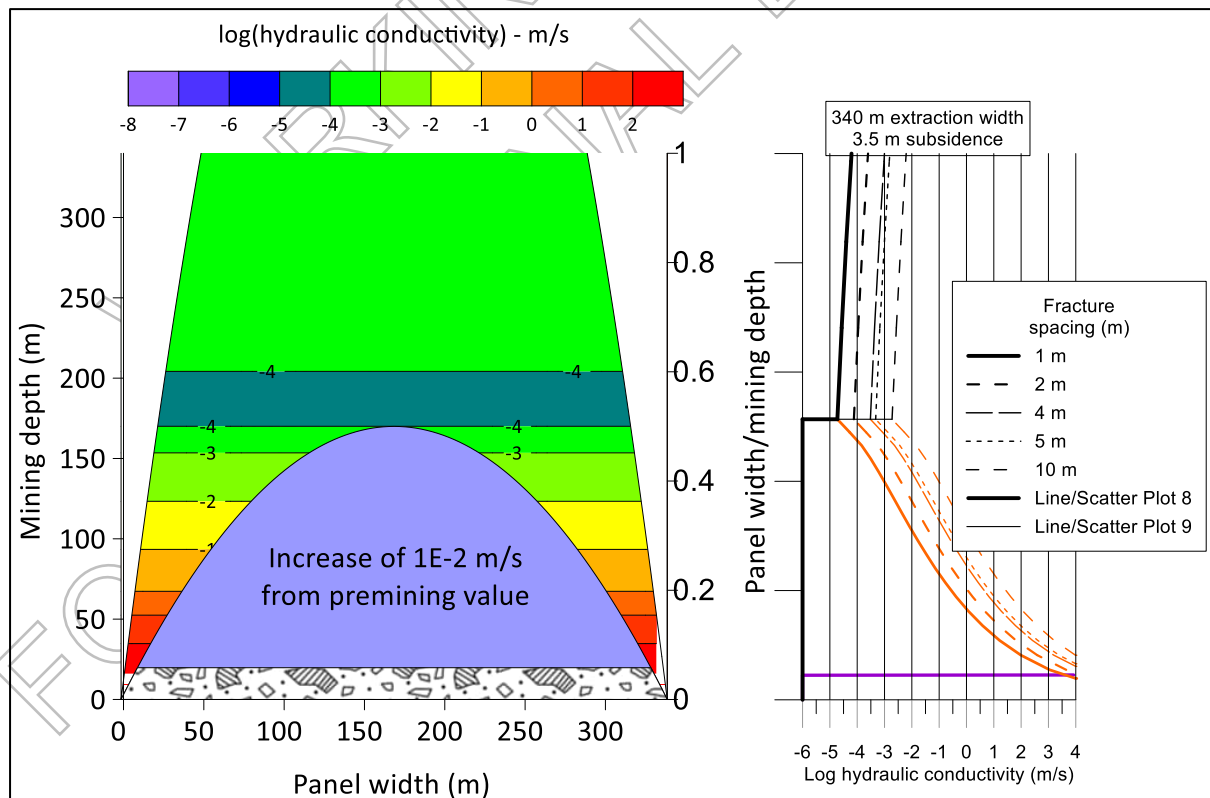


Figure 16 Example of hydraulic conductivity prediction for Broadmeadow with sensitivity to fracture spacing

7 IMPLEMENTATION IN GROUNDWATER STUDIES

7.1 Overburden

It is noted that Byrnes Geotechnical have separately recommended intentional flooding of undergrounds to initiate any subsequent subsidence deformation as soon as possible in order to reduce geotechnical uncertainties.

The geotechnical model could be implemented in groundwater models as follows:

- The surface footprint of the mine should be the edge of the extraction – not the angle of draw that defines the extent of surface subsidence.
- The adopted hydraulic conductivities should be based on a crack spacing of 2 m. The horizontal and vertical conductivities should be equal.
- Porosity – Within in the Disrupted zone: at depths greater than half the panel width the porosity can be calculated as $(\text{seam thickness} - \text{maximum subsidence})/\text{depth}$, At depth < half panel width – no mining-induced changes in porosity.
- Porosity – Within the ECZ

As mentioned in Section 6, there is no available validation of these suggestions.

7.2 Surface cracking

The technical literature consistently reports that there is no evidence that surface cracks are directly connected to the seam, but there will be an indirect connection via the disrupted zone. Site specific studies are recommended to provide data that can be used to confirm the currently available prediction tools.

Whether the cracks stay open will be a function of the surface lithology – sand, clay or rock. For soils the substrate will collapse over time, so the long term impact on the hydraulic conductivity is likely to be negligible.

There will be cracking at the surface where ever the induced tensile strains are in excess of about 5 mm/m. Figure 18 presents a typical subsidence cross line survey and shows how the tensile strains (positive values) develop near the edge of the extraction. The width of any rib side cracks is related to the induced tensile strains which themselves are related to the depth of mining and the extracted seam thickness. An upper bound estimate of the crack width can be derived from tensile strain and the peg spacing – all of the strain is accounted for by 1 crack. So for the example in Figure 18, the maximum tensile strain is 16.5 mm/m, indicating a crack width of 165 mm given that the survey pegs are at 10 m centres.

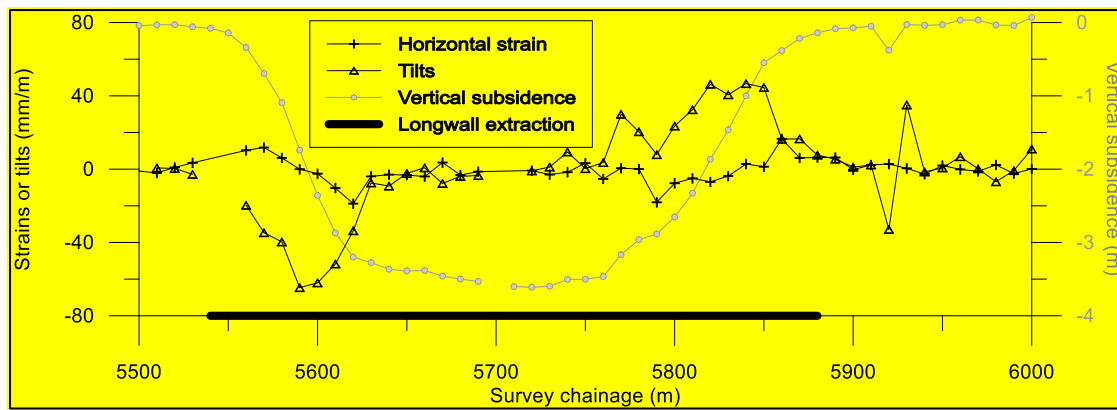


Figure 17 Typical subsidence survey cross line – survey pegs at 10 m centres.

The question of the depth of cracking has not been adequately studied or reported in the technical literature. For the USA mines studied, Kendowski suggested a surface zone that included temporary open fractures with a maximum thickness of 15 m (50 ft) but noted that the fractures did not extend through the full thickness of the zone and were only temporarily open; in 1993 he suggested the same depths and noted that the possibility of filling. It would appear that his case studies involved soils and friable materials at the surface – not rock.

Assuming rigid body movements, the survey data could be used to obtain an estimate of the depth of cracking – crack width/differential tilt either side of the crack. Referring to Figure 18, the maximum strain of 16.5 mm/m implies a crack width of 165 mm and this is associated with a differential tilt of 28 mm/m. The possible depth extent of the crack would be 5.9 m ($0.165/0.028$). Early application of this approach has given depths of up to 20 m for shallow longwall extraction.

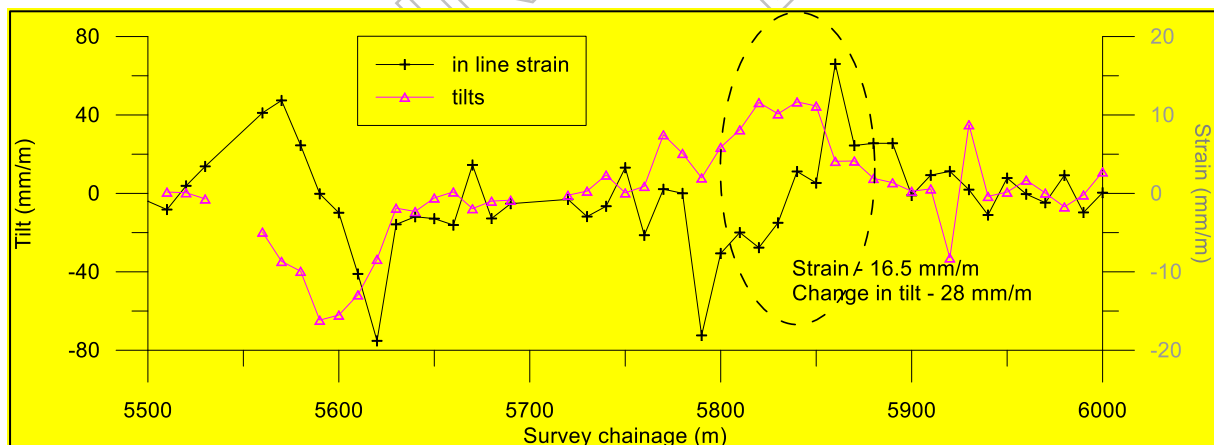


Figure 18 Detail of high strain and high tilt recorded on a subsidence cross line (180 m depth).

7.3 Risks and uncertainties

Any quantification will be challenged as nothing validated and not possible without case studies.

Can improve surface crack knowledge but unlikely to be material if there is a soil cover.

Inevitable that undergrounds will fill from the portal as bulkheads are not installed so surface infiltration may not be material.

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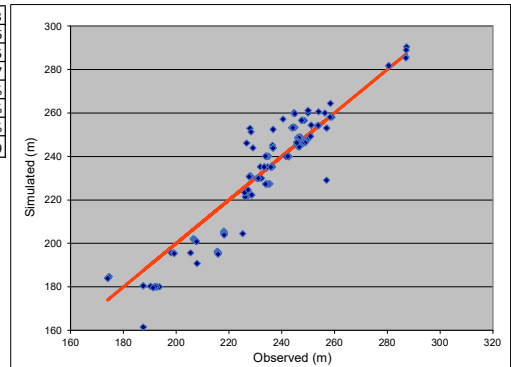
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Appendix C

Calibration

Well	Easting	Northing	Obs (m)	Cal (m)	Obs Cal	Res*2	Layer
DR-BH01	601292.419	7584122.067	226.6	2.22E+02	4.79	22.97285	4
DR-BH01	601292.419	7584122.067	226.9	2.22E+02	5.14	26.40932	4
DR-BH01	601292.419	7584122.067	226.9	2.22E+02	5.16	26.60496	4
DR-BH01	601292.419	7584122.067	226.9	2.22E+02	5.18	26.87386	4
DR-BH01	601292.419	7584122.067	226.8	2.22E+02	5.11	26.07124	4
DR-BH01	601292.419	7584122.067	226.8	2.22E+02	5.13	26.35796	4
DR-BH01	601292.419	7584122.067	226.7	2.22E+02	5.05	25.5126	4
DR-BH01	601292.419	7584122.067	226.4	2.22E+02	4.81	23.14572	4
DR-BH01	601292.419	7584122.067	226.3	2.22E+02	4.74	22.44864	4
DR-BH01	601292.419	7584122.067	226.2	2.22E+02	4.66	21.68765	4
DR-BH01	601292.419	7584122.067	226.1	2.22E+02	4.60	21.1416	4
DR-BH02	601301.669	7584005.468	226.6	2.24E+02	2.92	8.503056	4
DR-BH02	601301.669	7584005.468	226.8	2.24E+02	3.15	9.941409	4
DR-BH02	601301.669	7584005.468	226.8	2.24E+02	3.17	10.0489	4
DR-BH02	601301.669	7584005.468	226.9	2.24E+02	3.29	10.83726	4
DR-BH02	601301.669	7584005.468	226.8	2.24E+02	3.21	10.3041	4
DR-BH02	601301.669	7584005.468	226.7	2.24E+02	3.13	9.821956	4
DR-BH02	601301.669	7584005.468	226.6	2.24E+02	3.05	9.296401	4
DR-BH02	601301.669	7584005.468	226.4	2.23E+02	2.90	8.415801	4
DR-BH02	601301.669	7584005.468	226.2	2.23E+02	2.72	7.425625	4
DR-BH02	601301.669	7584005.468	226.1	2.23E+02	2.64	6.980164	4
DR-BH02	601301.669	7584005.468	225.9	2.23E+02	2.48	6.1504	4
DR-BH04	601335.479	7583739.129	174.6	1.85E+02	-10.12	102.3335	6
DR-BH04	601335.479	7583739.129	174.5	1.85E+02	-10.11	102.2728	6
DR-BH04	601335.479	7583739.129	174	1.84E+02	-10.19	103.8157	6
DR-BH04	601335.479	7583739.129	174.1	1.84E+02	-9.97	99.38096	6
DR-BH04	601335.479	7583739.129	174	1.84E+02	-10.00	99.90003	6
GN2480	603095.291	7607320.428	280.55	2.82E+02	-1.25	1.552516	1
GN2480	603095.291	7607320.428	280.54	2.82E+02	-1.21	1.466521	1
GN2481	603318.181	7607579.166	287.07	2.86E+02	1.24	1.545049	1
GN2481	603318.181	7607579.166	286.98	2.85E+02	1.61	2.601769	1
GN2482	603024.531	7608167.823	287.27	2.91E+02	-3.27	10.71253	1
GN2482	603024.531	7608167.823	287.09	2.89E+02	-1.85	3.433609	1
GRM_BH1	598515.474	7587336.538	249.5	2.48E+02	1.96	3.849444	1
GRM_BH1	598515.474	7587336.538	249	2.47E+02	1.81	3.286969	1
GRM_BH1	598515.474	7587336.538	248.9	2.47E+02	1.81	3.283344	1
GRM_BH1	598515.474	7587336.538	248.9	2.47E+02	1.89	3.556996	1
GRM_BH1	598515.474	7587336.538	248.8	2.47E+02	1.93	3.721041	1
GRM_BH1	598515.474	7587336.538	248.8	2.47E+02	2.03	4.108729	1
GRM_BH1	598515.474	7587336.538	248.7	2.47E+02	2.03	4.1209	1
GRM_BH1	598515.474	7587336.538	248.7	2.47E+02	2.08	4.343056	1
GRM_BH1	598515.474	7587336.538	248.9	2.47E+02	2.38	5.640625	1
GRM_BH1	598515.474	7587336.538	249	2.46E+02	2.55	6.492304	1
GRM_BH1	598515.474	7587336.538	248.9	2.46E+02	2.54	6.4516	1
GRM_BH11	598003.996	7586750.999	240.5	2.57E+02	-16.71	279.3244	1
GRM_BH1A	598508.847	7587324.113	236.4	2.45E+02	-8.77	76.87782	4
GRM_BH1A	598508.847	7587324.113	236.6	2.44E+02	-7.59	57.62328	4
GRM_BH1A	598508.847	7587324.113	236.7	2.44E+02	-7.43	55.24949	4
GRM_BH1A	598508.847	7587324.113	236.7	2.44E+02	-7.26	52.63503	4
GRM_BH1A	598508.847	7587324.113	236.7	2.44E+02	-7.15	51.1368	4
GRM_BH2	598384.785	7587059.009	247.3	2.46E+02	1.27	1.610361	1
GRM_BH2	598384.785	7587059.009	246.9	2.46E+02	1.26	1.580049	1
GRM_BH2	598384.785	7587059.009	246.6	2.46E+02	1.06	1.1236	1
GRM_BH2	598384.785	7587059.009	246.5	2.45E+02	1.04	1.077444	1
GRM_BH2	598384.785	7587059.009	246.1	2.45E+02	0.89	0.793831	1
GRM_BH2	598384.785	7587059.009	246.1	2.45E+02	0.99	0.988036	1
GRM_BH2	598384.785	7587059.009	246	2.45E+02	0.95	0.908209	1
GRM_BH2	598384.785	7587059.009	246	2.45E+02	1.05	1.096209	1
GRM_BH2	598384.785	7587059.009	246.2	2.45E+02	1.32	1.750329	1
GRM_BH3	598539.067	7586975.078	247.7	2.46E+02	1.99	3.976036	1
GRM_BH3	598539.067	7586975.078	247.2	2.45E+02	1.90	3.625216	1
GRM_BH3	598539.067	7586975.078	246.9	2.45E+02	1.71	2.934369	1
GRM_BH3	598539.067	7586975.078	246.6	2.45E+02	1.50	2.238016	1
GRM_BH3	598539.067	7586975.078	246.4	2.45E+02	1.46	2.128681	1
GRM_BH3	598539.067	7586975.078	246.3	2.45E+02	1.47	2.146225	1
GRM_BH3	598539.067	7586975.078	246.2	2.45E+02	1.48	2.205225	1
GRM_BH3	598539.067	7586975.078	246.1	2.45E+02	1.44	2.079364	1
GRM_BH3	598539.067	7586975.078	246.2	2.45E+02	1.64	2.686321	1
GRM_BH3	598539.067	7586975.078	246.5	2.44E+02	2.02	4.0804	1
GRM_BH3	598539.067	7586975.078	246.6	2.44E+02	2.22	4.919524	1
GRMMB1001	599908.557	7584131.005	228.6	2.22E+02	6.25	39.0375	1
GRMMB1001	599908.557	7584131.005	228.6	2.22E+02	6.25	39.11252	1
GRMMB1001	599908.557	7584131.005	228.6	2.22E+02	6.26	39.21264	1
GRMMB1002	599903.255	7584138.951	205.4	1.96E+02	9.67	93.45089	14
GRMMB1002	599903.255	7584138.951	198	1.96E+02	2.28	5.193841	14
GRMMB1002	599903.255	7584138.951	198.9	1.96E+02	3.28	10.7584	14
GRMMB1002	599903.255	7584138.951	199.1	1.95E+02	3.60	12.9672	14
GRMMB1002	599903.255	7584138.951	199.2	1.95E+02	3.83	14.69956	14
GRM_MB_102_02	600178.596	7584579.081	187.5	1.81E+02	6.94	48.20525	12
GRM_MB_102_02	600178.596	7584579.081	187.5	1.81E+02	7.00	49	12
GRM_MB_103_02	600832.376	7584437.281	207.9	1.91E+02	17.06	291.0436	14
GRM_MB_104_01	596513.999	7592622	250	2.60E+02	-10.09	101.8888	1
GRM_MB_105_01	596871.731	7592581.368	250	2.61E+02	-11.20	125.5296	1
GRM_MB_119	597460	7587279.999	259	2.58E+02	0.90	0.813604	1
GRM_MB_119	597460	7587279.999	258.3	2.58E+02	0.21	0.045369	1
GRM_MB_120_01	598018.995	7587281.999	253.7	2.54E+02	-0.57	0.328329	1
GRM_MB_120_01	598018.995	7587281.999	253.7	2.54E+02	-0.57	0.327184	1
GRM_MB_120_01	598018.995	7587281.999	253.7	2.54E+02	-0.57	0.327184	1
GRM_MB_120_01	598018.995	7587281.999	253.5	2.54E+02	-0.77	0.599076	1
GRM_MB_120_01	598018.995	7587281.999	253.9	2.54E+02	-0.37	0.139876	1
GRM_MB_120_01	598018.995	7587281.999	253.8	2.54E+02	-0.47	0.224676	1

Mean Error	0.73
RMSE	8.66
SD	8.65
Head range	113.27
Scaled ME	0.64%
Scaled RMSE	7.6%
Scaled SD	7.6%
R ²	0.89

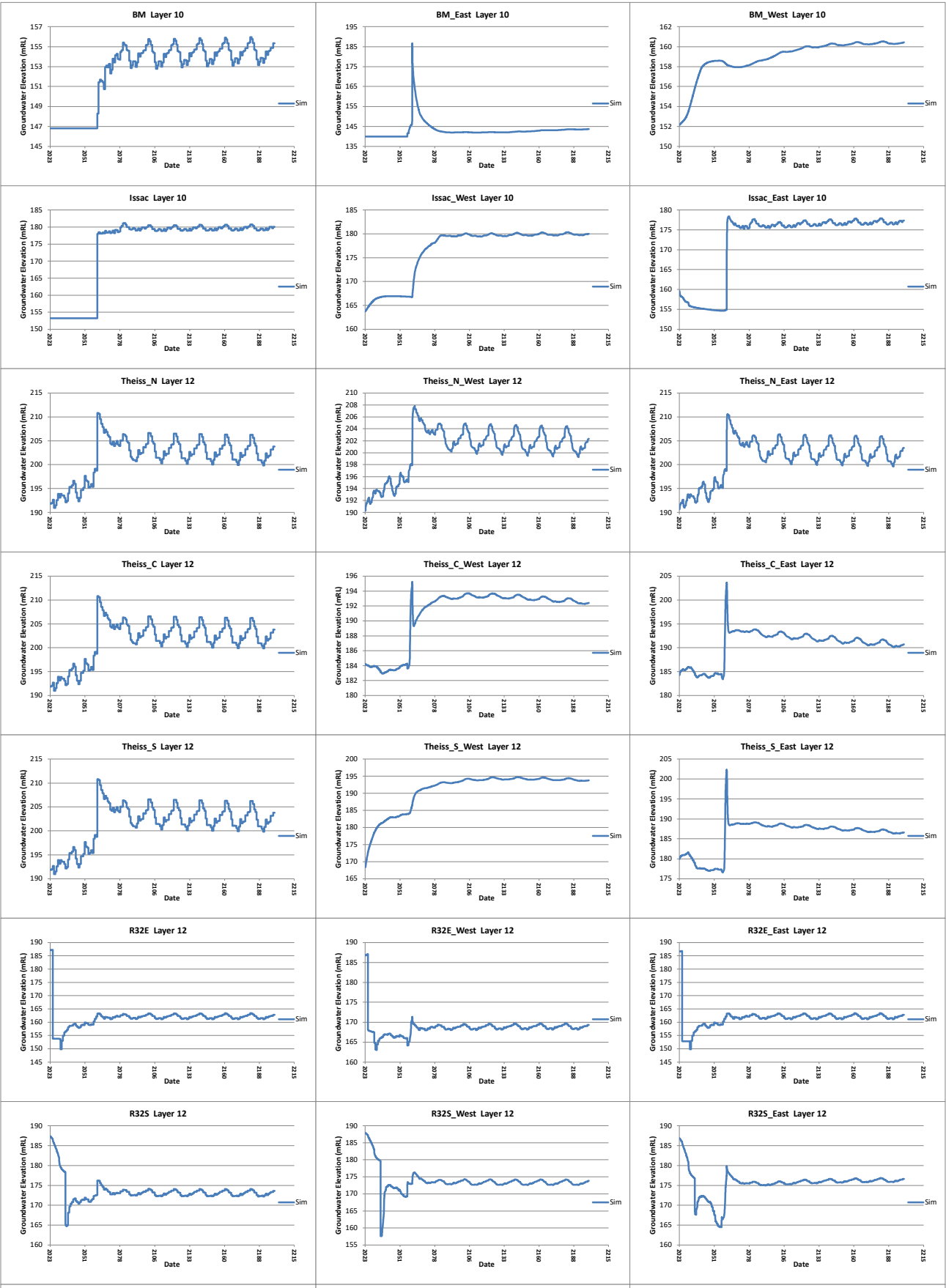


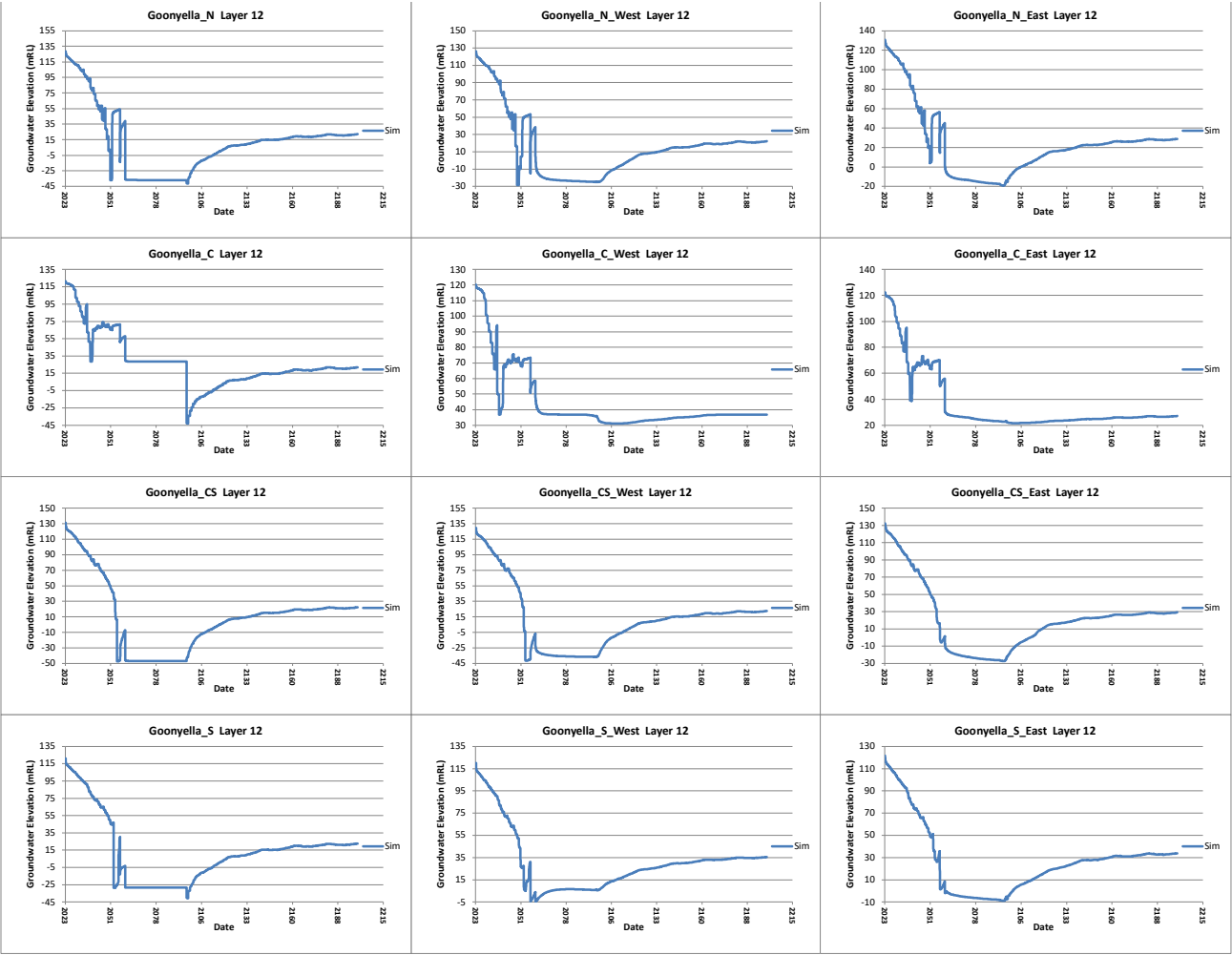
GRM_MB_120_01	598018.995	7587281.999	253.8	2.54E+02	-0.47	0.224676	1
GRM_MB_121	597466.001	7587106.999	244.5	2.60E+02	-15.46	239.0734	1
GRM_MB_121	597466.001	7587106.999	244.6	2.60E+02	-15.36	235.991	1
GRM_MB_121	597466.001	7587106.999	244.6	2.60E+02	-15.36	236.0525	1
GRM_MB_121	597466.001	7587106.999	244.7	2.60E+02	-15.26	232.9897	1
GRM_MB_121	597466.001	7587106.999	244.7	2.60E+02	-15.26	232.9897	1
GRM_MB_122_02	598212.995	7586970	245	2.53E+02	-8.44	71.30114	1
GRM_MB_122_02	598212.995	7586970	244.8	2.53E+02	-8.64	74.6496	1
GRM_MB_122_02	598212.995	7586970	244.5	2.53E+02	-8.93	79.79849	1
GRM_MB_122_02	598212.995	7586970	244.4	2.53E+02	-9.03	81.59509	1
GRM_MB_122_02	598212.995	7586970	244.4	2.53E+02	-9.03	81.59509	1
GRM_MB_122_02	598212.995	7586970	244.4	2.53E+02	-9.03	81.57702	1
GRM_MB_122_02	598212.995	7586970	244.5	2.53E+02	-8.93	79.78062	1
GRM_MB_123	598555.005	7586722.999	247.1	2.49E+02	-1.87	3.500641	1
GRM_MB_123	598555.005	7586722.999	246.8	2.49E+02	-2.12	4.477456	1
GRM_MB_123	598555.005	7586722.999	246.6	2.49E+02	-2.28	5.180176	1
GRM_MB_123	598555.005	7586722.999	246.2	2.49E+02	-2.55	6.477025	1
GRM_MB_123	598555.005	7586722.999	246.1	2.49E+02	-2.59	6.7081	1
GRM_MB_123	598555.005	7586722.999	246	2.49E+02	-2.66	7.091569	1
GRM_MB_123	598555.005	7586722.999	246.2	2.49E+02	-2.42	5.841889	1
GRM_MB_123	598555.005	7586722.999	246.4	2.49E+02	-2.18	4.743684	1
GRM_MB_123	598555.005	7586722.999	246.5	2.49E+02	-2.03	4.116841	1
GRM_MB_126	598346.468	7586716.581	246.2	2.47E+02	-0.91	0.824464	1
GRM_MB_126	598346.468	7586716.581	246	2.47E+02	-0.94	0.876096	1
GRM_MB_126	598346.468	7586716.581	245.8	2.47E+02	-0.89	0.793881	1
GRM_MB_126	598346.468	7586716.581	245.7	2.47E+02	-0.89	0.799236	1
GRM_MB_126	598346.468	7586716.581	245.7	2.47E+02	-0.84	0.703921	1
GRM_MB_126	598346.468	7586716.581	245.7	2.46E+02	-0.75	0.567009	1
GRM_MB_126	598346.468	7586716.581	245.7	2.46E+02	-0.68	0.4624	1
GRM_MB0202	598326.116	7591515.466	227.3	2.25E+02	2.53	6.416089	14
GRM_MB0303	603153.027	7582829.14	187.5	1.61E+02	26.02	676.9884	14
GRM_MB0402	606839.503	7599011.499	251.1	2.54E+02	-3.30	10.91642	1
GRM_MB0402	606839.503	7599011.499	251.1	2.54E+02	-3.30	10.91642	1
GRM_MB0403	606839.003	7599010.999	250.9	2.49E+02	1.59	2.515396	2
GRM_MB0403	606839.003	7599010.999	250.9	2.49E+02	1.59	2.515396	2
GRM_MB104	596513.999	7592622	256.3	2.60E+02	-3.80	14.46281	1
GW004A	604809	7590705	235	2.40E+02	-5.10	26.05082	1
GW004A	604809	7590705	234.5	2.40E+02	-5.62	31.55069	1
GW004A	604809	7590705	234.3	2.40E+02	-5.82	33.90733	1
GW004A	604809	7590705	234.2	2.40E+02	-5.93	35.21236	1
GW004A	604809	7590705	234.3	2.40E+02	-5.84	34.12896	1
GW004A	604809	7590705	234.2	2.40E+02	-5.95	35.3906	1
GW004A	604809	7590705	234	2.40E+02	-6.16	37.88403	1
GW004A	604809	7590705	233.8	2.40E+02	-6.36	40.43688	1
GW004B	604809	7590705	231.6	2.30E+02	1.60	2.56	2
GW004B	604809	7590705	230.5	2.30E+02	0.50	0.25	2
GW004B	604809	7590705	231.3	2.30E+02	1.30	1.69	2
GW004B	604809	7590705	231.3	2.30E+02	1.30	1.692601	2
GW004B	604809	7590705	232.3	2.30E+02	2.30	5.294601	2
GW004B	604809	7590705	231.2	2.30E+02	1.20	1.444804	2
GW004B	604809	7590705	231	2.30E+02	1.00	1.004004	2
GW004B	604809	7590705	231.1	2.30E+02	1.10	1.216609	2
GW007A	604966	7596895	257	2.53E+02	3.89	15.10877	1
GW007A	604966	7596895	256.9	2.53E+02	3.77	14.22044	1
GW007B	604966	7596895	242.6	2.40E+02	2.60	6.754801	2
GW007B	604966	7596895	242.6	2.40E+02	2.59	6.723649	2
GW007B	604966	7596895	242.6	2.40E+02	2.59	6.702921	2
GW007B	604966	7596895	242.7	2.40E+02	2.68	7.193124	2
GW007B	604966	7596895	242.6	2.40E+02	2.58	6.646084	2
GW007B	604966	7596895	242.6	2.40E+02	2.57	6.6049	2
GW007B	604966	7596895	241.6	2.40E+02	1.56	2.442969	2
GW007B	604966	7596895	242.6	2.40E+02	2.55	6.522916	2
GW007B	604966	7596895	242.3	2.40E+02	2.25	5.044516	2
MB20GRM05T	596804	7594820	258.4	2.64E+02	-6.05	36.56621	1
MB20GRM06A	599996.347	7582044.539	228	2.31E+02	-3.01	9.048064	1
MB20GRM06A	599996.347	7582044.539	228.1	2.31E+02	-2.89	8.3521	1
MB20GRM06A	599996.347	7582044.539	228.2	2.31E+02	-2.75	7.568001	1
MB20GRM06A	599996.347	7582044.539	228	2.31E+02	-2.91	8.444836	1
MB20GRM06A	599996.347	7582044.539	227.9	2.31E+02	-2.98	8.8804	1
MB20GRM06A	599996.347	7582044.539	227.9	2.31E+02	-2.96	8.785296	1
MB20GRM06A	599996.347	7582044.539	227.8	2.31E+02	-3.03	9.199089	1
MB20GRM06A	599996.347	7582044.539	227.7	2.31E+02	-3.11	9.665881	1
MB20GRM06A	599996.347	7582044.539	227.6	2.31E+02	-3.18	10.13786	1
MB20GRM07P	600004.181	7582053.168	218	2.06E+02	12.33	152.0536	4
MB20GRM07P	600004.181	7582053.168	218	2.06E+02	12.49	155.9252	4
MB20GRM07P	600004.181	7582053.168	218.1	2.05E+02	12.90	166.4358	4
MB20GRM07P	600004.181	7582053.168	218.1	2.05E+02	13.25	175.536	4
MB20GRM07P	600004.181	7582053.168	218.1	2.05E+02	13.44	180.7411	4
MB20GRM07P	600004.181	7582053.168	225.2	2.05E+02	20.67	427.0836	4
MB20GRM07P	600004.181	7582053.168	218.2	2.04E+02	13.89	192.9043	4
MB20GRM07P	600004.181	7582053.168	218.2	2.04E+02	14.06	197.768	4
MB20GRM07P	600004.181	7582053.168	218.2	2.04E+02	14.25	203.1195	4
MB20GRM08P	597829.347	7601264.539	253.9	2.61E+02	-6.67	44.4889	14
MB20GRM10T	598124.347	7593518.539	244.9	2.60E+02	-14.90	222.0994	14
MB20GRM11T	596740.566	7588713.433	227.9	2.53E+02	-25.08	629.0566	14
MB20GRM11T	596740.566	7588713.433	228.4	2.51E+02	-22.90	524.3184	14
MB20GRM12A	598157.658	7587227.806	244.7	2.53E+02	-8.70	75.75962	1
MB20GRM12A	598157.658	7587227.806	244.6	2.53E+02	-8.77	76.9129	1
MB20GRM12A	598157.658	7587227.806	244.3	2.53E+02	-9.06	82.06548	1
MB20GRM12A	598157.658	7587227.806	244.1	2.53E+02	-9.25	85.5625	1
MB20GRM12A	598157.658	7587227.806	244.1	2.53E+02	-9.23	85.22982	1
MB20GRM12A	598157.658	7587227.806	243.9	2.53E+02	-9.42	88.7364	1

MB20GRM12A	598157.658	7587227.806	243.8	2.53E+02	-9.51	90.4401	1
MB20GRM12A	598157.658	7587227.806	243.7	2.53E+02	-9.61	92.27524	1
MB20GRM12A	598157.658	7587227.806	243.9	2.53E+02	-9.40	88.30361	1
MB20GRM12A	598157.658	7587227.806	244.1	2.53E+02	-9.19	84.43772	1
MB20GRM12A	598157.658	7587227.806	244.2	2.53E+02	-9.08	82.42824	1
MB20GRM13T	598174.595	7587205.887	226.7	2.46E+02	-19.48	379.2756	4
MB20GRM13T	598174.595	7587205.887	229	2.44E+02	-15.00	224.88	4
MB20GRM15T	599509.748	7584101.525	236.4	2.35E+02	1.14	1.290496	1
MB20GRM15T	599509.748	7584101.525	236.4	2.35E+02	1.15	1.329409	1
MB20GRM15T	599509.748	7584101.525	231.9	2.35E+02	-3.34	11.14224	1
MB20GRM15T	599509.748	7584101.525	236	2.35E+02	0.77	0.594441	1
MB20GRM15T	599509.748	7584101.525	234.6	2.35E+02	-0.62	0.378225	1
MB20GRM15T	599509.748	7584101.525	233.4	2.35E+02	-1.80	3.250809	1
MB20GRM15T	599509.748	7584101.525	233.3	2.35E+02	-1.90	3.598609	1
MB20GRM15T	599509.748	7584101.525	235.9	2.35E+02	0.77	0.591361	1
MB20GRM15T	599509.748	7584101.525	235.9	2.35E+02	0.78	0.6084	1
MB20GRM16P	599508.681	7584096.733	206.4	2.02E+02	4.21	17.68203	14
MB20GRM16P	599508.681	7584096.733	206.7	2.02E+02	4.71	22.2218	14
MB20GRM16P	599508.681	7584096.733	206.8	2.02E+02	4.91	24.09828	14
MB20GRM16P	599508.681	7584096.733	206.8	2.02E+02	5.00	25.02	14
MB20GRM16P	599508.681	7584096.733	206.8	2.02E+02	5.12	26.24513	14
MB20GRM16P	599508.681	7584096.733	207.1	2.02E+02	5.53	30.52563	14
MB20GRM16P	599508.681	7584096.733	207.2	2.02E+02	5.68	32.27376	14
MB20GRM16P	599508.681	7584096.733	207.1	2.01E+02	5.95	35.36681	14
MB20GRM16P	599508.681	7584096.733	207.5	2.01E+02	6.40	40.99841	14
MB20GRM16P	599508.681	7584096.733	207.6	2.01E+02	6.61	43.70532	14
MB20GRM16P	599508.681	7584096.733	207.7	2.01E+02	6.82	46.55333	14
MB20GRM18P	600039.475	7584114.619	215.5	1.96E+02	19.01	361.3801	14
MB20GRM18P	600039.475	7584114.619	215.6	1.96E+02	19.31	372.992	14
MB20GRM18P	600039.475	7584114.619	215.7	1.96E+02	19.60	383.964	14
MB20GRM18P	600039.475	7584114.619	215.8	1.96E+02	19.82	392.7928	14
MB20GRM18P	600039.475	7584114.619	215.8	1.96E+02	19.92	396.8462	14
MB20GRM18P	600039.475	7584114.619	215.8	1.96E+02	19.98	399.0406	14
MB20GRM18P	600039.475	7584114.619	215.8	1.96E+02	20.22	409.0102	14
MB20GRM18P	600039.475	7584114.619	215.7	1.95E+02	20.22	408.7675	14
MB20GRM18P	600039.475	7584114.619	215.8	1.95E+02	20.37	415.0999	14
MB20GRM18P	600039.475	7584114.619	215.8	1.95E+02	20.48	419.3485	14
MB20GRM18P	600039.475	7584114.619	215.8	1.95E+02	20.60	424.2364	14
MB20GRM18P	600039.475	7584114.619	215.8	1.95E+02	20.73	429.8573	14
MB21GRM03P	597032.115	7592090.401	236.7	2.52E+02	-15.76	248.2515	14
MB21GRM81P	598649.845	7588659.261	256.9	2.29E+02	27.82	773.7855	14
MB21GRM82T	597564.531	7587465.928	247.7	2.57E+02	-8.92	79.54856	1
MB21GRM82T	597564.531	7587465.928	248.6	2.57E+02	-8.01	64.17612	1
MB21GRM82T	597564.531	7587465.928	247.7	2.57E+02	-8.91	79.31684	1
MB21GRM82T	597564.531	7587465.928	247.6	2.57E+02	-9.00	81.036	1
MB21GRM82T	597564.531	7587465.928	247.6	2.57E+02	-8.99	80.85606	1
MB21GRM82T	597564.531	7587465.928	247.6	2.57E+02	-8.99	80.8201	1
MB21GRM82T	597564.531	7587465.928	247.6	2.57E+02	-8.99	80.78414	1
MB21GRM82T	597564.531	7587465.928	247.6	2.57E+02	-8.99	80.7482	1
MB21GRM82T	597564.531	7587465.928	247.5	2.57E+02	-9.08	82.50089	1
MB21GRM89C	600338.245	7587492.277	234.3	2.27E+02	6.89	47.45832	4
MB21GRM89C	600338.245	7587492.277	235.4	2.27E+02	8.00	64.06402	4
MB21GRM89C	600338.245	7587492.277	235.3	2.27E+02	7.91	62.58392	4
MB21GRM89C	600338.245	7587492.277	235	2.27E+02	7.62	58.03392	4
MB21GRM89C	600338.245	7587492.277	234.5	2.27E+02	7.13	50.80838	4
MB21GRM89C	600338.245	7587492.277	234	2.27E+02	6.64	44.04977	4
MB21GRM89C	600338.245	7587492.277	233.8	2.27E+02	6.44	41.49936	4
MB21GRM93C	600296.045	7585515.379	190.2	1.80E+02	9.92	98.42624	12
MB21GRM93C	600296.045	7585515.379	191.8	1.80E+02	11.61	134.7224	12
MB21GRM93C	600296.045	7585515.379	192.9	1.80E+02	12.78	163.4307	12
MB21GRM93C	600296.045	7585515.379	193.6	1.80E+02	13.53	183.1692	12
MB21GRM93C	600296.045	7585515.379	192.5	1.80E+02	12.47	155.5757	12
MB21GRM93C	600296.045	7585515.379	192	1.80E+02	12.00	143.904	12
MB21GRM93C	600296.045	7585515.379	191.2	1.80E+02	11.51	132.4571	12

Appendix D

Hydrographs







BHP Billiton Mitsubishi Alliance

FINAL

Soil and Land Suitability Assessment

Red Hill Mining Lease

Environmental Impact Statement

URS03-029

September 2013



GSS ENVIRONMENTAL
Environmental, Land and Project
Management Consultants

**GSS ENVIRONMENTAL**Environmental, Land and Project
Management Consultants**Red Hill Mining Lease Environmental Impact Statement;
Soil and Land Suitability Assessment**

Prepared for **URS Australia Pty Ltd**

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APPENDICES

Appendix 1 – Glossary

Appendix 2 – Laboratory and Field Assessment Techniques

Appendix 3 – Laboratory Results

EXECUTIVE SUMMARY

BM Alliance Coal Operations Pty Ltd proposes to convert the existing Red Hill Mining Lease Application (MLA 70421) to enable the continuation of mining operations associated with the existing GRB mine complex. Specifically, the mining lease conversion will allow for:

- An incremental expansion of the existing Goonyella Riverside Mine;
- An extension of three longwall panels (14, 15 and 16) of the existing Broadmeadow underground mine ;and
- A future incremental underground expansion option on the Red Hill Mining Lease (Red Hill Mine)

These three elements are collectively referred to as the project.

URS Australia Pty Ltd (URS) commissioned GSS Environmental (GSSE) to undertake a soil and land suitability assessment for the project for inclusion in the project's environmental impact statement (EIS). This report involves the compilation of two previous soil surveys undertaken on site, GJR Holdings 2007 and GSSE 2009, with an additional fieldwork and assessment component undertaken by GSSE in 2011. Based on the information from these three studies, this soil and land suitability assessment report provides:

- A description of the soil and land suitability classification across the EIS study area in accordance with the Australian Soil Classification system (ASC) and the Queensland technical guidelines for assessing land suitability;
- Recommendations on soil stripping depths for all soil types in the EIS study area, including recommendations for topsoil handling, stockpiling and amelioration for reuse in rehabilitation;
- Identification of unfavourable materials, which require specific management and handling practices; and
- A description of the Agricultural Land Classes across the EIS study area.

The soil and land suitability field survey was undertaken at a scale of 1:50,000 for the entire EIS study area and 1:25,000 for disturbance areas, in accordance with the *Guidelines for Surveying Soil and Land Resources* (2008). Soil samples were analysed for various physical and chemical soil attributes by a National Association of Testing Authorities accredited laboratory. Results of the analysed field and laboratory data showed that eight major soil units occurred throughout the EIS study area, which consist of 11 soil types, as listed below:

- | | | |
|--------------------|--------------------|-------------------------|
| 1. Lithic Rudosol | 4. Brown Kurosol | 8a. Shallow Vertosol |
| 2. Tenosol | 5. Brown Chromosol | 8b. Deep Vertosol |
| 3a. Red Kandosol | 6. Brown Sodosol | 8c. Deep Salic Vertosol |
| 3b. Brown Kandosol | 7. Brown Dermosol | |

The majority of these soils are considered appropriate for stripping for reuse in rehabilitation, if required. The soils were also tested for erodibility parameters to determine erosion rates for various disturbances. The results indicate that the construction phase of infrastructure associated with gas drainage and following subsidence of longwall panels are the highest erosion hazard during which time material is unprotected by vegetation, potentially cracked upon the surface and highly exposed to the rainfall and runoff water.

The EIS study area was also assessed for its suitability for agricultural activities and its agricultural importance for the region. Land suitability classification ranges from Class 2 to Class 5 land for rainfed broadacre cropping, and Class 2 to Class 5 land for beef cattle grazing. The EIS study area is dominated by the Sodosol, Kandosol and Vertosol soil types, which are currently used for grazing enterprises. The

strategic cropping land (SCL) trigger maps released by the Department of Natural Resources and Mines (formerly Queensland Department of Environment and Resource Management) indicate that there is potential SCL in areas in the north eastern section of the EIS study area.

Based on the assessment of the existing site conditions and soil types, and the proposed mining associated activities to be undertaken, this report has recommended management strategies to be implemented to minimise the impacts on soil and land suitability.

1.0 INTRODUCTION

1.1 Project Background

GSS Environmental (GSSE) was commissioned by URS Australia Pty Ltd (URS) on behalf of BHP Billiton Mitsubishi Alliance (BMA) to undertake a soil survey and strategic land cropping (SLC) assessment for the Red Hill Mining Lease (the project). This is to form part of an environmental impact statement (EIS) to support the development application for the project. The proposed project will include the following:

1. The extension of BRM longwall panels 14, 15, and 16 into MLA70421. Key elements include;
 - No new mining infrastructure is proposed other than infrastructure required for drainage of incidental mine gas (IMG) to enable safe and efficient mining.
 - Management of waste and water produced from drainage of IMG will be integrated with the existing BRM waste and water management systems.
 - The mining of the BRM panel extensions is to sustain existing production rates of the BRM mine and will extend the life of mine (LOM) by approximately one year.
 - The existing BRM workforce will complete all work associated with the extensions.
2. The incremental expansion of the Goonyella Riverside Mine including
 - Underground mining associated with the RHM underground expansion option to target the GMS;
 - a new mine industrial area (MIA);
 - a CHPP adjacent to the Riverside MIA on MLA 1764 and ML 1900 – the Red Hill CHPP will consist of up to three 1,200 tonne per hour (tph) modules;
 - construction of a drift for mine access;
 - a conveyor system linking RHM to the Red Hill CHPP;
 - associated coal handling infrastructure and stockpiles;
 - a new conveyor linking product coal stockpiles to a new rail load-out facility located on ML 1900;
 - means for providing flood protection to the mine access and MIA, potentially requiring a levee along the west bank of the Isaac River.
3. A potential new Red Hill underground mine expansion option to the east of the GRB mine complex, to target the GMS on MLA 70421. The proposed mine layout consists of a main drive extending approximately west to east with longwall panels ranging to the north and south;
 - A network of bores and associated surface infrastructure over the underground mine footprint for mine gas pre-drainage (IMG) and management of goaf methane drainage to enable the safe extraction of coal;
 - a ventilation system for the underground workings;
 - a bridge across the Isaac River for all-weather access. This will be located above the main headings, and will also provide a crossing point for other mine related infrastructure including water pipelines and power supply;
 - a new accommodation village (Red Hill accommodation village) for the up to 100 per cent remote construction and operational workforces with capacity for up to 3,000 workers;
 - potential production capacity of 14mtpa of high quality hard coking coal over a life of 20 to 25 years

This report involves the compilation of two previous soil surveys undertaken on site: GJR Holdings 2007 and GSSE 2009. An additional fieldwork and assessment component was also undertaken in 2011 to satisfy the Department of Natural Resources and Mines (formerly Queensland Department of Environment and Resource Management) requirements. The purpose of bringing these studies together and finalising the additional requirements is to characterise the terrain conditions in the proposed mine expansion areas in order to facilitate mine and infrastructure planning, as well as undertake an environmental impact assessment for the expansion programme.

As the BRM panel extensions and the RHM footprint will be developed within a previously undisturbed (by mining) area to the east of GRB mine complex, soil resources will be impacted by mining operations. The proposed greenfield underground mining activities, service roads, and drains will result in ground disturbance within the existing GRB mine on ML1763 and on MLA70421. To ensure sufficient topsoil resources are available for post-mining rehabilitation, it is important that all suitable natural topsoil reserves are identified and recovered ahead of this disturbance. Topsoil management and erosion controls are required during both construction and operation phases to manage potential impacts on watercourses. Disturbance to the ground surface and landscape character may also reduce the agricultural suitability of land within the EIS study area or downstream.

1.2 Project Location

The project is located within the Belyando Shire, in the northern part of the Bowen Basin, approximately 135 kilometres southwest of Mackay and approximately 30 kilometres north of Moranbah. A locality map, showing the EIS study area in a regional context, is provided in **Figure 1**. The proposed project is shown in **Figure 2**.

The region contains rich thermal and metallurgical coal resources at depth, and several open-cut and underground coal mines operating nearby supply both domestic and export markets. BMA mines, including Peak Downs (some 40 kilometres to the south), have been operating since 1968. Other regional industries include beef cattle grazing and limited cropping.

1.3 EIS Study Area

The EIS study area includes underground mining, gas drainage infrastructure and buffer land with nil disturbance, totalling **12,327.38** hectares. The EIS study area has been divided into key areas of disturbance for assessment purposes, as shown in **Figure 2**. The key disturbance areas are described as follows:

- **Subsidence Disturbance** (subsided land from underground mining): This area consists of 3,600.4 hectares or 29.2 per cent of the EIS study area for the Red Hill Mine expansion footprint, and 121.35 hectares for the Broadmeadow panel extensions 14, 15 and 16. These areas include land to be subsided by longwall mining on average three to five metres and up to six metres. Soil stripping will also occur on this land for gas drainage infrastructure, apart from 100 metre buffer around the Isaac River. Given the predicted subsidence profiles surface water drainage, ponding and erosion issues are also considered.
- **Infrastructure Areas:** This area consists of approximately 247.8 hectares or two per cent of the EIS study area. The breakdown of the infrastructure areas are listed below:
 - Red Hill MIA – 30.2ha
 - Red Hill CHPP – 53.9ha
 - Red Hill Conveyor – 55.0ha
 - Red Hill Accommodation Village – 108.7ha



FIGURE 1

Red Hill Mining Lease
Locality Plan

Project:

Red Hill Mining Lease EIS

Client:

URS Australia Pty Ltd

File:

Fg1_URS03-029_LocationPlan_130613

Projection:

MGA 94 Zone 55

Version	Date:	Author:	Checked:	Approved:
1	06/12/11	KC/LH	CR	CR
2	12/06/13	LF	AK	CR



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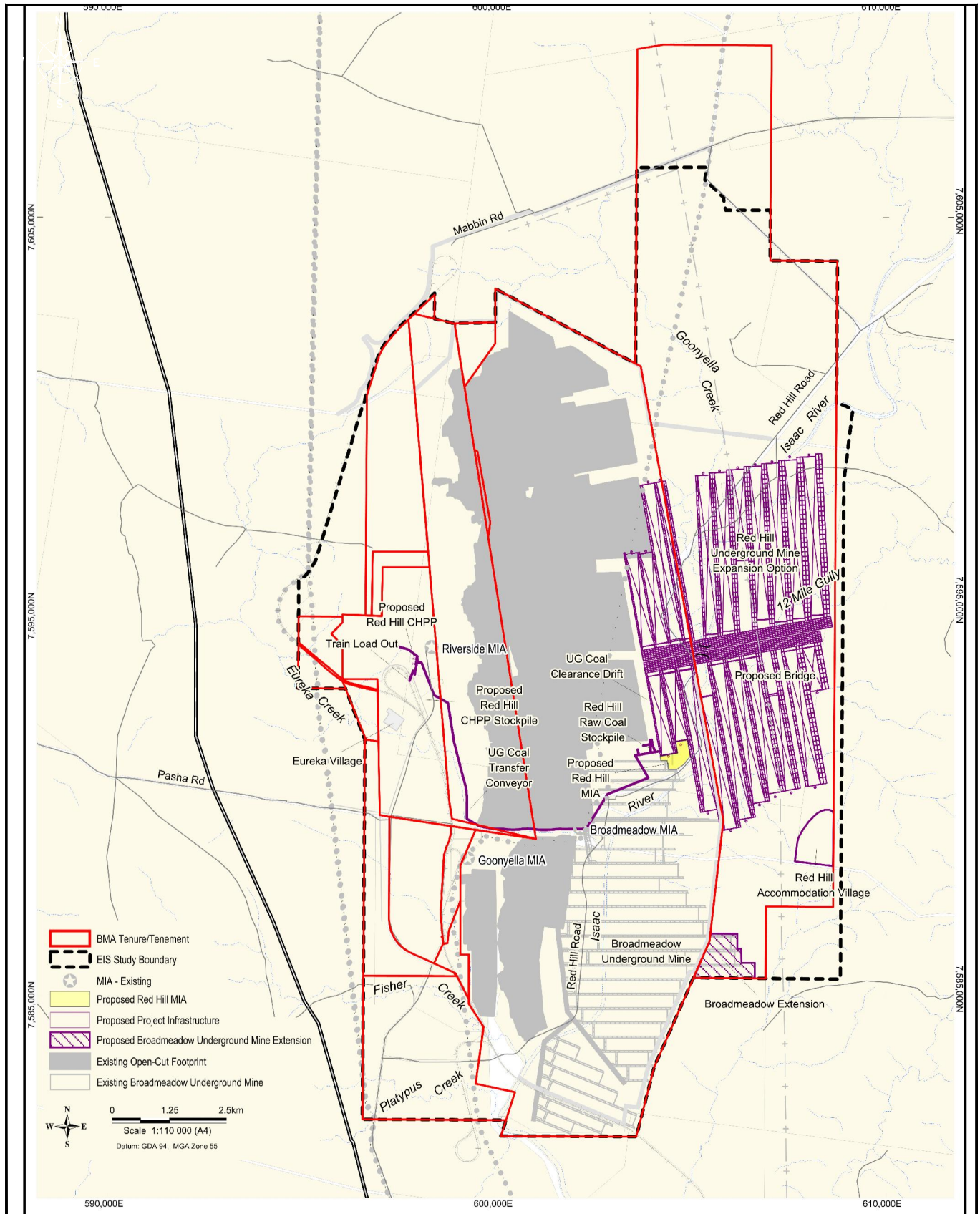


FIGURE 2

Red Hill Mining Lease Layout

Project:	Red Hill Mining Lease EIS
Client:	URS Australia Pty Ltd
File:	Fg2_URS03-029_ProjectLayout_130823
Projection:	MGA 94 Zone 55

Version	Date:	Author:	Checked:	Approved:
1	02/05/12	KC	CR	CR
2	12/06/13	LF	AK	CR



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1.4 Study Objectives

To assist BMA with operational topsoil and land management, a survey of soil resources and pre-mining assessment of agricultural land suitability was undertaken. The major objectives of the Soil and Land Suitability Assessment, according to the project's terms of reference (ToR), were to:

Objective 1 Classify and determine the soil types within the EIS study area;

To satisfy Objective 1, the soil taxonomic classification system used was the Australian Soil Classification (ASC) system. This system is routinely used as the soil classification system in Australia. The scale of mapping used for this project was 1:25,000 for disturbance areas and 1:50,000 across the overall site.

Objective 2 Assess the pre-mining and post-mining Land Suitability (LS) classes within the EIS study area;

To satisfy Objective 2, the *Guidelines for Agricultural Land Evaluation in Queensland* (DPI 1990) were used. This includes a standard list of limitations for assessing agricultural land suitability in Queensland.

Objective 3 Assess the pre-mining and post-mining Agricultural Land Classes (ALC) within the EIS study area;

To satisfy Objective 3, the *Planning Guidelines: The Identification of Good Quality Agricultural Land* (DPI 1993) was used. This guideline defines four classes of agricultural land.

Objective 4 Assess the pre-mining and post-mining Good Quality Agricultural Land (GQAL) classes within the EIS study area;

To satisfy Objective 4, the *Planning Guidelines: The Identification of Good Quality Agricultural Land* (DPI 1993) was used. This guideline sets conditions for land in terms of limitations, rating the ability of the land to maintain a sustainable level of agricultural productivity.

Objective 5 Assess the pre-mining and post-mining SCL within the EIS study area and provide soil management recommendations for the topsoil management;

To satisfy Objective 5, the relevant guideline applied was the *Protecting Queensland's strategic cropping land; Guidelines for applying the proposed strategic cropping land criteria* (DERM 2011). The guideline provides guidance on assessing SCL in terms of preliminary assessment, field mapping, criteria and next steps for validation.

Objective 6 Assess the suitability of the current topsoil for future rehabilitation including the identification of unfavourable materials in the EIS study area;

To satisfy Objective 6, the *Guide for Selection of Topdressing Material for Rehabilitation of Disturbed Areas* (Elliot & Veness 1981) was utilised to determine the soils that are suitable for conserving and utilising in the EIS study area's rehabilitation program. The approach described in this guideline remains the benchmark for land resource assessment in the Australian mining industry.

Objective 7 Assess the potential erosion rates for various scenarios during the construction, operational and post mining phases of the project;

To satisfy Objective 7, the Revised Universal Soil Loss Equation was used to calculate erosion rates and potential erosion hazards, as sourced from Landcom (2004) *Managing Urban Storm Water - Appendix 1A, NSW Government*.

2.0 EXISTING ENVIRONMENT

2.1 Climate

The EIS study area experiences a semi-arid climate, with local climatic conditions characterised by erratic rainfall and extremes of temperature.

Data for long term climate statistics of the EIS study area have been sourced from the Bureau of Meteorology (BoM) climate statistics for the Moranbah water treatment plant (WTP) which is located in Moranbah, to the southeast of the EIS study area. This data indicates the mean annual rainfall is approximately 600 millimetres and is received primarily between the months of November through March with approximately 50 per cent of rainfall occurring during summer

Long term ambient air temperature statistics suggest that the maximum daily temperatures in summer average between 33.1°C and 34°C with overnight minimums averaging between 21.1°C and 21.9°C. During winter, the maximum daily temperatures average between 23.8°C and 25.5°C with overnight minimums averaging between 9.9°C and 11.2°C

The wind directions in the vicinity of the project are predominantly from the east-northeast through to the east-southeast. The plot highlights that the site generally experiences low to moderate winds reaching a maximum of c. 7.5 metres per second (m/s) and an average speed over all hours of c. 2.7 m/s. The study is characterised by very infrequent winds from the west.

2.2 Geology

The geological regimes that outcrop, or occur as surface exposures within the EIS study area, are as listed below (GJR Holdings 2007). These are based on geological mapping data for 1:100,000 scale Harrybrandt (8554) and Wyena (8454) map sheets by the Geological Survey of Queensland (GSQ) (2004).

2.2.1 Quaternary Alluvium (Qa)

- ➔ River and Floodplain Deposits; clay, silt, sand, gravel.

The Quaternary Alluvial Deposits (Qa) are largely confined to the floodplain and alluvial plains adjacent to the Isaac River and its tributaries in the central eastern, north eastern and central southern sectors of the RHM area.

2.2.2 Tertiary-Quaternary Older Alluvial Deposits (TQa)

- ➔ Somewhat dissected high-level alluvial deposits in re-entrant valley floors and footslopes; clay, silt, sand, gravel.

Older Alluvial Deposits (TQa) occur as gently inclined mildly dissected high level alluvial deposits on footslopes and in higher parts of valley floors, mainly in the central sector of the RHM. They also occur in the north western and to a limited extent in the central and south western sectors to the west of the GRB mine complex.

2.2.3 Tertiary-Quaternary Residual Soils and Colluvium (TQr)

- ➔ Siliceous and ferruginous gravely residual soils and colluvium; locally occurring as (TQr\Qf) mainly siliceous gravely alluvial fan deposits (bajadas) or (TQr\f) highly ferruginous (lateritic) residual soils and/or colluviums.

Residual Soils and Colluvial Deposits (TQr) have been mapped in various locations within the EIS study area. As mapped, they occur associated with various substrate lithological types mainly in the central eastern, south eastern and central western sectors of the EIS study area. In the central eastern sector of the EIS study area terrain units in the (TQr) geological regime locally includes (undifferentiated) occurrences of Quaternary alluvial fan deposits (Qf). They occur as depositional plains (bajadas) of fan-shaped debris deposited by sheet floods. In the south eastern, central western and south western sectors of the EIS study area the TQr sediments occur in association with or are underlain mainly by the Tertiary Suttor Formation (Ts) and locally by occurrences of Tertiary Basalt (Tb). Terrain units identified in these areas have mainly ferruginous (lateritic) gravelly residual soils and/or colluvium and have been designated by the symbol (TQrf).

2.2.4 Tertiary Basalt Flows and Plugs (Tb)

Tertiary Basalt (Tb) remnants of flows and plugs occur mainly in the north eastern sector and locally along the western margin of the EIS study area. These comprise extensive outflows of basalt lava that occurred during the Tertiary Era with consequent infilling of valleys in the Pre-Tertiary landscape.

2.2.5 Tertiary Suttor Formation (Ts)

- ➔ Fluvial and lacustrine sediments; quartz sandstone, clayey sandstone, mudstone, conglomerate and minor interbedded basalt.

The Tertiary Suttor Formation (Ts) occurs as low broadly rounded rises and interfluvies and remnant low plateau-like areas or elevated plains locally bounded by dissected and eroded low scarps in the central eastern and central western sectors and also in the south eastern and south western sectors of the EIS study area. Terrain units identified in these areas have mainly sandy surface red earths and ferruginous (lateritic) gravelly residual soils underlain by ferruginous sandstone.

2.2.6 Late Permian Fort Cooper Coal Measures (Pwt)

- ➔ Lithic sandstone, conglomerate, mudstone carbonaceous shale, coal, tuff and tuffaceous (cherty) mudstone.

The Late Permian Fort Cooper Coal Measures conformably overlie the Moranbah Coal Measures, and are present across the eastern portion of the EIS study area. A number of coal seams are contained within the Fort Cooper Coal Measures. The seams are typically thick (up to 70 metres in the case of the GF2 seam), highly stone-banded and contain high inherent ash coal and are, therefore, not considered economic for the project. The lower boundary of the Fort Cooper Coal Measures is taken as the base of the GF0 seam, a thick and widespread sequence of interbedded dull and stony coal, carbonaceous mudstone and tuff. This unit lies approximately 60 to 70 metres above the Goonyella Upper Seam.

2.2.7 Rangal Coal Measures

- ➔ Light grey, cross-bedded, fine to medium grained sandstone, grey siltstone, mudstone, and coal seams. Cemented sections are common in the sandstone.

The Rangal Coal Measures only outcrop/subcrop in the north-east of the EIS study area. The transition between the Fort Cooper Coal Measures and the Rangal Coal Measures is generally clearly marked by the Yarrabee Tuff; a basin-wide marker bed comprising weak, brown tuffaceous claystone.

The conformably overlying Triassic Rewan Group does not occur within the EIS study area.

2.3 Topography and Hydrology

The designated sites involved with the proposed project exhibit topographical features consistent with the regional landscape of the Bowen Basin. The topography is dominated by flat to gently sloping landforms and low rolling hills. There are five creeks that exist within the EIS study area; Goonyella Creek, Eureka Creek, Fisher Creek, Platypus Creek and 12 Mile Gully. These are all tributaries of the Isaac River, which runs to the east of the current operations within the site boundary, forming part of the Isaac River Catchment.

The groundwater regime in the area of the proposed project comprises Quaternary alluvial aquifers associated with the creeks and river in the area, Tertiary sediment and basalt aquifers, and Permian sedimentary fractured rock and coal seam aquifers.

2.4 Land Use

The proposed EIS study area and areas adjoining the current operations are used for beef cattle grazing and coal mining which is consistent with the predominant land uses in Belyando Shire and Nebo Shire. Grazing activity occurs to the north, east and west of the site on partially cleared land of native and buffel grass pastures. The adjoining properties are predominantly large rural holdings used for grazing cattle on freehold and leasehold land. Denham Park, Riverside, Broadmeadow and Red Hill properties are to be directly affected by the project. Coal mining is undertaken to the north, west and south of the EIS study area with North Goonyella underground and open cut mine (Eaglefield Pit) to the north, the GRB mine complex to the west, and the Moranbah North underground coal mine to the south.

The town of Moranbah is located 30 kilometres south of the project. Moranbah is a purpose-built mining town in the northern part of the Belyando Shire, with a population of nearly 8000 people. Belyando Shire Planning Scheme and Nebo Shire Planning Scheme are the two planning schemes that cover the project's footprint. The EIS study area is to occur on land designated as rural and extractive industry in the local planning schemes and the proposed RHM is compatible with the land's zoning and designations in the local planning schemes.

There are no identified environmentally sensitive areas in the immediate vicinity of the project. Homevale National Park and Resource Reserve are the nearest environmentally sensitive areas to the project. Homevale National Park is approximately 45 kilometres north-east of the project.

2.5 Land Systems

The 1:500,000 scale Isaac-Comet Land Systems report by Galloway *et al* (1967) showed the EIS study area contains the following land system units:

Durrandella Land System

The Durrandella Land System is characterised by hills with lancewood and narrow-leaved ironbark on weathered Tertiary and Permian rocks. The land system is comprised of six land units. Landforms are most commonly Tabular hills and breakaways/ small stony hills. This land system also includes footslopes and alluvial flats. Rocky outcrops are widespread and sheet erosion and gullying have been observed to be active in steeper margins.

Soil types are mainly shallow and rocky soils, which include loamy red and yellow earths and texture contrasts. A variety of vegetation assemblages exist characterise this land system, including Savannah woodland, Lancewood or Bendee, Mixed scrub and Brigalow.

Connors Land System

The Connors Land System is characterised by alluvial plains with box on texture contrast soils. This land system is comprised of seven land units. Common landforms include alluvial plains, terraces and levees. Additionally back swamps and channels are present throughout the landscape. Large areas of land are subject to flooding and there are some permanent water holes.

Soil types are predominantly texture contrast soils with sandy surface soils. There are also uniform, medium to fine textured alluvial soils and cracking clay soils. Vegetation assemblages consist primarily of Savannah woodland, and to a lesser extent mixed shrub woodland and brigalow.

Monteagle Land System

The Monteagle Land System is characterised by lowlands with box and texture contrast soils on undissected Tertiary land surface. This land system is comprised of six land units. Land forms are most commonly plains, lowlands and colluvial footslopes. Also present are rises and interfluvies, depressions and shallow valleys, and alluvial flats. Throughout the landscape there are occasional gilgai and gravels, and gullying has been observed.

Soil types include texture contrast soils of thin sandy or loamy surface soils with strongly alkaline subsoils, and to a lesser extent cracking clay soils and sandy red earths. Vegetation assemblages consist primarily of savannah woodland, with brigalow and mixed shrub woodland also present. The details of this study were used as a source of reference for soil types encountered in the field.

3.0 SOIL SURVEY

This soil survey provides an analysis of the main soil types located within the EIS study area. This section outlines the methodology and results for the soil survey.

3.1 Soil Survey Methodology

3.1.1 Background Reference Information

An initial broad scale reconnaissance soil map for the portion of the EIS study area, which has not been previously approved, was developed using the following background information, resources and techniques:

3.1.1.1 Aerial photographs and topographic maps

Aerial photographs and topographic map interpretation was used as a remote sensing technique allowing detailed analysis of the landscape, and mapping of features expected to be related to the distribution of soils within the EIS study area.

3.1.1.2 Reference information

Source materials were used to obtain correlations between pattern elements and soil properties that may be observable in the field. These materials included cadastral data, prior and current physiographic, geological, vegetation and water resources studies. Source materials included reports which detail previous soil and land suitability mapping for the EIS study area and its surrounds. These reports are listed in date order below:

- i. Colour aerial photography – BMA Goonyella Project (AAMH 3155-2c) flown 25 July 2005 by AAM Hatch, Runs 1 and 2 at a nominal scale 1:36,000;
- ii. Colour aerial photography – BMA Goonyella Project (AAMH 3102-3c), flown 22 March 2005, Run 1 at nominal scale 1:40,000;

These source materials were used to gain an understanding of the area in terms of vegetation characteristics and distribution, topographic features and the presence of visible colour of surface soils. Vegetation is influenced largely by soil type and topography often dictates soil type, therefore these characteristics were important to analyse as a preliminary stage of assessment. Topography dictates soil development and soil type and is therefore an important factor at the initial assessment stage, and later during the soil mapping stage. Soil colour gives a basic understanding of the prevalence and distribution of similar soils within the EIS study area.

- iii. Project topographic data provided by BMA with 0.5 and 2 metre contour intervals;

As aforementioned regarding topography, areas that are flat have greater development capacity than those on steep slopes where erosive processes act quicker than the soil can develop. Topography can also be an important influence on the drainage characteristics of soils.

- iv. GSQ Geoscience Data 1:100,000 Sheet areas Harrybrandt (8554) and Wyena (8454), compiled by Natural Resource Sciences – GSQ (2004);

The geology of the area was analysed in order to gain an understanding of the parent material of the soil types throughout the site. Geology has an important influence on the early development of a soil, especially in areas where there is little deposition.

- v. CSIRO Australia Land Research Series No.19 – Lands of the Isaac-Comet Area Queensland by Story *et al* (1967);

Such background information was obtained and used as a reference to the land characteristics of the site, aiding the process of identification and justification of soil types and land assessments.

- vi. Land Suitability Study of the Collinsville-Nebo-Moranbah Region, Department of Natural Resources and Mines, Land Resources Bulletin QB 84010 ISSN 0155-221X, by P.G. Shields, DPI (1984);

Reference information used as a consultation tool during the process of land suitability assessments. This study was undertaken to determine the cropping potential of the Collinsville-Nebo-Moranbah region. Initial documentation provided a foundation from which the land assessment could be based and supported.

- vii. Land Reclamation Services Pty Ltd (January 1993) Report on Soil Survey of Future Open Cut Mining Areas of the Goonyella Riverside Mine;

Such background information was obtained and used as a reference to the land characteristics of the site, aiding the process of identification and justification of soil types and land assessments.

- viii. Galloway *et al* (1967) 1:500,000 Isaac-Comet Land Systems;

This survey was originally requested by the Queensland Government to cover part of an area of central Queensland experiencing new activity in pastoral and agricultural pursuits. The aim was to provide a broad inventory of the natural features of an area by subdividing it into *land systems*, each with its own capacity for agricultural use. The area covered was over 40,000 square kilometres and was mapped and described in terms of 28 land systems.

Within the land systems four major soil groups were recognised; Cracking clay soils; Texture-contrast soils; Red and yellow earths; and Shallow rocky soils. In addition to these there were small areas of alluvial soils and uniform coarse textured soils too small to map separately.

Furthermore, the survey outlined that the dominant land use at the time was beef cattle raising and outlined this was due to restrictions imposed by climate, soil and topography. It was noted that there was considerable scope for pasture improvement and some scope for cultivation and irrigation.

- ix. GJR Holdings 2007; and

This study was used as a reference for Geology, Terrain and Soils information within a significant portion of the study area. Laboratory test results and field profile descriptions from this report were used as a baseline for soil type descriptions.

- x. GSSE 2009.

The purpose of the GJR Holdings 2007 and the GSSE 2009 studies was to characterise the soil conditions in the proposed mine expansion areas, to facilitate mine and infrastructure planning as well as environmental impact assessment that may result from the expansion programme. The GJR Holdings 2007 and the GSSE 2009 studies were the foundation from which this final report has been produced.

3.1.2 Field Survey Methodology

GSSE used a qualitative integrated free survey for the project. An integrated survey assumes that many land characteristics are interdependent and tend to occur in correlated sets (NCST 2008). Background reference information derived from sources cited in **Section 3.1.1** (including observable air photography)

were used to predict the distribution of soil attributes in the field. Characteristics evaluated include geology, landform and vegetation. A free survey is a conventional form of integrated survey and its strength lies in its ability to assess soil and land at medium to detailed-scales. Survey points are located irregularly, according to the survey teams' expertise and judgement, to enable the delineation of soil boundaries.

The soil mapping was undertaken at a high intensity survey scale of 1:25,000 for all areas to be impacted by the project, whilst the overall area was surveyed at a medium scale of 1:50,000. This survey scale offers an adequate dataset of soil types within the study area and appropriate detail to assess the potential impact on these soils following the proposed operations. To satisfy this scale in accordance with the *Guidelines for Surveying Soil and Land Resources* (NCSR 2008), the number of observations per unit area required was: one observation per 6.25 hectares for the 1:25,000 scale area, and one observation per 25 hectares for 1:50,000 scale. The majority of these observations were considered 'minor' observations, such as exposed cuttings, 0.30 metres auger holes and rock outcrops.

The soil profiles were assessed in accordance with the Australian Soil and Land Survey Field Handbook soil classification procedures. Detailed soil profile descriptions were logged using GSSE soil data sheets. The information recorded consisted of the parameters specified in **Table 1**. Photographs and GPS locations were taken at each site and all soil test pits were backfilled immediately following field assessment.

Table 1 – Detailed Profile Description Parameters

Descriptor	Application
Horizon Depth	Weathering characteristics, soil development
Field Colour	Soil naming convention, permeability, susceptibility to dispersion /erosion
Field Texture Grade	Erodibility, hydraulic conductivity, moisture retention, root penetration
Boundary Distinctness and Shape	Erosional / dispositional status, textural grade
Consistence Force	Structural stability, dispersion, ped formation
Structure Pedality Grade	Soil structure, root penetration, permeability, aeration
Structure Ped & Size	Soil structure, root penetration, permeability, aeration
Stones – Amount & Size	Water holding capacity, weathering status, erosional / depositional character
Roots – Amount & Size	Effective rooting depth, vegetative sustainability
Ants, Termites, Worms etc	Biological mixing depth

Soil layers at each profile site were also assessed according to a procedure devised by Elliot and Veness (1981) and Elliot and Reynolds (2000) for the recognition of suitable topdressing material. This procedure assesses soils based on grading, texture, structure, consistency, mottling and root presence.

3.1.1 Laboratory Soil Assessment

Laboratory results from the three latest surveys have been used to distinguish physical and chemical properties of 11 soil units across the EIS study area. Given the variability in testing undertaken over the past five years by the three different surveys, the results were amalgamated to gain an overall thorough understanding of the chemical properties of each soil type. A total of 23 sites were laboratory tested as outlined in **Table 2** below. Majority of sites were analysed in accordance with *Guidelines for Agricultural Land Evaluation in Queensland* (DPI 1990), and were analysed for the following parameters at National Australian Testing Authorities (NATA) accredited laboratories:

Every sample:

- ECe, pH and Chloride.

Every major soil horizon:

- Exchangeable Cations;
- Cation Exchange Capacity (CEC);
- Particle Size Analysis (PSA); and
- Total Phosphorus, Potassium, Sulphur.

Surface soil horizon:

- Micronutrients;
- Aluminium;
- Free and total iron;
- Sulphate;
- Total Nitrogen; and
- Organic Carbon;

Representative samples were also analysed for the following parameters in order to satisfy other components of the TOR's:

- Colour;
- Gravimetric Water Content; and
- K-factor.

Table 2 – Observation Points per Study

Soil Type	URS 2007 (denoted with an 'A')	GSSE 2009 (denoted with a 'B')	GSSE 2011 (denoted with a 'C')
1. Lithic Rudosol	None	B12, B42	C67
2. Tenosol	A26	None	C119, C120
3a. Red Kandosol	A33, A34, A35, A38, A54, A55, A56, A57, A58, A59, A69, A71, A75, A76	B37, B39	C68, C91, C92
3b. Brown Kandosol	A22, A28, A31	None	C104, C105, C106
4. Brown Kurosol	A77	None	None
5. Brown Chromosol	A18, A20 , A23, A40, A43, A44, A109, A110, A111	B36	C66, C82 , C95, C96, C97, C115, C116, C117, C118, C119, C121
6. Brown Sodosol	A24, A27, A29, A37, A41, A42, A105, A108	B38, B40, B41	C77, C79, C80 , C87, C88, C93, C94, C102, C107, C109, C110, C114, C122 , C123
7. Brown Dermosol	A32, A36 A70 , A73, A78, A79, A81, A83, A68	B21, B22	C72, C76
8a. Shallow Vertosol	A3, A5, A7, A8, A11, A106, A107	None	C54 , C55, C61, C62, C63, C69, C108
8b. Deep Vertosol	A10 , A12, A15	None	None

Soil Type	URS 2007 (denoted with an 'A')	GSSE 2009 (denoted with a 'B')	GSSE 2011 (denoted with a 'C')
8c. Deep Salic Vertosol	A2 , A4 , A6, A9, A13, A14, A16 , A17, A21 , A30, A39, A45, A112	B34 , B35	C51, C52, C53, C56, C57, C58, C59, C60, C64, C71, C73, C74, C75, C78, C81, C83, C84, C85, C89, C90, C98, C99, C100, C101, C103, C111, C112, C113, C124

(Note: **Bold** indicates laboratory analysis)

Laboratory results from all three surveys can be found in **Appendix 3**. These soil types are detailed in the following sections, with **Tables 4–12** and **Plates 1–22** presenting the physical and chemical characteristics of each.

3.1.2 Soil Classification

GSSE adopted the Australian Soil Classification system nomenclature to identify and label soil units within the EIS study area, as required by the ToR. The standard is routinely used as the soil classification system in Australia and will form the key descriptor throughout this report. In this system, soil layers are termed horizons and the A and B horizons are together referred to as the Solum.

3.2 SOIL SURVEY RESULTS

3.2.1 Soil Types Overview

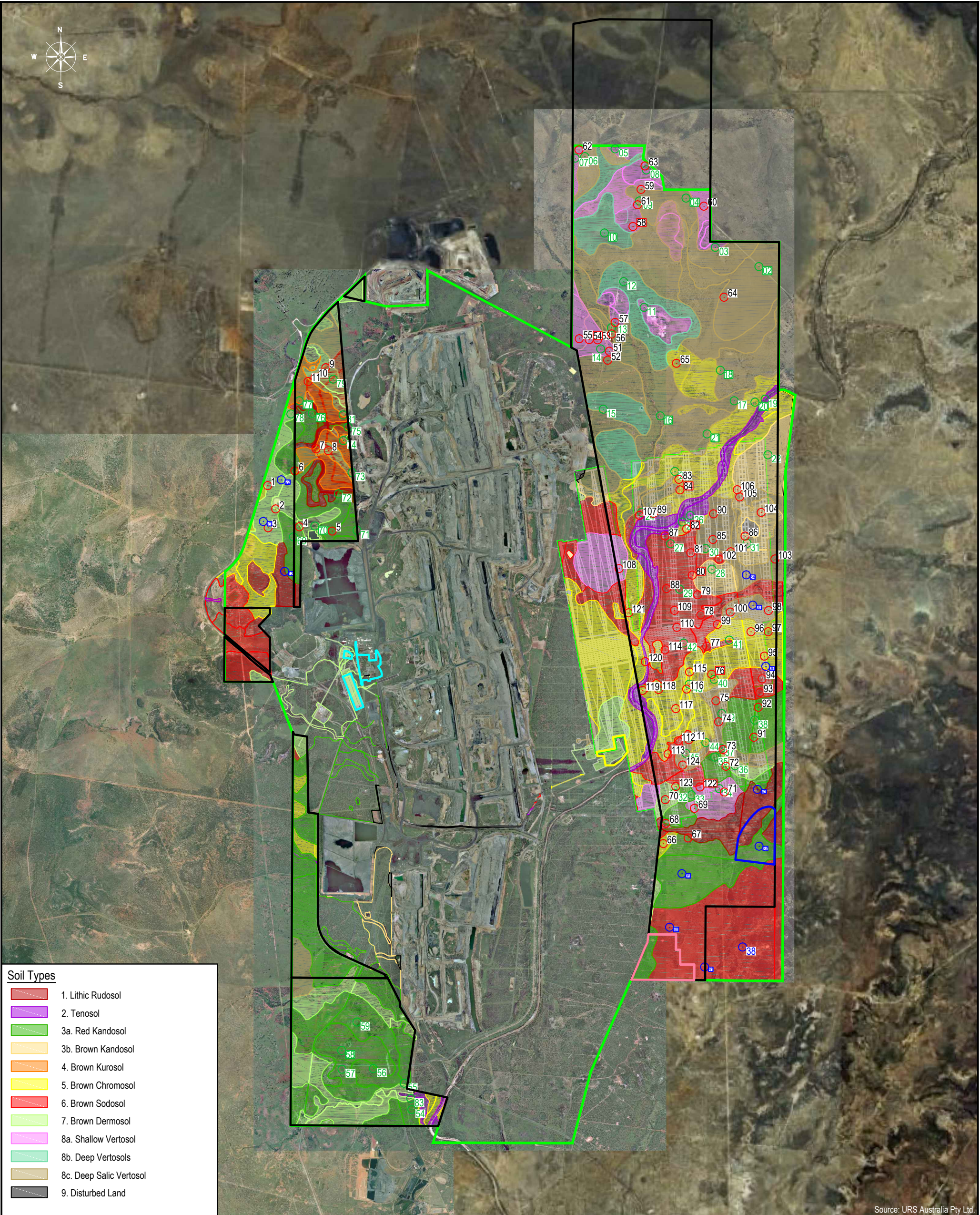
Within the EIS study area 11 soil types were identified. **Table 3** provides an overview of each soil type and their quantitative distribution within the EIS study area. **Figure 3** illustrates their spatial distribution.

Table 3 – Soil Types

Soil Type Number	Soil Types	EIS study area within proposed mining lease	EIS study area within current mining lease	Area (%)
		Area (ha)	Area (ha)	
1	Lithic Rudosol	426.0	2.8	3.5
2	Tenosol	269.51	25.18	2.4
3a	Red Kandosol	2,051.8	0.35	16.6
3b	Brown Kandosol	386.0	16.7	3.3
4	Brown Kurosol	186.7	nil	1.5
5	Brown Chromosol	1,444.53	416.7	15.1
6	Brown Sodosol	1,757.31	176.4	15.7
7	Brown Dermosol	816.6	168	8.0
8a	Shallow Vertosol	692.1	154.6	6.8
8b	Deep Vertosol	589.2	nil	4.8
8c	Deep Salic Vertosol	2674.8	36.8	22

Soil Type Number	Soil Types	EIS study area within proposed mining lease	EIS study area within current mining lease	Area (%)
		Area (ha)	Area (ha)	
n/a	Disturbed Terrain	1.83	35.3	0.3
Total		11,294.55	1,032.83	100%

These soils types have been derived from the current survey (2011) as well as previous field surveys of the site (GJR Holdings 2007; GSSE 2009). The observation points from each of these surveys and the associated soil types are shown on **Figure 3**.



Soil Types

[Red]	1. Lithic Rudosol
[Purple]	2. Tenosol
[Green]	3a. Red Kandosol
[Yellow]	3b. Brown Kandosol
[Orange]	4. Brown Kurosol
[Light Yellow]	5. Brown Chromosol
[Red]	6. Brown Sodosol
[Light Green]	7. Brown Dermosol
[Pink]	8a. Shallow Vertosol
[Light Green]	8b. Deep Vertosols
[Light Brown]	8c. Deep Salic Vertosol
[Dark Grey]	9. Disturbed Land

LEGEND

[Green Circle]	Sampling Locations - 2007	[Green Circle]	Tested Sampling Locations - 2007
[Blue Circle]	Soil Test Pits - 2009	[Blue Circle]	Tested Soil Test Pits - 2009
[Red Circle]	Soil Test Pits - 2011	[Red Circle]	Tested Soil Test Pits - 2011
[Black Outline]	Proposed Mining Lease		
[Yellow Outline]	MIA (30.2)		
[Pink Outline]	Broadmeadow Extension (131.35 ha)		
[Cyan Outline]	CHPP (53.9 ha)		
[Blue Outline]	Accommodation Village (108.7 ha)		

0 2.0 4.0km
Scale 1:90000
Base Plan Data Source: RWC & Geo-spectrum (Australia) Pty Ltd.

Version	Date:	Author:	Checked:	Approved:
1	31/10/11	ZJ	MH	CR
2	18/11/11	LH	MH	CR
3	1/12/11	LH	MH	CR
4	6/12/11	LF	AR	CR
5	02/02/12	RH	RH	CR
6	12/06/13	RH	RH	CR

FIGURE 3

**Soil Units and
Soil Test Pit Locations**

GSS ENVIRONMENTAL
Environmental, Land and Project
Management Consultants

Project:
Red Hill Mining Lease EIS

Client:
URS Australia Pty Ltd

File:
Fg3_URS03-029_SoilUnits-PitLocation_130823

Projection:
MGA 94 Zone 55

3.2.2 Soil Type 1 – Lithic Rudosols

Description: The Lithic Rudosols are of limited extent throughout the EIS study area, and are characterised by shallow rocky (skeletal) soils with a clay loam or clayey soil matrix associated with, or underlain by shallow bedrock or gravelly colluvium. They are mainly shallow (<0.5 metres) and exhibit minimal profile development apart from some darkening near the surface due to the influence of organic matter. The topsoil is structurally stable with low potential for dispersion, and is generally of moderate salinity and is strongly acidic. Similarly, the subsoil has a low potential for dispersion, is generally moderately saline and is strongly acidic. In places the Lithic Rudosols comprise ferruginous gravel and gravelly colluvium derived from weathering of the Permian and Tertiary sedimentary rocks in the area. No samples of this soil type within the EIS study area were collected for laboratory analysis, however descriptions were used from the 2007 at sites adjacent the EIS study area. The rocky nature of this soil type restricted excavation within the EIS study area.

Location: These soils occur on the low hills and on lower escarpment slopes of sections throughout the eastern and western portion of the EIS study area. They also occur in association with somewhat deeper uniform and gravelly clay soils (Soil Type 7: Brown Dermosols) on low hilly lands and rises, encompassing an area of 428.8 hectares, or 3.5 per cent of the EIS study area, as shown in **Figure 3**. This soil type is represented by site B12.

Landuse: The land overlying these soils is currently used for extensive grazing; however clearing has been limited to the flatter areas where this soil type occurs. The steeper slopes and crests of the small hills are covered by native tree species with some native and introduced grass species.

Management: This soil type is generally shallow with coarse rocky topsoil. The topsoil is considered generally unsuitable for use as surface cover in rehabilitation due to its shallow, gravelly, and strongly acidic nature.



Plate 1: Lithic Rudosol Soil Profile

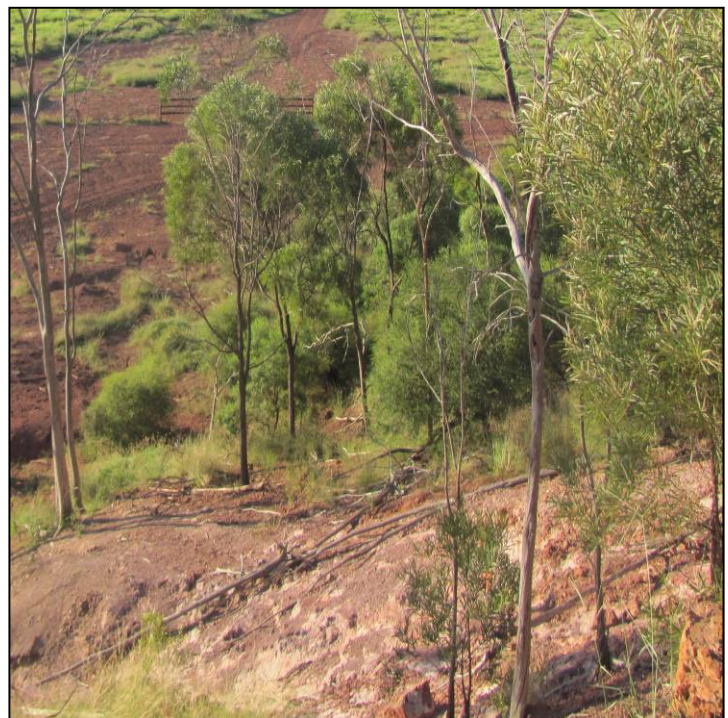


Plate 2: Lithic Rudosol Landscape Setting

3.2.3 Soil Type 2 – Tenosol

Description: The Tenosol soils are characterised by poor structure and loose sandy texture. They comprise deep (>1 metre) sand or silty sand grading to loamy or light clayey sand subsoils, usually with some ferruginous concretions associated with mottled sandy clay-clayey sand substrate soils. The topsoil is generally non-dispersive, and has low levels of salinity, with a neutral pH. The subsoil is slightly to moderately dispersive, low in salinity and generally neutral pH. There were no samples of this soil type collected for laboratory analysis within the EIS study area, however descriptions were used based on samples taken adjacent the EIS study area from the 2007 survey. This soil type includes unconsolidated uniform sand, silty sand or gravelly sand deposits in the channel floor in the Isaac River or its main tributaries.

Location: This soil type occurs on flat lower area of the catchment, within drainage lines or on the immediate floodplain of the Isaac River, on the eastern side of the EIS study area, encompassing an area of 294.7 hectares, or 2.4 per cent of the EIS study area, as shown in **Figure 3**. This soil type is represented by site C120.

Landuse: The land overlying these soils is currently used for extensive grazing, having been previously cleared of trees, cultivated and improved with native and exotic pasture species. However, on the immediate banks of the Isaac River riparian vegetation is largely intact.

Management: These soils are considered suitable for use in rehabilitation. The silty sand topsoil does not display any specific management risk related to potential disturbance during stripping. The loamy sand subsoil also displays characteristics beneficial for use in rehabilitation. It is recommended that the topsoil be stripped to a depth of 0.4 metres, and that the subsoil be stripped to a depth of 0.8 metres; however the subsoil is moderately dispersive and should only be used as an intermediate layer in rehabilitation.



Plate 3: Tenosol Soil Profile



Plate 4: Tenosol Landscape Setting

3.2.4 Soil Type 3a – Red Kandosols

Description: The Red Kandosol includes ferruginous (lateritic) gravelly and non or sparse gravelly massive red earth soils. These are mostly deep (>1 metre) soils with a sandy loam to loamy surface grading to yellowish red or red clay loam, or medium to heavy clay subsoils, locally underlain by ferruginous gravelly clay-clayey gravel substrates. The topsoil is non-dispersive to moderately dispersive, mainly non-saline to slightly saline with a sample that was moderately saline. The topsoil varies from slightly acidic to mildly alkaline, although when tested it was consistently neutral. The subsoils are typically non-dispersive, although extremely sodic soils with elevated levels of dispersability are also present. The subsoil is generally non-saline to slightly saline, and from mildly alkaline to neutral. The analytical information of the representative site for this soil type is presented in **Table 4** below.

Location: This soil type occurs on gently to moderately inclined slopes and undulating low rises, as well as some higher alluvial terraces and outwash slopes, on undulating plains and dissection slope interfluvies, on crestral plains, lower slopes and on mid to lower valley slopes. They encompass an area of 2052.2 hectares, or 16.6 per cent of the EIS study area, as shown in **Figure 3**. This soil type is represented by sites B37, C68 and C91.

Landuse: The land overlying these soils is currently used for extensive grazing, having been previously cleared of trees, cultivated and improved with native and exotic pasture species.

Management: Generally the topsoil and immediate subsurface soil of this soil type do not display any specific management risk related to potential disturbance during stripping. Both layers exhibit structure and chemical characteristics that would be suitable as surface cover in rehabilitation. The increased presence of clay with depth throughout the profile restricts the use of the subsoil as a topdressing material. Therefore, topsoil can be salvaged for reuse in rehabilitation at a recommended depth of approximately 30 centimetres.



Plate 5: Kandosols Soil Profile



Plate 6: Red Kandosols Landscape Setting

Table 4 – Red Kandosol Laboratory Results

Depth	Colour	pH		ECe		CEC		ESP		EAT	
cm	Munsell	#	Rating	%	Rating	#	Rating	%	Rating	#	Rating
0 - 20	Dark reddish-brown	6.26	Slightly acid	0.3	Non saline	4.51	Very low	4	Non sodic	3(2)	Slight
20 - 60	Yellowish-red	7.38	Neutral	0.3	Non saline	5.78	Very low	21	Strongly sodic	3(4)	Moderate
60 - 100	Yellowish-red	7.74	Mildly alkaline	0.4	Non saline	6.65	Low	102	Extremely sodic	3(4)	Moderate

The Red Kandosol profile is represented by: **Figure 3aA**, which shows the ECe and pH trend with depth, **Figure 3aB**, which shows the soil texture throughout the profile, and **Figure 3aC**, which shows the trend of exchangeable cations with depth. The entire data collection for this soil type, which includes laboratory results from the 2007, 2009 and 2011 studies, can be found in **Appendix 3**.

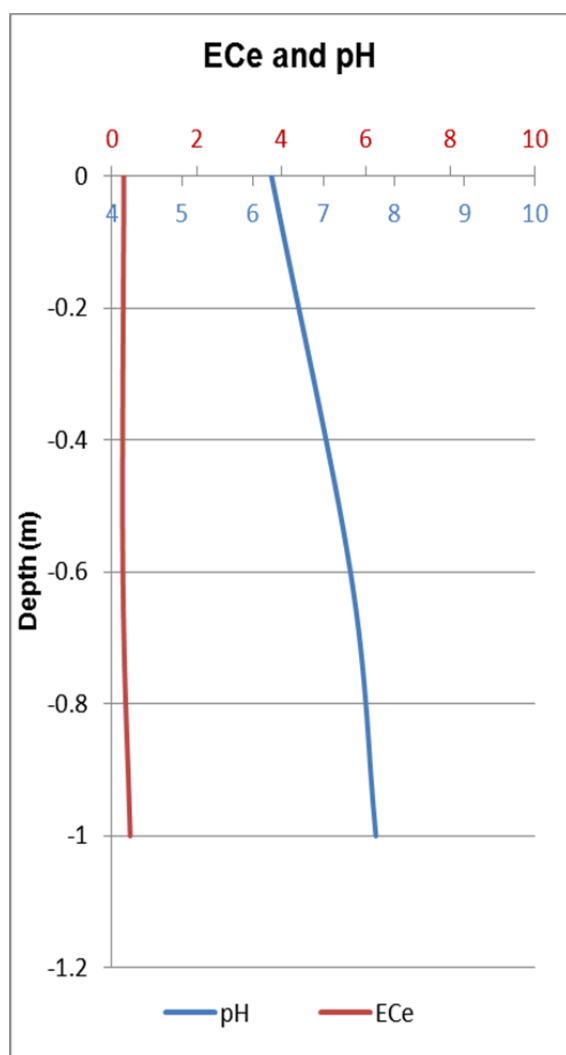


Figure 3aA :ECe and pH profile trends

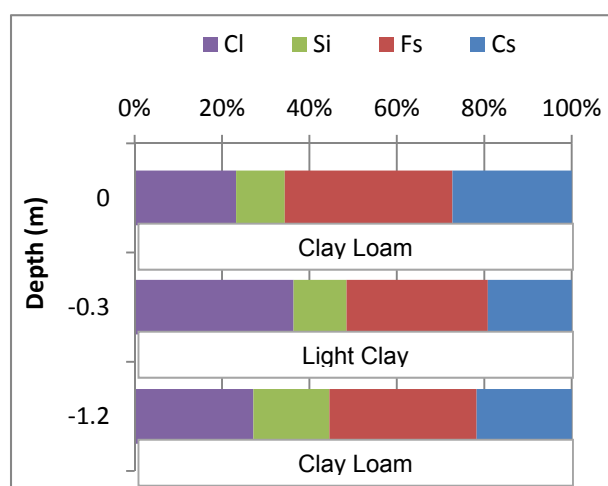


Figure 3aB: Particle Size Analysis

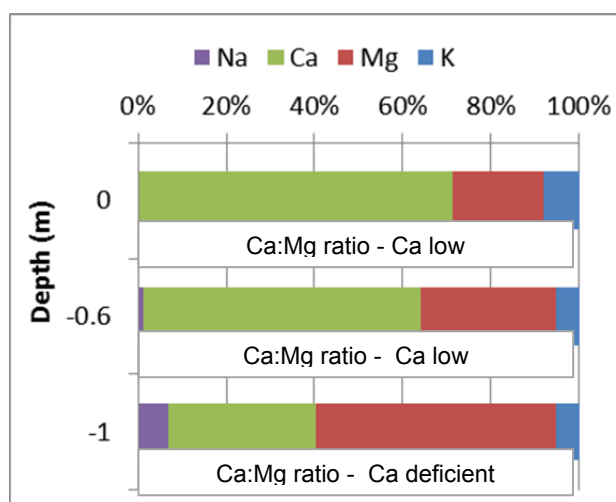


Figure 3aC: Exchangeable Cations

3.2.5 Soil Group 3b – Brown Kandosol

Description: The Brown Kandosol comprise deep (>1 metre) mainly massive yellow-brown earths with sandy loam to light clayey surface soils grading to light to medium or heavy clay subsoils, locally with ferruginous gravelly layers included. The topsoil is typically slightly to moderately dispersive, non-saline, though in some instances slightly saline, and mainly neutral to slightly acidic. The subsoils are moderately to strongly dispersive, generally non-saline, with some slightly to moderately saline soils present, and mildly to moderately alkaline. The analytical information of the representative site for this soil type is presented in **Table 5** below.

Location: This soil type occurs on gently inclined slopes to drainage lines, on flat to depressional plains, in depressional drainage ways and on gently inclined broadly rounded interfluvies and low rises. They encompass an area of 402.7 hectares, or 3.3 per cent of the EIS study area as shown in **Figure 3**. This soil type is represented by site C104.

Landuse: The land overlying these soils is currently used for extensive grazing, having been previously cleared of trees, cultivated and improved with native and exotic pasture species.

Management: Generally the topsoil does not display any specific management risk related to potential disturbance during stripping. The topsoil layer exhibits structure and chemical characteristics that would be suitable as surface cover in rehabilitation. The subsoil ranges from moderate to strongly dispersive and would require erosion control structures to be implemented if disturbed. An application of gypsum to reduce the management risks in the subsoil when stripped may be beneficial. The recommended stripping depth of this soil is 0.50 metres.



Plate 7: Brown Kandosol Soil Profile



Plate 8: Brown Kandosol Landscape Setting

Table 5 – Brown Kandosol Laboratory Results

Depth	Colour	pH		ECe		CEC		ESP		EAT	
		#	Rating	%	Rating	#	Rating	%	Rating	#	Rating
0 - 5	Brown	6.8	Neutral	0.38	Non saline	8.47	Low	0	Non sodic	5	Slight
5 - 15	Brown	6.8	Neutral	0.26	Non saline	5.62	Very low	0	Non sodic	3(1)	Slight
15 - 50	Brown	6.9	Neutral	0.1	Non saline	3.8	Very low	0	Non sodic	2(1)	Moderate to high
50 - 70	Yellowish brown	7.4	Mildly alkaline	0.17	Non saline	5.34	Very low	2	Non sodic	2(1)	Moderate to high
130 - 140	Yellowish brown	7.9	Moderately alkaline	0.6	Non saline	7.56	Low	13	Sodic	2(1)	Moderate to high

The Brown Kandosol profile is represented by: **Figure 3bA**, which shows the ECe and pH trend with depth, **Figure 3bB**, which shows the soil texture throughout the profile, and **Figure 3bC**, which shows the trend of exchangeable cations with depth. The entire data collection for this soil type, which includes laboratory results from the 2007, 2009 and 2011 studies, can be found in **Appendix 3**.

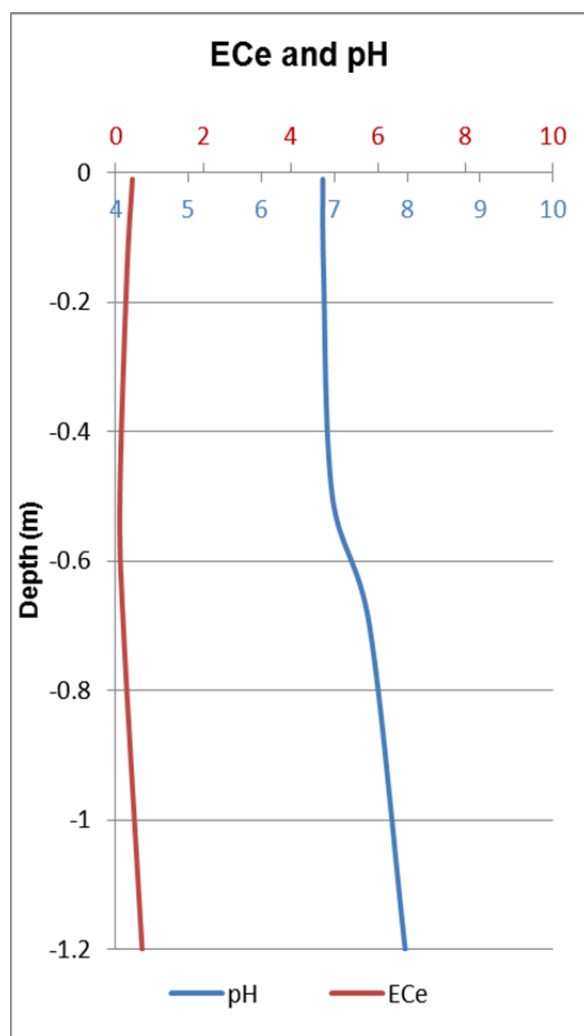


Figure 3bA: ECe and pH profile trends

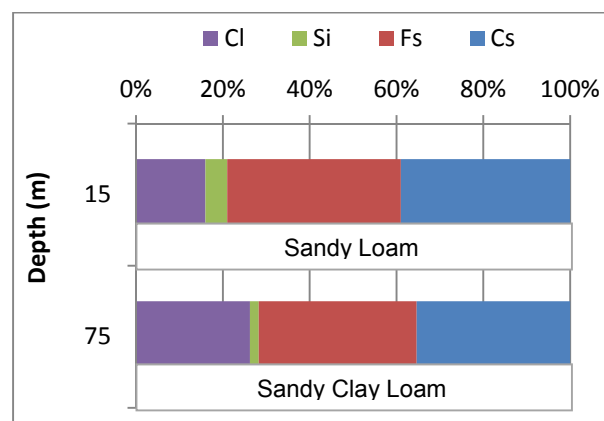


Figure 3bB: Particle Size Analysis

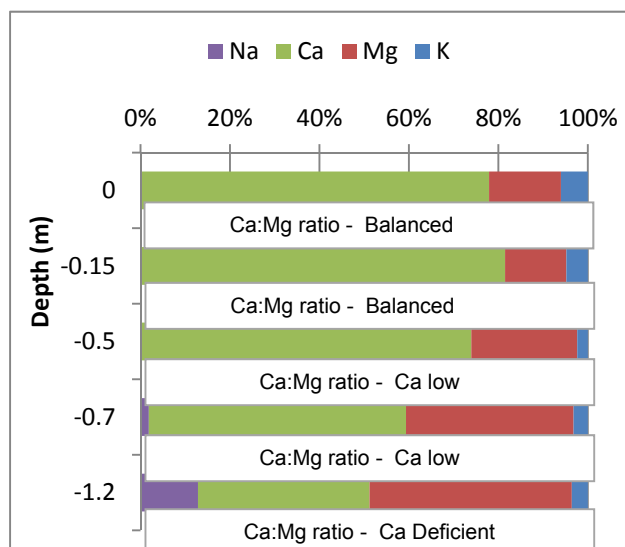


Figure 3bC: Exchangeable Cations

3.2.6 Soil Group 4 – Brown Kurosol

Description: The Brown Kurosol is comprised of a deep loamy surface duplex soil with a pale gravelly clay sub-surface horizon, an acidic to strongly acidic dark brown heavy clay subsoil horizon, underlain by mottled reddish-brown and grey heavy clay lower subsoil where approaching the (very strongly acidic) weathered rock substrate. The topsoil is moderately dispersive and slightly to moderately saline with a neutral pH. The subsoil's were strongly dispersive, highly saline and highly acidic. The analytical information of the representative site for this soil type is presented in **Table 6** below.

Location: This soil type occurs on gently to moderately inclined foot slopes in a small area to the north west of the EIS study area, encompassing an area of 186.7 hectares, or 1.5 per cent of the EIS study area as shown in **Figure 3**. This soil type is represented by site A77.

Landuse: The land overlying these soils is currently used for extensive grazing, having been largely cleared of trees, cultivated and improved with native and exotic pasture species.

Management: Generally the topsoil does not display any specific management risk related to potential disturbance during stripping. The topsoil layer exhibits structure and chemical characteristics that would be suitable as surface cover in rehabilitation. However, where stone content becomes prohibitive to re-use on rehabilitation, material should not be salvaged for that purpose. The subsoil is strongly dispersive, highly saline and highly acidic and are therefore not suitable for use as a topdressing in rehabilitation. Furthermore, erosion control measures should be implemented during the exposure of this soil. The recommended stripping depth of this soil is 0.30 metres.



Plate 9: Kurosol Soil Profile



Plate 10: Kurosol Landscape setting

Table 6 – Brown Kurosol Laboratory Results

Depth	Colour	pH		ECe		CEC		ESP		EAT	
cm	Munsell	#	Rating	%	Rating	#	Rating	%	Rating	#	Rating
0 - 15	Dark brown	7.2	Neutral	0.34	Non saline	14.8	Moderate	9	Marginally sodic	3(3)	Moderate
15 - 30	Dark brown	7.5	Mildly alkaline	3.27	Slightly saline	22.5	Moderate	65	Strongly sodic	3(4)	Moderate
60 - 80	Dark brown	8.4	Moderately alkaline	8.6	Highly saline	27.4	High	110	Strongly sodic	2(2)	High
100 - 110	Strong brown	4.7	Very strongly acid	10.8	Highly saline	23.4	Moderate	165	Strongly sodic	2(2)	High

The Brown Kandosol profile is represented by: **Figure 4A**, which shows the ECe and pH trend with depth, and **Figure 4B**, which shows the trend of exchangeable cations with depth. The entire data collection for this soil type, which includes laboratory results from the 2007 study, can be found in **Appendix 3**.

3.2.7 Soil Group 5 – Brown Chromosol

Description: The Brown Chromosol includes deep (>1 metre) mostly thick sandy and loamy surface duplex soils generally with a pale (A2) horizon over brown or yellow-brown, sometimes diffusely mottled non-sodic to marginally sodic, non-saline sandy clay or medium to heavy clay subsoils. The topsoil is structurally stable with a low potential for dispersion. The majority of topsoil is non-saline although can be slightly saline and is slightly acidic to moderately alkaline. The subsoil varies from slightly dispersive to strongly dispersive, is generally slightly to non-saline, although occasionally moderately saline, and is neutral to slightly alkaline pH value. The analytical information of the representative site for this soil type is presented in **Table 7** below.

Location: These soils occur on alluvial terraces and on broadly rounded rises and dissection slope interfluvies, common throughout the eastern areas of the EIS study area, encompassing an area of 1861.2 hectares, or 15.1 per cent of the EIS study area as shown in **Figure 3**. This soil type is represented by C82 and C121.

Landuse: The land overlying these soils is currently used for extensive grazing, having been previously cleared of trees, cultivated and improved with native and exotic pasture species.

Management: Generally the topsoil of this soil unit does not display any specific management risk related to potential disturbance during stripping. The clay subsoils should not be recovered or used as a surface cover in rehabilitation due to high clay content, massive structure and alkalinity. The sandy loam topsoil is considered generally suitable as a surface cover during rehabilitation. The topsoil is suitable for stripping to a depth of 0.4 metres.



Plate 11: Chromosol Soil Profile



Plate 12: Chromosol Landscape Setting

Table 7 – Brown Chromosol Laboratory Results

Depth	Colour	pH		ECe		CEC		ESP		EAT	
		#	Rating	%	Rating	#	Rating	%	Rating	#	Rating
0 - 15	Dark brown	6.4	Slightly acid	0.5	Non saline	1.79	Very low	0	Non sodic	5	Slight
15 - 40	Dark brown	6.5	Slightly acid	0.2	Non saline	1.13	Very low	0	Non sodic	5	Slight
40 - 100	Dark yellowish brown	7.1	Neutral	0.7	Non saline	11.7	Low	7	Marginally sodic	5	Slight

The Brown Kandosol profile is represented by: **Figure 5A**, which shows the ECe and pH trend with depth, **Figure 5B**, which shows the soil texture throughout the profile, and **Figure 5C**, which shows the trend of exchangeable cations with depth. The entire data collection for this soil type, which includes laboratory results from the 2007, 2009 and 2011 studies, can be found in **Appendix 3**.

3.2.8 Soil Group 6 – Brown Sodosols

Description: The Brown Sodosol comprise medium to deep hard-set thin loamy surface duplex soils usually with a pale or bleached sub-surface (A2) horizon with dark brown, yellowish-brown and in places reddish-brown, light medium to heavy clay deep subsoils. The topsoil is non-dispersive to moderately dispersive, is generally moderately saline, and the topsoil was generally neutral, or in some instances moderately acidic. The subsoils are generally highly sodic and dispersive, moderately to highly saline, and moderately acidic to moderately alkaline. The analytical information of the representative site for this soil type is presented in **Table 8** below.

Location: These soils occur on alluvial flats, back-plains and older alluvial plains, on gently inclined plains, gently undulating rises dissection and on slope interfluvies and slopes to drainage, encompassing an area of 1933.7 hectares, or 15.7 per cent of the EIS study area as shown in **Figure 3**. This soil type is represented by site B40.

Landuse: The land overlying these soils is currently used for extensive grazing, having been previously cleared of trees, cultivated and improved with native and exotic pasture species.

Management: Generally the sandy clay loam topsoil does not display any specific management risk related to potential disturbance during stripping. The clay subsoils are generally considered unsuitable for stripping, mainly due to the high sodicity and associated dispersion characteristics of Sodosols. The clay subsoils should not be recovered or used as surface cover for rehabilitation. Due to the variation in the topsoil depth, the sandy loam topsoil is considered suitable for stripping to a depth of 0.25 metres. The topsoil is believed to be suitable as a surface cover in the establishment of vegetation.



Plate 13: Sodosol Soil Profile



Plate 14: Sodosol Landscape Setting

Table 8 – Brown Sodosol Laboratory Results

Depth cm	Colour Munsell	pH		ECe		CEC		ESP		EAT	
		#	Rating	%	Rating	#	Rating	%	Rating	#	Rating
0 - 25	Dark yellowish brown	7	Neutral	0.92	Non saline	8.52	Low	0	Non sodic	5	Slight
25 - 50	Dark yellowish brown	7.4	Mildly alkaline	0.6	Non saline	12.8	Moderate	7	Marginally sodic	2 (3)	Very high
50 - 90	Yellowish brown	8	Moderately alkaline	1.12	Non saline	15.6	Moderate	12	Sodic	2 (3)	Very high

The Brown Kandosol profile is represented by: **Figure 6A**, which shows the ECe and pH trend with depth, **Figure 6B**, which shows the soil texture throughout the profile, and **Figure 6C**, which shows the trend of exchangeable cations with depth. The entire data collection for this soil type, which includes laboratory results from the 2007, 2009 and 2011 studies, can be found in **Appendix 3**.

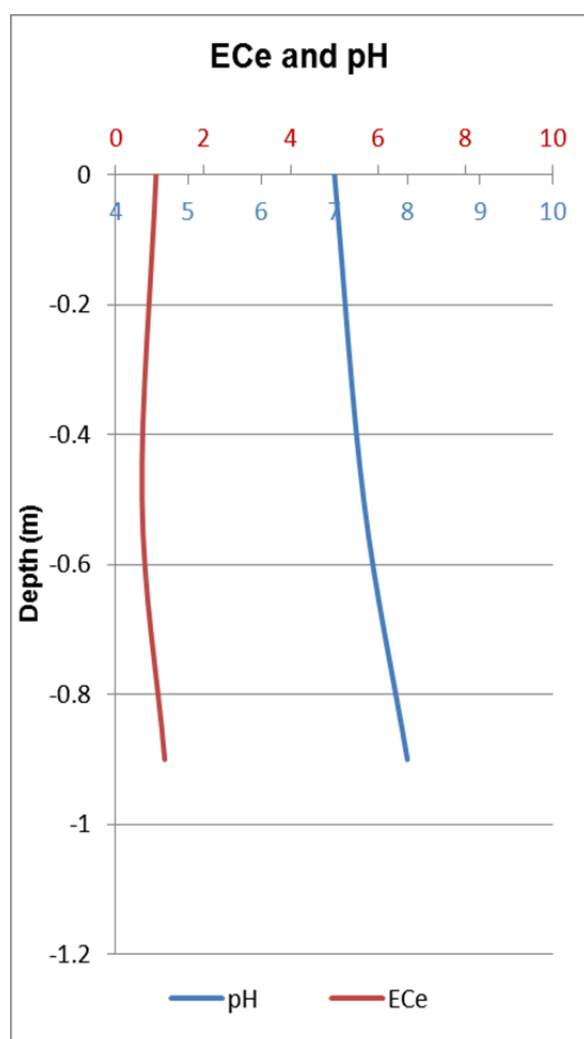


Figure 6A: ECe and pH profile trends

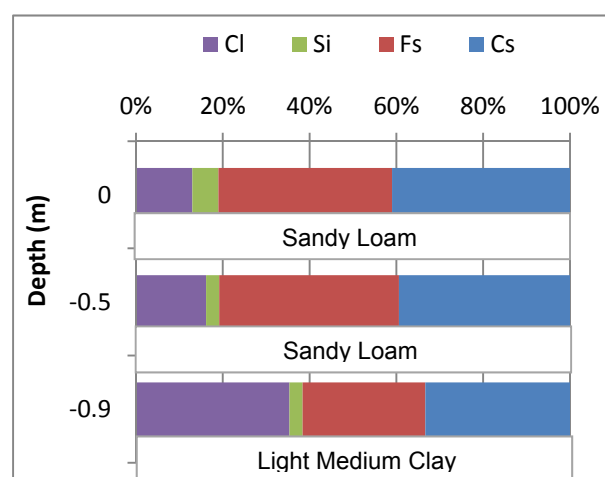


Figure 6B: Particle Size Analysis

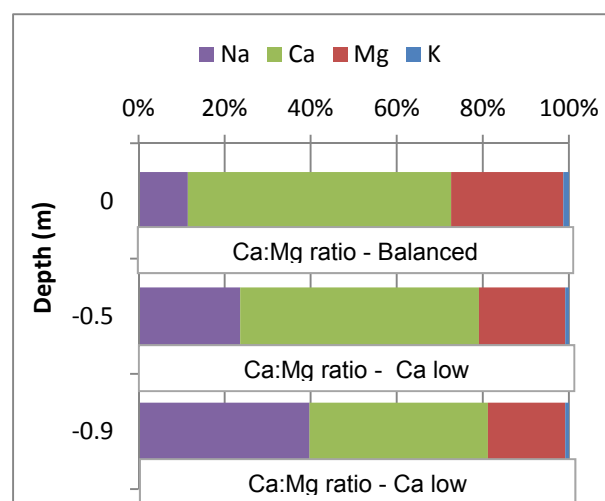


Figure 6C: Exchangeable Cations

3.2.9 Soil Group 7 – Brown Dermosols

Description: The Brown Dermosols generally include deep (>1 metre) mainly uniform clay soil profiles in places with a hard-set or thin weak self-mulching clay loam to medium clay surface horizon over dark brown structured clay soils (locally tending to incipient cracking clay soils); or, brown to yellow-brown weakly structured to massive, clay subsoils. The topsoil is non-dispersive to moderately dispersive, is non-saline and varied from slightly acidic to moderately alkaline, with occasionally high gravel content. The subsoils are generally moderately to highly dispersive, though are occasionally slightly to non-dispersive, are mainly saline and varied from acidic to highly alkaline. The analytical information of the representative site for this soil type is presented in **Table 9** below.

Location: These soils occur on alluvial plains, on depressional plains with prominent gilgai development and on older alluvial plains. The soils are common throughout the western areas of the EIS study area, encompassing an area of 984.6 hectares, or 8 per cent of the EIS study area as shown in **Figure 3**. This soil type is represented by sites B21 and C72.

Landuse: The land overlying these soils is currently used for extensive grazing, having been previously cleared of trees, cultivated and improved with native and exotic pasture species.

Management: The topsoil is generally considered suitable for stripping for use as surface cover or intermediate layer below the surface layer in rehabilitation. The clay subsoils are considered to be unsuitable for stripping for use as surface cover due to high sodicity, moderate salinity and pH ranges generally limiting for the growth of vegetation. The recommended stripping depth for this soil is 0.2 metres.



Plate 15: Dermosol Soil Profile



Plate 16: Dermosol Landscape Setting

Table 9 – Brown Dermosol Laboratory Results

Depth	Colour	pH		ECe		CEC		ESP		EAT	
cm	Munsell	#	Rating	%	Rating	#	Rating	%	Rating	#	Rating
0 - 10	Brown	8.3	Moderately alkaline	0.8	Non saline	20.6	Moderate	2	Non sodic	2(3)	Very high
10 - 30	Strong brown	9.1	Very strongly alkaline	5.1	Moderately saline	27.2	High	19	Strongly sodic	2(3)	Very high
30 - 120	Strong brown	8.5	Strongly alkaline	8.9	Highly saline	21.3	Moderate	44	Strongly sodic	2(3)	Very high

The Brown Kandosol profile is represented by: **Figure 7A**, which shows the ECe and pH trend with depth, **Figure 7B**, which shows the soil texture throughout the profile, and **Figure 7C**, which shows the trend of exchangeable cations with depth. The entire data collection for this soil type, which includes laboratory results from the 2007, 2009 and 2011 studies, can be found in **Appendix 3**.

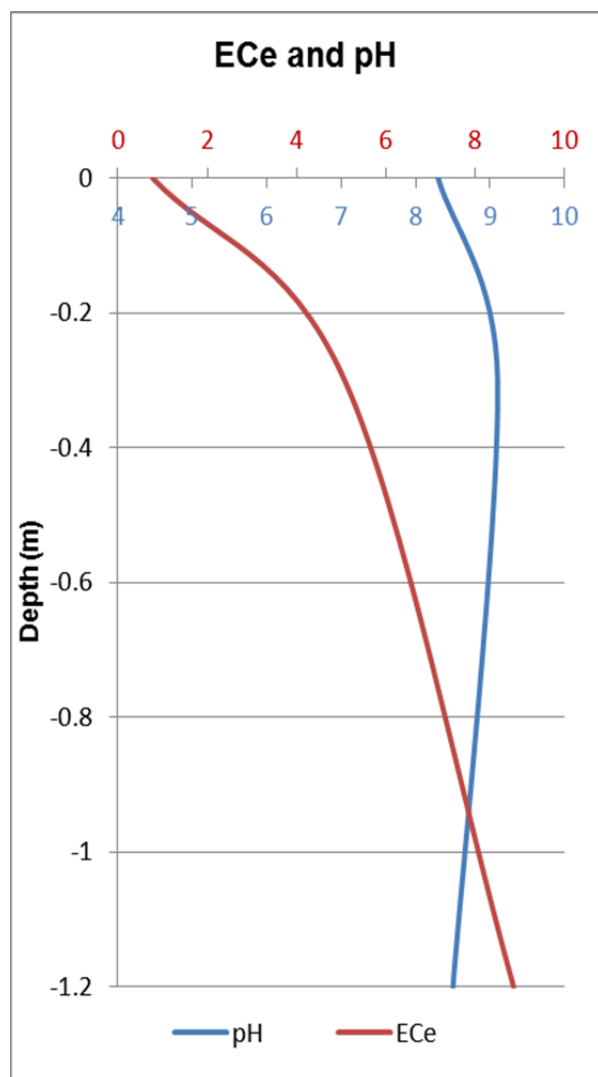


Figure 7A: ECe and pH profile trends

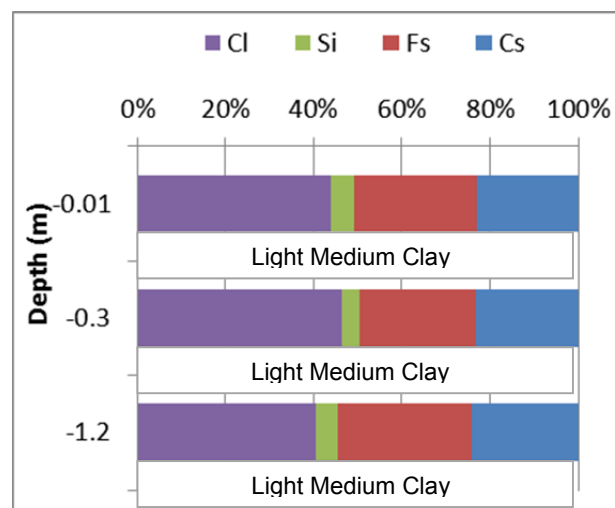


Figure 7B: Particle Size Analysis

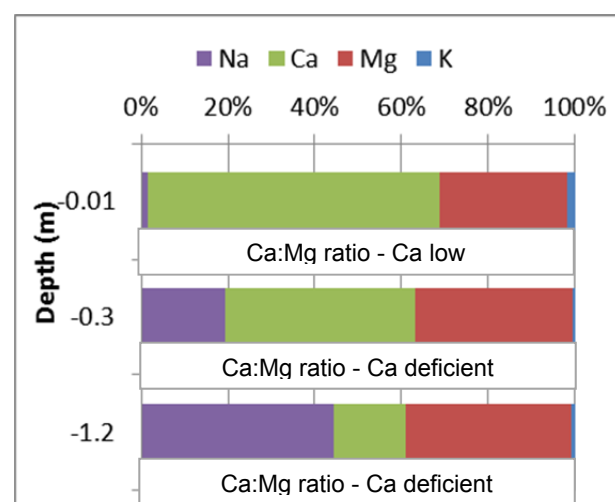


Figure 7C: Exchangeable Cations

3.2.10 Soil Group 8a – Shallow Vertosols

Description: The Vertosols comprises shallow to medium deep (<1 metre) cracking clay soils with a thin weak self-mulching surface soil over dark brown or brownish black sodic moderately saline heavy clay subsoils underlain by weathered rock. The topsoil is typically non-dispersive, although occasionally has moderate dispersion ratings, is non-saline to slightly saline, and neutral to slightly alkaline. The subsoils are sometimes non-dispersive, although are generally moderately to highly dispersive. They vary from non-saline to highly saline and are slightly acidic to moderately alkaline. The key characteristics of the Vertosols is their uniform medium to heavy clay texture throughout the profile, pronounced swelling and shrinkage properties on wetting and drying, and usually moderate to high levels of sodicity and/or salinity in the subsoil horizons. Unlike the Deep Vertosols, the Shallow Vertosols are not typically associated with gilgai presence. The analytical information of the representative site for this soil type is presented in **Table 10** below.

Location: These soils occur on undulating plains and gently to moderately inclined slopes, but mainly on cretal areas and lower slopes in strongly undulating lands and on low rocky rises associated with the Tertiary Basalt geological regime. They encompass an area of 846.7 hectares, or 6.9 per cent of the EIS study area as shown in **Figure 3**. This soil type is represented by site C54.

Landuse: The land overlying these soils is currently used for extensive grazing, having been previously cleared of trees, cultivated and improved with native and exotic pasture species.

Management: These soils are texturally unsuitable for use as surface cover for rehabilitation.



Plate 17: Shallow Vertosol Soil Profile



Plate 18: Shallow Vertosol Landscape Setting

Table 10 – Shallow Vertisol Laboratory Results

Depth	Colour	pH		ECe		CEC		ESP	
		#	Rate	%	Rate	#	Rate	%	Rate
0 - 20	Brownish Black	8.2	Moderately alkaline	0.1	Non saline	38.5	High	0	Non sodic
20 - 40	Brownish Black	8.5	Strongly alkaline	0.2	Non saline	43.3	Very high	0	Non sodic

The Shallow Vertisol profile is represented by: **Figure 8aA**, which shows the ECe and pH trend with depth, **Figure 8aB**, which shows the soil texture throughout the profile, and **Figure 8aC**, which shows the trend of exchangeable cations with depth. The entire data collection for this soil type, which includes laboratory results from the 2007 and 2011 studies, can be found in **Appendix 3**.

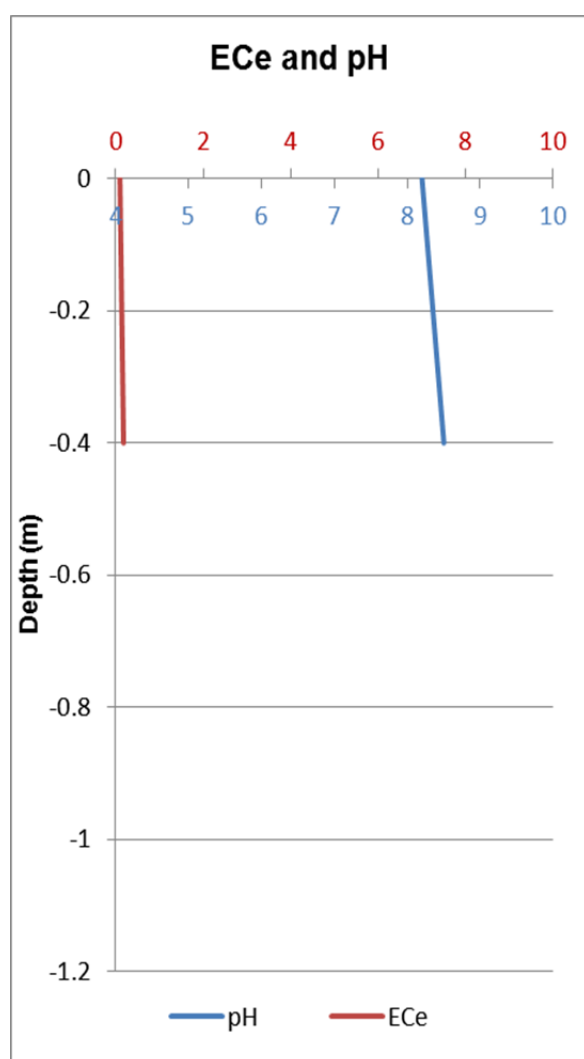


Figure 8aA: ECe and pH profile trends

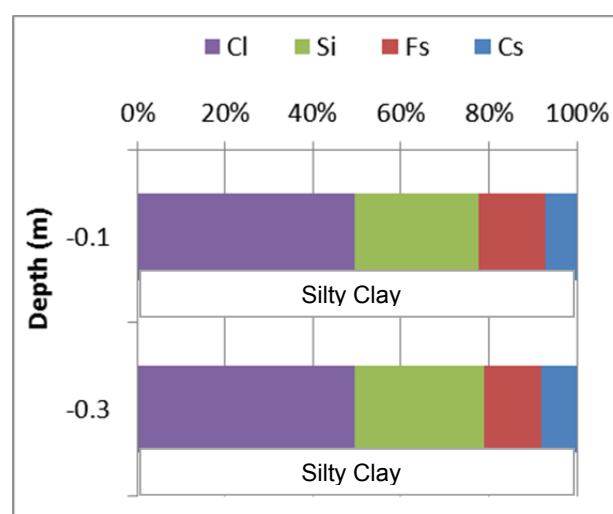


Figure 8aB: Particle Size Analysis

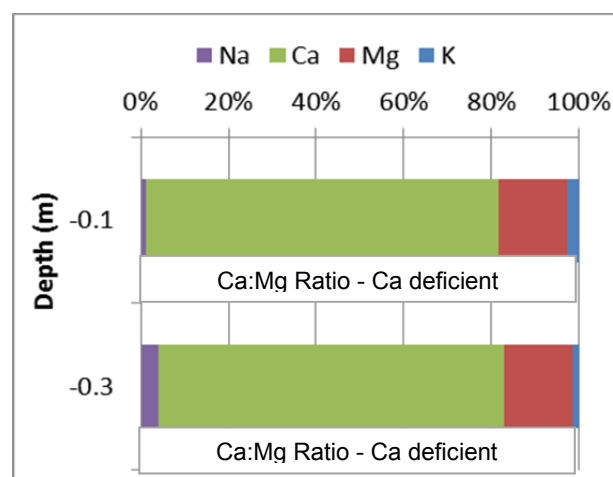


Figure 8aC : Exchangeable Cations

3.2.11 Soil Type 8b - Deep Vertosol

Description: Vertosols are characterised by deep (>1 metre) cracking clay soils with a thin weak self-mulching surface soil over dark brown or brown strongly structured mostly sodic heavy clay subsoils, tending to massive, strongly sodic, often calcareous heavy clay in the deeper subsoils. The topsoil is mainly non-dispersive, occasionally moderately dispersive. It varies from non-saline to moderately saline and is slightly acidic to slightly alkaline. The subsoils are generally non-dispersive to moderately dispersive, moderately saline to extremely saline, and neutral to moderately alkaline. The key characteristics of the Vertosols is their uniform medium to heavy clay texture throughout the profile, pronounced swelling and shrinkage properties on wetting and drying. The Deep Vertosols are widely associated with gilgai micro relief. The analytical information of the representative site for this soil type is presented in **Table 11** below.

Location: This soil type occurs extensively mainly in the northern sector of the EIS study area comprising drainage-ways, drainage flats and alluvial plain, on near level older alluvial plains and gently undulating plain, and on gently inclined slopes, foot-slopes and low rises. They encompass an area of 589.2 hectares, or 4.77 per cent of the EIS study area, as shown in **Figure 3**. This soil type is represented by observation point A10.

Landuse: The land overlying these soils is currently used for extensive grazing, having been previously cleared of trees, cultivated and improved with native and exotic pasture species.

Management: These soils are texturally unsuitable for use as surface cover for rehabilitation.



Plate 19: Deep Vertosol Soil Profile



Plate 20: Deep Vertosol Landscape Setting

Table 11 – Deep Vertisol Laboratory Results

Depth	Colour	pH		ECe		CEC		ESP		EAT	
		#	Rate	%	Rate	#	Rate	%	Rate	#	Rate
0 - 20	Very dark grey-brown	7.06	Neutral	0.4	Non saline	62	Very high	1	Non sodic	5	Slight
20 - 60	Very dark grey-brown	7.45	Mildly alkaline	1.2	Non saline	65.5	Very high	2	Non sodic	5	Slight
60 - 100	Very dark grey-brown	8.1	Moderately alkaline	0.8	Non saline	66.9	Very high	3	Non sodic	5	Slight
110 - 170	Very dark grey-brown	8.12	Moderately alkaline	1.9	Non saline	69.3	Very high	4	Non sodic	5	Slight

The Deep Vertisol profile is represented by: **Figure 8bA**, which shows the ECe and pH trend with depth, and **Figure 8bB**, which shows the trend of exchangeable cations with depth. The entire data collection for this soil type, which includes laboratory results from the 2007 and 2009 studies, can be found in **Appendix 3**.

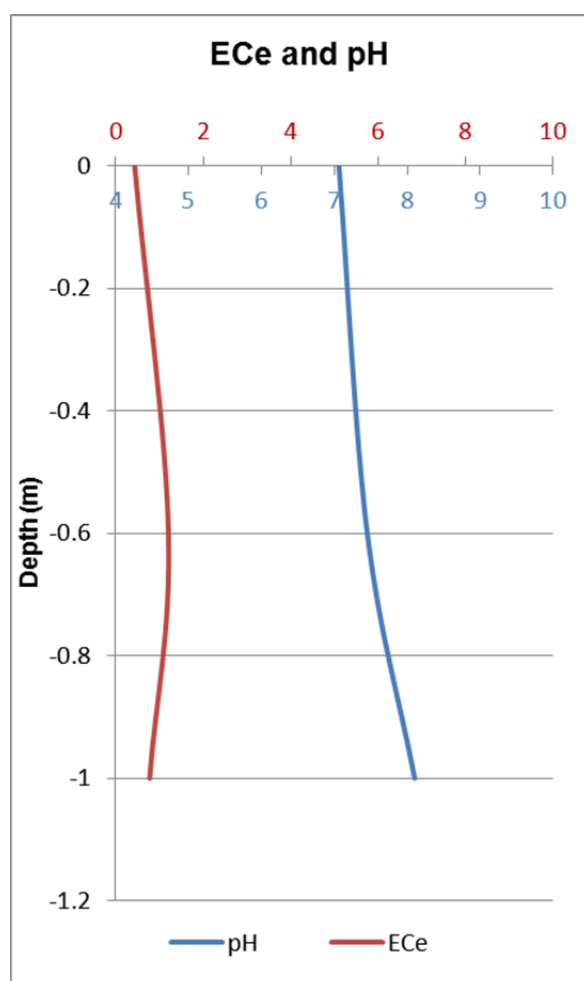


Figure 8bA: ECe and pH profile trends

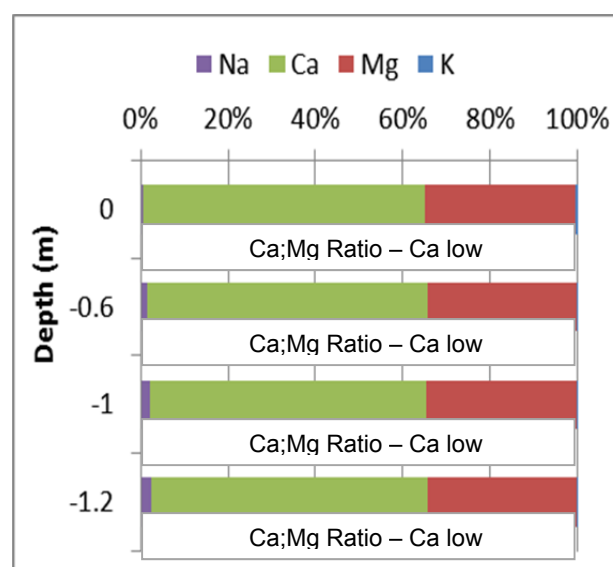


Figure 8bB: Exchangeable

3.2.12 Soil Group 8c – Deep Salic Vertosols

Description: Vertosols are characterised by deep (>1 metre) cracking clay soils mostly with self-mulching surface soils over dark grey-brown or brownish black strongly structured heavy clay subsoils with shiny slickensides surfaces tending to massive calcareous, marginally to highly saline heavy clay in the deeper subsoils. The topsoil is mainly non-dispersive, varies from non-saline to high saline and is moderately acidic to moderately alkaline. The subsoil is mainly non-dispersive, occasionally moderately dispersive, is moderately saline to extremely saline and neutral to moderately alkaline. The key characteristics of the Deep Vertosols are: their uniform medium to heavy clay texture throughout the profile, pronounced swelling and shrinkage properties on wetting and drying, and usually moderate to high levels of sodicity and/or salinity in the subsoil horizons. The Deep Salic Vertosols are widely associated with gilgai micro relief. The analytical information of the representative site for this soil type is presented in **Table 12** below.

Location: This soil type occurs extensively in the EIS study area and is particularly common in the north eastern areas, comprising drainage-ways, drainage flats and alluvial plain, on near level older alluvial plains and gently undulating plain, and on gently inclined slopes, foot-slopes and low rises. They encompass an area of 589.2 hectares, or 4.77 per cent of the EIS study area, as shown in **Figure 3**. This soil type is represented by pit B35.

Landuse: The land overlying these soils is currently used for extensive grazing, having been previously cleared of trees, cultivated and improved with native and exotic pasture species.

Management: These soils are texturally unsuitable for use as surface cover for rehabilitation. Potential for these soils to impact on infrastructure such as the incidental mine gas management infrastructure should be assessed as part of detailed design, and management such as use of hydrated lime may be required.



Plate 21: Deep Salic Vertosol Soil Profile



Plate 22: Deep Salic Vertosol Landscape Setting

Table 12 – Deep Salic Vertisol Laboratory Results

Depth	Colour	pH		ECe		CEC		ESP		EAT	
cm	Munsell	#	Rate	%	Rate	#	Rate	%	Rate	#	Rate
0 - 0.15	Dark brown	7.1	Neutral	0.86	Non saline	21.8	Moderate	1	Non sodic	5	Slight
0.15 - 0.4	Dark brown	8.4	Moderately alkaline	2.06	Slightly saline	38.6	High	2	Non sodic	5	Slight
0.4 - 0.9	Dark brown	8.4	Moderately alkaline	5.25	Moderately saline	37.8	High	7	Marginally sodic	5	Slight

The Deep Salic Vertisol profile is represented by: **Figure 8cA**, which shows the ECe and pH trend with depth, **8cB**, which shows the soil texture throughout the profile, and **Figure 8cC**, which shows the trend of exchangeable cations with depth. The entire data collection for this soil type, which includes laboratory results from the 2007, 2009 and 2011 studies, can be found in **Appendix 3**.

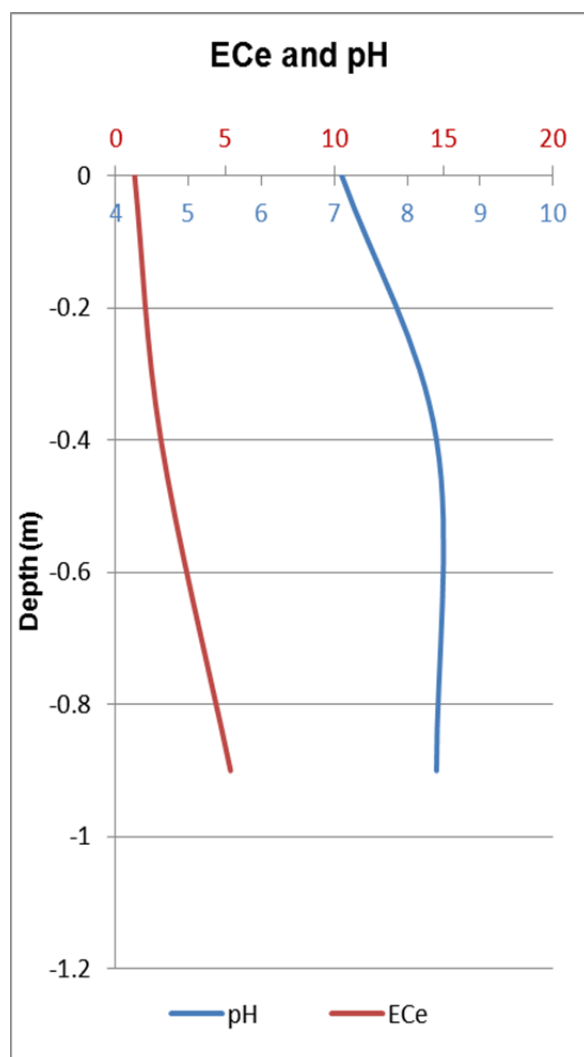


Figure 8cA : ECe and pH profile trends

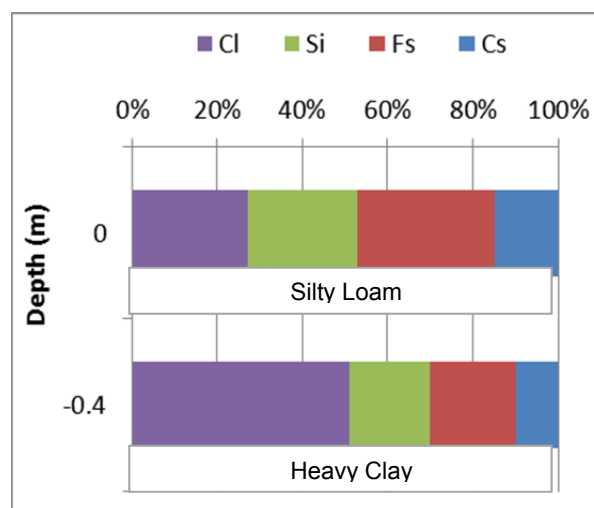


Figure 8cB : Particle Size Analysis

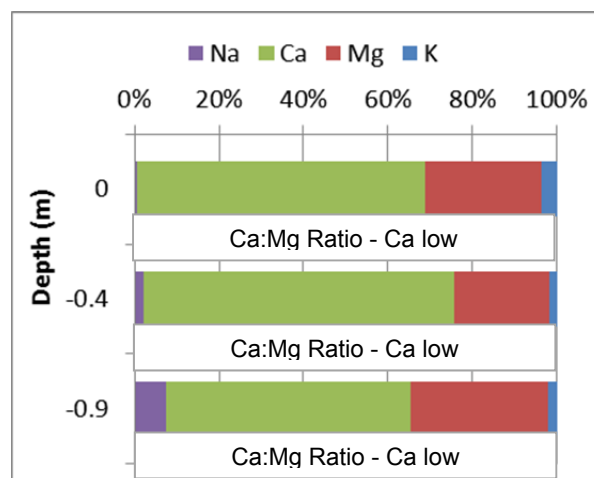


Figure 8cC: Exchangeable Cations

4.0 AGRICULTURAL LAND ASSESSMENT

Land is assessed for its suitability for agricultural activities and its relative agricultural importance for the region. This comprises a two part process. Firstly, the EIS study area's overall suitability ranking for each soil type is determined in accordance with the Department of Environment and Heritage Protection (formerly DERM) land suitability classification system (**Section 4.1**). Secondly, these suitability rankings are interpreted using the *Planning Guidelines: The Identification of Good Quality Agricultural Land* (DPI 1993) and translated into ALC (**Section 4.2**). These land classes are subsequently compared against the local shire planning document to determine which classes are considered to be Good Quality Agricultural Land (GQAL) for the specific region (**Section 4.3**). Land Assessment is carried out for both pre and post- mining circumstances.

4.1 Land Suitability Assessment

Agricultural land suitability of the EIS study area has been assessed largely using criteria provided in the *Guidelines for agricultural land evaluation in Queensland* (DPI 1990). The method of land suitability assessment takes into account a range of factors including climate, soils, geology, geomorphology, soil erosion, topography and the effects of past land uses. The classification does not necessarily reflect the existing land use. Rather, it indicates the potential of the land for such uses as crop production, pasture improvement and grazing. The system allows for land to be allocated into five possible classes (with land suitability for productive agriculture decreasing progressively from Class 1 to Class 5) on the basis of a specified land use that allows optimum production with minimal degradation to the land resource in the long term. Land is considered less suitable as the severity of limitations for a land use increases. Increasing limitations may reflect any combination of:

- Reduced potential for production;
- Increased inputs to achieve an acceptable level of production; and/or
- Increased inputs required to prevent land degradation.

The agricultural land suitability classes are described in **Table 13**.

Table 13 – Scheme for Classifying Land Suitability

LS Class	Orders	LS Class Descriptor	Description
1	S Suitable	S1 None/Minor Limitations (Highly Suitable)	Land with negligible limitations, which is highly productive requiring only simple management practices to maintain economic production.
2		S2 Minor Limitations (Moderately Suitable)	Land with minor limitations which either reduce production or require more than the simple management practices of Class 1 land to maintain economic production.
3		S3 Moderate Limitations (Marginally suitable)	Land with moderate limitations which either further lower production or require more than those management practices of Class 2 land to maintain economic production.

LS Class	Orders	LS Class Descriptor	Description
4	N Not Suitable	N1 (or S4) Marginal Land (Presently Unsuitable)	Marginal lands with severe limitations which make it doubtful whether the inputs required achieving and maintaining production outweigh the benefits in the long term (presently considered unsuitable due to the uncertainty of the land to achieve sustained economic production)
5		N2 (or S5) Unsuitable	Unsuitable land with extreme limitations that preclude its use for the proposed purpose.

Source: NCST 2008.

A land suitability assessment provides an analysis on how 'fit' a given area of land is for a specific type of land utilisation (e.g. rainfed cropping or grazing). The analysis considers the area's land use characteristics (e.g. soil pH), land quality attributes (e.g. moisture availability) and how these match conditions that are necessary for 'successful and sustained' implementation of a specific land utilisation type (NCST 2008; DME 1995; Shields and Williams 1991).

GSSE's land suitability analysis provides a proportional land suitability assessment whereby each soil type's characteristics and attributes are cross-referenced against the Queensland Department of Mines & Energy (DME) (1995) 'criteria checklist' for 'rainfed broadacre cropping' and 'beef cattle grazing'. The overall land suitability ranking for each specific soil type is determined by the most severe limitation, or a combination of the varying limitations. For this reason the major limiting factors determining land suitability will be presented.

4.1.1 Calculation of Plant Available Water Capacity and Effective Rooting Depth

The primary land suitability assessment attribute is 'moisture'. The indicator for moisture is plant available water capacity (PAWC). PAWC is an estimate of the amount of moisture stored in the soil profile that is available for plant extraction. It is generally defined as the difference between field capacity and permanent wilting point. PAWC is calculated for the soil profile by summing the available water capacity values at regular intervals for the distance of the soil's effective rooting depth (ERD).

ERD is defined as the soil depth to which 90 per cent of the plant roots will extract water (Burgess 2005). ERD can be estimated through observed rooting depth, soil chemical parameters or a standardised depth can be used (McKenzie *et al* 2008). For the purposes of this project, area assessment ERD has been determined from both observed rooting depth and the chemical parameters as defined in **Table 14**.

Table 14 – Effective Rooting Depth Criteria

Limitation #	Descriptor	ERD occurs where:
1	EC _{1:5} for sorghum and wheat ¹ (90% yield reduction threshold)	>0.8 dS/m
2	Chlorine (Cl) 1:5	>1000 ppm
3	ESP	>20% where clay content is >25%
4	pH	<5.5
5	Depth to C horizons	--
6	Unsuitable subsoil structure	moderate or strong columnar structure, sandy free draining horizons, significant rock content

Source: Burgess 2003

PAWC can be directly measured in the field, estimated from textural classes or interpolated using a Queensland approved software program (PAWCER). GSSE calculated PAWC using the PAWCER software program for each soil unit. Each soil unit's PAWC is detailed in **Table 15**. These values are used in the Land Suitability Assessment.

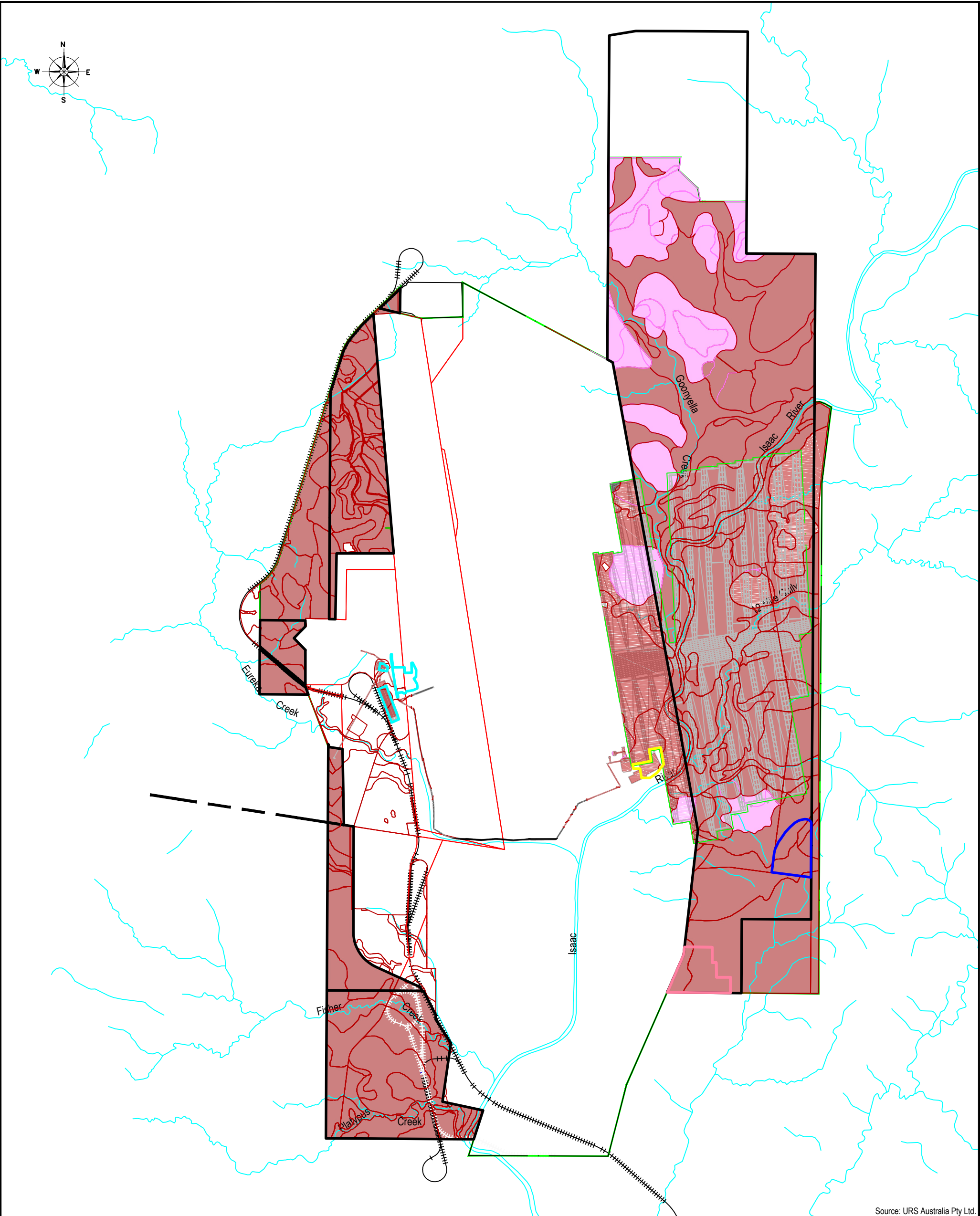
Table 15 – Effective Rooting Depth (ERD), Available Water Capacity (AWC) and PAWC

Soil Unit	Horizon	Limitation/s	Average ERD Depth (cm)	Average AWC (mm)	Average PAWC (mm)
1. Lithic Rudosol	1	-	n/a	n/a	n/a
Total			0	0	0
2. Tenosol	1	none	40	64	64
	2	6	40	64	0
Total			80	128	64
3a. Red Kandosol	1	2	20	48	48
	2	2	40	52	52
	3	1,2	40	96	96
Total			100	196	196
3b. Brown Kandosol	1	none	30	48	48
	2	none	50	80	80
Total			80	128	128
4. Brown Kurosol	1	none	15	19.5	19.5
	2	none	15	19.5	19.5
	3	1, 2, 3	30	36	0
	4	1, 3, 4	50	60	0
Total			110	39	39
5. Brown Chromosol	1	none	15	30	30
	2	none	25	50	50
	3	none	60	78	78
Total			100	158	158
6. Brown Sodosol	1	none	25	50	50
	2	none	25	50	50
	3	none	40	52	52
Total			90	152	152

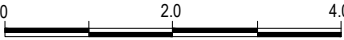
7. Brown Dermosol	1	none	10	13	13
	2	none	20	26	26
	3	1, 2, 3	90	117	0
Total			120	156	39
8a. Shallow Vertosols	1	none	20	24	24
	2	none	20	24	24
	3	none	60	72	72
Total			100	120	120
8b. Deep Vertosols	1	none	20	26	26
	2	none	40	52	52
	3	none	50	65	65
	4	none	60	78	78
Total			170	221	221
8c. Deep Salic Vertosols	1	3	15	19.5	0
	2	3	30	39	0
	3	3	75	97.5	0
Total			120	156	0

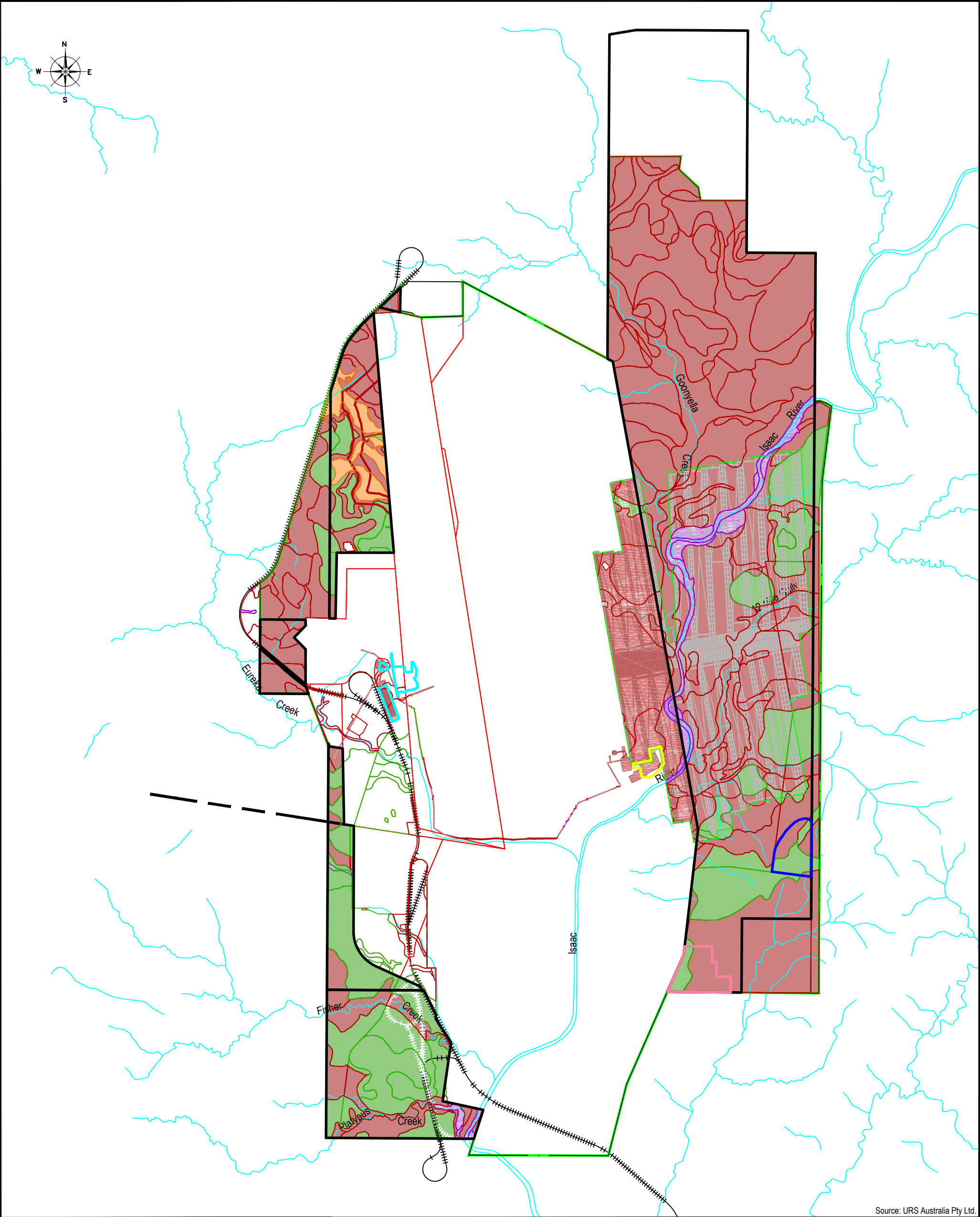
4.1.2 Land Suitability Rankings

The EIS study area's soil units have been assessed against the criteria for 'rainfed cropping' and 'broadacre grazing' land utilisation types as per the guidelines. The first limitation for land utilisation is moisture and each soil unit's average PAWC is provided in **Table 16**. The adjusted water availability value considers soil characteristics as well as the requirement for adequate rainfall which is required for sustainable yields. Where soil units have been classified as unsuitable for cropping (**Table 16**), these soil units have been subsequently assessed for their suitability for pastoral activities (refer **Table 17**). **Figure 9** and **Figure 10** illustrate their spatial distribution.



Source: URS Australia Pty Ltd.

LEGEND		Scale		FIGURE 9		Project:
				Land Suitability - Cropping		Red Hill Mining Lease EIS
	Project Site					Client:
	BMA ML & MLA Boundaries - Dec 2008					URS Australia Pty Ltd
	Rail Line	Base Plan Data Source: RWC & Geo-spectrum (Australia) Pty Ltd.				File:
	Proposed Mining Lease					Fg9_URS03-029_LandSuitability-Cropping_130822
	MIA (30.2)	Version	Date:	Author:	Checked:	Approved:
	Broadmeadow Extension (131.35 ha)	2	23/11/11	ZJ	MH	CR
	CHPP (53.9 ha)	3	30/11/11	ZJ/LF	MH	CR
	Accommodation Village (108.7 ha)	4	1/12/11	LF	MH	CR
		5	6/12/11	LF	AR	CR
		6	02/02/12	RH	RH	CR
		7	12/06/13	LF	AK	CR
				Environmental, Land and Project Management Consultants		Projection:
						MGA 94 Zone 55



Source: URS Australia Pty Ltd.

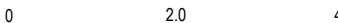
LEGEND		<u>Land Suitability - Grazing</u>				FIGURE 10		Project: Red Hill Mining Lease EIS																																				
 Project Site		 Class 2		Base Plan Data Source: RWC & Geo-spectrum (Australia) Pty Ltd.		Land Suitability - Grazing		Client: URS Australia Pty Ltd																																				
 BMA ML & MLA Boundaries - Dec 2008		 Class 3																																										
 Rail Line		 Class 4						File: Fg10_URS03-029_LandSuitability-Grazing_130822																																				
 Proposed Mining Lease		 Class 5				 GSS ENVIRONMENTAL Environmental, Land and Project Management Consultants		Projection: MGA 94 Zone 55																																				
 MIA (30.2)																																												
 Broadmeadow Extension (131.35 ha)																																												
 CHPP (53.9 ha)																																												
 Accommodation Village (108.7 ha)																																												
				<table><tr><td>Version</td><td>Date:</td><td>Author:</td><td>Checked:</td><td>Approved:</td></tr><tr><td>2</td><td>23/11/11</td><td>ZJ</td><td>MH</td><td>CR</td></tr><tr><td>3</td><td>30/11/11</td><td>ZJ/LF</td><td>MH</td><td>CR</td></tr><tr><td>4</td><td>1/12/11</td><td>LF</td><td>MH</td><td>CR</td></tr><tr><td>5</td><td>6/12/11</td><td>LF</td><td>AR</td><td>CR</td></tr><tr><td>6</td><td>02/02/12</td><td>RH</td><td>RH</td><td>CR</td></tr><tr><td>7</td><td>12/06/13</td><td>LF</td><td>AK</td><td>CR</td></tr></table>		Version	Date:	Author:	Checked:	Approved:	2	23/11/11	ZJ	MH	CR	3	30/11/11	ZJ/LF	MH	CR	4	1/12/11	LF	MH	CR	5	6/12/11	LF	AR	CR	6	02/02/12	RH	RH	CR	7	12/06/13	LF	AK	CR				
Version	Date:	Author:	Checked:	Approved:																																								
2	23/11/11	ZJ	MH	CR																																								
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6	02/02/12	RH	RH	CR																																								
7	12/06/13	LF	AK	CR																																								

Table 16 – Land Suitability Ranking for Rainfed Broadacre Cropping

Limitations	Soil Types										
	1	2	3a	3b	4	5	6	7	8a	8b	8c
Tabled Water availability	n/a	5	1	2	5	1	1	5	3	1	5
Adjusted Water availability	5	5	5	5	5	5	5	5	4	4	5
Nutrient deficiency	n/a	n/a	2	3	2	2	2	5	2	2	2
Soil physical factors	3	2	2	2	3	3	3	3	2	3	3
Soil workability	2	1	1	1	2	2	2	2	1	2	2
Salinity	n/a	n/a	1	1	5	1	1	4	1	1	1
Rockiness	4	1	1	2	2	1	1	1	1	1	1
Microrelief	1	1	1	1	1	1	1	1	1	3	3
Wetness	1	1	1	1	1	3	2	1	2	3	3
Topography	1	1	2	2	1	2	3	1	1	1	1
Water erosion	4	2	2	2	3	2	3	2	2	2	2
Flooding	1	2	1	1	1	1	1	1	1	1	1
Overall Ranking:	5	5	5	5	5	5	5	5	4	4	5
Soil Type Suitable?	No	No	No	No	No	No	No	No	Marginal	Marginal	No

Table 17 – Land Suitability Ranking for Beef Cattle Grazing

Limitations	Soil Types										
	1	2	3a	3b	4	5	6	7	8a	8b	8c
Water availability	n/a	4	1	1	5	1	1	5	2	1	5
Nutrient deficiency	1	2	1	1	1	1	1	1	2	2	2
Soil physical factors	2	1	1	1	2	2	2	2	2	3	3
Salinity	n/a	n/a	1	1	2	1	1	2	1	1	1
Rockiness	2	1	1	2	2	1	1	1	1	1	1
Microrelief	1	1	1	1	1	1	1	1	1	2	2
pH	n/a	n/a	2	2	2	2	2	3	3	3	3
ESP %	n/a	n/a	1	1	2	1	1	4	1	2	3
Wetness	1	2	2	2	1	2	2	2	2	2	2
Topography	1	1	1	1	1	1	1	1	1	1	1
Water erosion	3	1	1	1	1	1	3	1	1	1	1
Flooding	1	2	1	1	1	1	1	1	1	1	1
Vegetation regrowth	1	1	1	1	1	1	1	1	1	1	1
Overall Ranking:	3	4	2	2	5	2	3	3*	3	3	3*
Soil Type Suitability	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

* Modified due to field observations.

4.1.3 Post-mining Land Suitability

The proposed post-mining land use for the EIS study area is expected to be a mosaic of grassland and bushland as it is now, however given the proposed post mining landform there will also be areas of ponding throughout the disturbance footprint. In terms of soil conservation and agricultural land suitability, there is minimal planned disturbance over the areas suitable for rainfed cropping. However, disturbance within the RHM, which is dominated by grazing land, is anticipated to include subsidence of longwall panels on average three to five metres and up to six metres, and surface disturbance for gas drainage infrastructure. The proposed disturbances are predicted to have an impact on the land suitability classes associated with beef cattle grazing, as outlined in **Table 18** below and shown in **Figure 11**.

Table 18 – Land Suitability Pre and Post Mining

Land Suitability Class (Beef Cattle Grazing)	Existing Area External ML	Existing Area Internal ML	Post Mining Area External ML	Post Mining Area Internal ML
	ha	ha	ha	ha
2	3886.8	17.1	3838.2	7.6
3	7002.7	955.3	6665.2	813.9
4	269.51	25.2	260.71	25.2
5	135.44	nil	530.34	150.9
Total Area	11,294.45	997.5	11,294.45	997.5

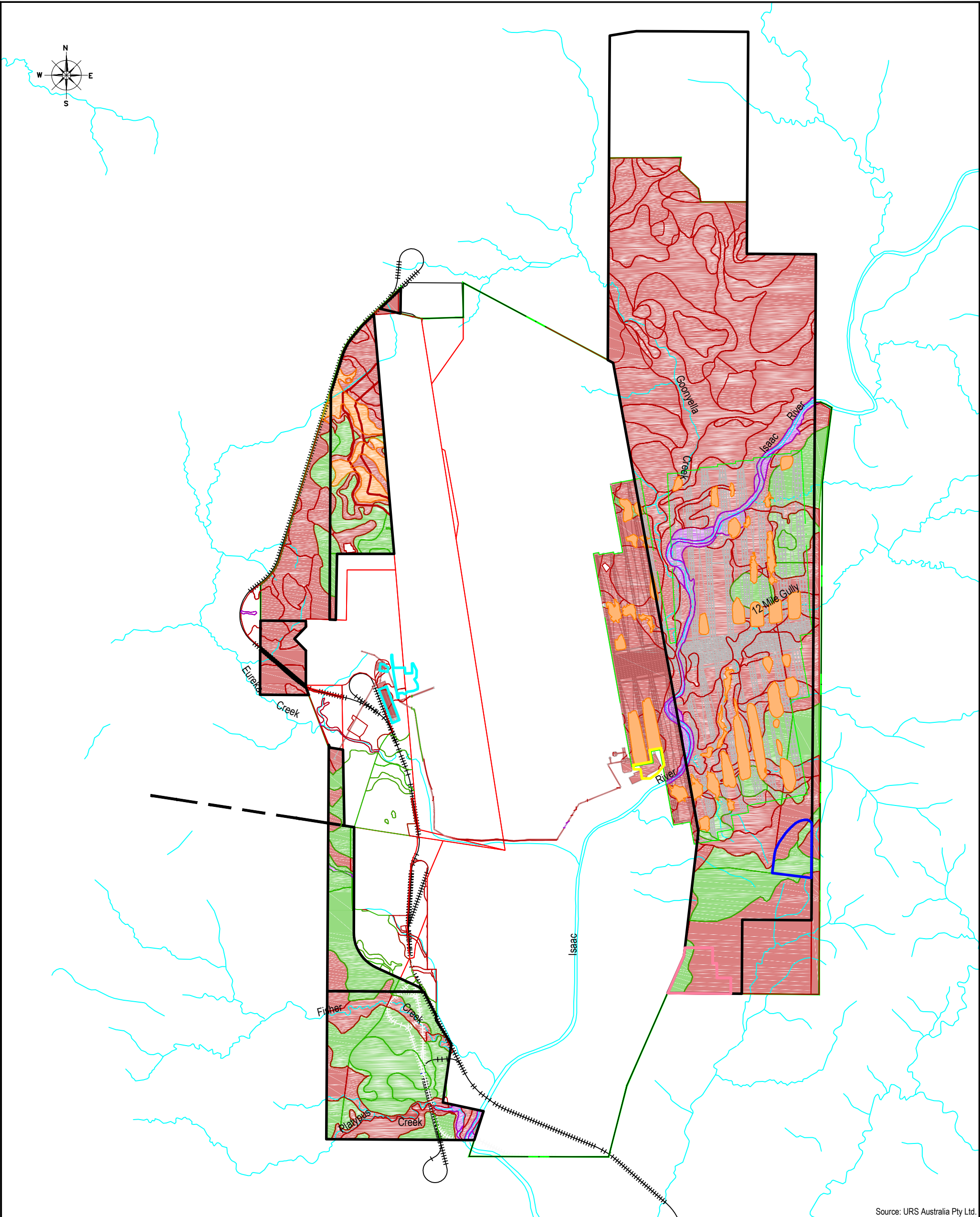
According to the Red Hill Mining lease EIS Section 7, the mapped potential ponding extent represents the worst case scenario. The ponding modelling assumes that no works are undertaken to drain or partially drain the voids, no erosion occurs along the overflow flowpaths, and no sedimentation occurs in the voids. It is expected that if no drainage works are undertaken, their storage capacities could gradually diminish overtime as erosion of the overflow flowpaths occurs, and sediment is deposited in the voids, similar to the processes described in the subsidence impacts on Isaac River geomorphology in **Section 7.2.6**, however there will be no change to the surface area of the ponds shown in **Figure 11** as Land Suitability Class 5 and **Figure 12** as ALC D.

Despite these relatively simple assumptions to define a worst case scenario for potential ponding in the subsidence voids, the mapped potential ponding extents were considered a reasonable basis to assess worst case potential impacts of ponding on Land Suitability and ALC.

The mapping of potential subsidence void ponding extents and volumes (outside the Isaac River channel) identified 44 significant ponding areas (larger than two hectares). The areas of potential ponding would be up to 40 hectares, and the average area would be approximately 12 hectares.

In order to sustain the desired land use without degradation, it is important that the post-mining land only be used in accordance with the limits of the land suitability class. Soil conservation practices such as erosion and sediment control, stocking rate control and establishment or re-establishment of permanent pasture are recommended for areas of mining impact. The overriding principle is to maintain the most beneficial future use of land that can be sustained in view of the range of limiting factors. The proposed post-mining land must provide and sustain a sufficient bulk of nutritious forage in addition to the following management considerations in the event of future low density grazing:

- The ability to access and manage livestock;
- Flood free and relatively dry ground conditions in non-ponded areas;
- Adequate stock drinking water and shelter; and
- Stock routes throughout the land.



Source: URS Australia Pty Ltd.

LEGEND		02.04.2013	FIGURE 11					Project:
			Post Mining Land Suitability - Grazing					Red Hill Mining Lease EIS
Project Site	Land Suitability - Grazing		0 2.0 4.0km					Client:
BMA ML & MLA Boundaries - Dec 2008	Class 2							URS Australia Pty Ltd
Rail Line	Class 3		Base Plan Data Source: RWC & Geo-spectrum (Australia) Pty Ltd.					File:
Proposed Mining Lease	Class 4							Fg11_URS03-029_PostLS-Grazing_130822
MIA (30.2)	Class 5		Version	Date:	Author:	Checked:	Approved:	Projection:
Broadmeadow Extension (131.35 ha)			2	23/11/11	ZJ	MH	CR	MGA 94 Zone 55
CHPP (53.9 ha)			3	30/11/11	ZJ/LF	MH	CR	
Accommodation Village (108.7 ha)			4	1/12/11	LF	MH	CR	
			5	6/12/11	LF	AR	CR	
			6	02/02/12	RH	RH	CR	
			7	14/03/12	LF	CR	CR	
			8	13/06/12	LF	AK	CR	
			GSS ENVIRONMENTAL Environmental, Land and Project Management Consultants					

4.2 Agricultural Land Class Assessment & GQAL

The EIS study area was also assessed against the ALC system, which is used to identify potential GQAL in accordance with the *Guidelines for the identification Good Quality Agricultural Land* (DPI 1993) (referred to as the GQAL guidelines). Agricultural land is defined as land used for crop or animal production, but excluding intensive animal uses (i.e. feedlots and piggeries). GQAL is land which is capable of sustainable use for agriculture, with a reasonable level of inputs, and without causing degradation of land or other natural resources.

The DPI guidelines have been introduced to provide local authorities and development proponents with a system to identify areas of GQAL for planning and project approval purposes. Descriptions of the ALCs are provided in **Table 19**.

The ALC classification system combines land suitability assessments for a number of specific land utilisation types into a single land classification. This ALC classification system has four categories: Arable (A), Limited arable (B), Pastoral (C) and Non-agricultural (D) (refer **Table 20**).

Table 19 – Scheme for Classifying Agricultural Land

Class	Name	Description
A	Arable land (Crop land)	Land that is suitable for current and potential crops with limitations to production which range from none to moderate levels.
B	Limited arable land (Limited crop land)	Land that is marginal for current and potential crops due to severe limitations; and suitable for pastures. Engineering and/or agronomic improvements may be required before the land is considered suitable for cropping.
C	Pastoral land	Land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production; but some areas may tolerate a short period of ground disturbance for pasture establishment.
D	Non-agricultural land	Land not suitable for agricultural uses due to extreme limitations. This may be undisturbed land with significant habitat, conservation and/or catchment values or land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop or poor drainage.

Source: DPI 1993.

Table 20 – Broadacre Cropping Land Suitability Ranking and Agricultural Land Class Correlation

LS Ranking	Description	ALC
1	High quality land with few or minor limitations	A
2	Land with minor limitations	A
3	Moderate limitations to sustaining its use.	A
4	Marginal land requiring major inputs to sustain the use.	B or C
5	Unsuitable due to extreme limitations.	C or D

The overall land suitability rating of 1-5 is translated into an ALC rating of A-D. Additionally, for the Central West Queensland region, ALC C is further divided into three sub-classes of C1, C2 and C3, according to potential grazing quality, as outlined in **Table 21** below.

Table 21 – Beef Cattle Grazing Land Suitability Ranking and ALC

LS Rating	Land Suitability Description (DME 1995)	ALC	ALC Description	B. Forster DERM (per comm., 2010))
1	High quality land with few or minor limitations	C1	Good quality grazing and/or highly suitable for pasture improvement	Brigalow vegetation; appropriate for fattening beef cattle; good grazing on sown pastures and can withstand ground disturbance.
2	Land with minor limitations	C1		Brigalow vegetation and/or transitional vegetation to poplar box vegetation communities.
3	Moderate limitations to sustaining its use	C2	Moderate quality grazing and/or moderately suitable for pasture improvement.	Eucalypt woodland, poplar box, narrow-leaved eucalyptus, gum-top woodlands; low-moderate PAWC and low-moderate fertility; good grazing on native pastures without ground disturbance; appropriate for beef cattle breeders.
4	Marginal land requiring major inputs to sustain the use	C3	Low quality grazing, grazing of native pastures with limited suitability for pasture improvement.	Tea-tree vegetation; usually characterised by steep country or mangrove flats.
5	Unsuitable due to extreme limitations.	D	Not suitable	Unsuitable due to extreme limitations.

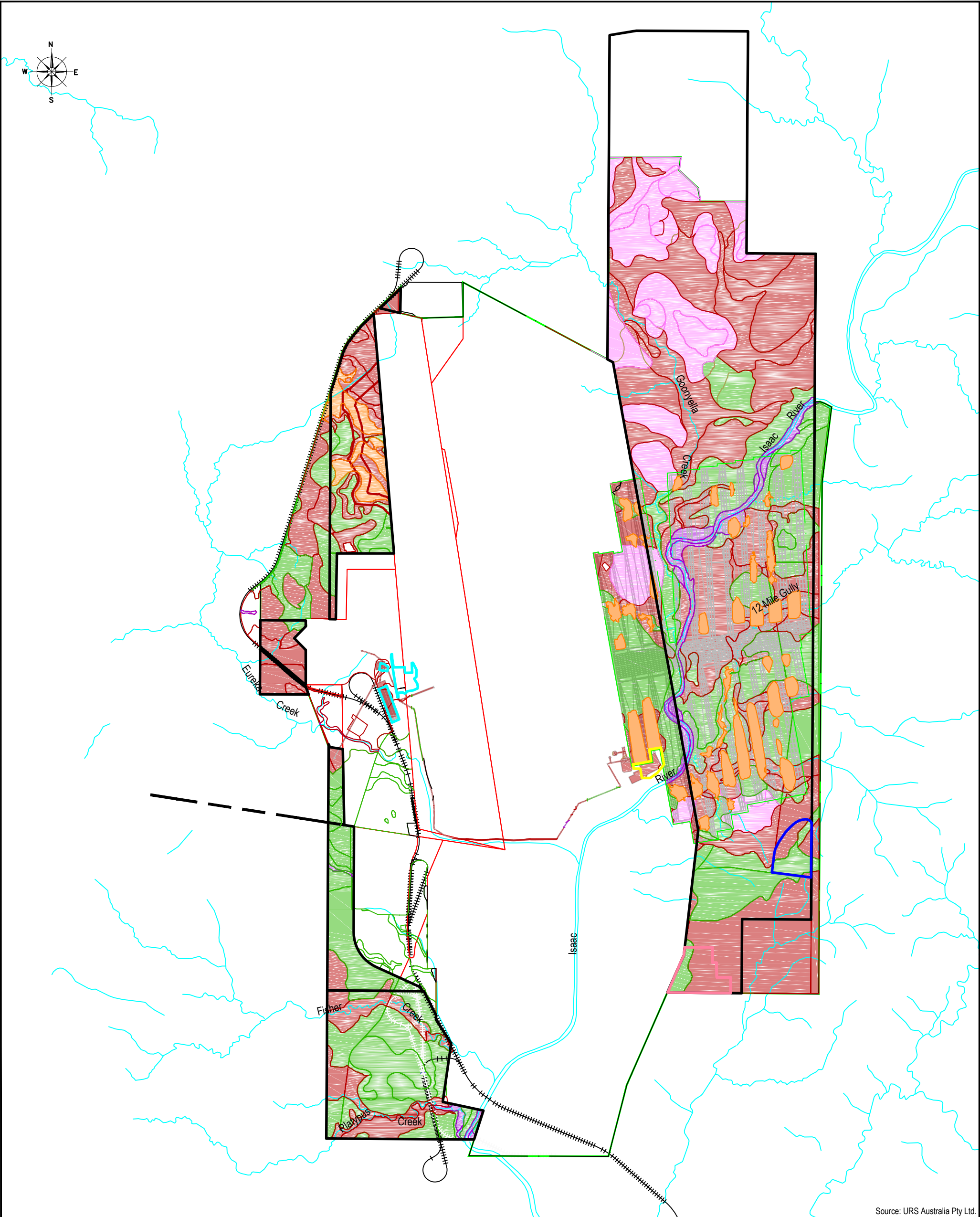
4.2.1 Good Quality Agricultural Results

The Isaac Regional Council classifies the ALC Classes A, B and C1 as GQAL. As such, **Table 22** shows the amount of GQAL in the EIS study area. According to the Isaac Regional Council Planning Scheme ALC A, B & C1 are considered GQAL. The EIS study area contains 6,161.06 hectares of GQAL under the above definition. The spatial distribution of this classification is shown in **Figure 12**.

Table 22 – Agricultural Land Class (ALC) and GQAL

Soil Type	Cropping LS Rating	Grazing LS Rating	Equivalent ALC	GQAL	EIS study area (external mining lease)	EIS study area (internal mining lease)	Area (%)
					Area (ha)	Area (ha)	
1. Lithic Rudosol	-	3	C2	No	426.0	2.8	3.5
2. Tenosol	-	4	C3	No	269.51	25.18	2.4
3a. Red Kandosol	-	2	C1	Yes	2051.8	0.35	16.6
3b. Brown Kandosol	-	2	C1	Yes	386.0	16.7	3.3
4. Brown Kurosol	-	5	D	No	186.7	x	1.5
5. Brown Chromosol	-	2	C1	Yes	1,444.53	416.7	15.1
6. Brown Sodosol	-	3	C2	No	1,757.31	176.4	15.7
7. Brown Dermosol	-	3	C2	No	816.6	168	8.0
8a. Shallow Vertosol	4	3	B	Yes	692.1	154.6	6.8
8b. Deep Vertosol	4	3	B	Yes	589.2	x	4.8
8c. Deep Salic Vertosol	-	3	C2	No	2674.8	36.8	22
Total					11,294.55	1,032.83	100%

Based on the anticipated ponding in the proposed post mining landform, there is a reduction of 394.9 hectares external to the mining lease and 150.9 hectares inside the existing mining lease, of grazing land (ALC – C) to permanent or semi-permanent ponding unsuitable for grazing (ALC – D). The ponding may be considered a potential water storage source for cattle however for the purposes of this assessment it is considered ALC – D.



Source: URS Australia Pty Ltd.

LEGEND		02.04.2013 0 2.0 4.0km Base Plan Data Source: RWC & Geo-spectrum (Australia) Pty Ltd. <table><tr><th>Version</th><th>Date:</th><th>Author:</th><th>Checked:</th><th>Approved:</th></tr><tr><td>2</td><td>23/11/11</td><td>ZJ</td><td>MH</td><td>CR</td></tr><tr><td>3</td><td>30/11/11</td><td>ZJ/LF</td><td>MH</td><td>CR</td></tr><tr><td>4</td><td>1/12/11</td><td>LF</td><td>MH</td><td>CR</td></tr><tr><td>5</td><td>6/12/11</td><td>LF</td><td>AR</td><td>CR</td></tr><tr><td>6</td><td>02/02/12</td><td>RH</td><td>RH</td><td>CR</td></tr><tr><td>7</td><td>14/03/12</td><td>LF</td><td>CR</td><td>CR</td></tr><tr><td>7</td><td>13/06/13</td><td>LF</td><td>AK</td><td>CR</td></tr></table>					Version	Date:	Author:	Checked:	Approved:	2	23/11/11	ZJ	MH	CR	3	30/11/11	ZJ/LF	MH	CR	4	1/12/11	LF	MH	CR	5	6/12/11	LF	AR	CR	6	02/02/12	RH	RH	CR	7	14/03/12	LF	CR	CR	7	13/06/13	LF	AK	CR	FIGURE 12		Project:
Version	Date:						Author:	Checked:	Approved:																																								
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Project Site BMA ML & MLA Boundaries - Dec 2008 +++++ Rail Line Proposed Mining Lease MIA (30.2) Broadmeadow Extension (131.35 ha) CHPP (53.9 ha) Accommodation Village (108.7 ha)	Agricultural Land Class Class B (GQAL) Class C1 (GQAL) Class C2 Class C3 Class D	Agricultural Land Class - GQAL		Client:																																													
		GSS ENVIRONMENTAL Environmental, Land and Project Management Consultants		File:																																													
				Projection:																																													

4.4 Strategic Cropping Land Assessment

An assessment of the potential for the project to infringe on SCL has been undertaken using the *Protecting Queensland's Strategic Cropping Land: A Policy Framework* (DERM 2010; referred to as the Policy) as guidance.

In 2010 the Queensland Government released the Policy to protect Queensland's best cropping land from permanent alienation or diminished productivity due to the competing land-uses of agricultural, mining and urban development. This Policy provides a new framework and approach for the conservation and management of Queensland's best cropping land for long-term food production and regional growth. This land is called SCL and includes the best land that is currently being cropped as well as the best land resources that could be cropped in the future.

SCL is defined by soil, climatic and landscape characteristics which result in an area highly suitable for crop production. A staged assessment process has been used to identify whether SCL is present. As shown below in **Table 23**.

Table 23 – Process of Assessing SCL

Step	Process	Action
1	Check if the land is in an SCL zone	Yes —Proceed to step 2 No —Land outside of the SCL zones is not subject to the SCL policy
2	Is the land shown as likely SCL on the trigger map?	No —Development proponent: No further assessment required under SCL policy No —Landholder: May wish to conduct an assessment of the land to determine whether it is likely to be SCL and apply to 'opt in' to trigger map Yes —Proceed to Step 3
3	Identify which SCL zone the land is in—Western Cropping, Eastern Darling Downs, Coastal Queensland, Wet Tropics or Granite Belt zone.	Consult the appropriate SCL criteria
4	Conduct an on-ground assessment using the appropriate SCL criteria and guidelines. Proceed to Step 5.	
5	If the land is SCL and within a Strategic Cropping Protection Area, no further SCL validation assessment is required and development will be assessed under the SCL policy. If the land is SCL and within the Strategic Cropping Management Area, the property will also need to be assessed for a history of cropping. If the land meets the SCL criteria and the history of cropping test, no further SCL validation assessment is required and development will be assessed under the SCL policy. Otherwise, the SCL policy will not apply.	

Source: DERM 2011.

Initially, publicly available trigger maps were consulted to determine whether the EIS study area was likely to interact with an area of SCL. There is approximately 500 hectares of trigger mapped SCL that required field assessment and ground truthing. Preliminary field investigations were undertaken prior to the release of the SCL assessment guidelines in September 2011. This preliminary fieldwork found that there was potential SCL within the trigger mapped areas, however this would require further investigation and testing against the final SCL criteria to accurately determine if soil conditions meet the requirements. The soil criteria used to identify SCL is outlined below in **Table 24**.

Table 24 – Summary of Criteria for Identifying SCL

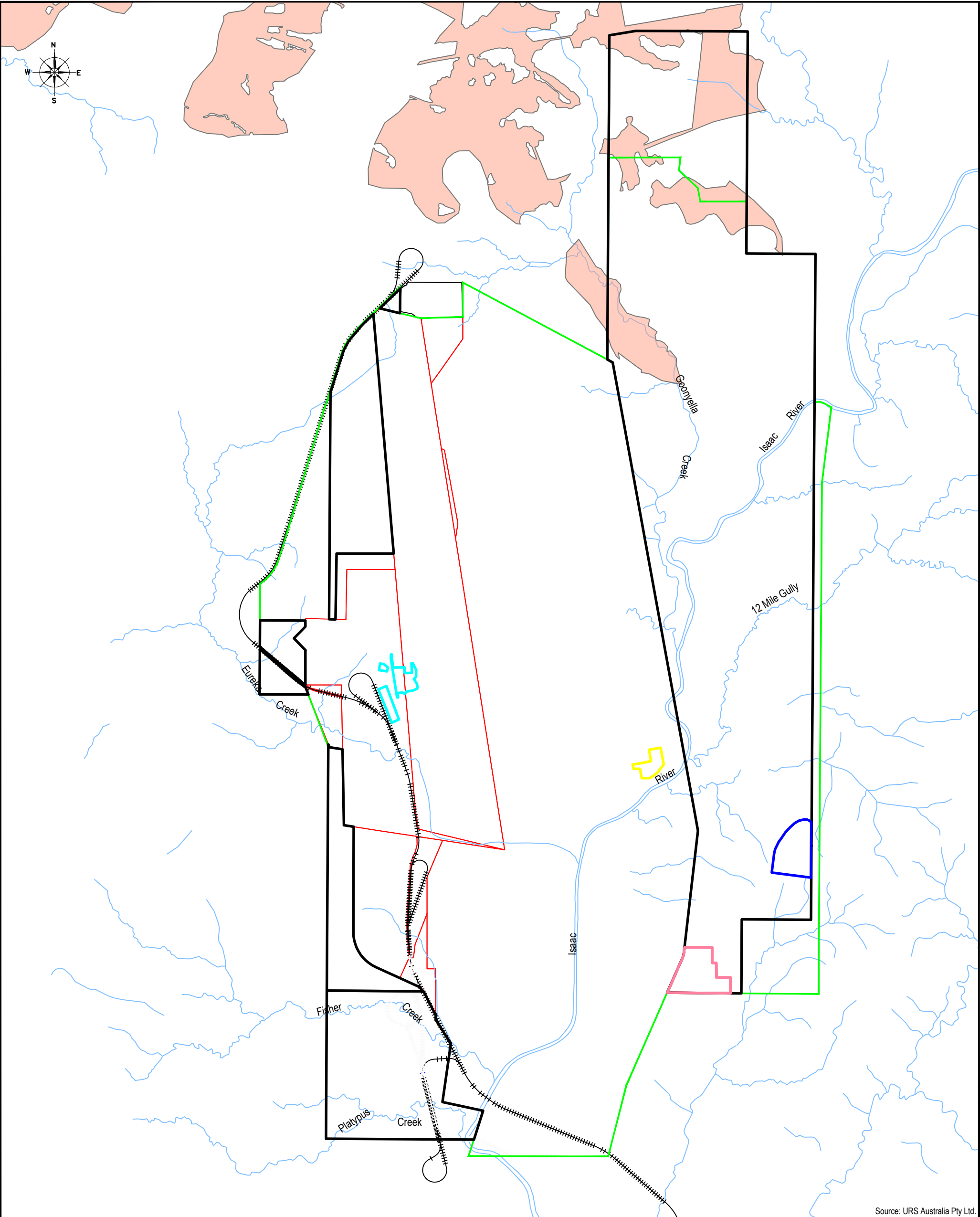
Criteria	Criteria thresholds for each SCL zone				
	Western Cropping	Eastern Darling Downs	Coastal Queensland	Wet Tropics	Granite Belt
1. Slope	≤ 3%	≤ 5%			
2. Rockiness	≤ 20% for rocks > 60 mm diameter				
3. Gilgai microrelief	< 50% of land surface being gilgai microrelief of > 500 mm in depth				
4. Soil depth	≥ 600 mm				
5. Soil wetness	Has favourable drainage				Has satisfactory drainage
6. Soil pH	For non-rigid soils, the soil at 300 mm and 600 mm soil depth must be greater than pH 5.0. For rigid soils, the soil at 300 mm and 600 mm soil depth must be within the range of pH 5.1 to pH 8.9 inclusive.				
7. Salinity	Chloride content < 800 mg/kg within 600 mm of the soil surface		EC _{1.5} < 0.56 dS/m within 600 mm of the soil surface		
8. Soil water storage	≥ 100 mm to a soil depth or soil physico-chemical limitation of ≤1000 mm	≥ 75 mm to a soil depth or soil physico-chemical limitation of ≤1000 mm	≥ 50 mm to a soil depth or soil physico-chemical limitation of ≤1000 mm	≥ 25 mm to a soil depth or soil physico-chemical limitation of ≤1000 mm	

Section 4 of the *Protecting QLD's strategic cropping Land – Guidelines for applying the proposed strategic cropping land criteria* (DERM 2011) outlines the detail of each of the eight criteria and methodology for assessment.

Whilst preliminary field investigations found some areas meeting most criteria shown above, there was no evidence of regular cropping and no evidence of cropping within the last 10 to 15 years. The history of cropping is a requirement for an area to be assessed under the SCL policy within the SCL Management Zone, which includes the EIS study area, as shown in Point 5 of **Table 23**.

Figure 13 shows the presence of trigger mapped SCL in the north-eastern area of the site. This area of the EIS study area is not expected to be disturbed by mining operations, and it can be confirmed that there are no current or foreseeable impacts on the designated SCL. Should the scope of project activities change and potentially impact on a mapped area of SCL, BMA will undertake the following steps:

1. Undertake a 'History of Cropping' assessment for the project site to determine if a validation decision could be applied for without further ground truthing.
2. In the event the EIS study area is considered not to fulfil all the required criteria for SCL, as preliminary investigations have indicated due to the lack of evidence of cropping in the area, a validation application will be prepared and submitted to the Department of Natural Resources and Mines for a validation decision, as described in Sections 42 and 44 - 50 of the *Strategic Cropping Land Act 2011*.
3. Alternatively, in the event the EIS study area is considered to fulfil all the required criteria for SCL, a protection application will be prepared and submitted to the Department of Natural Resources and Mines for a protection decision, as described in Sections 95 - 97 of the *Strategic Cropping Land Act 2011*.



Source: URS Australia Pty Ltd.

LEGEND Project Site BMA ML & MLA Boundaries - Dec 2008 Rail Line Trigger Mapped Potential SCL Proposed Mining Lease MIA (30.2) Broadmeadow Extension (131.35 ha) CHPP (53.9 ha) Accommodation Village (108.7 ha)	02.04.0km					FIGURE 13		Project: Red Hill Mining Lease EIS	
	Base Plan Data Source: RWC & Geo-spectrum (Australia) Pty Ltd.					SCL Trigger Mapping		Client: URS Australia Pty Ltd	
	Version	Date:	Author:	Checked:	Approved:	GSS ENVIRONMENTAL Environmental, Land and Project Management Consultants		File: Fg13_URS03-029_SCL-TriggerMap_130613	
	1	10/08/11	LH	MH	CR			Projection: MGA 94 Zone 55	
	2	23/11/11	ZJ	MH	CR				
3	30/11/11	ZJ/LF	MH	CR					
4	1/12/11	ZJ/LF	MH	CR					
5	6/12/11	LF	AR	CR					
6	13/6/13	LF	AK	CR					

5.0 SOIL MANAGEMENT

5.1 Acid Sulfate Soil Potential

The potential for acid generation from regolith material (topsoil and subsoil) within the EIS study area is low. This does not include acid generation potential within the overburden material (consolidated bedrock below two to three metres depth). Acid Sulphate Soils (ASS), which are the main cause of acid generation within the soil mantle, are commonly found less than five metres above sea level, particularly in low-lying coastal areas such as mangroves, salt marshes, floodplains, swamps, wetlands, estuaries, and brackish or tidal lakes. The EIS study area is located within the Central Highlands region (which is approximately 150 kilometres from the coast at >260 metres AHD). There has been little history of acid generation from regolith material within this region.

5.2 Soil Stripping Assessment

All soils within the EIS study area have been assessed to determine suitability for stripping and re-use on rehabilitation sites. This assessment is an integral process for successful rehabilitation of the EIS study area. This report provides information on the following key areas related to the management of the soil resources associated with the project:

- Soil stripping assessment, which provides a soil stripping depth map indicating recommended stripping depths for soil salvage and re-use as topdressing in rehabilitation; and
- Soil management for soil that is stripped, stored and used as a topdressing material for rehabilitation.

The laboratory test results were used in conjunction with the field assessment results to determine the depth of soil material that is suitable for stripping and re-use for the rehabilitation of disturbed areas.

5.2.1 Soil Stripping Assessment Methodology

Determination of suitable soil to conserve for later use in mine rehabilitation has been conducted in accordance with Elliott and Veness (1981) and Elliot and Reynolds (2000). The approach remains the benchmark for land resource assessment in the Australian mining industry. This procedure involves assessing soils based on a range of physical and chemical parameters. **Figure 14** summarises the procedure for the selection of soil material for use as topdressing of areas disturbed by the project and **Table 25** lists the key parameters and corresponding desirable selection criteria.

Table 25– Soil Stripping Suitability Criteria

Parameter	Desirable criteria
Structure Grade	>30% peds
Coherence	Coherent (wet and dry)
Mottling	Absent
Macrostructure	>10 cm
Force to Disrupt Peds	≤ 3 (moderately weak force and above)
Texture	Finer than a Fine Sandy Loam
Gravel & Sand Content	<60%
pH	4.5 to 8.4
Salt Content	<1.5 dS/m

Gravel and sand content, pH and salinity were determined for all samples using the laboratory test results. Texture was determined in the field and cross referenced with laboratory results, specifically particle size analysis. All other physical parameters outlined in **Table 23** were determined during the field assessment.

Structural grade is significant in terms of the soil's capability to facilitate water relations and aeration. Good permeability and adequate aeration are essential for the germination and establishment of plants. The ability of water to enter soil generally varies with structure grade and depends on the proportion of coarse peds in the soil surface. Well-structured soils have higher infiltration rates and better aeration characteristics. Structureless soils, without pores, are considered unsuitable as topdressing materials.

The shearing test is used as a measure of the soil's ability to maintain structure grade. Brittle soils are not considered suitable for revegetation where structure grade is weak or moderate. This is because peds are likely to be destroyed and structure is likely to become massive following mechanical work associated with the excavation, transportation and spreading of topdressing material. Consequently, surface sealing and reduced infiltration of water may occur which will restrict the establishment of plants.

The force to disrupt peds, when assessed on soil in a moderately moist state, is an indicator of solidity and the method of ped formation. Deflocculated soils are hard when dry and slake when wet, whereas flocculated soils produce crumbly peds in both the wet and dry state. The deflocculated soils are not suitable for revegetation and may be identified by a strong force required to break aggregates.

The presence of mottling within the soil may indicate reducing conditions and poor soil aeration. These factors are common in soil with low permeability; however some soils are mottled due to other reasons, including proximity to high water-tables or inheritance of mottles from previous conditions. Reducing soils and poorly aerated soils are unsuitable for revegetation purposes.

5.2.2 Potential Soil Stripping Depths

Table 26 lists the recommended stripping depths for each soil type within the entire proposed EIS study area, however the soil types likely to undergo surface disturbance and be stripped of topsoil are those that lie on the areas which will be required for surface facilities. Therefore soils within the gas drainage infrastructure disturbance areas will be stripped and stockpiled adjacent the actual disturbance area and re-instated during rehabilitation. Whilst the subsoils in Table 26 are considered unsuitable for topdressing, they may be suitable for use as an intermediate or subsoil layer below the topsoil in the rehabilitated profile.

Table 26 – Potential Stripping Depth for each Soil Type

Soil Type #	Soil Type	Area in EIS study area (ha)	Potential Topsoil Stripping Depth (m)	Potential Subsoil Stripping Depth*
1	Lithic Rudosol	428.8	Nil	Nil
2	Tenosol	294.69	0.4	0.8
3a	Red Kandosol	2052.15	0.3	Nil
3b	Brown Kandosol	402.7	0.5	Nil
4	Brown Kurosol	186.7	0.3	Nil
5	Brown Chromosol	1861.23	0.4	Nil
6	Brown Sodosol	1933.71	0.25	Nil

Soil Type	Soil Type	Area in EIS study area	Potential Topsoil	Potential Subsoil
7	Brown Dermosol	984.6	0.2	Nil
8a	Shallow Vertosol	846.7	Nil	Nil
8b	Deep Vertosol	589.2	Nil	Nil
8c	Deep Salic Vertosol	2711.6	Nil	Nil

5.2.3 Soil Management

The following management and mitigation strategies are recommended during mining, in order to reduce the potential for degradation within the EIS study area and adjoining lands. These strategies are based on the assessment of the existing site conditions and experience with the management of mining surface impacts at sites throughout New South Wales and Central Queensland, and apply to both topsoil and subsoil stripping, the following points should be read in conjunction with Section 5.5.7 of the Red Hill Mining Lease EIS and final management plans should be determined prior to the commencement of construction activities:

- Strip material to the depths stated in **Table 26**, subject to further field investigations during stripping activities.
- Soil should preferably be stripped in a slightly moist condition.
- Place stripped material directly onto the area to be rehabilitated and spread immediately (if mining sequences, equipment scheduling and weather conditions permit) to avoid the requirement for stockpiling.
- Grade or push soil into windrows with graders or dozers for later collection by open bowl scrapers or for loading into rear dump trucks by front-end loaders. These techniques are examples of preferential less aggressive soil handling systems. This minimises compression effects of the heavy equipment that is often necessary for economical transport of soil material.
- Soil transported by dump trucks may be placed directly into storage. Soil transported by scrapers is best pushed to form stockpiles by other equipment (e.g. dozer) to avoid tracking over previously laid soil.
- The surface of soil stockpiles should be left in as coarsely structured a condition as possible in order to promote infiltration and minimise erosion until vegetation is established, and to prevent anaerobic zones forming.
- As a general rule, maintain a maximum stockpile height of three metres. Clayey soils should be stored in lower stockpiles for shorter periods of time compared to coarser textured sandy soils.
- If long-term stockpiling is planned (i.e. greater than 12 months), seed and fertilise stockpiles as soon as possible. An annual cover crop species that produce sterile florets or seeds should be sown. A rapid growing and healthy annual pasture sward provides sufficient competition to minimise the emergence of undesirable weed species. The annual pasture species will not persist in the rehabilitation areas but will provide sufficient competition for emerging weed species and enhance the desirable micro-organism activity in the soil.

- Prior to re-spreading stockpiled topsoil onto disturbed areas (particularly onto designated tree seeding areas), an assessment of weed infestation on stockpiles should be undertaken to determine if individual stockpiles require herbicide application and / or 'scalping' of weed species prior to topsoil spreading.
- An inventory of available soil should be maintained to ensure adequate topsoil materials are available for planned rehabilitation activities.
- Topsoil will be spread to a minimum depth range of 0.1 metre. Soil resspreading on steep slopes at depths exceeding 0.1 metre can be deleterious because of the 'sponge' effect which can cause slippage of the topsoil from the slope.

5.2.4 Topsoil Stripping Criteria

The potential for major land disturbance is likely to result from excavation of the infrastructure areas. It is recommended that topsoil be recovered in these areas of disturbance.

Soil analysis results were used in conjunction with the field assessment to determine the depth of soil materials suitable for recovery. Structural and textural properties of subsoils are the most significant limiting factors in determining depth of soil suitable for re-use. Salinity levels, pH and dispersion potential are also limiting factors in some soils in the EIS study area. Elliot and Reynolds (2000) described the basic procedure adopted in this survey for the recognition of suitable topdressing materials (refer **Table 27**). This procedure has been adapted to include sandy loams as suitable.

Table 27 – Topsoil Stripping Criteria

Descriptor	Reasoning	Desirable criteria
Structure Grade	Good permeability to water and adequate aeration are essential for the germination and establishment of plants. The ability of water to enter soil generally varies with structure grade and depends on the proportion of coarse peds in the soil surface. Better structured soils have higher infiltration rates and better aeration characteristics. Structureless soils without pores are considered unsuitable as topdressing materials.	- 30% peds present - coherent when wet or dry - EAT: < 2 (2) - conductivity: < 1.5 dS/m - exchangeable Na% < 12% - pH: > 4.5 & < 8.4 - no mottle present - finer than sandy loam - sand & gravel content < 60%
Consistence – Shearing Test	The shearing test is used as a measure of the ability of soils to maintain structure grade. Brittle soils are not considered suitable for revegetation where structure grade is weak or moderate because peds are likely to be destroyed and structure is likely to become massive following mechanical work associated with the extraction, transportation and spreading of topdressing material. Consequently, surface sealing and reduced infiltration of water may occur which will restrict the establishment of plants.	
Consistence – Disruptive Test	The force to disrupt peds, when assessed on soil in a moderately moist state, is an indicator of solidity and the method of ped formation. Deflocculated soils are hard when dry and slake when wet, whereas flocculated soils produce crumbly peds in both the wet and dry state. The deflocculated soils are not suitable for revegetation and may be identified by a strong force required to break aggregates	
Mottling	The presence of mottling within the soil may indicate reducing conditions and poor soil aeration. These factors are common in soil with low permeability; however some soils are mottled due to other reasons, including proximity to high water-tables or inheritance of mottles from previous conditions. Reducing soils and poorly aerated soils are unsuitable for revegetation purposes.	

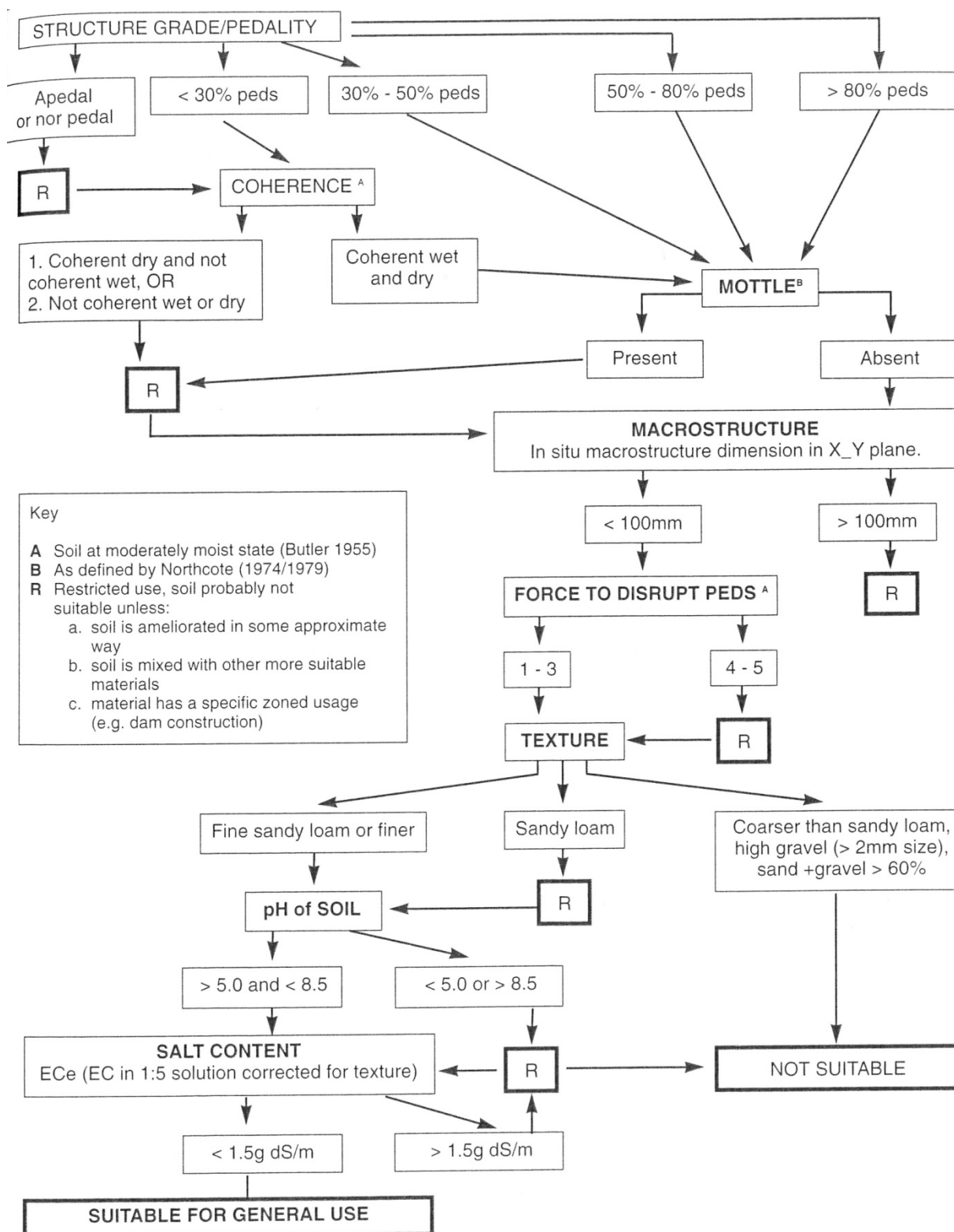


Figure 14: Selection Process for Topdressing Material (Source: Elliot and Reynolds 2000)

5.2.5 Erosion Potential of Soil Types

Soil samples were laboratory tested for dispersion using the Emerson Aggregate Test (EAT) and sodicity, using the Exchangeable Sodium Percentage (ESP). These tests indicate the susceptibility of a soil to losing its structure and binding capacity when wet, and therefore the erosion potential of the soil. Furthermore, a selection of soils were tested to determine the soil erodibility or k-factor by considering particle size analysis, mechanical dispersion and organic carbon.

In general all surface soils displayed low to moderate k-factors and therefore low to moderate erodibility. One sample of Brown Chromosol surface soil contained a high rating. If disturbance occurs within the vicinity of a drainage line, a moderately erodible soil could impact on the health of downstream watercourses, through an increase in the sediment load. These soils should, therefore, be managed to ensure that the soils are not disturbed without suitable erosion and sediment controls being implemented. These measures include the construction of structural soil conservation works such as contour, graded and diversion banks and drop structures, together with sediment control dams. The use of cover crops and/or organic ameliorants will reduce soil dispersion and surface crusting thereby reducing runoff and increasing infiltration, which will subsequently reduce erosion and sedimentation.

Appropriate erosion and sediment control measures should be in place prior to all surface disturbance of soils, as the risk of erosion is high once the ground cover is removed and subsoil is exposed. Appropriate measures are outlined in **Section 5.2.7** of this report, with further detailed measures to be developed in the erosion and sediment control plan which will be developed in conjunction with mine approvals.

5.2.6 Potential Erosion Rates

There are three disturbance types to be assessed within the proposed project, consisting of underground mining footprint and infrastructure such as access tracks, gas drainage facilities, Red Hill accommodation village and the Red Hill CHPP. The Revised Universal Soil Loss Equation (RUSLE) has been used for the assessment of these areas to estimate the long term average soil loss rates that may result from sheet and rill flow during various levels of disturbance. It must be noted that wind and gully erosion is discussed separately in the section below.

The RUSLE calculates annual erosion rates based on the following equation:

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

Where: A = annual soil loss due to erosion [t/ha/yr]

R = rainfall erosivity factor

K = soil erodibility factor

LS = topographic factor derived from slope length and slope gradient

C = cover and management factor

P = erosion control practice factor

Table 28 offers a comparison of disturbance levels which aims to highlight the higher risk activities in regard to erosion rates. It must be noted that assumptions have been made as to the specific values of soil and overburden characteristics, vegetation establishment success, climatic conditions, slope gradients and lengths and various management practices, and therefore the following values should only be used for comparison purposes. The calculations were made based on 'worst case' scenarios used consistently for all disturbance levels.

Table 28 – Estimated Erosion Rates using the RUSLE

Disturbance Level	Rainfall Erosivity Factor (R)	Adjusted* Soil Erodibility Factor (K)	Topographic Factor (LS)	Cover and Management Factor (C)	Erosion Control Practice Factor (P)	Annual Soil Loss (A) (t/ha/yr)
Undisturbed Surface Pre Disturbance and Subsidised Underground Areas	1804	0.030	1.00	0.01	1.0	0.54
Surface cleared of vegetation and topsoil	1804	0.020	1.00	1.00	1.3	47.84

* Adjusted for dispersive materials by +20 per cent

Table 28 above shows the disturbance level during mining and infrastructure activities. The key factor to observe in this result is the cover and management factor (C) which reflects the effect of cropping and management practices on erosion rates. However it is recommended that these areas and times of highest risk should have adequate sedimentation controls in place downstream to capture any material eroded from these slopes. Given the short duration of exposure and assuming typical sediment controls are established, this rate of soil loss would be adequately captured and within the site and therefore is considered an acceptable risk. The surface cleared of vegetation and topsoil category includes the infrastructure items such as gas drainage and Red Hill accommodation village, which will be located on relatively flat land, show a risk of moderate erosion due to the high cover and management factor. The underground mining footprint is considered with pre mining cover and management factors given the integrity of the surface protection will be maintained, albeit modified slope given the subsidence. Some surface cracking may be evident and may require repair on access tracks and other trafficable areas.

Gully erosion is not considered within the RUSLE equation above, however given the succession of erosion severity from rill to gully erosion, it is predicted that the same disturbance levels will contain the same risk rankings for gully erosion rates as the RUSLE equation has displayed. Gully erosion should be repaired and rehabilitated as soon as possible to reduce further erosion and sedimentation downstream.

Wind erosion has the potential to cause loss of material from exposed surfaces during the mining process. Management practices during mining may limit the extent of wind erosion. This can include reducing vehicle movements and earthworks on highly exposed areas during periods of extreme wind conditions. Furthermore, mine planning considerations for minimising exposed surfaces and timely rehabilitation activities may protect surface soil from wind erosion.

5.2.7 Landform Design and Erosion Control Measures

The main objective of regrading subsidised slopes is to produce slope angles, lengths and shapes that are compatible with the proposed land use and not prone to an unacceptable rate of erosion. Integrated with this is a drainage pattern that is capable of conveying runoff from the newly created catchments whilst minimising the risk of erosion and sedimentation. The subsidised landform will potentially create moderate to steep slopes above the edges of longwall panels which could increase the risk of erosion, especially with livestock movements to and from freshwater ponds. The status of erosion on these moderate to steep slopes will be monitored regularly and mitigation measures implemented if erosion becomes unacceptable. Refer to Section 5.5.7.2 of the Red Hill Mining Lease EIS.

Conservation earthworks have the effect of dividing a long slope into a series of short slopes with the catchment area commencing at each bank or furrow. This prevents runoff from reaching a depth of flow or velocity that would cause erosion. As the slope angle increases, the banks or furrows must be spaced closer together until a point is reached where they are no longer effective.

Contour ripping across the grade is by far the most common form of structural erosion control on mine sites, as it simultaneously provides some measure of erosion protection and cultivates the surface in readiness for sowing if required.

The construction of sediment control dams is recommended for the purpose of capturing sediment laden runoff from disturbed areas such as access tracks and gas drainage infrastructure, prior to off-site release. Sediment control dams are responsible for improving water quality throughout the mine site, and through the provision of semi-permanent water storages, enhance the ecological diversity of the area.

The following points should be considered when selecting sites for sediment control dams:

- Each dam should be located so that runoff may easily be directed to it, without the need for extensive channel excavation or for excessive channel gradient. Channels must be able to discharge into the dam without risk of erosion. Similarly, spillways must be designed and located so as to safely convey the maximum anticipated discharge;
- The material from which the dam is constructed must be stable. Dispersive clays will require treatment with gypsum to prevent failure of the wall by tunnel erosion. Failure by tunnelling is most common in dams which store a considerable depth of water above ground level, or whose water level fluctuates widely. Dams should always be well sealed, as leakage may lead to instability, as well as allowing less control over the storage and release of water; and

5.2.8 Topsoil Respreding & Seedbed Preparation

Sampling and analysis of topsoil resources, whether stockpiled or in-situ, is recommended prior to respreding. This will assist in identifying potential soil deficiencies and estimating required rates of fertiliser or ameliorant (i.e. gypsum or lime) application.

Where possible, suitable topsoil should be re-spread directly onto areas to be rehabilitated. Where topsoil resources allow, topsoil should be spread to a minimum depth of 10 centimetres on all regraded slopes. Topsoil should be spread, treated with fertilizer or ameliorants (if required) and seeded in one consecutive operation. This will reduce the potential for topsoil loss to wind and water erosion.

Prior to re-spreading stockpiled topsoil onto infrastructure sites, an assessment of weed infestation on stockpiles should be undertaken to determine if individual stockpiles require herbicide application and / or 'scalping' of weed species prior to topsoil spreading.

Thorough seedbed preparation should be undertaken to ensure optimum establishment and growth of vegetation. All topsoiled areas should be contour ripped (after topsoil spreading) to create a 'key' between the soil and the disturbed area subsoil. Ripping should be undertaken on the contour and the tynes lifted for approximately two metres every 200 metres to reduce the potential for channelised erosion. Best results will be obtained by ripping when soil is moist, and when undertaken immediately prior to sowing. The respread topsoil surface should be scarified prior to or during seeding in order to reduce run-off and increase infiltration. This can be undertaken by contour tilling with a fine-tyned plough or disc harrow.

5.2.9 Summary

The underground mining footprint and infrastructure such as access tracks, gas drainage infrastructure, accommodation village and the Red Hill CHPP has been calculated to cause an annual soil loss of 257.87 t/ha/yr. This can result in the sedimentation of nearby and catchment linked waterways, the degradation of soil surface resources and has the potential to compromise the post mining land-use.

Throughout the construction and operation phases of the project, soils should not be disturbed without suitable erosion and sediment controls being implemented, such as the following;

- Grading to produce appropriate slope angles, lengths and shapes;
- Contour ripping across the grade;
- Construction of sediment control dams; and
- Vegetation cultivation to establishment topsoil stability.
- Temporary erosion and sediment control structures

Additionally, general gully erosion is predicted that the same disturbance levels, and wind erosion is expected to cause loss of material from exposed surfaces during the mining process. Targeted mitigation measures should also be implemented to reduce the impact of these, including gully repair and exposed surface rehabilitation.

These measures are as per best practice and successful implementation will be effective in mitigating impacts to the immediate and surrounding landscape and the productivity of the land.

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Red Hill Mine (RHM) Progressive Rehabilitation and Closure Plan (PRCP) - Community Consultation Register

COMMUNITY MEMBERS AND PREVIOUS ENGAGEMENT				PRCP DEVELOPMENT ENGAGEMENT			ENGAGEMENT OUTCOMES			
Group	Stakeholder Title	Organisation/ Property	Previous engagement	Consultation type	Consultation date	Information provided	Issues raised/discussed	How issues were considered	Decisions/outcomes of engagement	Commitments
Traditional Owners	Chair	Barada Barna Aboriginal Corporation (BBAC)	BMA has regular engagement with Barada Barna People on a range of issues including cultural heritage and community and economic development. BMA holds a Native Title Project Agreement with BBAC on behalf of Barada Barna peoples. The Agreement was signed on 31 July 2024. Engagement includes meetings and correspondence through the BBAC-BMA Relationship Committee and regular Barada Barna and BMA Closure Planning Working Group meetings. Businesses owned by BBAC and/ or their members are currently involved in rehabilitation works at BMA sites.	Letter, via email to BBAC Chair Meeting and correspondence Monthly meeting	4/07/2024 Frequent FY 24 monthly	Queensland Government requirements for mine rehabilitation and closure planning PRCP inclusions Asset location Environmental Authority held for RHM PRCP submission date Mining leases within the EA area and approved activities Life of asset BMA's commitment to progressive rehabilitation Rehabilitation objective and methods EP Act requirements for rehabilitation PRCP requirements Progressive rehabilitation timeframes (in general terms) Approved post-mining land use (PMLU) options Commitment to future engagement on PRCPs Invitation to seek information or discussion about PRCP Contacts for further information Seeding requirements and recommendations (Barada Barna only)	No issues raised in response to the letter, but issues discussed in other engagements between BMA and BBAC include opportunities to be involved in rehabilitation execution via Barada Barna-owned businesses, cultural heritage management and access to land that is no longer required for mining.	Ongoing opportunities for the involvement of Barada Barna People and businesses in rehabilitation works and land management are planned across BMA assets, as rehabilitation is a core contracting commitment in the BMA and BBAC Native Title Project Agreement.	Traditional Owners will have access to land within the EA area in accordance within the terms of the registered Indigenous Land Use Agreement. Ongoing opportunities for the involvement of Barada Barna People and businesses in rehabilitation works and land management are planned across BMA, as rehabilitation is a core contracting commitment in the Native Title Project Agreement. Barada Barna People's interest in environmental management and mine rehabilitation will be progressed as part of ongoing engagement with them.	BMA will continue to consult with the Barada Barna People, and seek their inputs on rehabilitation and PMLUs. BMA will engage with Traditional Owners and Indigenous businesses to understand business capabilities and the pipeline of opportunities that relate to rehabilitation work and land management, and to involve Traditional Owners' businesses in supplying progressive rehabilitation works.
	Secretary	Widi People of the Nebo Estate #1	BMA has a constructive relationship with Widi People of the Nebo Estate #1, meeting as needed.	Letter, via email to Secretary	4/11/2024	As detailed in the first row.	No feedback received and no issues raised.	No feedback received and no issues raised.	Opportunities for the involvement of Widi People of the Nebo Estate #1 and businesses in rehabilitation works and land management are anticipated.	BMA will continue to consult with Widi People of the Nebo Estate #1, and seek their inputs on rehabilitation and PMLUs. BMA will engage with Traditional Owners and Indigenous businesses to understand business capabilities and the pipeline of opportunities that relate to rehabilitation work and land management, and to involve Traditional Owners' businesses in supplying progressive rehabilitation works.
	Secretary	Widi People of the Nebo Estate #2	BMA has a constructive relationship with Widi People of the Nebo Estate #2, meeting as needed.	Letter, via email to Secretary	4/11/2024	As detailed in the first row.	No feedback received and no issues raised.	No feedback received and no issues raised.	Opportunities for the involvement of Widi People of the Nebo Estate #2 and businesses in rehabilitation works and land management are anticipated.	BMA will continue to consult with Widi People of the Nebo Estate #2, and seek their inputs on rehabilitation and PMLUs. BMA will engage with Traditional Owners and Indigenous businesses to understand business capabilities and the pipeline of opportunities that relate to rehabilitation work and land management, and to involve Traditional Owners' businesses in supplying progressive rehabilitation works.
Local Government	Mayor, Councillors and CEO	Isaac Regional Council (IRC)	BMA has regular bi-annual meetings with IRC, and meets with Councillors and officers as needed on specific issues. BMA provides regular briefings and updates to Council on BMA's PRCPs. IRC owns land within the EA area for road reserves (Red Hill Road and Mabbinn Road). BMA and IRC engage in commercial discussions regarding use of IRC land within the EA area, as required.	Bi-annual meetings with Council Additional meetings with Council with a focus on roads on 19/1/24, 16/4/24 and 30/5/24	06/11/2023 30/05/2024 19/01/24 16/04/24 30/05/2024	As detailed in the first row.	Council receives regular updates and opportunities for discussion on PRCPs for BMA assets via IRC-BMA meetings. The future use, management and maintenance of roads within the EA area is of significant interest to Council i.e. Red Hill Road and Mabbinn Road within the EA area, and Goonyella Road which is a private BMA road used by the public.	Engagement processes for PRCPs will include a strategic approach to consultation with Council, to minimise demands on Council's time and maximise the value derived from consultation. IRC road reserves within the EA area are considered in the PRCP. Prior information and consultation will be required with IRC regarding the future use of the road reserve within the EA area.	The CEO of the IRC sent an acknowledgement email of the letter that was sent to IRC in relation to the RHM PRCP. No issues were raised with respect to the RHM PRCP in general. BMA will continue to engage with IRC regarding the PRCP for RHM. PRCP updates will be provided at each meeting between BMA and IRC, or as agreed with IRC. BMA will also consult IRC on management plans if rehabilitation and/or closure activities would impact on IRC assets including road management and recycling facilities. Future engagement with Council will include discussion of rehabilitation methods and milestones.	BMA will engage with IRC to understand Council's strategic analysis and planning for the Isaac LGA and the RHM project area as relevant. BMA will work with Council and other stakeholders in future PRCP consultations to identify and implement social value opportunities. BMA will engage with IRC regarding any impacts on Council roads or road reserves as part of the progressive rehabilitation and closure process, and will update IRC on PRCPs regularly. The PRCP landform proposes a realignment of Red Hill Road. To effect realignment, BMA acknowledge it would need to apply for and obtain, a Works On Road Corridor Permit from IRC. Engineering studies will need to be completed before the permit is applied for. Concerns raised by IRC in relation to any realignment proposal for Red Hill Road will be considered during the permitting process. If changes are made to the proposed realignment as a result of future planning or permitting processes that impact the PRCP schedule, a PRCP amendment will be required.
	Executive Manager of Advocacy and External Affairs and Manager Galilee and Bowen Basin Operations	IRC	BMA meets with Council officers from time to time on issues of shared interest.	Letter to stakeholders and community members provided to Council managers, via email	21/06/2024	As detailed in the first row.	No feedback received and no issues raised.	As above.	As above.	As above.
Underlying and adjacent private landholder and licensee (see also Utility Owners)	Owner	Private grazing business	BHP has a long and constructive working relationship with the owner of the land underlying and adjacent to the EA area, including with respect to underlying land and a license agreement for use of BMA-owned land. BMA engages with the landowner as a licensee regarding licence terms and conditions, and on matters relating to land use management from time to time.	Letter, via email and post	14/06/2024	As detailed in the first row.	No feedback or enquiries were received. BMA's regular engagements with the landowner indicate that they are interested in long-term grazing options.	The landowner's interest in use of the land for grazing was considered in framing PMLUs.	Land within the MLs will continue to be available for grazing under existing agreements with the landholder. The landholder and cattle will be excluded from affected areas while land disturbance is occurring. As disturbed land becomes available, it will be rehabilitated to a state suitable for the approved PMLU e.g. grazing, woodland, water courses.	BMA will continue to consult with the underlying (and adjacent) landowner and seek their inputs on RHM's rehabilitation schedule and PMLUs.

Red Hill Mine (RHM) Progressive Rehabilitation and Closure Plan (PRCP) - Community Consultation Register

COMMUNITY MEMBERS AND PREVIOUS ENGAGEMENT				PRCP DEVELOPMENT ENGAGEMENT			ENGAGEMENT OUTCOMES			
Group	Stakeholder Title	Organisation/ Property	Previous engagement	Consultation type	Consultation date	Information provided	Issues raised/discussed	How issues were considered	Decisions/outcomes of engagement	Commitments
Utility owners	Surveyor/HV Transmission Line Designer	Q.E.C. Ltd (Powerlink)	Q.E.C. Ltd. (Powerlink) has an easement within the Red Hill EA area and owns a small parcel of land within the EA area for a substation. Engagement with Powerlink is via routine correspondence on commercial and statutory issues, with meetings held as required on specific issues.	Letter, via email	19/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will maintain correspondence with Powerlink regarding progressive rehabilitation activities as they affect Powerlink assets, and undertake consultation regarding crossing/interface agreements, if required.	BMA will advise and consult Powerlink regarding any impacts of the closure/rehabilitation activity that may affect Q.E.C. Ltd./Powerlink assets.
	Property Projects Coordinator	Ergon Energy	Ergon Energy have powerlines overlapping the Red Hill EA area.	Letter, via email	20/06/2024	As detailed in the first row.	No feedback received or issues raised.	No feedback received and no issues raised.	BMA will maintain correspondence with Ergon Energy regarding progressive rehabilitation activities as they affect Ergon Energy assets, and undertake consultation regarding crossing/interface agreements, if required.	BMA will advise and consult Ergon Energy regarding any impacts of the closure/rehabilitation activity that may affect Ergon Energy assets.
	Commercial Manager	Middlemount Water Pipeline Pty Ltd (Centurion Coal Mining Pty Ltd)	Centurion Coal Mining Pty Ltd (previously Peabody (Bowen) Pty. Ltd.) owns the Middlemount Water Pipeline which overlaps the EA area, and also owns land within the EA area. Engagement with Centurion Coal Mining Pty Ltd is via routine correspondence on commercial and statutory issues, with meetings held as required on specific issues.	Letter, via email	14/06/2024	As detailed in the first row.	No feedback received or issues raised.	No feedback received and no issues raised.	BMA will maintain correspondence with Centurion Coal Mining Pty Ltd regarding progressive rehabilitation activities as they affect Centurion Coal Mining Pty Ltd assets, and undertake consultation regarding crossing/interface agreements, if required.	BMA will advise and consult Centurion Coal Mining Pty Ltd regarding any impacts of the closure/rehabilitation activity that may affect their asset.
	Customer Account Manager	Aurizon Network	Goonyella Hay Point Railway, North Goonyella Railway, Goonyella Mine Loop and Riverside Mine Loop are within the adjacent Goonyella Riverside Broadmeadow Mine EA and are owned by Aurizon Network. Engagement with Aurizon Network is via routine correspondence on commercial and statutory issues, with meetings held as required on specific issues.	Letter, via email	19/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will advise Aurizon Network of any substantive changes to closure planning or the rehabilitation schedule as part of future PRCP processes.	BMA will maintain engagement with Aurizon Network regarding its progressive rehabilitation activities as they affect rail assets, and undertake engagement regarding the decommissioning of rail infrastructure prior to its closure, in accordance with agreements between BMA and Aurizon Network at the time.
Moranbah Community	Community Members	Moranbah residents, businesses and community groups	BMA communicates with Moranbah residents and businesses through stakeholder meetings, community events and forums, media and social media, and Community Connect, a regular newsletter. There are no personnel employed at RHM.	Letter box drop to Moranbah postcode (4744) Information provided through Community Connect	15/07/2024 - 19/07/24 10/6/24 - 16/6/24	Information provided via the letterbox drop as per first row. Information provided in Community Connect included: Progressive rehabilitation as a key focus for BMA PRCP requirements and purpose Timing for PRCP development Commitment to ongoing engagement Contact details for further information or queries.	No feedback received or issues raised.	No feedback received and no issues raised.	BMA will keep community members (including future RHM personnel) updated as the PRCP is implemented and revised.	BMA will continue to provide information about PRCPs to Moranbah community members and future RHM personnel, provide community updates on RHM's PRCP if there are any substantive changes, and consider their feedback in future PRCP development.
	Moranbah Smart Transformation Advisory Council (STAC)	Moranbah STAC	The Smart Transformation Project including the Moranbah and Dysart Smart Transformation Advisory Councils (STACs) was established by BMA in 2019. Moranbah STAC members meet every two months to consider a range of issues and priorities related to the future and sustainability of Moranbah's community and economy.	Letter, via email	12/07/2024	As detailed in the first row.	No feedback received or issues raised.	No feedback received and no issues raised.	BMA will keep Moranbah STAC members updated as the PRCP is implemented and revised.	BMA will continue to provide information about PRCPs to Moranbah STAC members, and consider their feedback in future PRCP development. BMA will participate in initiatives led by the Council, industry or local communities which aim to harness social value from mine closure and rehabilitation planning, and/or work towards economic transformation.
	Chair	Isaac Business Chamber	The Isaac Business Chamber has recently formed to represent businesses within the Isaac LGA. BMA has financially supported the Isaac Business Chamber and attended its launch event.	Letter, via email	15/07/2024	As detailed in the first row.	No feedback received or issues raised.	No feedback received and no issues raised.	BMA will keep the Isaac Business Chamber updated as the PRCP is implemented and revised.	BMA will continue to provide information about PRCPs to the Isaac Business Chamber, and consider their feedback in future PRCP development.
Adjacent and nearby mining interests	Manager Tenements Portfolio Australia	Centurion Coal Mining Pty Ltd (previously Peabody (Bowen) Pty. Ltd.)	Centurion Coal Mining Pty Ltd (previously Peabody (Bowen) Pty. Ltd.) owns an open-cut mine known as Eaglefield and an underground mine previously known as North Goonyella and now called Centurion Coal Mine, to RHM's north. Centurion Coal Mining Pty Ltd, a Peabody-owned company also owns land within the EA area, owns the overlapping Middlemount Water Pipeline, and holds an adjacent Petroleum Lease and an adjacent MDL. Engagement to date, with Peabody (Bowen) Pty. Ltd., is via routine correspondence on commercial and statutory issues.	Letter via email	14/06/2024	As detailed in the first row.	No feedback received or issues raised.	No feedback received and no issues raised.	BMA will engage with Centurion Coal Mining Pty Ltd regarding any effects of rehabilitation or closure works on adjacent mining operations.	BMA will keep Centurion Coal Mining Pty Ltd updated if there are substantive future changes to the PRCP.
	Tenure and Compliance Manager, and Site and Third Party Interface Manager	Anglo American Australia	Anglo American Australia owns the Moranbah North Coal Mine to the south of RHM. Engagement with Anglo American is via routine correspondence on commercial and statutory issues.	Letter via email	14/06/2024	As detailed in the first row.	Acknowledgement of letter received	No feedback received and no issues raised.	BMA will keep Anglo American Australia updated as PRCPs are implemented and revised.	BMA will keep Anglo American Australia updated if there are substantive future changes to the PRCP.

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	Authorised Holder Representative	Fitzroy (CQ) Pty. Ltd.	Fitzroy (CQ) Pty Ltd hold the adjacent EPC 722. There has been no specific consultation about GRM and BRM with Fitzroy (CQ) Pty. Ltd.	Letter via email	14/06/2024	As detailed in the first row.	Acknowledgement of letter received	No feedback received and no issues raised.	BMA will keep Fitzroy (CQ) Pty Ltd updated as PRCPs are implemented and revised.	BMA will keep Fitzroy (CQ) Pty Ltd updated if there are substantive future changes to the PRCP.
	Manager Tenure & Senior Geologist	Stanmore SMC Pty Ltd	Stanmore SMC Pty Ltd owns the Wards Well underground development project, which is located immediately north of the Peabody's Centurion (North Goonyella) Mine, as well as properties north of RHM. BMA and Stanmore have previously engaged with respect to the transfer of ownership of the Wards Well project from BMA to Stanmore.	Letter via email	19/06/2024	As detailed in the first row.	No feedback received or issues raised.	No feedback received and no issues raised.	BMA will keep Stanmore SMC Pty Ltd updated as PRCPs are implemented and revised.	BMA will keep Stanmore SMC Pty Ltd updated if there are substantive future changes to the PRCP.
Petroleum tenement holders	Principal Commercial Adviser	Arrow Bowen Pipeline Pty Ltd (Arrow Energy Pty. Ltd.)	Arrow Bowen Pipeline Pty. Ltd. (a wholly owned subsidiary of Arrow Energy Pty. Ltd.) holds PPL 2016, adjacent to Red Hill, for the Arrow Bowen Pipeline.	Letter via email	19/06/2024	As detailed in the first row.	No feedback received or issues raised.	No feedback received and no issues raised.	BMA will advise Arrow Energy Pty Ltd of any substantive changes to the closure or rehabilitation schedule as part of future PRCP processes for RHM.	BMA will advise Arrow Energy Pty Ltd of any substantive changes to closure or rehabilitation schedule as part of future PRCP processes for RHM.
	Land and Overlapping Tenure Manager	QPM Energy Pty Ltd and QPM Energy (MGP Upstream) Pty Ltd	QPM Energy Pty Ltd hold a nearby PPL 2073. QPM Energy (MGP Upstream) Pty Ltd hold adjacent Petroleum Lease PL 191. BMA communicates with Authorised Resource Holders regarding tenure issues on an as-needed basis.	Letter via email	19/06/2024	As detailed in the first row.	Acknowledgement of letter received	No feedback received and no issues raised.	BMA will advise QPM Energy Pty Ltd of any substantive changes to the closure or rehabilitation schedule as part of future PRCP processes for RHM.	BMA will advise QPM Energy Pty Ltd of any substantive changes to closure or rehabilitation schedule as part of future PRCP processes for RHM.
	Principal Commercial Adviser	CH4 Pty Ltd (Arrow Energy Pty. Ltd.)	CH4 Pty Ltd (owned by Arrow Energy Pty. Ltd.) holds an Authority to Prospect (ATP1103) which overlaps ML70421. There is a Co-Development Agreement in place between Arrow Energy and BMA, which governs and coordinates activities on Red Hill ML 70421 and Arrow Energy's overlapping PL 486. BMA communicates with Authorised Resource Holders regarding tenure issues on an as-needed basis.	Letter via email	19/06/2024	As detailed in the first row.	No feedback received or issues raised.	No feedback received and no issues raised.	BMA will advise CH4 Pty. Ltd./ Arrow Energy Pty. Ltd. of any substantive changes to the closure or rehabilitation schedule as part of future PRCP processes for RHM.	BMA will advise CH4 Pty. Ltd./Arrow Energy Pty Ltd of any substantive changes to closure or rehabilitation schedule as part of future PRCP processes for RHM.
State Government	PRCP Team	Department of Environment Science and Innovation (DESI)	BMA and DESI have engaged through meetings and correspondence regarding the preparation and delivery of the PRCP.	Pre-submission meeting	25/11/2024	Draft PRCP main points	Site specific issues	DESI feedback was considered in the development of the PRCP	The PRCP will be completed in accordance with BMA's agreements with DESI.	BMA will comply with the legislative and regulatory requirements for PRC plans.
	Deputy Director-General Georesources	Department of Resources	BMA provides briefings to the Deputy Director General Georesources on an as needed basis, and meets and corresponds with Department of Resources regarding resource development commitments.	Letter via email	20/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will update the Deputy Director-General Georesources on any future changes to the PRCP.	BMA will provide updates on PRCPs to the Deputy Director General Georesources as requested
	Acting Director Native Title Services and Coal Hub, Rockhampton	Department of Resources	BMA provides briefings to the Deputy Director General Georesources on an as needed basis, and meets and corresponds with Department of Resources regarding resource development commitments.	Letter via email	20/06/2024	As detailed in the first row.	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will update the Director Native Title Services and Coal Hub, Rockhampton on any substantive future changes to the PRCP.	BMA will provide updates on PRCPs to the Director Native Title Services and Coal Hub, Rockhampton as requested.
	Chief of Staff/Secretary	Office of the Minister for Resources and Critical Minerals	BMA provides briefings to the Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Minister's office as requested.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Office of the Minister for Agriculture Industry Development and Fisheries; and Minister Rural Communities	BMA provides briefings to the Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Minister's office as requested.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Office of the Minister Energy, and Clean Economy Jobs	BMA provides briefings to the Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Minister's office as requested.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Office of the Minister for Environment, Science and Innovation and Minister for the Great Barrier Reef	BMA provides briefings to the Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Minister's office as requested.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Office of the Minister for Regional Development and Manufacturing and Minister for Water	BMA provides briefings to the Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Minister's office as requested.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Queensland Parliament - Member for Burdekin	BMA provides briefings to the Member for Burdekin's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Member's office as requested.	BMA will update the Member's office on any substantive future changes to the PRCP.

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Group	Stakeholder Title	Organisation/ Property	Previous engagement	Consultation type	Consultation date	Information provided	Issues raised/discussed	How issues were considered	Decisions/outcomes of engagement	Commitments
	Chief of Staff/Secretary	Queensland Parliament - Shadow Minister for Natural Resources and Mines	BMA provides briefings to the Shadow Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Shadow Minister's office as requested.	BMA will update the Shadow Minister's office on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Shadow Minister for Environment and the Great Barrier Reef and Shadow Minister for Science and Innovation	BMA provides briefings to the Shadow Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Shadow Minister's office as requested.	BMA will update the Shadow Minister's office on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Shadow Minister for Energy and Cost of Living	BMA provides briefings to the Shadow Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Shadow Minister's office as requested.	BMA will update the Shadow Minister's office on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Shadow Minister for Water and the Construction of Dams	BMA provides briefings to the Shadow Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Shadow Minister's office as requested.	BMA will update the Shadow Minister's office on any substantive future changes to the PRCP.
	Chief of Staff/Secretary	Shadow Minister for Regional Development and Manufacturing	BMA provides briefings to the Shadow Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Shadow Minister's office as requested.	BMA will update the Shadow Minister's office on any substantive future changes to the PRCP.
Federal Government	Chief of Staff/Secretary	Office of the Minister and Dep. Sec. Environment Protection, Department of Climate Change, Energy, the Environment and Water (DCCEEW)	BMA provides briefings to the Minister's office on an as-needed basis.	Correspondence and meetings on request	Per agreed briefing schedule	Per PRCP discussion points, referencing information as detailed in the first row	No feedback or enquiries were received.	No feedback received and no issues raised.	BMA will provide updates on PRCPs to the Minister's office as requested.	BMA will update the Office of the Minister on any substantive future changes to the PRCP.



Red Hill Mine

Progressive Rehabilitation and Closure Plan Rehabilitation Flood Assessment

BHP Mitsubishi Alliance

409 Adelaide Street
Brisbane City
QLD 4000

Prepared by:

SLR Consulting Australia

SLR Project No.: 620.040713.0000

27 November 2024

Revision: 2.0

Revision Record

Revision	Date	Prepared By	Checked By	Authorised By
1.0	24 October 2024	TS	HM	HM
2.0	27 November 2024	TS	HM (RPEQ 27137)	HM

Basis of Report

This report has been prepared by SLR Consulting Australia (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with BHP Mitsubishi Alliance (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.



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Appendices

Appendix A	Flood Risk Profile Assessment
Appendix B	Fluvial Model Results
Appendix C	Pluvial Model Results



Acronyms and Abbreviations

ACARP	Australian Coal Association Research Program
AEP	Annual Exceedance Probability
ARF	Areal Reduction Factor
ARR	Australian Rainfall and Runoff
ASC	Australian Soil Classification
BoM	Bureau of Meteorology
CSM	Conceptual Site Model
DEM	Digital Elevation Model
DESI	Department of Environment, Science and Innovation
DNRM	Department of Natural Resources and Mines
EP	Environmental Protection
FFA	Flood Frequency Analysis
Fi	Fraction Impervious
FRP	Flood Risk Profile
GRM	Goonyella Riverside Mine
GTSMR	Revised Generalised Tropical Storm Method
IFD	Intensity Frequency Duration
LiDAR	Light Detection and Ranging
MFL	Maximum Foreseeable Loss
ML	Mining Lease
NUMA	Non-Use Management Area
PMF	Probable Maximum Flood
PMLU	Post-mining land use
PMP	Probable Maximum Precipitation
PRCP	Progressive Rehabilitation and Closure Plan
RFFE	Regional Flood Frequency Estimation
RHM	Red Hill Mine
RMC	Risk Management Center
RMG	Risk Management Guidelines
RRR	Residual Risk Rating
SGS	Sub-grid sampling
SRTM	Shuttle Radar Topography Mission
TEC	Threatened Ecological Communities
TP	Temporal pattern
TUFLOW	Two-Dimensional Unsteady Flow



USACE	US Army Corps of Engineers
USDA	United States Department of Agriculture
WBNM	Watershed Bounded Network Model



1.0 Introduction

1.1 Scope of Work

SLR was contracted by BHP Mitsubishi Alliance (BMA) to support the preparation of the Red Hill Mine (RHM) Progressive Rehabilitation and Closure Plan (PRCP). Specifically, the scope of work involved undertaking flood modelling of Red Hill Mine in accordance with Section 3.6.1 and Section 3.6.4 of '*Guideline – Progressive Rehabilitation and Closure Plans*', Department of Environment and Science and Innovation (DESI) (The Guideline) (Department of Environment, Science and Innovation 2024). Section 3.6.1 and Section 3.6.4 of The Guideline provides the following direction on general rehabilitation practices in relation to flooding:

Section 3.6.1 General Rehabilitation Practices (Flooding):

- Consider the location of domains in relation to potential flood levels;
- Consider alteration of flow upstream and downstream;
- Model flood levels (including probable maximum flood levels) for a range of design storm events; and
- Develop a flooding risk profile.

Section 3.6.4 Underground Mining:

- Changes to hydrological regime;
- Changes in surface topography and local drainage characteristics - this may result in some areas becoming more free-draining while runoff may be reduced in other areas, resulting in the ponding of water in areas where previously no ponding occurred; and
- Changes in surface drainage, leading to changes in the composition of vegetation communities and distribution of flora and fauna species.

This report details the assessments undertaken including hydrologic and hydraulic modelling of relevant watercourses and conceptual site modelling at the Red Hill Mine to address the above points.

1.2 Site Details

RHM is located in Central Queensland, approximately 170 kilometres west of Rockhampton and 20 kilometres north of Moranbah. **Figure 1-1** illustrates the location of RHM and key surrounding features including the Isaac River which drains through the Mine. RHM includes the Mining Leases shown in **Table 1-1**. It should be noted that this assessment considered that the final landform for RHM will be linked to the final landform of Goonyella Complex (which includes Goonyella, Riverside and Broadmeadow mines) and therefore was modelled with both Goonyella Complex and RHM in final landform conditions.



Table 1-1 Red Hill Mine Mining Leases

Red Hill Mine Mining Leases	
• ML1763 – Goonyella	• ML70421 – Red Hill

1.3 Relevant Documentation

This assessment was undertaken in accordance with the following guidelines and documentation:

- *Environmental Protection Act 1994*;
- *Environmental Protection Regulation 2019*.
- ‘*Guideline – Progressive Rehabilitation and Closure Plans*’, Version 3.01, Department of Environment and Science, September 2024 (PRCP Guideline);
- ‘*Information Sheet – Environmental Protection Act 1994 – Voids in Flood Plains*’, Department of Environment and Science, February 2024 (Voids in Flood Plains Information Sheet);
- ‘*Australian Rainfall and Runoff: A guide to Flood estimation*’, Geoscience Australia, v4.2 (Ball, et al. 2019); and
- ‘*Bowen Basin River Diversions – Design and Rehabilitation Criteria*’, Australian Coal Association Research Program, July 2002 (ACARP 2002)



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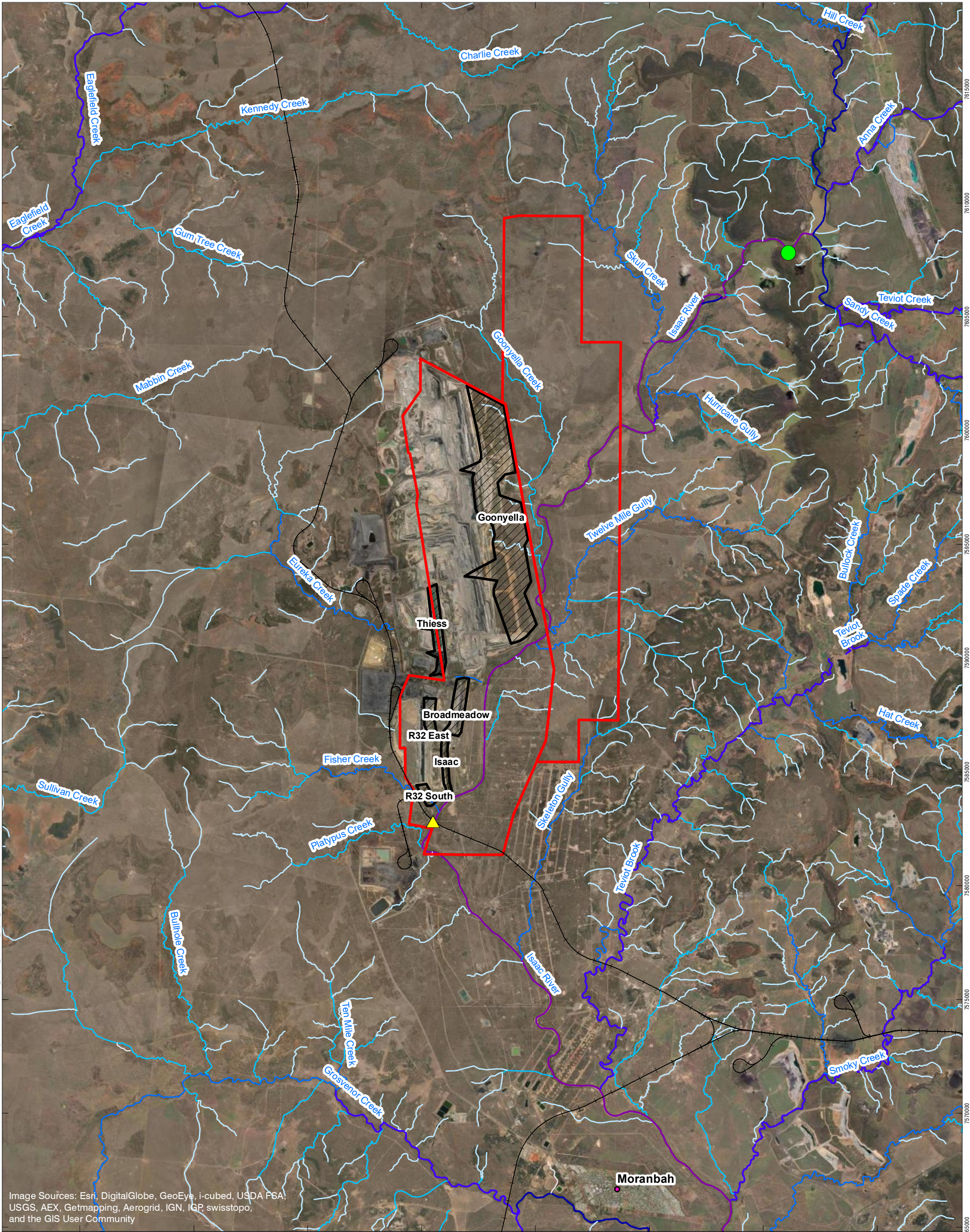


Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

0124

km

Coordinate System: GDA2020 MGA Zone 55

Scale: 1:150,000 at A3

Project Number: 620.040713

Date: 22-Oct-2024

Drawn by: TS

LEGEND

Mining Leases

Residual Voids

Rail Network

Isaac River at Burton Gorge Gauge

Isaac River at Goonyella Gauge

Watercourses

Stream Order

0

1

2

3

4

5

6

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Site Location

Figure 1-1

1.4 Assumptions and Limitations

This assessment was undertaken specifically for the purposes for undertaking floodplain modelling of relevant watercourses in accordance with the requirements of the EP Act and EP Regulation. The following assumptions and limitations apply to this assessment.

- The accuracy of the assessment is reliant on the accuracy of the utilised data, as detailed in **Section 3.0**. SLR has assumed all source data to be fit for purpose and sufficiently accurate for the purpose of this assessment. Except where noted, no verification of accuracy of the information has been carried out. In the event that some of the information which was relied upon for this assessment is found to be inaccurate, then some or all of the findings may change.
- Generation of the model landform for the assessment was undertaken in accordance with the PRCP Guidelines. Hydraulic modelling was undertaken only for the post-mining landform conditions.
- Although the analyses undertaken as detailed in this report were done so with the appropriate care and professionalism, this report shall only be used for the purposes intended. The analyses detailed in this report were undertaken solely for the purpose of addressing the requirements for general rehabilitation practices for RHM in accordance with the relevant documentation as detailed in **Section 2.0**.
- This report should be read in full, and no excerpts are to be taken as representative of the findings. This report has been prepared on behalf of BMA and SLR accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.
- The Flood Risk Profile outlined in this report was undertaken specifically in accordance with the BHP Risk Framework (refer **Appendix A**), and therefore may not be applicable with other risk assessment methodologies.
- The TUFLOW model results for velocity bed shear stress and stream power are calculated using a depth-averaged approach for each model grid cell. Results of the TUFLOW hydraulic model were therefore utilised for general indication (only) of watercourse stability. TUFLOW does not account for geomorphological processes including watercourse re-alignment, therefore the assessment was based on the assumption of static topographic conditions.
- Groundwater levels in the area will have no significant effect on the outcomes of the flood modelling.

1.5 Document Structure

The structure of this report is set out as follows:

- **Section 1** – Introduction;
- **Section 2** - Relevant legislation and guidelines;
- **Section 3** - Data Review and Gap Analysis, including details of the model landform;
- **Section 4** - Hydrologic Modelling;
- **Section 5** - Hydraulic Modelling;
- **Section 6** – Flood Risk Profile;



- **Section 7** – Outcomes;
- **Section 8** – Conclusions; and
- **Section 9** – References.

Details of each component of the assessment are provided in the following sections.



2.0 Legislation and Guidelines

2.1 Relevant Legislation and Guidelines

The relevant documentation for this assessment is detailed in **Section 1.3**. Key details in the context of the assessment are provided below.

The Environmental Protection Act 1994 states:

'In accordance with Section 126D(3) of the EP Act, if land the subject of the proposed PRCP schedule will contain a void situated wholly or partly in a flood plain, the schedule must provide for the rehabilitation of the land to a stable condition.'

The Environmental Protection Regulation 2019 Section 41C(3) also states:

'The administering authority must treat the land as a flood plain to the extent the results of the flood plain modelling show that, when all relevant activities carried out on the land have ended, the land is the same height as, or lower than, the level modelled as the peak water level 0.1% AEP for a relevant watercourse under the ARR'

Further guidance is provided in the PRCP Guideline and the Voids in Flood Plains Information Sheet.

Sections 3.4 and 3.6.1 of the PRCP Guideline both require a floodplain assessment to be carried out. Specifically, Section 3.4 requires a Void in Floodplain assessment for all unapproved Non-Use Management Area (NUMA) voids (i.e. floodplain assessment of the pre-mining landform), whilst Section 3.6.1 requires a post-mining landform assessment irrespective whether a post-mining land use (PMLU) or NUMA is proposed. This current assessment was undertaken only to address the requirements of Section 3.6.1.

The hydrologic and hydraulic analyses were undertaken in accordance with ARR.

2.2 Applicability to the Project

Based on the review of the EP Act, EP Regulation, PRCP Guideline and the Voids in Floodplains information sheets, it is considered that the legislative requirements set out in **Table 2-1** are applicable to the project.

Table 2-1 Applicable Legislative Requirements

Requirement	Application to the Project	Source
For transitional sites, a floodplain assessment is required where: - A void has been identified as a NUMA in a land outcome document, but the location has not been specified; or - Where there are no land outcomes in the land outcome document.	There are six final voids in the Goonyella Mine Lease which are proposed to be developed as NUMAs. However, the Red Hill Mine Lease does not contain any voids. Therefore, floodplain assessment was not required.	PRCP Guideline Section 3.4
The requirement for a flood assessment under section 3.6.1 of the Guideline applies to the post mining landform across the whole site irrespective of whether a PMLU	There are no voids within the Red Hill Mine Lease, but a flood assessment was required regardless, and therefore was undertaken.	PRCP Guideline Section 3.6.1.



Requirement	Application to the Project	Source
or a NUMA are proposed. Furthermore, section 3.6.1 is not only required to indicate flood risk but also to demonstrate the final landform (including waste rock dumps and diversions) will remain in a stable condition in a range of flood flow conditions.		
Section 3.6.4 Underground Mining	The PRCP for RHM includes rehabilitation of underground mining domains including subsidence. Therefore, assessment of the relevant flooding aspects in relation to the planned subsidence is required.	PRCP Guideline Section 3.6.4.

2.3 Definitions and Terminology

Table 2-2 provides the definitions and terminology that are utilised in this assessment, in accordance with the PRCP Guideline and the Voids in Flood Plains Information Sheet.

Table 2-2 Definitions and Terminology

Term	Definition	Source
Voids	An area of land to be excavated in carrying out a mining activity. Therefore, all voids (PMLU or NUMA) are subject to the requirements of the EP Act.	Section 126D of the EP Act.
Flood plain	A void is considered to be located in a flood plain if the flood plain modelling shows that, when all relevant activities carried out on the land have ended, the land is the same height as, or lower than, the level modelled as the peak water level in a 0.1% AEP for a relevant watercourse under the guideline Australian Rainfall and Runoff (2019) (ARR).	Section 41C of the EP Regulation; and PRCP Guideline Section 3.4.
Stable condition	- The land is safe and structurally stable; - There is no environmental harm being caused by anything on or in the land; and - The land can sustain a PMLU.	Section 126D(3) of the EP Act; and PRCP Guideline Section 3.6.3.
Relevant watercourse	- A watercourse classified as stream order 4 or higher under the Strahler stream order classification system; or - If a watercourse mentioned in paragraph (a) is permanently diverted under – - A condition, or proposed condition, of an environmental authority mentioned in the Water Act 2000, section 98; or - A water license or proposed water license under the Water Act 2000; - the watercourse as permanently diverted.	PRCP Guideline Section 8; and Voids in Flood Plains information Sheet Section 5.



Term	Definition	Source
Flood plain modelling	For land the subject of a PRCP schedule, means modelling of the landform of the land – a) Carried out under the ARR; (and) b) Excluding any artificial features for the land	PRCP Guideline Section 8; and Voids in Flood Plains information Sheet Section 4.
Artificial feature	For land the subject of a PRCP schedule, means – a) A structure or feature that is temporary and, under the PRCP schedule or otherwise, is to be removed from the land; or b) A structure or feature that, under the PRCP schedule, will require a level of maintenance after the land is surrendered that is greater than the level of maintenance that would be required for the land if the relevant activities the subject of the PRCP schedule had not been carried out; or c) A feature forming part of the landform of the land, other than the natural landform, if the feature interferes with or affects – • A relevant watercourse; or • The natural flow of water on the land.	PRCP Guideline Section 8; and Voids in Flood Plains information Sheet Section 6.



3.0 Data Review and Gap Analysis

3.1 Available Data

The following data was provided to SLR by BMA for use in the assessment:

- Goonyella Riverside Mine Complex – Characterisation Study (Landloch 2024);
- PRCP Final Landform DEM;
- Additional LiDAR topographic data (dated 2024) within Goonyella Mine extents as a DEM with 1m grid cell spacing;
- Aerial imagery dated 2024;
- Goonyella and Broadmeadow Hydraulic Assessment (WRM 2019); and
- GRM Operational TUFLOW hydraulic model.

Additional data was obtained from publicly available sources including:

- Watercourse Lines – Queensland GIS dataset (Department of Resources, 2023);
- 1 second SRTM 30 metre DEM terrain data (Geoscience Australia);
- Rainfall intensity-frequency-duration (IFD) data for the area (Bureau of Meteorology (BoM));
- Catchment specific hydrologic data (ARR Data Hub);
- Historic gauged stream flow data for the Isaac River at Goonyella (130414A) and Isaac River at Burton Gorge (130402A) Stream Gauges (DNRM); and
- Burton Gorge Dam Emergency Action Plan (Peabody 2023).

The provided data was analysed for suitability for the purposes of this assessment. The outcomes of the review are detailed below.

3.2 Watercourses

A review of the existing watercourses in the vicinity of RHM was undertaken using hydrologic streamline data sourced from the Department of Resources. The following watercourses were included in the assessment:

- Isaac River: Isaac River runs north to south with a span of over 450 km and along the eastern side of Goonyella Mine, which is located in the upper part of the river. Much of the river is diverted permanently to the eastern side of the voids. It has a catchment area of approximately 1100km².
- 12 Mile Gully: 12 Mile Gully spans east to west for over 15 km. It is located east of Goonyella Mine and transects Red Hill Mine and drains into the Isaac River at the southern end of Goonyella Void. It has a catchment area of approximately 67km².
- Goonyella Creek: Goonyella Creek spans approximately 20 km from north of Goonyella Mine and along the western side of Red Hill Mine. It flows south before draining into the Isaac River. It has a catchment area of approximately 87km².



3.3 Landform

3.3.1 Landform Data

For the purposes of the hydrologic modelling, a landform DEM was developed which utilised the following topographic datasets, layered in order from bottom to top:

- SRTM DEM (outside RHM extents only);
- Existing topography (1m resolution) for RHM (2024); and
- RHM PRCP Landform DEM (1m resolution).

The landform DEM is illustrated in **Figure 3-1**.

3.3.2 Conceptual Site Model

As part of this assessment, a Conceptual Site Model (CSM) was developed for the extent of the landform that included subsidence. Preliminary results of the pluvial hydraulic modelling (refer **Section 5.4**) were utilised to inform the development of the CSM. Where significant subsidence ponding was identified, conceptual modifications to the landform were incorporated to limit the depth of ponding to less than 1m depth in the 2% AEP event, and provide free drainage to the Isaac River, including:

- Backfilling within subsidence depressions; and
- Drainage paths (generally 10m-30m width) between subsidence depressions.

The depth of ponding limit was chosen by the teams managing the rehabilitation and ecosystems on site, based on the proposed vegetation.

Mapped threatened ecological communities (TECs) were obtained from BMA, and these areas were avoided where possible.

The CSM is illustrated in **Figure 3-1**.



H:\Projects\SLR\620-BNE\620-040713\00001 GRM RHM PRCP Rehab Flood Asses\06 SLR Data\01 CAD\GIS\GIS\Ac\Figures\RHM\620040713_Final_Landform_Fig3-1_001.mxd



 0 0.4 0.8 1.6 km

Coordinate System: GDA2020 MGA Zone 55
Scale: 1:50,000 at A3
Project Number: 620.040713
Date: 03-Oct-2024
Drawn by: GN

LEGEND

-  Mining Leases
-  Proposed Backfill Areas
-  TECs
-  Proposed Drains

**Red Hill Mine PRCP
Rehabilitation Flood Assessment**

Final Landform and CSM



Figure 3-1

4.0 Hydrologic Modelling

4.1 Software

A hydrologic model was developed for the Goonyella and Red Hill Mine catchments using Watershed Bounded Network Model (WBNM) Version 2017. The WBNM software is an industry standard rainfall-runoff routing program. Storm Injector Version 1.3.9.0 was utilised to assist in setup and analysis of ARR design storm ensembles and to review model results.

4.2 Model Setup

4.2.1 Catchment

The hydrologic model covers a total area of 1,240 km². Sub-catchments for the WBNM model were delineated based on the landform DEM detailed in **Section 3.3**. The WBNM model layout is illustrated in **Figure 4-1**.

The total catchment for Isaac River is 1,096km².

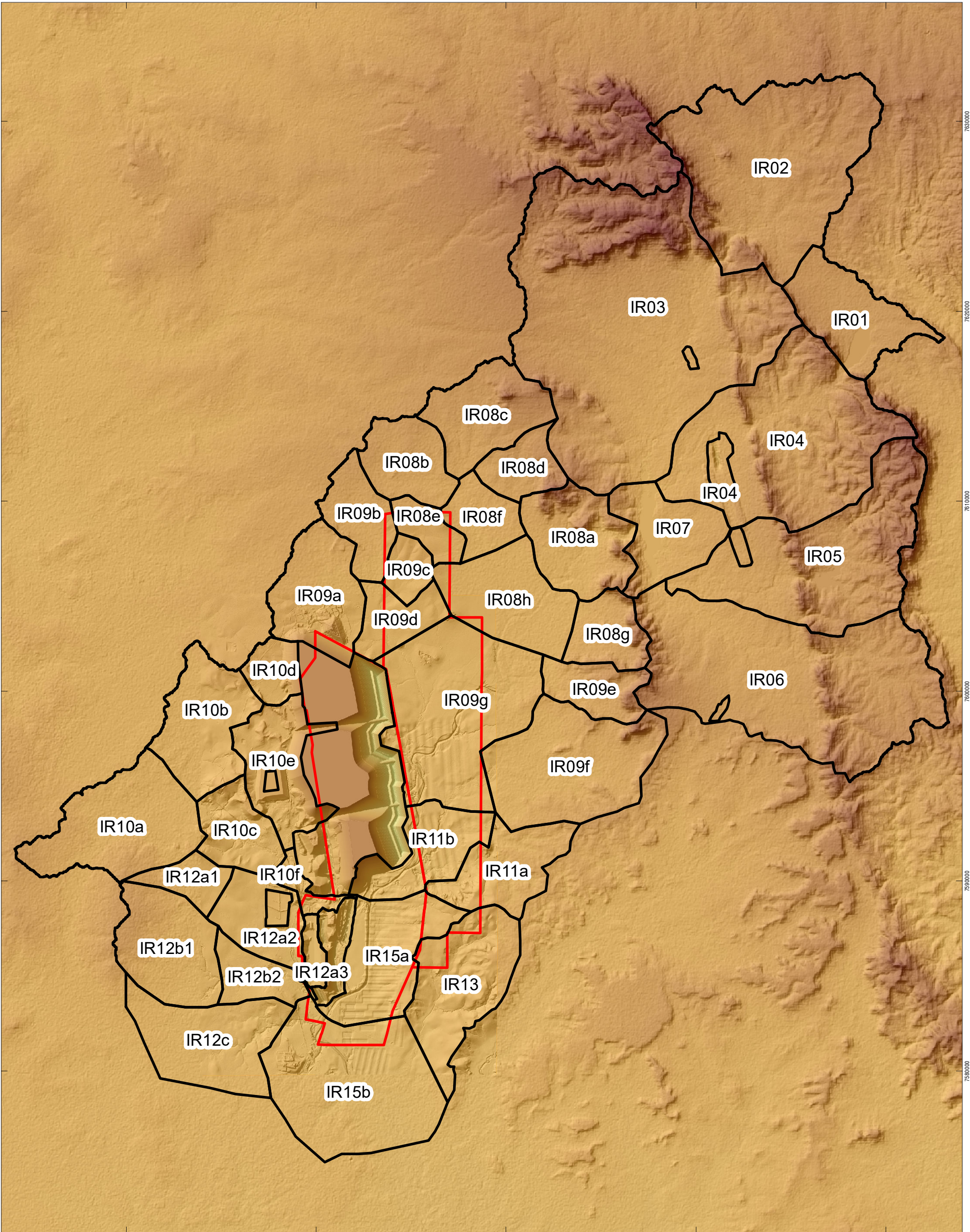
Catchment land use was adopted based on the final landform and aerial imagery. The predominant land use within the catchment is rural. Therefore, the majority of the catchment was modelled as fully pervious, with areas of imperviousness incorporated where appropriate including water surfaces. The fraction impervious (Fi) values adopted for the various land use categories are shown in **Table 4-1**.

Table 4-1 Land Use Fraction Pervious

Category	Fraction Impervious
Water Bodies	1
Natural / Undisturbed	0
Rehabilitated	0



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0

1.25

2.5

5

km

Coordinate System:

GDA2020 MGA Zone 55

Scale:

1:180,000 at A3

Project Number:

620.040713

Date:

23-Oct-2024

Drawn by:

TS

LEGEND

 Mining Leases

 WBNM Catchment Boundaries

Red Hill Mine PRCP
Rehabilitation Flood Assessment

WBNM Layout



Figure 4-1

4.3 Design Storm Analysis

4.3.1 Design Storm Events

The WBNM model was simulated for the 39%, 2%, 1%, 0.1% AEP and PMP events with a range of storm durations between 1 hour to 48 hours and ten temporal patterns for each duration accordance with ARR.

For each AEP-duration combination, the design storm temporal pattern which produced a peak flow nearest to the mean peak flow of the suite of 10 temporal patterns was adopted as the design storm. Preference was given to flows greater than the mean, with a bias factor of 2 applied. The adopted temporal pattern event for each creek was selected based on the focal point in the creek as given in **Table 4-2**.

Table 4-2 WBNM model adopted focal points for temporal pattern selection

River / Creek	Sub-catchment
Isaac River	IR15a

For the 0.1% AEP event, in accordance with the procedures outlined in ARR, the Revised Generalised Tropical Storm Method (GTSMR) was applied. The GTSMR temporal pattern, which is applicable for long durations (from 24 hours), was extended to the 12 hour event with time steps adjusted accordingly. This approach ensures that the critical duration was accurately captured. The GTSMR temporal pattern was applied to storm durations from 12 hours to 48 hours. The model was simulated for durations ranging from 12 hours to 48 hours for the 0.1% AEP event.

For the PMP event, the GTSMR 1000km² temporal pattern was applied for events between 24 hours and 48 hours.

A critical duration assessment was undertaken using the hydraulic model. The results of the assessment are provided in **Section 5.3**.

4.3.2 Intensity-Frequency-Duration Data

Rainfall Intensity-Frequency-Duration (IFD) data for the catchment was sourced from the Bureau of Meteorology (BoM) online IFD data portal. The IFD data adopted in the model is provided in **Table 4-3**.

Table 4-3 Rainfall Intensity-Frequency Duration Data

Storm Duration (min)	Design AEP Event Rainfall Intensity (mm/h)			
	39%	2%	1%	0.1%
60	41.8	75.5	82.2	132
90	46.8	86.3	94.1	151
120	50.2	94.2	103	165
180	54.9	106	117	188
270	59.9	120	134	216
360	63.8	132	148	239
540	70.2	151	171	277



Storm Duration (min)	Design AEP Event Rainfall Intensity (mm/h)			
	39%	2%	1%	0.1%
720	75.7	167	191	309
1080	85.2	195	224	362
1440	93.2	217	251	404
1800	100	237	275	438
2160	107	253	295	466
2880	117	281	328	512

4.3.3 Losses

Rainfall initial and continuing losses for the catchment were sourced from the ARR Online DataHub. The initial loss for each design storm event was calculated by subtracting the median pre-burst rainfall depth from the global catchment initial loss, in accordance with the methodology outlined in ARR. The adopted global initial and continuing loss values are shown in **Table 4-4**.

Table 4-4 Design Rainfall Losses – ARR Data Hub

Global Storm Loss	Loss Value
Initial Loss	36 mm
Continuing loss	2.7mm/h

For the 0.1% AEP and PMP events, an initial loss of 0 mm was adopted, given an event of such magnitude would typically occur following a period of significant antecedent rainfall. The continuing loss values were not changed for the 0.1% AEP and PMP events.

4.3.4 Lag Parameter

A catchment lag parameter of 1.6 was applied for the design storm events, which is within the range recommended in the WBNM documentation (typically 1.3 to 1.8).

4.3.5 Areal Reduction Factor

Areal reduction factors (ARFs) are required under ARR, as design rainfall IFDs are based on specific points in a catchment rather than the whole catchment, and these point rainfall intensities are not representative of the areal average rainfall intensity across the catchment. The ARFs represent the ratio between the areal average rainfall and point rainfall for the same AEP and storm duration. ARFs are calculated based on the catchment area, AEP, and storm duration.

For the Isaac River catchment, the Areal Reduction Factor (ARF) was based on the catchment area of 1,100km².

An ARF of 1.0 was used for the PMP event.



4.3.6 Probable Maximum Precipitation Event

A Probable Maximum Precipitation (PMP) analysis was undertaken in accordance with ARR. PMP rainfall depths were calculated using the Generalised Tropical Storm Method Revised (GTSMR) for the Isaac River catchment for durations between 24 and 120 hours.

4.4 Validation

4.4.1 Stream Gauge

Flood frequency analysis was undertaken for Isaac River. Stream gauge data upstream of the site was obtained from the Qld Government Water Monitoring Information Portal.

There are two stream gauges upstream of the site; Isaac River at Goonyella (13414A) and Isaac River at Burton Gorge (130402A). Although there is 38 years (1983-2021) of data available, due to the construction of the Burton Gorge Dam, the Isaac River at Goonyella gauge is considered to be lacking in homogeneity, and hence it is not suitable for flood frequency analysis.

Flood frequency analysis was therefore undertaken for the gauge at Isaac River at Burton Gorge (130402A). Data for this gauge is available between 1964 and 1988 (24 years). Burton Gorge Dam was constructed in 1992, so the dataset is not influenced by the dam.

4.4.2 Flood Frequency Analysis

RMC-BestFit v1.0, a Bayesian estimation and fitting software developed by the US Army Corps of Engineers (USACE) Risk Management Center (RMC), was used for flood frequency analysis.

A Log-Pearson Type III distribution was fitted to the data. The peak flow prediction beyond 1% AEP goes outside the 90% credible intervals, and therefore should not be used for comparison with hydrological model results. Note that the peak flow of 0m³/s from 1969 was treated as low outlier data and not included in the analysis.

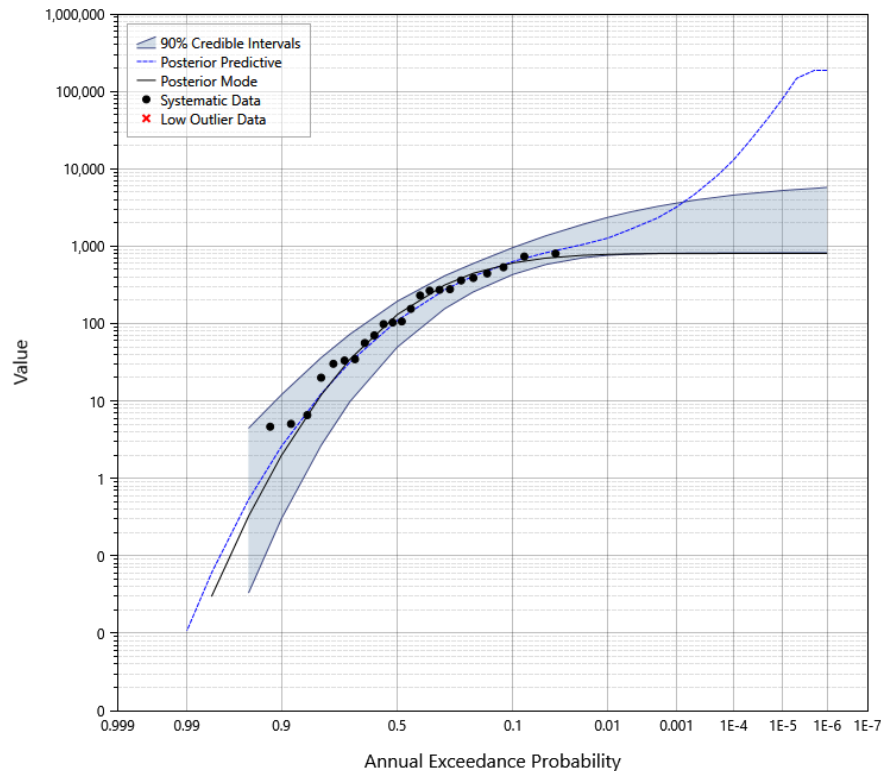
The results of the FFA are shown in **Table 4-5** and **Figure 4-2** below.

Table 4-5 FFA Results for Issac River at Burton Gorge gauge

AEP	Peak Flow (m ³ /s)	Lower 90% confidence limit (m ³ /s)	Upper 90% confidence limit (m ³ /s)
39%	165	83	273
20%	412	257	597
10%	635	433	961
5%	824	581	1,362
2%	1,052	710	1,914
1%	1,269	763	2,354



Figure 4-2 FFA Results for Issac River at Burton Gorge gauge



4.4.3 Comparison to 2019 FFA

A flood frequency analysis was undertaken for the Goonyella and Broadmeadow mines in the Goonyella and Broadmeadow Hydraulic Assessment (WRM 2019).

Analysis was undertaken for the Isaac River at Goonyella gauge. An “all-data” scenario using all 35 years of data and a “post-dam” scenario which uses only the data after Burton Gorge Dam construction (27 years) were undertaken. Although the Isaac River at Goonyella gauge was deemed not suitable for an FFA (refer to **Section 4.4.1**), the peak flows from the WRM FFA using the “post-dam” scenario and subsequent XP-RAFTS model results are of similar magnitude to the WBNM model output. Comparison to these results are shown in **Table 4-7**.

4.5 Results

The peak flows from the WBNM model at Burton Gorge gauge were compared to the peak flow from the FFA in **Table 4-6**.

The WBNM peak flows were generally consistent with the 2% and 1% AEP FFA results. The WBNM model peak flow was lower than the FFA results in the 39% AEP. However, the 39% AEP results were utilised to assess the peak flood bed shear stress, stream power and velocity and subsequently the associated scour and erosion risk, and these parameters are not significantly affected by relatively small changes in peak flow.



Table 4-6 Peak flow at Burton Gorge gauge

AEP (%)	WBNM Peak Flow (m ³ /s)	FFA Peak Flow (m ³ /s)	% difference from FFA	RFFE Discharge (m ³ /s)	RFFE Lower confidence Limit 5% (m ³ /s)	RFFE Upper confidence Limit 95% (m ³ /s)
39	112	165.6	-32%	-	-	-
10	463	635	-27%	707	334	1,560
5	682	825	-17%	874	397	2,010
2	1,025	1,052	-2%	1,110	476	2,700
1	1,307	1,270	3%	1,300	532	3,310
0.1	2,502	-	-	-	-	-

The peak flows from the WBNM model at Isaac River at Goonyella gauge were compared to the peak flow from the XP-RAFTS model results and FFA results from WRM as shown in **Table 4-7**.

Table 4-7 Peak flow at Isaac River at Goonyella

AEP (%)	WBNM Peak Flow (m ³ /s)	WRM (2019) "Post-Dam" FFA Peak Flow (m ³ /s)	WRM (2019) XP-RAFTS Peak Flow (m ³ /s)	% difference from WRM XP-RAFTS Peak Flow
10	718	896	830	-13%
5	1,080	1,308	1,167	-7%
2	1,689	1,786	1,707	-1%
1	2,187	2,078	2,079	5%
0.1	4,365	-	3,808	15%

The flows produced by the WBNM model are comparable to the peak flows from the FFA and the RFFE at Burton Gorge. The results are also comparable to the flows from the WRM (2019) FFA at Goonyella. Although the outcome suggests that the 0.1% AEP results may be conservative, there is insufficient gauge information to confirm this.

Therefore the WBNM model was deemed suitable for use for this assessment.

4.6 Climate Change Assessment

The effects of climate change were considered as part of the hydrologic analysis. Sensitivity analyses were carried out with respect to the modelled design rainfall Intensity-Frequency-Duration data. The three scenarios were modelled in accordance with the *CTD-WTR-GLD-001 Guideline for Climate Change Adaptation in Mine Water Planning and Hydrologic Assessments*:

- 6% increase in rainfall intensity;
- 11% increase in rainfall intensity; and



- 20% increase in rainfall intensity.

Hydrographs for each scenario for the 0.1% AEP events were extracted and utilised as inflows in the hydraulic model.

4.7 Consideration of Alteration of Flows

In accordance with Section 3.6.1 of the PRCP Guidelines, alteration of flows upstream and downstream should be considered. RHM is limited to underground mining and therefore there will be no changes to catchment areas.

Minor changes to peak flows caused by the attenuation due to the presence of subsidence is possible, however the subsidence areas will drain freely to downstream watercourses, as summarised in Section 5.5.3. Therefore the hydrologic regime of receiving watercourses (i.e. Isaac River) will not be significantly altered.



5.0 Hydraulic Modelling

5.1 Modelling Approach

2-dimensional hydraulic modelling was undertaken as part of the assessment. The following modelling approaches and the respective purposes were applied:

- The **Fluvial Model** was developed to quantify flooding conditions within the Isaac River for a range of design storm events. A traditional source inflow approach was applied for the model whereby discharge hydrographs generated by the WBNM model were applied as inflow conditions at appropriate discrete locations. The results of the model were utilised to assess the stability of the final landform and to assess the potential risk of inundation of the proposed final voids at Goonyella Complex, noting there are no final voids within RHM.
- The **Pluvial Model** was developed to simulate local catchment rainfall runoff behaviour over the areas of the final landform where subsidence will occur. A direct rainfall (Rain-on-Grid) approach was applied. The model results were utilised to investigate potential ponding in subsidence areas. This modelling was focused on the Red Hill Mining Lease. Assessment of the subsidence areas within the Goonyella Mining Lease was undertaken as part of the Goonyella Complex PRCP.

5.2 Software

The hydrodynamic modelling software TUFLOW (Build 2023-03-AE) was used for the hydraulic modelling. The sub-grid sampling (SGS) feature of TUFLOW provides increased definition of model terrain, which improves estimate of flow conveyance. This enables model resolution to be improved without significant increases in model run times.

5.3 Fluvial Model Setup

5.3.1 Topography

The final landform DEM received from BMA was adopted as the topography for the model. A model grid cell size of 10m was adopted.

A sub-grid sampling distance of 1m was applied, which was considered to provide adequate model resolution for the purposes of this assessment, which has creeks with channel widths of approximately 8 to 10m. The model DEM is shown in **Figure 5-1**.

Break lines were used to represent key discrete topographic features including creek beds and bunds around pits in order to capture the low and high points of the terrain in the model topography. The topography was increased by approximately 500mm at the northern side of R32 South Void to prevent pit ingress.

5.3.2 Hydraulic Roughness

The hydraulic roughness for the model was determined based on aerial imagery and the model landform. The model hydraulic roughness is shown in **Figure 5-2**. The Manning's n values adopted in the model are listed in **Table 5-1**.



Table 5-1 TUFLOW Model Manning's n Values

Land use	Manning's n
Sparse Trees	0.06
Dense Trees	0.08
Water Surfaces	0.02

5.3.3 Inflows

Flow hydrographs for the TUFLOW model were extracted from the WBNM model. The hydrographs were applied as inflow boundaries via source area polygons or polylines as total or local inflows at appropriate locations, as shown in **Figure 5-1**.

5.3.4 Downstream boundaries

Downstream model boundaries were applied as stage-discharge relationships based on the water surface gradient in the vicinity of the boundaries. The stage-discharge relationships are automatically calculated using the TUFLOW in-built functionality. The downstream boundaries are shown in **Figure 5-1**.

5.3.5 Hydraulic structures

Existing culverts were included in the model at two crossings. The structural data adopted for the modelled culverts was extracted from the hydraulic model used in the GRM operations model, received from BMA. There are two culverts in the model crossing Goonyella Road and the Coppabella to North Goonyella section of the Goonyella System, which are shown in **Figure 5-1**.

5.3.6 Critical Duration Assessment

A range of design storm events was simulated in the fluvial models for a range of AEPs which include 39%, 2%, 1%, 0.1% AEP and PMF (Probable Maximum Flood). Three climate change events were run for the 0.1% AEP. As there are multiple areas of interest, a range of durations were used to create a maximum grid for each AEP.

Critical durations are listed in **Table 5-2**.

Table 5-2 Critical Durations for Fluvial Model

AEP / Location	Critical Durations
39%	720, 1080, 1440 min
2%	720, 1080 min
1%	1080, 1440 min
0.1%	720, 1440 min
0.1% + 6% rainfall intensity CC	720, 1440 min



AEP / Location	Critical Durations
0.1% + 11% rainfall intensity CC	720, 1440 min
0.1% + 20% rainfall intensity CC	720, 1440 min
PMF	1440 min

5.4 Pluvial Model Setup

5.4.1 Topography

The final landform DEM received from BMA was adopted as the topography for the model. A model grid of 10m was adopted. A sub-grid sampling distance of 1m was applied.

The model DEM is shown in **Figure 5-3**.

5.4.2 Evaporation

Evaporation data was obtained from the SILO database on the state government Long Paddock website. The closest point (Latitude -21.8, Longitude 148) was chosen for evaporation data. The average evaporation rate applied in the model was 5.52 mm/day, or 0.23 mm/h.

5.4.3 Soil Type

The soil type within the pluvial model area was determined from the Australian Soil Classification (ASC) map from the *Goonyella Riverside Mine Complex- Material Characterisation Study* (Landloch 2024). The Australian soil types were matched to corresponding USDA soil types, which are used in the TUFLOW soils file to calculate infiltration rates. The choice of USDA soil types were confirmed with BMA's soils specialist on site. The ASC map as well as the USDA types corresponding to the ASC types are included in **Figure 5-5** and **Table 5-3** respectively.

Table 5-3 ASC Soil Types and corresponding USDA soil types

ASC Soil Type	USDA Soil Type
Anthroposol	Sandy Clay Loam*
Chromosol	Sandy Loam
Dermosol	Clay loam
Kandosol	Loam
Kurosol	Loam
Rudosol	Clay Loam
Sodosol	Loam
Vertosol	Clay
Rudosol-Tenosol	Sandy Clay Loam
Tenosol	Sand



* Note that Anthroposol does not have a corresponding USDA soil type but was nominally assumed to be sandy clay loam. There are no subsidence areas within the anthroposol classed areas.

5.4.4 Hydraulic Roughness

The hydraulic roughness for the fluvial model was also used in the pluvial model, shown in **Figure 5-4**.

5.4.5 Inflows

Inflows were applied using the direct rainfall method in TUFLOW, where rainfall is directly applied to 2D cells over the entire model area, as shown in **Figure 5-3**.

All ten temporal patterns were simulated for each design storm duration, and the median temporal pattern based on peak flood levels was adopted for each duration across the model domain using the TUFLOW post-processing utility. A maximum grid for all the envelope of durations for each AEP was then calculated.

Rainfall depths were determined using the ARR to TUFLOW tool for the 2% AEP Event. ARF was applied to all events. Initial loss and continuing loss were not applied for the pluvial model as infiltration was accounted for in the TUFLOW soils file.

5.4.6 Downstream boundaries

Downstream model boundaries were applied as stage-discharge relationships based on the water surface gradient in the vicinity of the boundaries. The stage-discharge relationships are automatically calculated using the TUFLOW in-built functionality. The downstream boundaries are shown in **Figure 5-3**.

5.4.7 Pond Backfill and Drainage Channels

The components of the CSM as described in **Section 3.3.2** were incorporated into the model terrain using the z-shape functionality within TUFLOW.

5.4.8 Critical Duration Assessment

A range of durations were simulated in the pluvial hydraulic model for the 2% AEP for all temporal patterns from the 45 minute storm to the 1800min event. The 2% AEP event was run to determine the worst ponding possible out of the events specified in the proposal. More frequent events will result in lower ponding depths.

The median temporal pattern was chosen for each duration and a maximum of these grids was analysed to determine the critical durations. The median temporal pattern was chosen to have a representative temporal pattern for each storm duration, as per ARR. The critical durations for the pluvial model are listed in **Table 5-4**.



Table 5-4 Pluvial model critical durations for 2% AEP event

Duration	Temporal Pattern
90min	TP08
360min	TP08
540min	TP10
720min	TP01
1440min	TP08



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Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community



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Coordinate System: GDA2020 MGA Zone 55

Scale: 1:75,000 at A3

Project Number: 620.040713

Date: 24-Sep-2024

Drawn by: GN



LEGEND

 Mining Leases

 TUFLOW Model Extent

 SA Inflows

 Downstream Boundary

 Upstream Inflow

 Gully Breaklines

 Culverts

Topography (mAHD)



High : 400

Low : -70

Red Hill Mine PRCP
Rehabilitation Flood Assessment

TUFLOW Fluvial Model Layout

Figure 5-1

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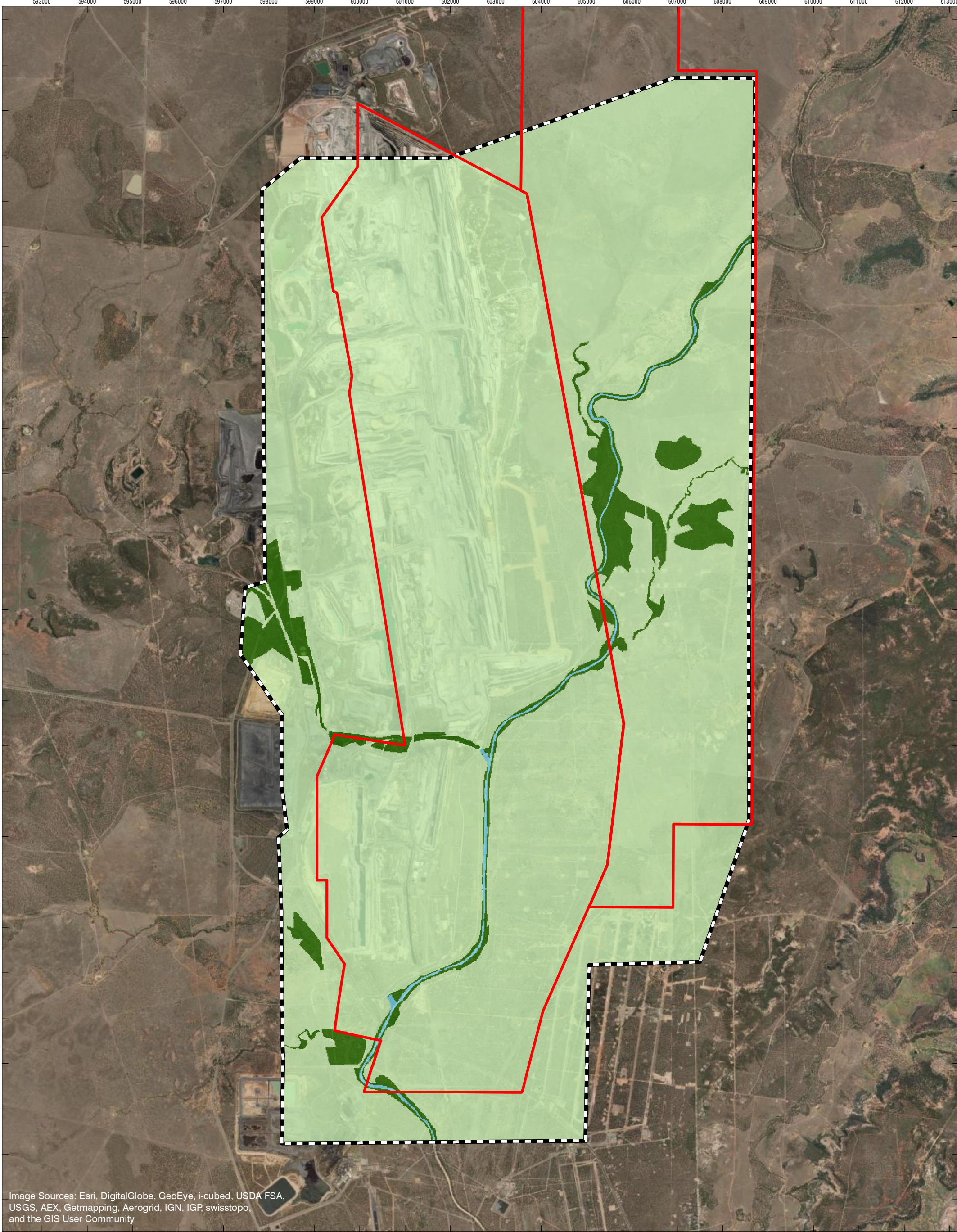


Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community



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0.5

1

2

km

Coordinate System: GDA2020 MGA Zone 55

Scale: 1:75,000 at A3

Project Number: 620.040713

Date: 24-Oct-2024

Drawn by: GN



LEGEND

 Mining Leases

 TUFLOW Model Extent

Manning's n Value

 0.06

 0.08

 0.02

Red Hill Mine PRCP
Rehabilitation Flood Assessment

TUFLOW Fluvial Model Hydraulic Roughness

Figure 5-2

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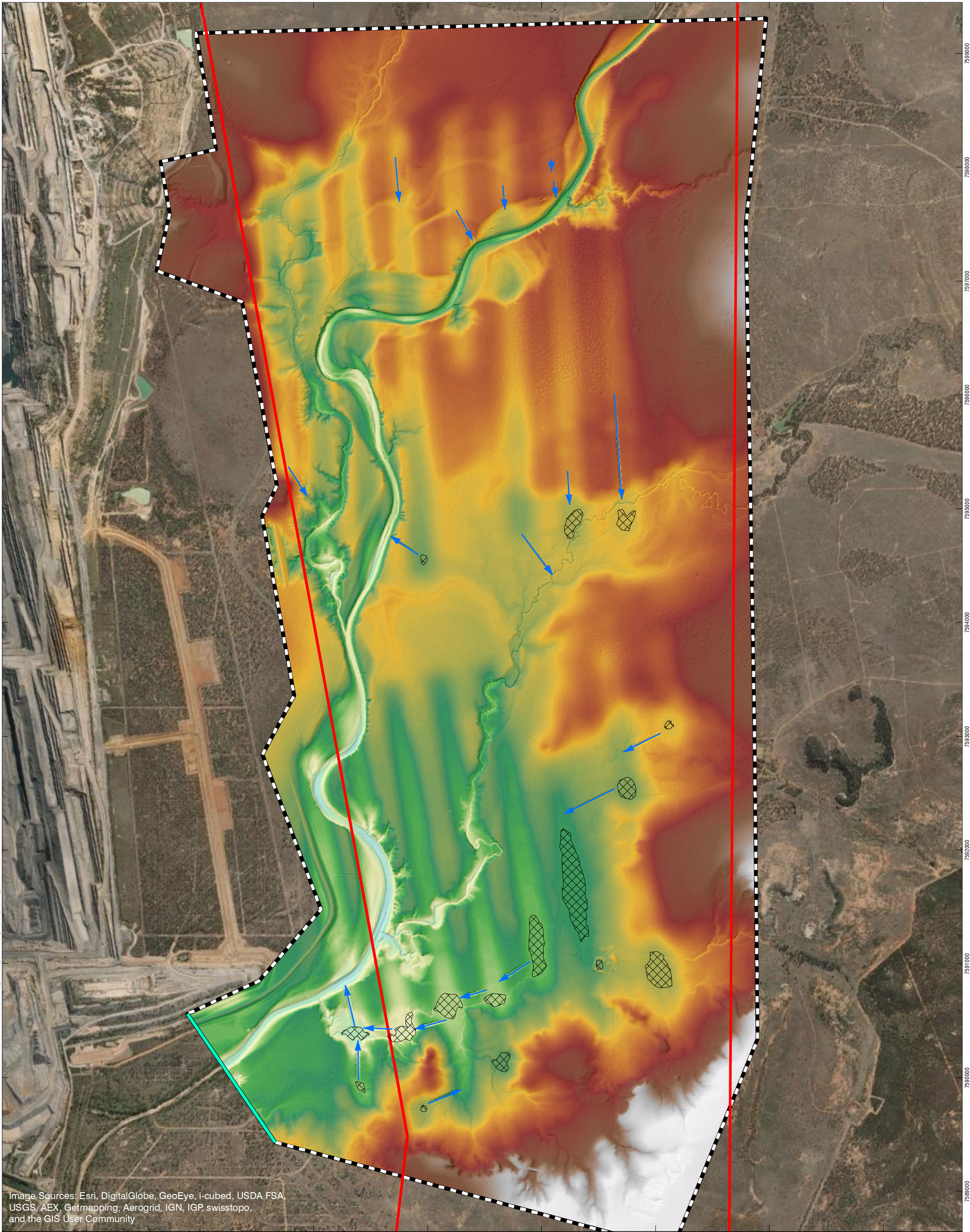
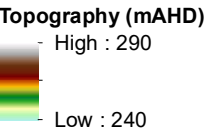


Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Coordinate System: GDA2020 MGA Zone 55		
Scale: 1:30,000 at A3		
Project Number: 620.040713		
Date: 09-Oct-2024		
Drawn by: GN		

LEGEND

-  Mining Leases
-  TUFLOW Model Extent
-  Proposed Backfill Areas
-  Downstream Boundary
-  Proposed Drains



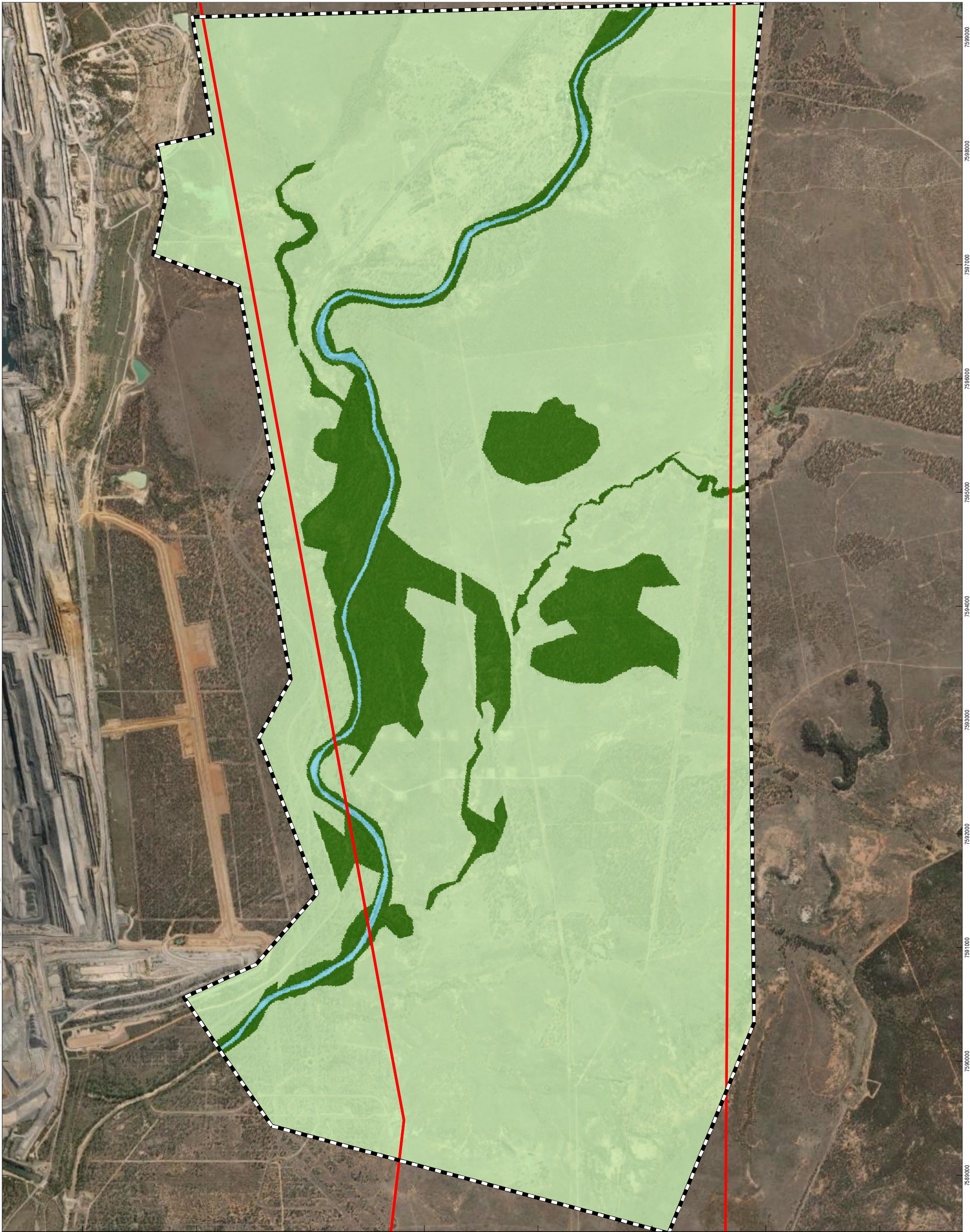
Red Hill Mine PRCP
Rehabilitation Flood Assessment

TUFLOW Pluvial Model Layout



Figure 5-3

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Drawn by: GN



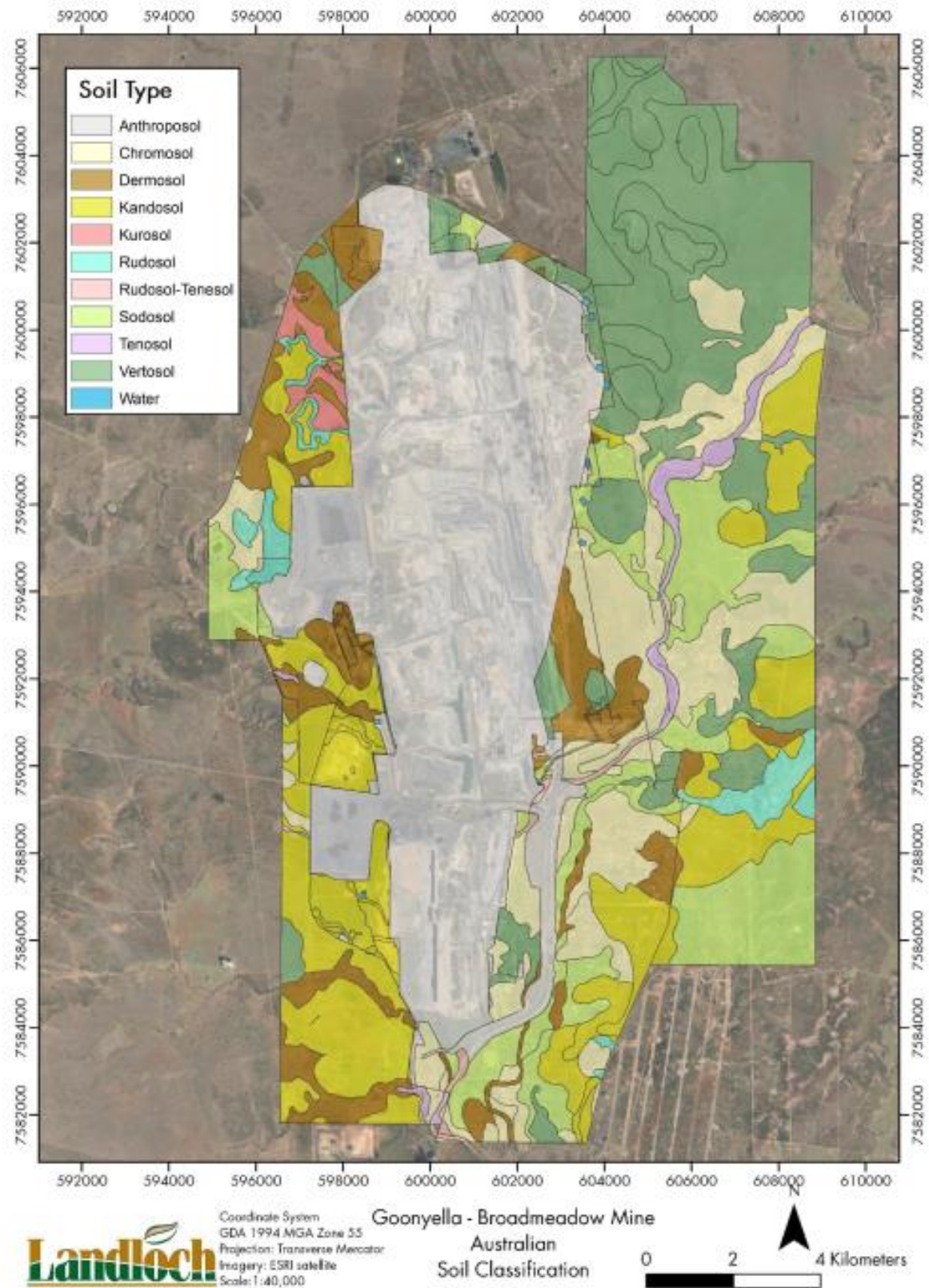
LEGEND
 Mining Leases
 TUFLOW Model Extent
Manning's n Value
 0.06
 0.08
 0.02

**Red Hill Mine PRCP
Rehabilitation Flood Assessment**

TUFLOW Model Hydraulic Roughness

Figure 5-4

Figure 5-5 Goonyella – Broadmeadow Mine Australian Soil Classification (Landloch 2024)



5.5 Results

5.5.1 Flood Ingress to Voids

The TUFLOW model results (refer **Figure 5-6**) show that all final voids are free from inundation from Isaac River, Goonyella Creek, and 12 Mile Gully in all modelled events up to and including the 0.1% AEP climate change event with 20% increase in rainfall intensity.

The results show that Goonyella Void, Isaac Void, Thiess Void, Broadmeadow Void, and R32 South Void are subject to inundation from Isaac River flooding in the PMF event, as shown in **Figure 5-7**.

5.5.2 Scour and Erosion Potential

Table 1 from DNRM's 'Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000' (State of Queensland 2019) provides indicative parameter thresholds for scour potential vegetated diversions in the Bowen Basin from ACARP. The criteria (refer to **Table 5-5**) is directed towards diversion design, which is not the purpose of this assessment. However it also provides general indication of scour and erosion potential in all waterways in the Bowen Basin and was therefore utilised in the analysis of the hydraulic model results.

Table 5-5 DNRM Design Criteria for Vegetated Bowen Basin Diversions

Scenario	Parameter	ACARP Criteria
39% AEP event	Stream Power (W/m ²)	<60
	Velocity (m/s)	<1.5
	Shear Stress (N/m ²)	<40
2% AEP event	Stream Power (W/m ²)	<150
	Velocity (m/s)	<2.5
	Shear Stress (N/m ²)	<80*

*Table 1 of the DNRM Guideline contains a known error for the 2% AEP Shear Stress value, which is listed as 50 N/m², but should be 80 N/m² in accordance with the ACARP documentation from which it is derived.

Depth-averaged bed shear stress, stream power, and velocities were extracted from the fluvial model results for the 2% and 39% AEP events. It is noted that the model results for velocity, bed shear stress, and stream power are calculated using a depth-averaged approach and were therefore used as indicative information only and likely provide a conservative estimate of erosion / scour potential.

The model results for the 39% AEP event showed that there are localised areas where the velocity, bed shear stress, and stream power exceeds the ACARP guideline values in Isaac River (refer **Appendices B1-3-1, B1-4-1, B1-5-1**). Generally, these localised areas are within the waterways and unlikely to destabilise any landforms.

A similar pattern is seen for the 2% AEP event (refer **Appendices B1-3-2, B1-4-2, B1-5-2**).

From the Isaac River results, some areas within the subsidence ponds show high bed shear stress and stream power values exceeding the ACARP guideline values, in addition to high values in the Isaac River (refer to **Figure 5-8**). Localised scour in these locations is also unlikely to destabilise any landforms.



Additionally, the values of shear stress, stream power, and velocity are generally consistent with the undisturbed reaches upstream and downstream of the site boundaries. Therefore, the characteristics are reflective of the natural conditions of the waterway and are not necessarily a product of the final landform configuration.

5.5.3 Subsidence ponding

Consultation with the Queensland Herbarium and the BMA ecology team was undertaken to determine what would constitute an acceptable ponding in the Broadmeadow final landform. The following was used as a guideline for criteria of acceptable subsidence ponding:

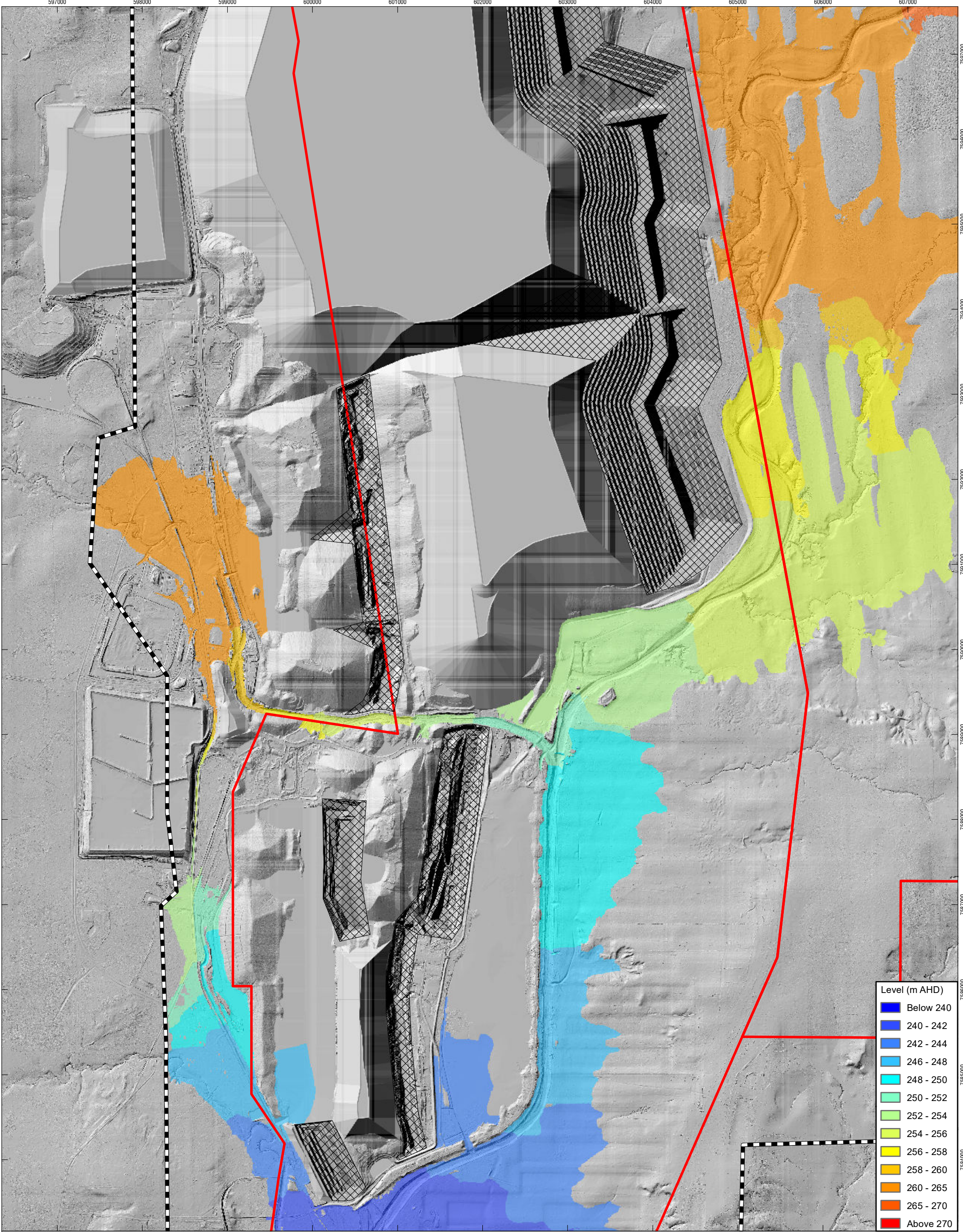
- Maximum 1m depth of ponding (2% AEP event);
- No specific duration of ponding;
- Mitigation approaches to include drains and backfilling of deeper points in the landform;
- For relatively minor ponded areas that would require extensive cutting of drains or off-site work, recommend keeping as ponds in support of PMLU.
- No limit of water take within the subsidence ponding.

Pond backfill and drainage channels as described in **Section 5.4.7** were included in the CSM and applied to the pluvial model. The pluvial model results are shown in **Appendix C**. The model results show that the ponding depths in subsidence areas are less than 1m in the 2% AEP event, except for areas where there are existing channels in the topography (e.g. refer to points 18-22, 29, 33, and 34 in **Figure 5-8**). The pond south of point 3 in **Figure 5-8** is an existing farm dam and therefore was not modified. It maintains its original function as a farm dam with subsidence and is not free-draining. In areas excluding existing watercourses, drainage lines, existing ponds, and dams, the subsidence areas will be predominantly free-draining.

Drains connecting ponds at points 1 to 10 have not been placed on existing waterways to avoid TECs and to maintain the existing channel as a low flow channel. Drain sizes have been specified as proof of concept only and were not optimised as part of this assessment. Further refinement of the CSM components including drain sizing should be considered in future design phases.



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Coordinate System: GDA2020 MGA Zone 55

Scale: 1:40,000 at A3

Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

LEGEND

 Mining Leases

 Voids

 TUFLOW Model Extent

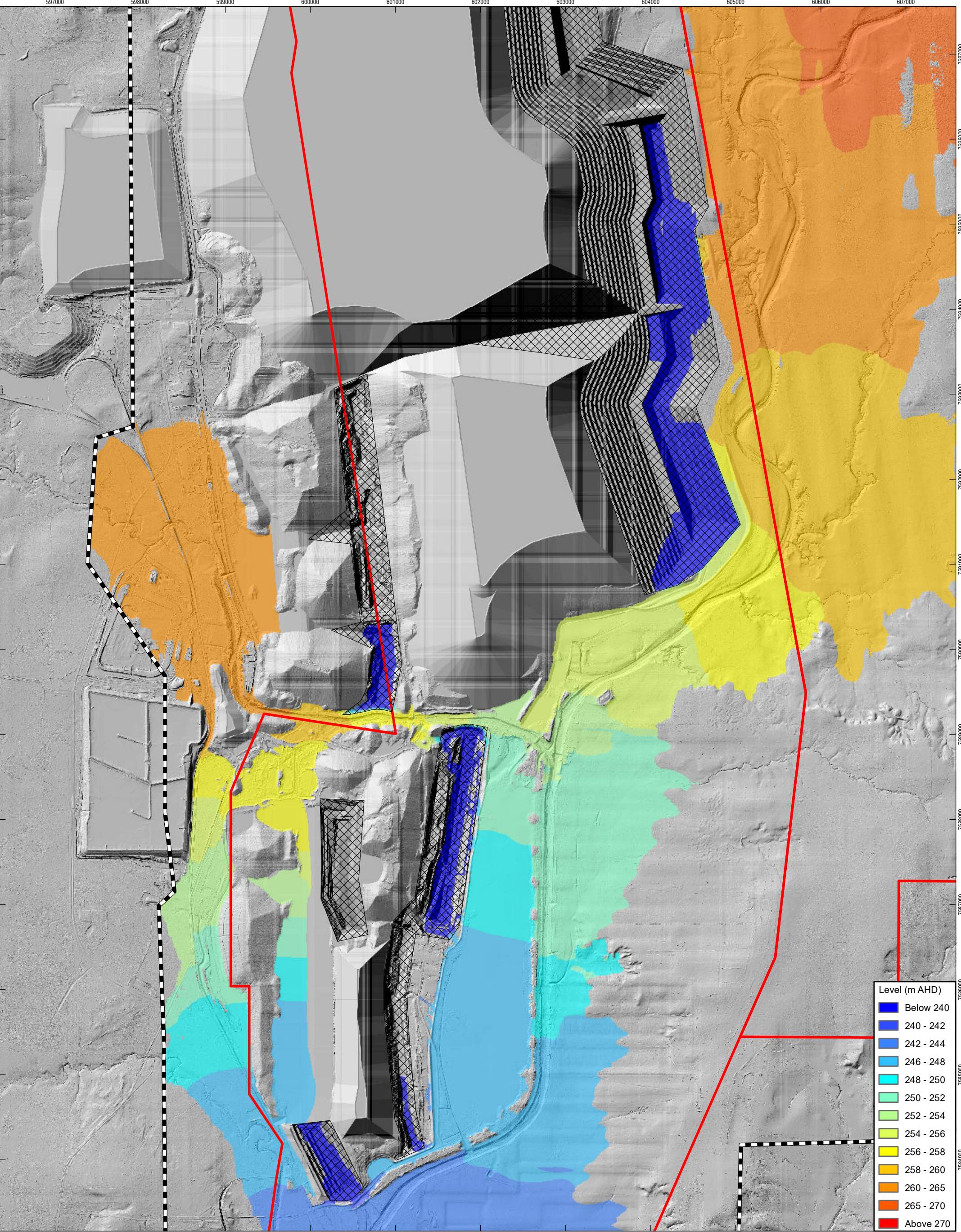
**Red Hill Mine PRCP
Rehabilitation Flood Assessment**

**Isaac River PRCP Conditions
Peak Levels - 0.1% AEP + 20% rainfall intensity**



Figure 5-6

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Level (m AHD)	
	Below 240
	240 - 242
	242 - 244
	246 - 248
	248 - 250
	250 - 252
	252 - 254
	254 - 256
	256 - 258
	258 - 260
	260 - 265
	265 - 270
	Above 270



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Coordinate System: GDA2020 MGA Zone 55

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Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

LEGEND

 Mining Leases

 Voids

 TUFLOW Model Extent

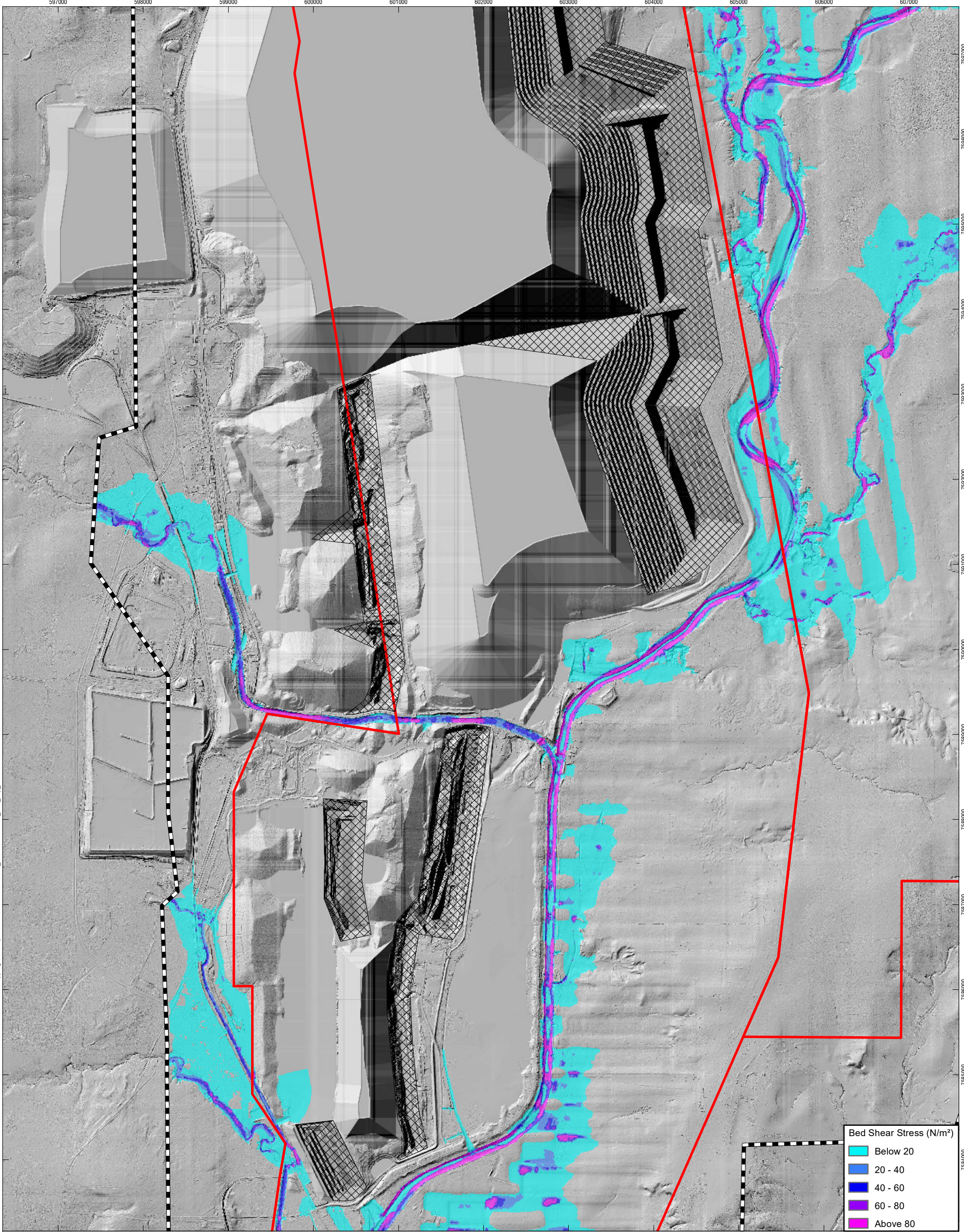
Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - PMF



Figure 5-7

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Coordinate System: GDA2020 MGA Zone 55

Scale: 1:40,000 at A3

Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

- LEGEND
-  Mining Leases

 Voids

 TUFLOW Model Extent

Bed Shear Stress (N/m²)	
	Below 20
	20 - 40
	40 - 60
	60 - 80
	Above 80

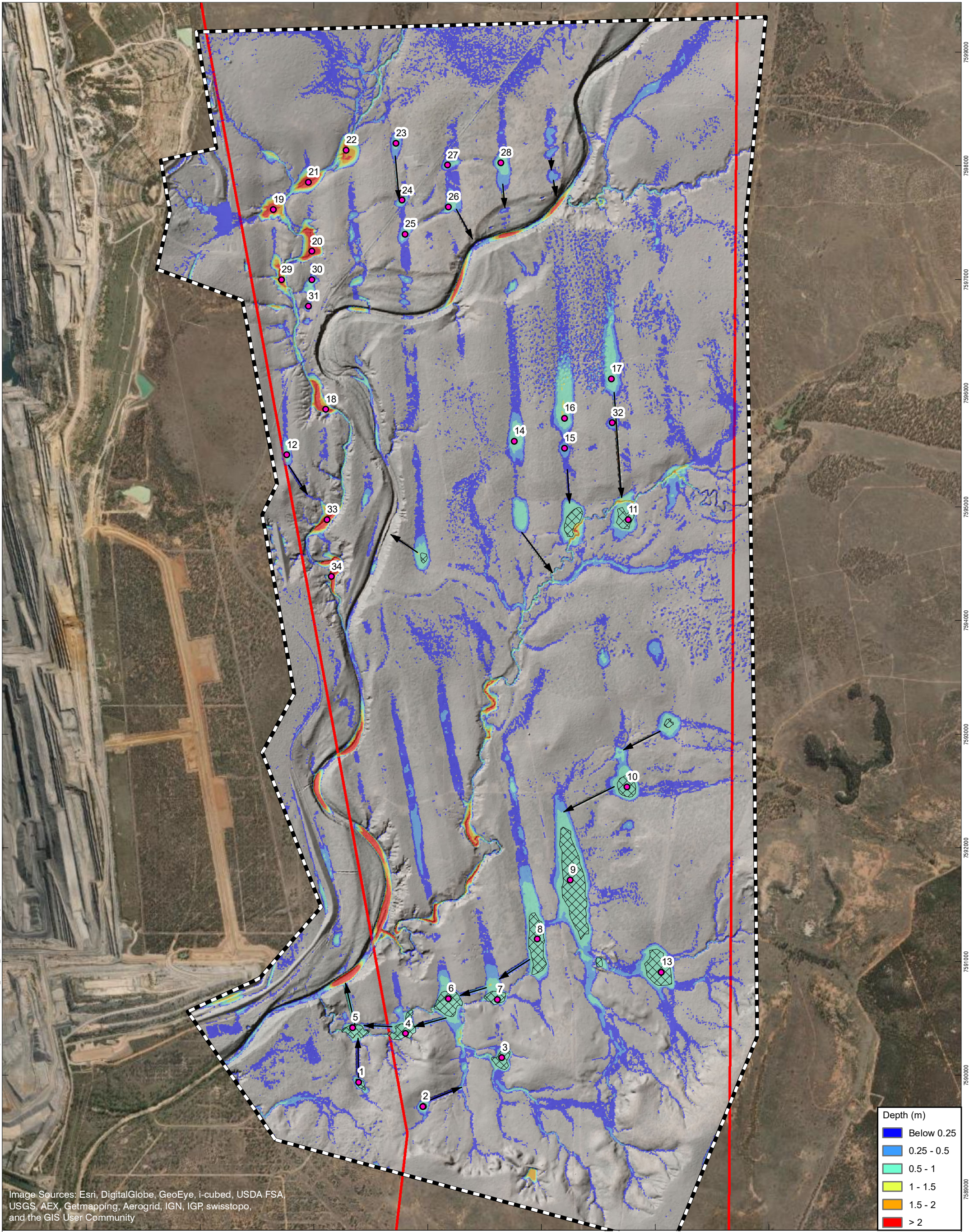
Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Bed Shear Stress - 2% AEP



Figure 5-8

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Coordinate System: GDA2020 MGA Zone 55

Scale: 1:30,000 at A3

Project Number: 620.040713

Date: 08-Oct-2024

Drawn by: TS

LEGEND

-  Mining Leases
-  TUFLOW Model Extent
-  Proposed Backfill Areas
-  Proposed Drains
-  Reporting Points

**Red Hill Mine PRCP
Rehabilitation Flood Assessment**

TUFLOW Pluvial Model Results



Figure 5-9

6.0 Flood Risk Profile

A Flood Risk Profile (FRP) was developed for RHM post-closure conditions. The FRP was based on the results of the hydraulic model (as detailed in **Section 5.3**), as applied to the BHP Risk Framework. The BHP Risk Management Guidelines (RMG) and results of the FRP assessment are provided in **Appendix A**.

The risk assessment was undertaken using the methodology outlined in the RMG as follows:

1. Identify Risk
2. Assess Risk (including determining Maximum Foreseeable Loss (MFL) level and identifying material risks).
3. Identify possible risk prevention/mitigation measures.
4. Calculate Residual Risk Rating (RRR) for material risks.
5. Determine appetite for Risk based on RRR factored by likelihood and severity, where $RRR < 90$ is within appetite, otherwise exceeding appetite.

A summary of the identified flood risks, MFL, possible mitigation measures and residual risk ratings (RRR) are detailed in **Table 6-1**.

Table 6-1 Flood Risk Profile Summary

Identified Risk	MFL	Mitigation / Prevention Measures	RRR	Residual Risk Appetite Category
Goonyella Pit Final Void floodwater ingress (PMF event only)	Serious impact to the environment, where recovery of ecosystem function takes between 3 and up to 10 years	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	0.3	Within appetite (RRR<90)
Isaac Pit Final Void floodwater ingress (PMF event only)	Serious impact to the environment, where recovery of ecosystem function takes between 3 and up to 10 years	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	0.3	Within appetite (RRR<90)
Broadmeadow Pit Final Void floodwater ingress (PMF event only)	Serious impact to the environment, where recovery of ecosystem function takes between 3 and up to 10 years	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	0.3	Within appetite (RRR<90)
Thiess Pit Final Void floodwater ingress (PMF event only)	Serious impact to the environment, where recovery of ecosystem function takes between 3 and up to 10 years	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	0.3	Within appetite (RRR<90)



Identified Risk	MFL	Mitigation / Prevention Measures	RRR	Residual Risk Appetite Category
R32 South Pit Final Void floodwater ingress (PMF event only)	Serious impact to the environment, where recovery of ecosystem function takes between 3 and up to 10 years	Stable landform design features to prevent ingress. E.g. backfill void, stable bunding structure.	0.3	Within appetite (RRR<90)

As shown in Table 6-1, the RRR for each identified flood risk is <90 and therefore within the appetite in accordance with the RMG.



7.0 Outcomes

The results of the assessment detailed in this report provided the following outcomes in relation to the scope of work outlined **Section 1.1**.

Section 3.6.1 General Rehabilitation Practices (Flooding)

- *Consider the location of domains in relation to potential flood levels.*

There are no residual voids within RHM. The results of the fluvial hydraulic model illustrate that the residual voids within Goonyella Complex are immune to inundation from riverine and creek floodwaters for all modelled design storm events up to and including the 0.1% AEP + 20% rainfall intensity increase climate change event.

- *Consider alteration of flow upstream and downstream.*

There will be no changes to the catchment areas within the Red Hill Mine Lease. Therefore no alteration of flows upstream or downstream of the site will occur.

- *Model flood levels (including probable maximum flood levels) for a range of design storm events.*

A range of design flood events were simulated using the fluvial hydraulic model including the 39%, 2%, 1%, 0.1% AEP and PMF. The effects of climate change were also assessed and the model was simulated for a range of future climate scenarios, as outlined in **Section 4.6**.

- *Develop a flooding risk profile.*

A risk profile was developed based on the results of the assessment using the BHP Risk Management Guidelines. Refer to **Section 6.0**.

Section 3.6.4 Underground Mining

- *Changes to hydrological regime.*

In areas where subsidence will occur, the final landform and CSM were developed based on the criteria for ponding as outlined in **Section 3.3.2** and **Section 5.5.3**.

- *Changes in surface topography and local drainage characteristics - this may result in some areas becoming more free-draining while runoff may be reduced in other areas, resulting in the ponding of water in areas where previously no ponding occurred.*

The final landform and CSM were developed such that ponding in subsidence areas will generally free-drain to discharge to the Isaac River in keeping with the pre-mining hydrologic regime.

- *Changes in surface drainage, leading to changes in the composition of vegetation communities and distribution of flora and fauna species.*

The criteria for allowable ponding within subsidence areas was informed by Queensland Herbarium and BMA ecology specialists as outlined in **Section 3.3.2** and **Section 5.5.3**. The results of the pluvial modelling illustrated that the criteria were generally achieved throughout the subsidence areas of the final landform.



8.0 Conclusions

SLR was contracted by BMA to support the preparation of the RHM Progressive Rehabilitation and Closure Plan (PRCP). The assessment detailed in this report was undertaken specifically to address Section 3.6.1 and 3.6.4 of the PRCP Guideline, which relates to the analysis of flooding as part of the PRCP.

A model landform was developed for the project, which was based on the post-mining surface provided by BMA and included the proposed subsidence within Red Hill Mine, final voids for Goonyella, Thiess, R32 East, Isaac, R32 South and Broadmeadow Pits as well as rehabilitated dump areas within the Goonyella Riverside Mine.

Using the model landform, hydrologic models were developed for the Isaac River catchment. The model was calibrated using recorded stream flow data for Isaac River. The results of the models were also verified against results of empirical flow estimation methods and previous studies. The hydrologic models were simulated for a suite of design storm events including a range of temporal patterns, storm durations and AEP events including the 0.1% AEP and PMF.

A fluvial hydraulic model covering the Isaac River catchment was developed. The model topography was based on the model landform for the purpose of assessing the post-mining flooding conditions in accordance with Section 3.6.1 and 3.6.4 of the PRCP Guideline. Flow hydrographs produced by the hydrologic models were utilised as inflows for the hydraulic model.

The results of the fluvial hydraulic model showed the proposed final voids are not subject to inundation for the modelled flood events up to and including the 0.1% AEP event with 20% increase in intensity scenario.

The results showed that the Goonyella, Isaac, Broadmeadow, Thiess, and R32 South Pit final voids are subject to inundation for the PMF event.

A pluvial hydraulic model was developed which was utilised to investigate potential ponding within RHM during local catchment rainfall events within the areas of the final landform where subsidence will occur. A Conceptual Site Model was developed including conceptual drainage connections and backfilling within subsidence depressions, which was driven by the defined criteria for ponding in subsidence areas.

The results of the model illustrated that the criteria for ponding can be achieved by the final landform including the CSM components.

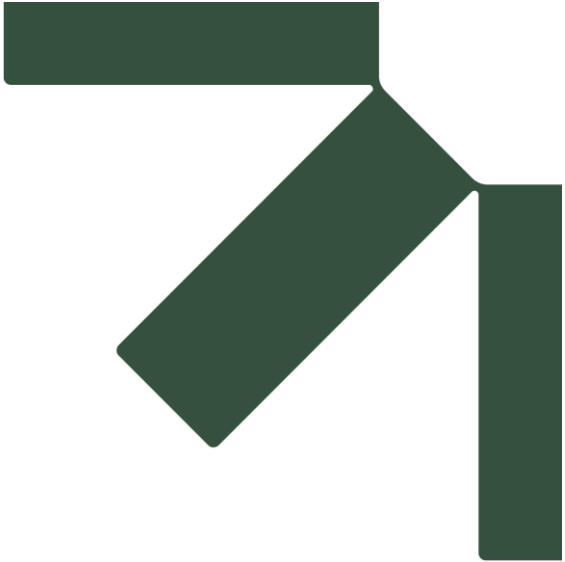
A Flood Risk Profile was developed based on the hydrologic and hydraulic model results. The FRP was developed using the framework provided in BHP's Risk Management Guideline. The outcome of the FRP was that the residual risk ratings of the identified flood risks are acceptable.



9.0 References

- ACARP. 2002. "Bowen Basin River Diversions - Design and Rehabilitation Criteria ."
- Ball, J, M Babister, R Nathan, E Weinmann, M Retallick, and I Testoni. 2019. *Australian Rainfall and Runoff - A Guide to Flood Estimation* . v4.2. Commonwealth of Australia (Geoscience Australia).
- Department of Environment and Science. 2024. "Guideline - Progressive Rehabilitation and Closure Plan (PRC Plans)."
- Landloch. 2024. "Goonyella RIVERSIDE Mine Complex - Material Characterisation Study ."
- Peabody. 2023. "Burton Gorge Dam Emergency Action Plan."
- State of Queensland. 2019. "Guideline: Works that interfere with water in a watercourse for a resource activity - watercourse diversions authorised under the Water Act 2000."
- WRM . 2019. "Goonyella and Broadmeadow Hydraulic Assessment."





Appendix A Flood Risk Profile Assessment

Red Hill Mine

Progressive Rehabilitation and Closure Plan Rehabilitation Flood Assessment

BHP Mitsubishi Alliance

SLR Project No.: 620.040713.0000

27 November 2024

Risk Management Our Requirements

Why is this important?

Through the delivery of best in class risk management, we protect what BHP has today and grow value for tomorrow.

The identification and management of risks is central to achieving our strategic objectives. It protects us against downside risk; enables us to take risk for strategic reward; and improves our resilience against emerging risks.

An essential element of effective risk management is to have an enterprise view so that the full risk exposure can be prioritised, and the aggregate impact from cumulative risks can be understood. As such, BHP operates to one [Risk Framework](#) for all risks.

In addition to [Our Requirements for Risk Management](#), other [Our Requirements](#) set minimum controls for managing specific areas of risk (e.g. Safety, Aviation, Environment and Climate Change, Water and Tailings Storage Facilities, Capital Projects, Closure and Finance).

Who does this apply to?

- Anyone involved in identifying, assessing, controlling, monitoring or reporting risks or using this information to make decisions.



See [Our Code of Conduct](#) for the standard of behaviour expected of you at BHP.



See [Our Requirements for Organisation Design](#) for [functional](#) accountabilities.

What approvals are required?



[Alternative risk governance model](#)



[Operate while remediation plan is implemented to bring performance within defined key risk indicator limits](#)



[Operate outside of defined key risk indicator limits](#)



[Risk register completeness and continued management of risks within appetite](#)



[Operate while remediation plan is implemented to bring risk within appetite](#)



[Operate while risk is within tolerance](#)

Risk Strategy

Risk Framework

- Apply BHP's [Risk Framework](#) for the identification and management of all risks.
- Strengthen our risk culture.



Strengthen our risk culture by demonstrating the following behaviours that support great risk management:

- everyone can speak up without fear;
- leaders own and prioritise threats and opportunities;
- we learn from mistakes and successes;
- everyone takes responsibility for risk;
- we encourage the right behaviour.



A strong risk culture enables us to make decisions that balance risk and reward and actively seek to take risk within appetite.



BHP operates to a global risk framework aligned to ISO31000. The level of effort applied should be prioritised commensurate with the level of risk. Notify the Global Risk team of any opportunities to improve BHP's [Risk Framework](#).

Strategic business decisions

- When making a [strategic business decision](#) for BHP:
 - use BHP's [Risk Appetite Statement](#) and [Group Risk Architecture](#) to make sure the decision is within BHP's appetite for risk;
 - use [recommended techniques](#) from the [Risk Framework](#) when additional analysis is required to be certain that a decision is within appetite; and
 - apply the [risk process](#) to the selected decision.



BHP's [Risk Appetite Statement](#) and [Group Risk Architecture](#) are central to understanding the type and extent of risk BHP chooses to accept in pursuit of achieving strategic and [operational](#) objectives.

Risk Governance

- Implement the [Three Lines](#) model for all [Group Risks](#) or [get approval](#) for an alternative risk governance model.
- When any of the defined [key risk indicator](#) limits (elevated or avoidant) specified in the [Group Risk Architecture](#) are exceeded:
 - review the appropriateness of the [Risk Appetite Statement](#) and defined [key risk indicator](#) limits and determine if an update is required; and
 - develop a remediation plan to bring performance within defined [key risk indicator](#) limits, and [get approval](#) to continue to operate while implementing the remediation plan; or
 - [get approval](#) to continue to operate outside of defined [key risk indicator](#) limits where there are no reasonable remediation actions to bring the [Group Risk](#) within appetite and have the [approval](#) reviewed annually.



Refer to the [Risk Framework](#) for a description of the [roles and responsibilities](#) for risk management under the [Three Lines](#) model.

Risk Process

Identify risk

- Identify threats and opportunities by considering:
 - what can go wrong and what must go right;
 - five year plans, Life of [Asset](#) planning and other deliverables from [Our Requirements for Corporate Alignment Planning](#);
 - purpose statements from [Our Requirements for Organisation Design](#);
 - the [Group Risk Architecture](#);
 - internal and external sources of risk;
 - intended and unintended consequences when introducing change;
 - [current risks](#) and [emerging risks](#).
- Prioritise for assessment and treatment any risks that can impact the achievement of strategic and [operational](#) business objectives.

Assess risk

- For each identified risk:
 - classify the risk as a [current risk](#) or an [emerging risk](#);
 - use one or more [recommended techniques](#) in the [Risk Framework](#) to perform a risk assessment;
 - use [Appendix 1](#) to determine the [maximum foreseeable loss \(MFL\)](#) and for each risk or [risk scenario](#) with an [MFL](#) ≥ level 4 impact determine the [residual risk rating \(RRR\)](#);
 - determine [maximum foreseeable gain \(MFG\)](#) for an opportunity;
 - tell the [Group Risk Representative](#) immediately of any newly identified risk with [MFL](#) level 5 impact;
 - review, and when applicable, update your risk assessment following any [risk relevant change](#); and
 - make sure people with relevant expertise and experience are involved in all risk assessments.
- For each [current risk](#), classify it as a current [material risk](#) if it has an [MFL](#) ≥ level 4 impact.
- For each current [material risk](#), identify [critical controls](#), and for each [critical control](#) determine:
 - the critical aspects of the design and operating performance criteria required to achieve the [control's](#) primary objective;
 - the verification activities required to check that the [critical control](#) is operating effectively according to its design; and
 - a manual test plan to test that the [critical control](#) is achieving its primary objective and effectively managing the risk.



[Critical controls](#) are not mandated for opportunities, [emerging risks](#), non-material risks or [one-off short-term material risks](#).



Some [risk events](#) may have multiple scenarios, in which case risk owners should consider whether these scenarios have a higher [RRR](#) than the [MFL scenario](#) and whether they have additional causes or impacts and require additional [controls](#).

Treat Risk

- For each [current risk](#) (either [material risk](#) or non-[material risk](#)) and each [one-off short-term material risk](#):
 - implement preventative [controls](#) to prevent the causes of a threat, and mitigating [controls](#) to reduce its impacts;
 - implement [controls](#) to enable and/or enhance an opportunity; and
 - if the [RRR](#) ≥ 90 , stop the activity or get [approval](#) to continue the activity by completing a risk evaluation under [Appendix 2](#).
- For each [emerging risk](#), make sure [contingency controls](#) are in place when the [RRR](#) ≥ 90 .

Monitor and Review

- For each current [material risk](#) follow [Appendix 2](#) to perform a [critical control](#) effectiveness test (CET) and risk evaluation at least annually.
- For each [emerging risk](#), review the risk at least annually to confirm:
 - the risk remains an [emerging risk](#) and has not become a [current risk](#);
 - the [RRR](#) remains accurate; and
 - any required [contingency controls](#) remain in place.
- Review the [risk register](#) for completeness and continued management of risks within appetite and [get approval](#) annually.

Communicate

- For each risk with an [MFL](#) $\geq$ level 4 impact, [record](#) the risk in [1SAP Governance Risk and Compliance](#) (GRC).



This requirement will be expanded to include each risk with an [MFL](#) level 3 impact once [material risks](#) are adequately represented and managed.



Remember to consult with the Global Risk team when providing risk information to the Board or Executive, [functional](#) or [asset](#) leadership teams.

Appendix 1 Severity and likelihood tables

Severity table¹: Use this table to select the [MFL](#) severity level and the [RRR](#) severity factor. The [RRR](#) severity factor measures the worst case expected outcome for the [risk event](#), assuming the mitigating [controls](#) that are in place are operating in accordance with their design.

Severity Level	Descriptor	Severity Factor
5	6 or more fatalities or 6 or more chronic life threatening illnesses; or Severe impact to the environment and where recovery of ecosystem function takes 10 years or more; or Severe impact on community lasting more than 12 months or a substantiated human rights violation impacting 6 or more people; or Severe impact on company reputation, investment attractiveness, legal rights or compliance, social value proposition or ability to access opportunities at a global level; or US\$2 billion or more ² .	1000
4	1-5 fatalities or 1-5 chronic life threatening illnesses; or Serious impact to the environment, where recovery of ecosystem function takes between 3 and up to 10 years; or Serious impact on community lasting 6-12 months or a substantiated human rights violation impacting 1-5 persons; or Serious impact on company reputation, investment attractiveness, legal rights or compliance, social value proposition or ability to access opportunities at a national level; or Between US\$250 million and up to US\$2 billion ² .	300
3	Life altering or long term/permanent disabling injury or illness to one or more persons; or Substantial impact to the environment, where recovery of ecosystem function takes between 1 and up to 3 years; or Substantial impact on community lasting 2-6 months; or Substantial impact on company reputation, legal rights or compliance, social value proposition, or ability to access opportunities at a sub national level (state, territory, province); or Between US\$50 million and up to US\$250 million ² .	100
2	Non-life altering or short-term disabling injury or illness to one or more persons; or Measureable but limited impact to the environment, where recovery of ecosystem function takes less than 1 year; or Measureable but limited community impact lasting less than one month; or Measureable but limited impact on company reputation, legal rights or compliance, or social value proposition at a local level (region , city, town); or Between US\$2 million and up to US\$50 million ² .	30
1	Low level impact resulting in first aid only; or Minor, temporary impact to the environment, where the ecosystem recovers with little intervention; or Minor, temporary community impact that recovers with little intervention; or Minor, temporary impact on company reputation, legal rights or compliance, or social value proposition; or Less than US\$2 million ² .	10

(1) Guidance on using the severity table is available [here](#).

(2) Assess the cash impact on revenue, operating cost and capital cost or cash equivalent impact (net [present value](#)). The impact should be assessed for the full life cycle of a single immediate occurrence of the event and calculated in US\$ (BHP share). If the sum of the initial impact assessed is greater than US\$250 million (BHP share) a valuation aligned to [Our Requirements for Decision Evaluation](#) should support the analysis.

Current risk likelihood table³: Use this table when calculating [RRR](#) to select the [current risk](#) likelihood factor. The likelihood factor measures the likelihood of the [risk event](#) occurring, assuming the preventative [controls](#) that are in place are operating in accordance with their design.

Calculate the [RRR](#) using the formula: $\text{RRR} = \text{severity factor} \times \text{current risk likelihood factor}$.

Uncertainty	Frequency	Likelihood factor
Highly Likely	Likely to occur within a 1 year period.	3
Likely	Likely to occur within a 1 - 5 year period.	1
Possible	Likely to occur within a 5 - 20 year period.	0.3
Unlikely	Likely to occur within a 20 - 50 year period.	0.1
Highly Unlikely	Not likely to occur within a 50 year period.	0.03

Emerging risk likelihood table: Use this table to measure the timeframe and velocity in the calculation of the [RRR](#).

Calculate the [RRR](#) using the formula: $\text{RRR} = \text{severity factor} \times \text{emerging risk likelihood factor}$.

Timeframe & Velocity	Description	Likelihood factor
Near Term & Fast	Risk event is possible within the next 2 years. Impact would occur within six months of the initial onset of the risk event .	3
Near Term & Slow	Risk event is possible within the next 2 years. Impact would occur slowly over a period of greater than six months from the initial onset of the risk event .	1
Medium Term & Fast	Risk event is possible within 2 - 5 years. Impact would occur immediately or within six months of the initial onset of the risk event .	0.3
Medium Term & Slow	Risk event is possible within 2 - 5 years. Impact would occur slowly over a period of greater than six months from the initial onset of the risk event .	0.1
Long Term (no velocity required)	Risk event is possible within 5 - 10 years, but not sooner.	0.03

(3) Guidance on using the likelihood table is available [here](#).

RRR heat map: Use this table to help determine whether a risk is exceeding appetite based on **RRR**.

Likelihood	Severity Level				
	1	2	3	4	5
Highly Likely	30	90	300	900	3000
Likely	10	30	100	300	1000
Possible	3	9	30	90	300
Unlikely	1	3	10	30	100
Highly Unlikely	0.3	0.9	3	9	30



The levels in the severity table are aligned to the Risk Appetite Statement to allow for screening that **RRR** is within appetite. When the **RRR** is ≥ 90 the risk is exceeding appetite.

Appendix 2 Critical control and risk evaluation

Critical control effectiveness test

A [critical control](#) effectiveness test (1SAP GRC control effectiveness manual test) must evaluate whether the [control](#) remains effective at managing the [risk event](#). At a minimum, it must consider results from: verification activities and any trends, actual or similar [control](#) failures, internal and external audits and management reviews.

Critical control effectiveness test	Explanation
Adequate	The design, operation and verification of the critical control are appropriate, effective and achieve the control objective.
Deficient	The design, operation or verification of the critical control is not appropriate, not effective or does not achieve the control objective.

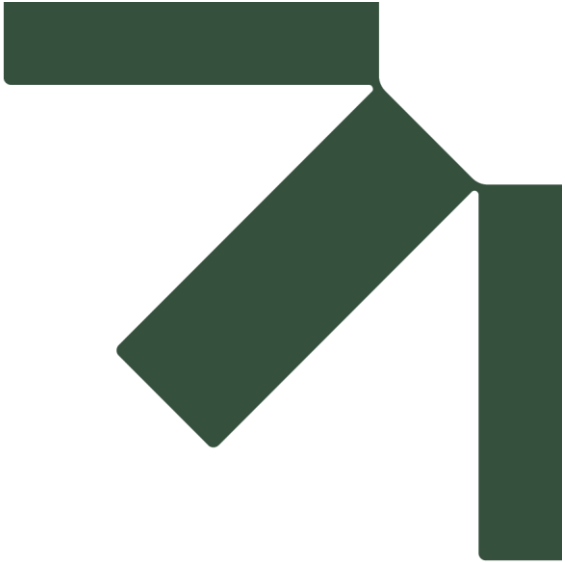
Issues identified from a [critical control](#) effectiveness test must be rated using the categories below and remediated.

Issue rating	Explanation
Low	The deficiency is unlikely to compromise the achievement of the control objective.
High	The deficiency is likely to compromise the achievement of the control objective.

Risk evaluation

Each current [material risk](#) and each non-[material risk](#) with an [RRR](#) ≥ 90 and [one-off short-term material risk](#) with an [RRR](#) ≥ 90 must be evaluated by the [Risk Owner](#) using the categories below. The risk evaluation must consider the overall effectiveness of the [control](#) environment, [critical control](#) effectiveness test(s), internal or external [control](#) failures related to the risk, audit findings, management reviews, and internal or external [risk relevant changes](#).

Rating	Explanation
Within appetite	- The RRR < 90; and - There are no deficient CETs with a high issue rating where the deficiency is specifically related to the risk being assessed.
Exceeding appetite with remediation	- The RRR ≥ 90; and/or - One or more CET(s) are rated as deficient with a high issue rating and the deficiency is specifically related to the risk being assessed; and Approval has been granted to continue to operate while a remediation plan is implemented to bring the risk back within appetite.
Within tolerance	- The RRR ≥ 90; and/or - One or more CETs are rated as deficient with a high issue rating and the deficiency is specifically related to the risk being assessed; and - There are no reasonable remediation actions to bring the risk within appetite; and - The activity has been stopped or approval has been granted to operate while the risk is within tolerance.



Appendix B Fluvial Model Results

Red Hill Mine

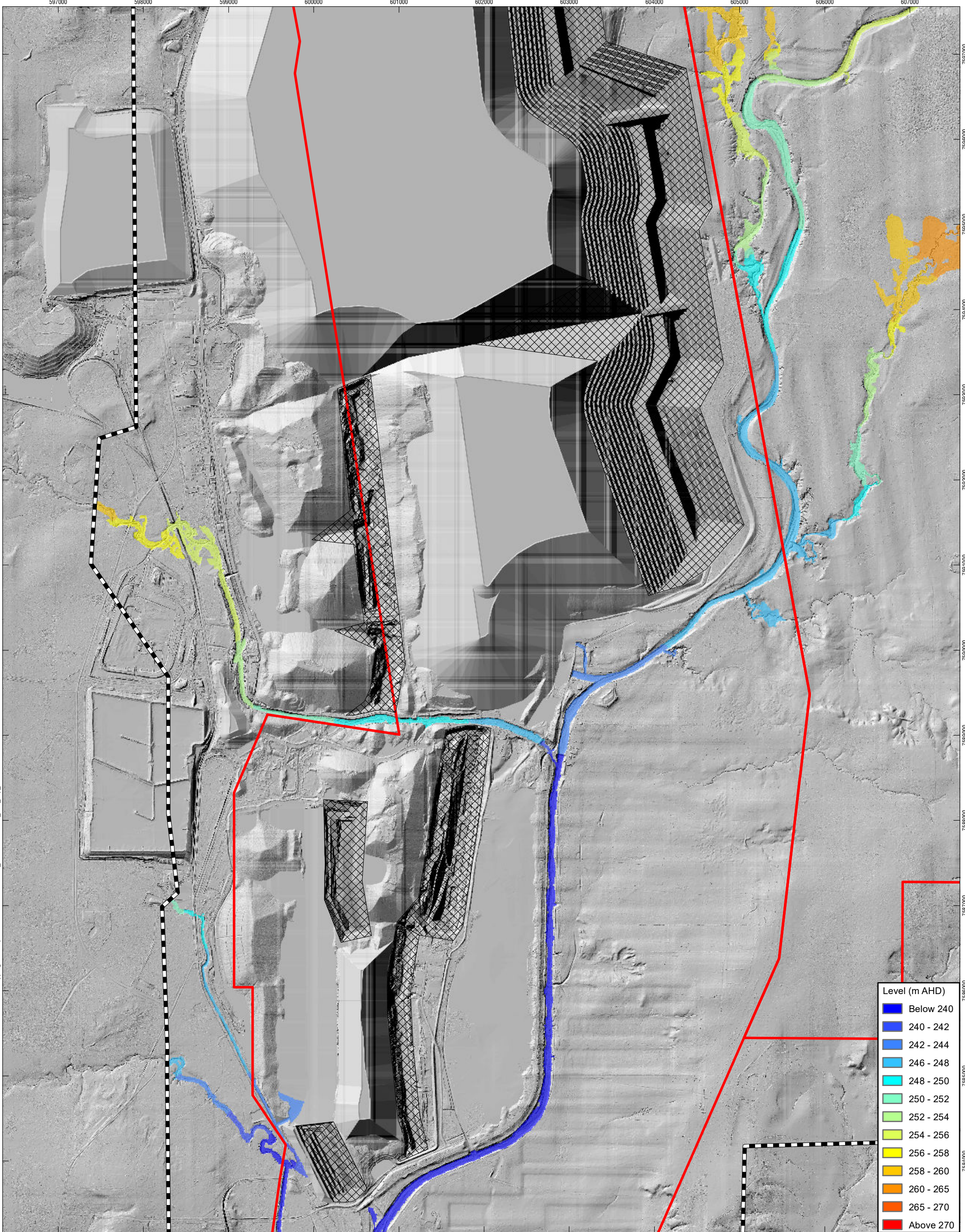
Progressive Rehabilitation and Closure Plan Rehabilitation Flood Assessment

BHP Mitsubishi Alliance

SLR Project No.: 620.040713.0000

27 November 2024

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Coordinate System: GDA2020 MGA Zone 55
Scale: 1:40,000 at A3
Project Number: 620.040713
Date: 23-Oct-2024
Drawn by: TS

LEGEND

- Mining Leases
- Voids
- TUFLOW Model Extent

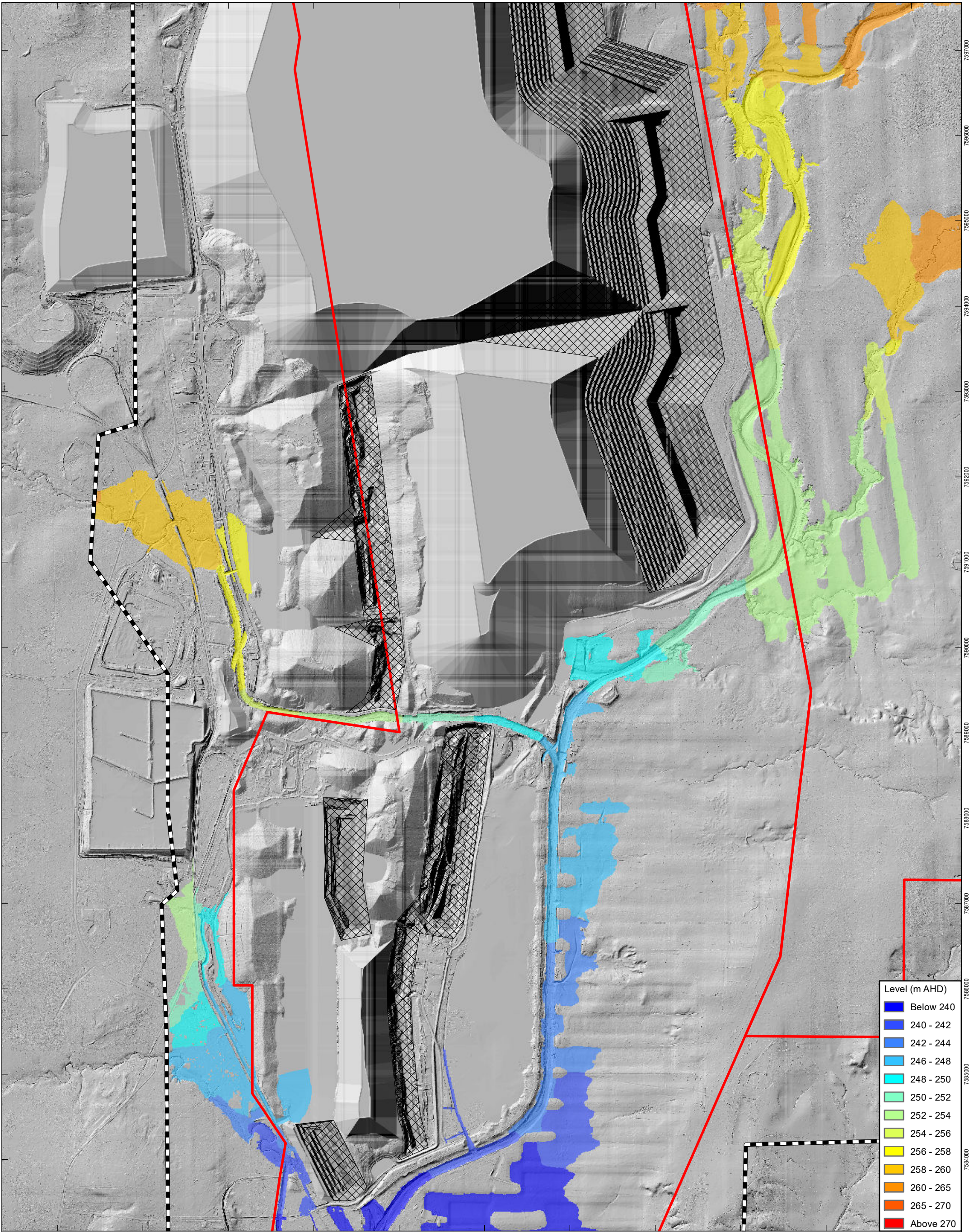
Level (m AHD)	
	Below 240
	240 - 242
	242 - 244
	246 - 248
	248 - 250
	250 - 252
	252 - 254
	254 - 256
	256 - 258
	258 - 260
	260 - 265
	265 - 270
	Above 270

Red Hill Mine PRCP Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - 39% AEP



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km

Coordinate System: GDA2020 MGA Zone 55

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Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

LEGEND

 Mining Leases

 Voids

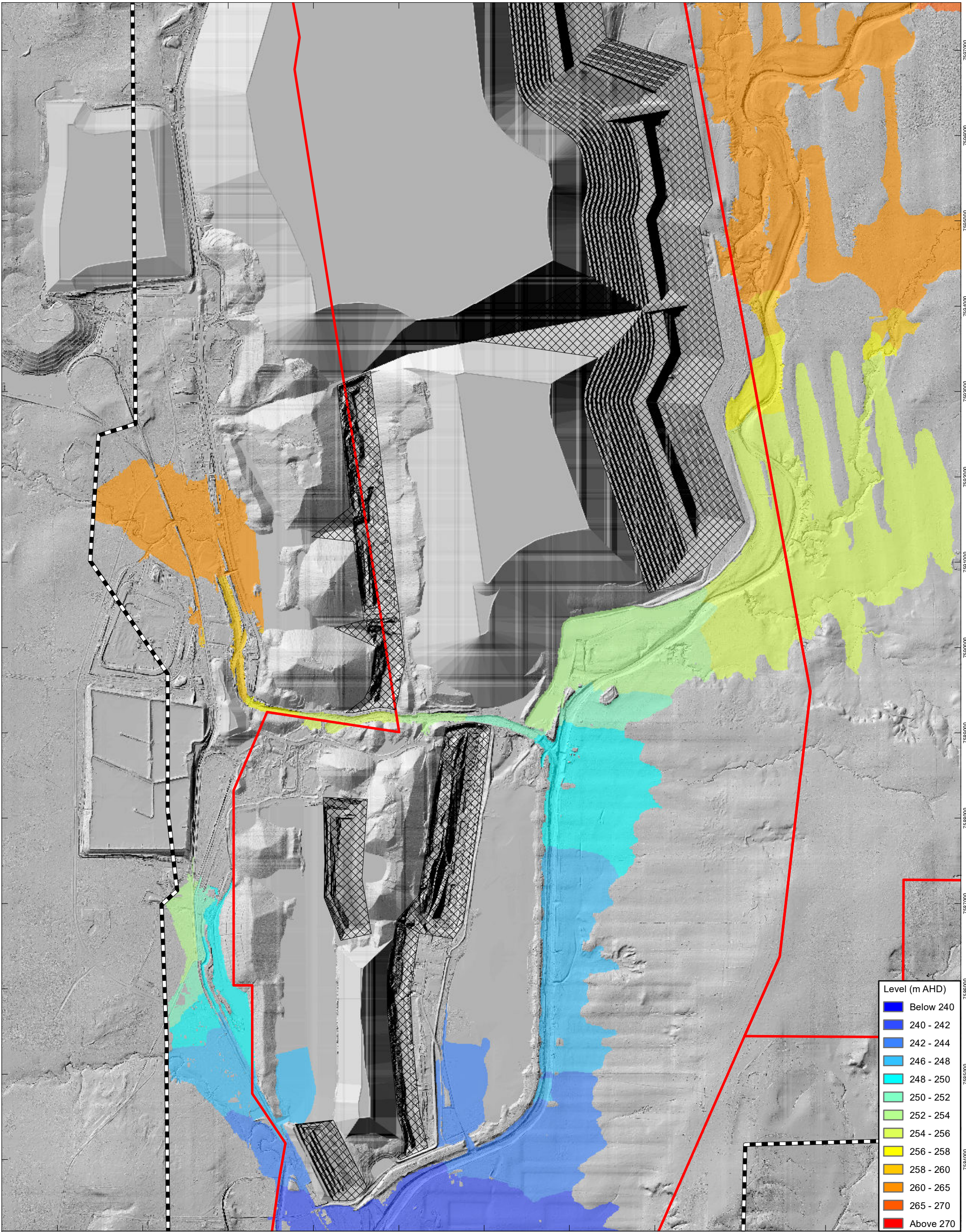
 TUFLOW Model Extent

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - 2% AEP



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Drawn by: TS

LEGEND

 Mining Leases

 Voids

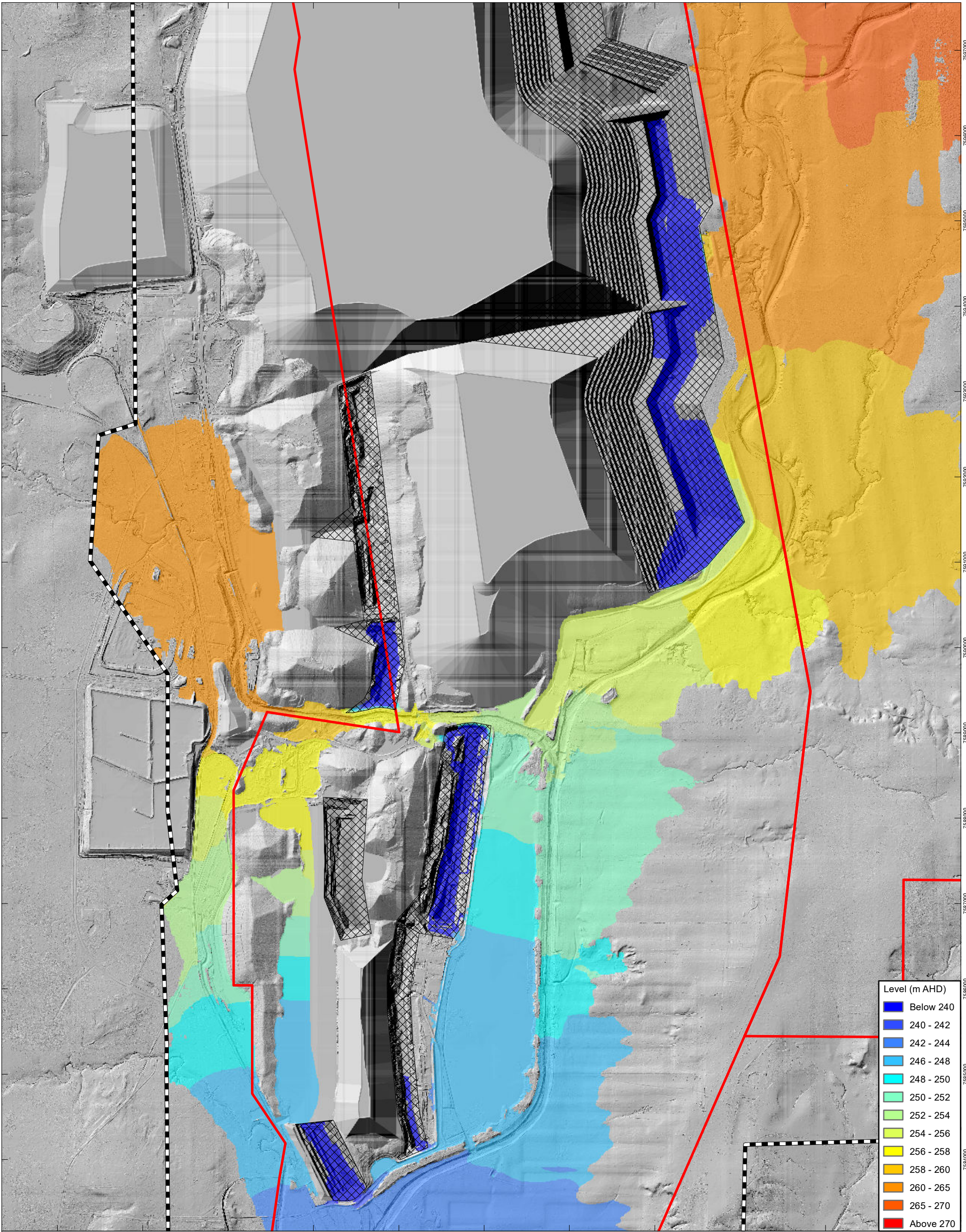
 TUFLOW Model Extent

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - 0.1% AEP



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Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

LEGEND

 Mining Leases

 Voids

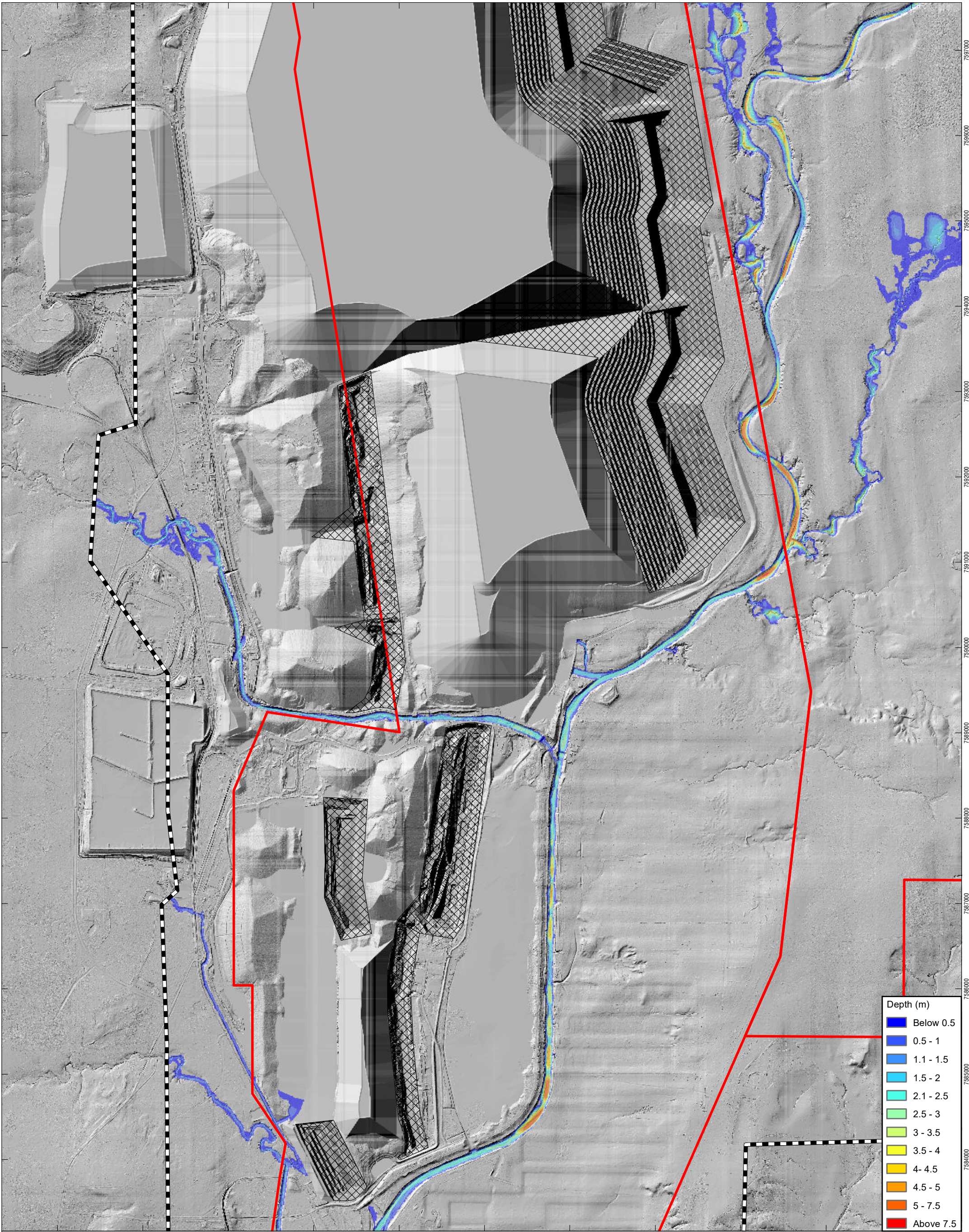
 TUFLOW Model Extent

**Red Hill Mine PRCP
Rehabilitation Flood Assessment**

**Isaac River PRCP Conditions
Peak Levels - PMF**



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Date: 23-Oct-2024

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LEGEND

 Mining Leases

 Voids

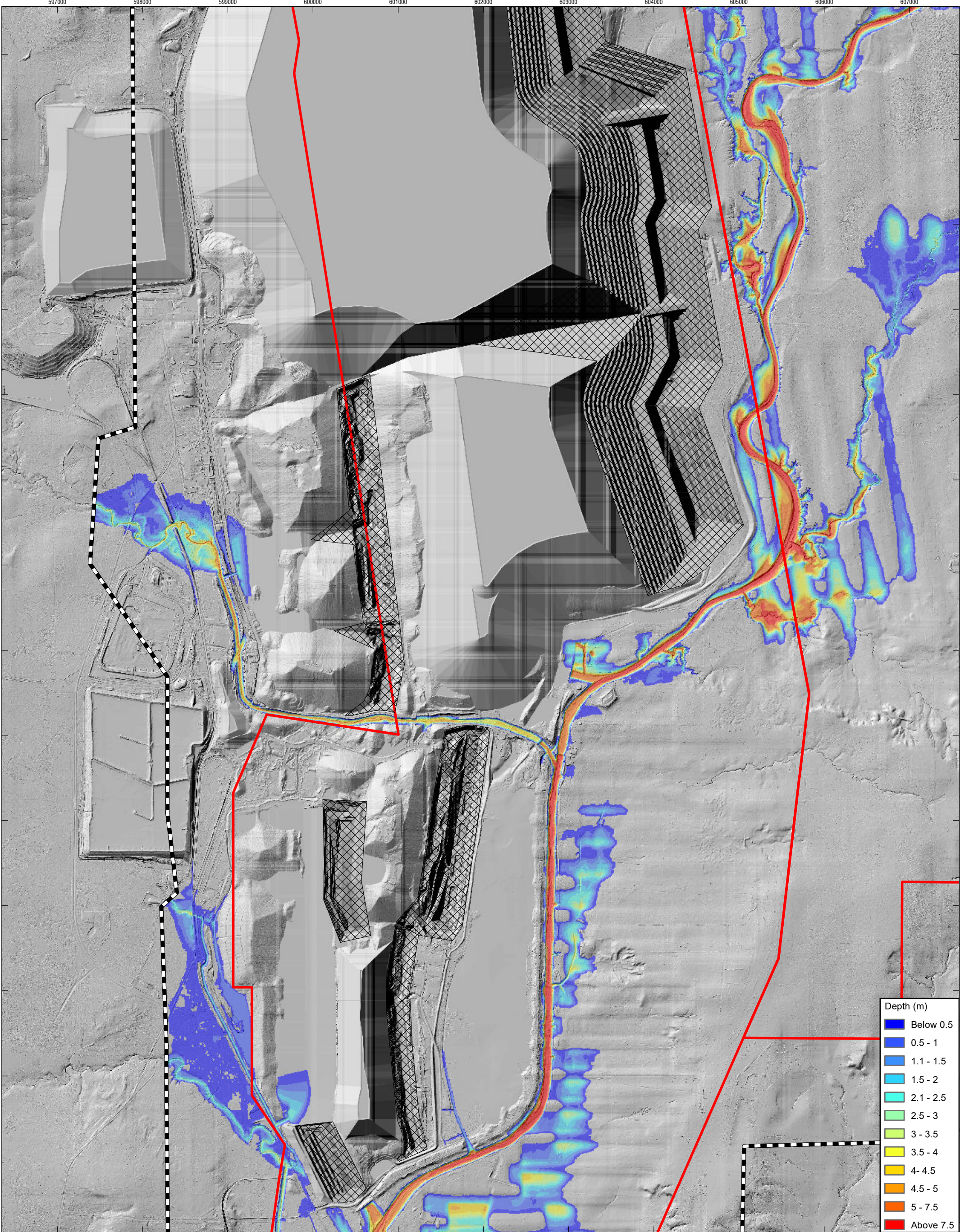
 TUFLOW Model Extent

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Depths - 39% AEP



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Coordinate System: GDA2020 MGA Zone 55

Scale: 1:40,000 at A3

Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

LEGEND

Mining Leases

Voids

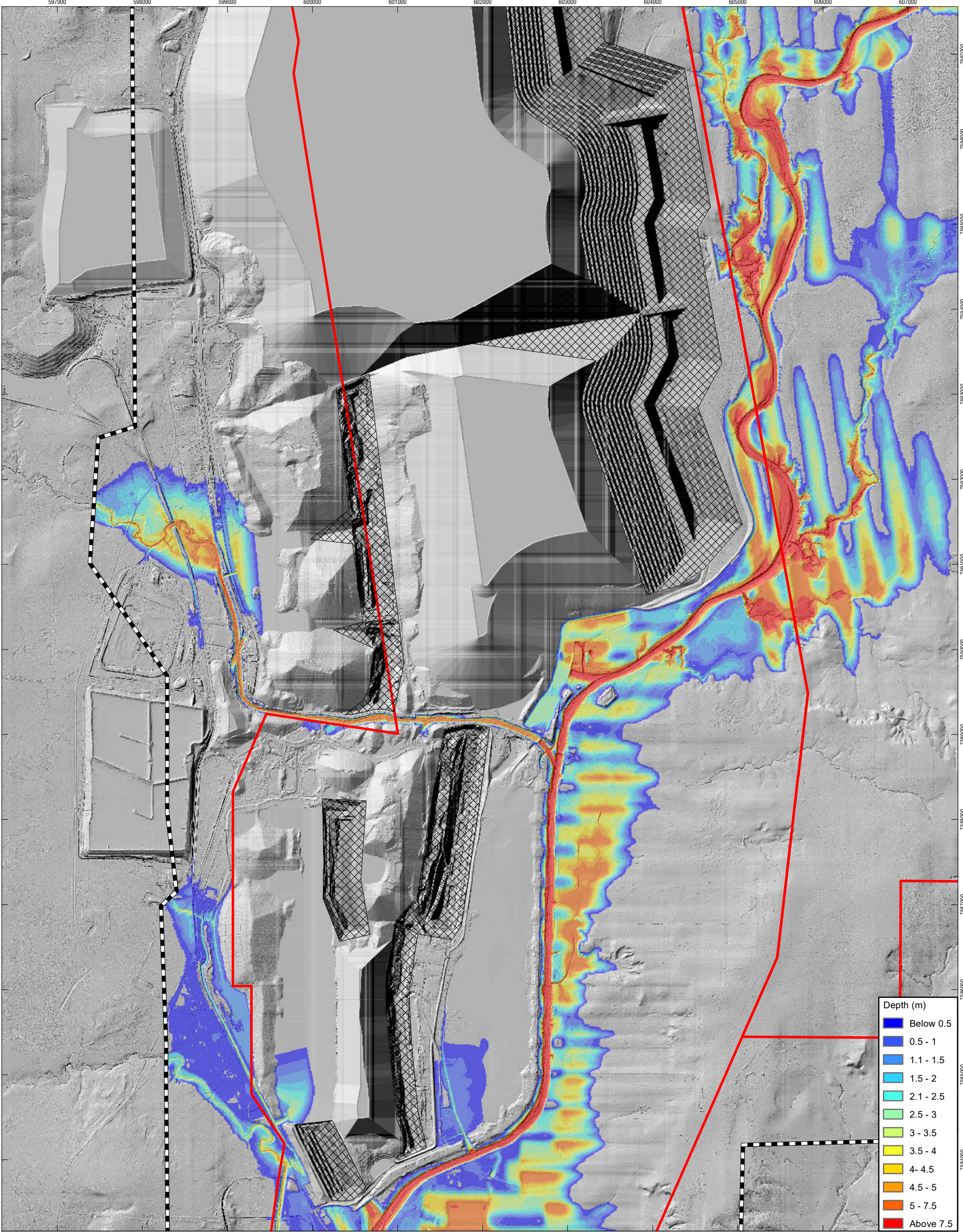
TUFLOW Model Extent

Red Hill Mine PRCP Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Depths - 2% AEP



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Coordinate System: GDA2020 MGA Zone 55

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Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

LEGEND

 Mining Leases

 Voids

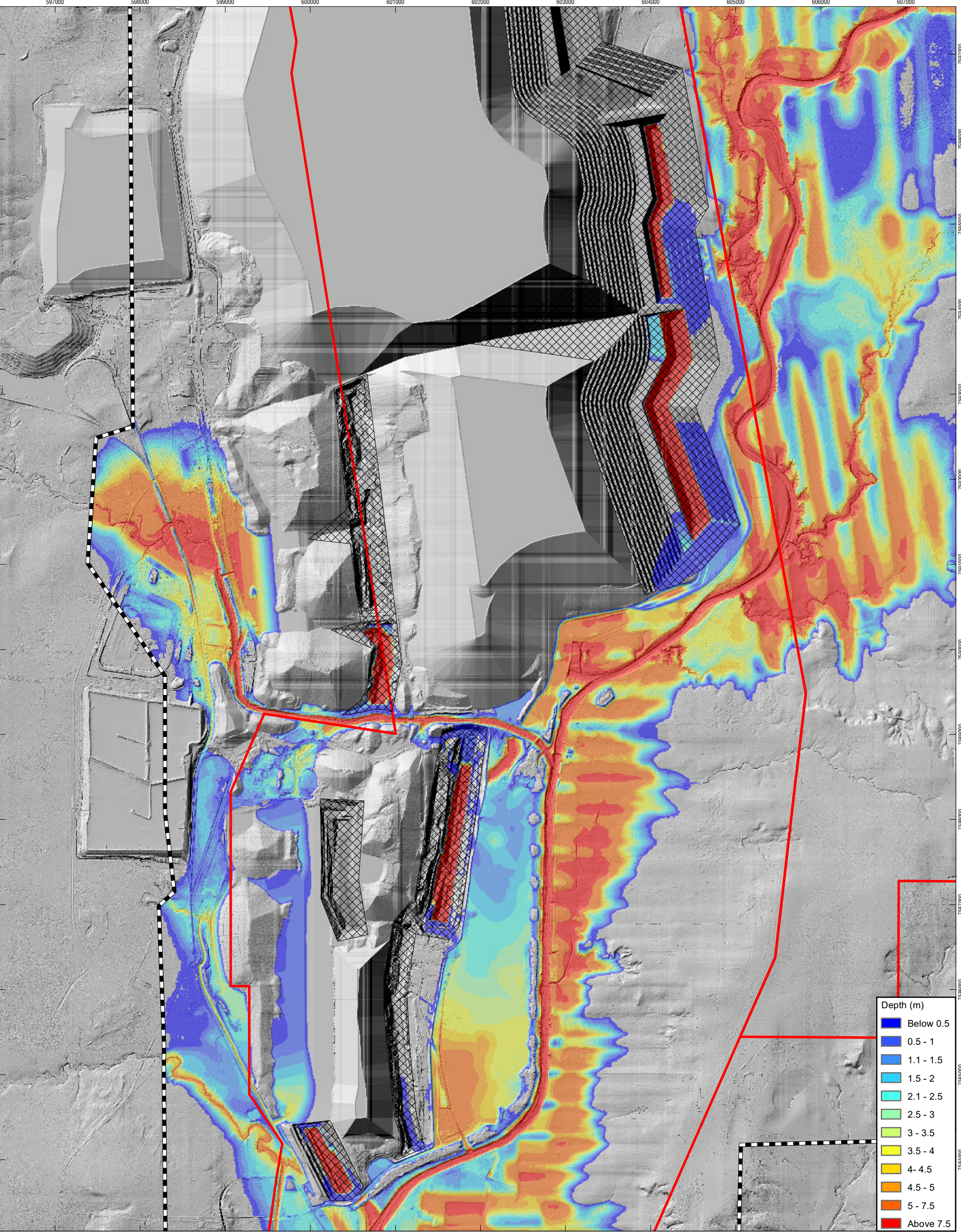
 TUFLOW Model Extent

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Depths - 0.1% AEP



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km

Coordinate System: GDA2020 MGA Zone 55

Scale: 1:40,000 at A3

Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

LEGEND

 Mining Leases

 Voids

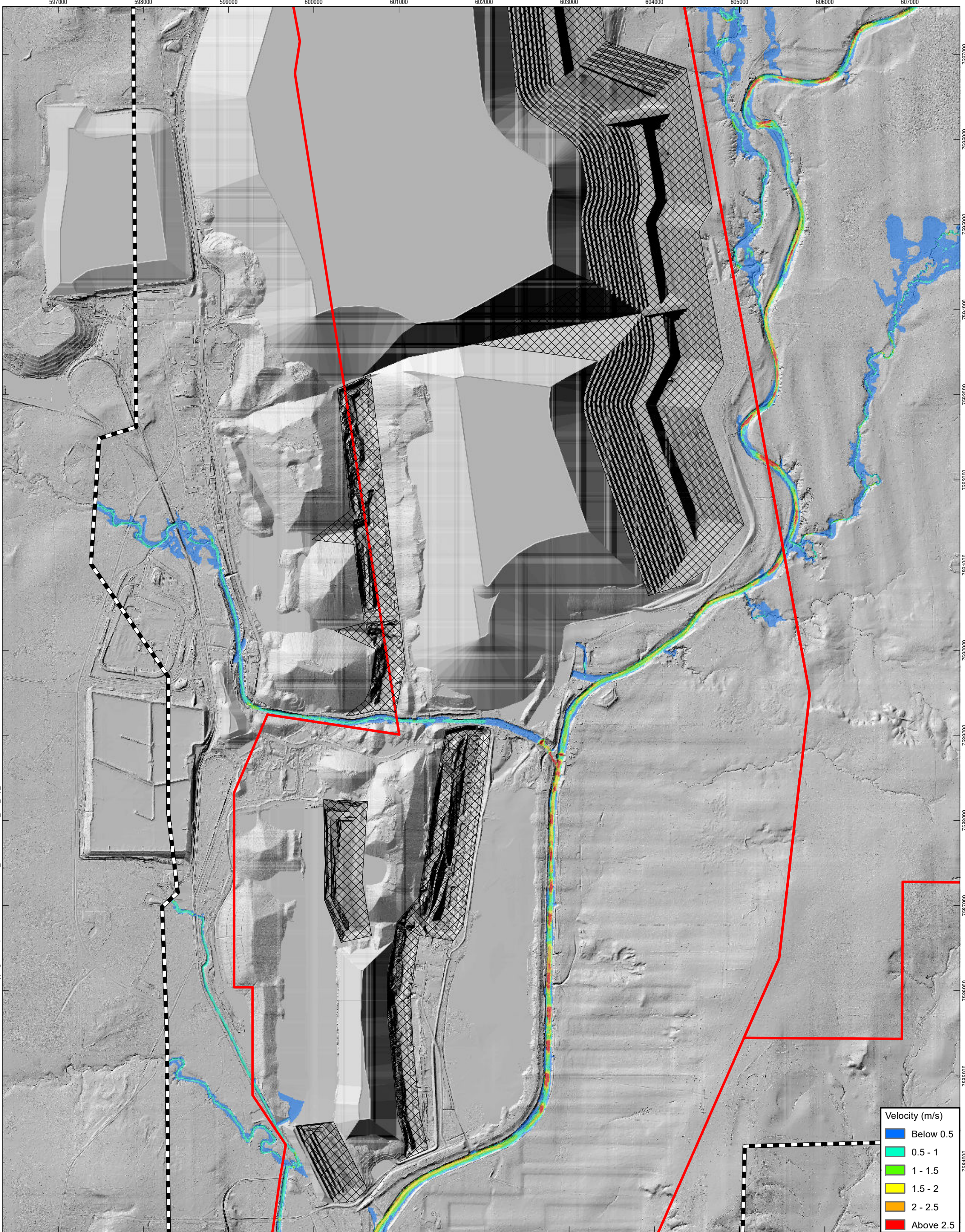
 TUFLOW Model Extent

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Depths - PMF



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km

Coordinate System: GDA2020 MGA Zone 55

Scale: 1:40,000 at A3

Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

LEGEND

 Mining Leases

 Voids

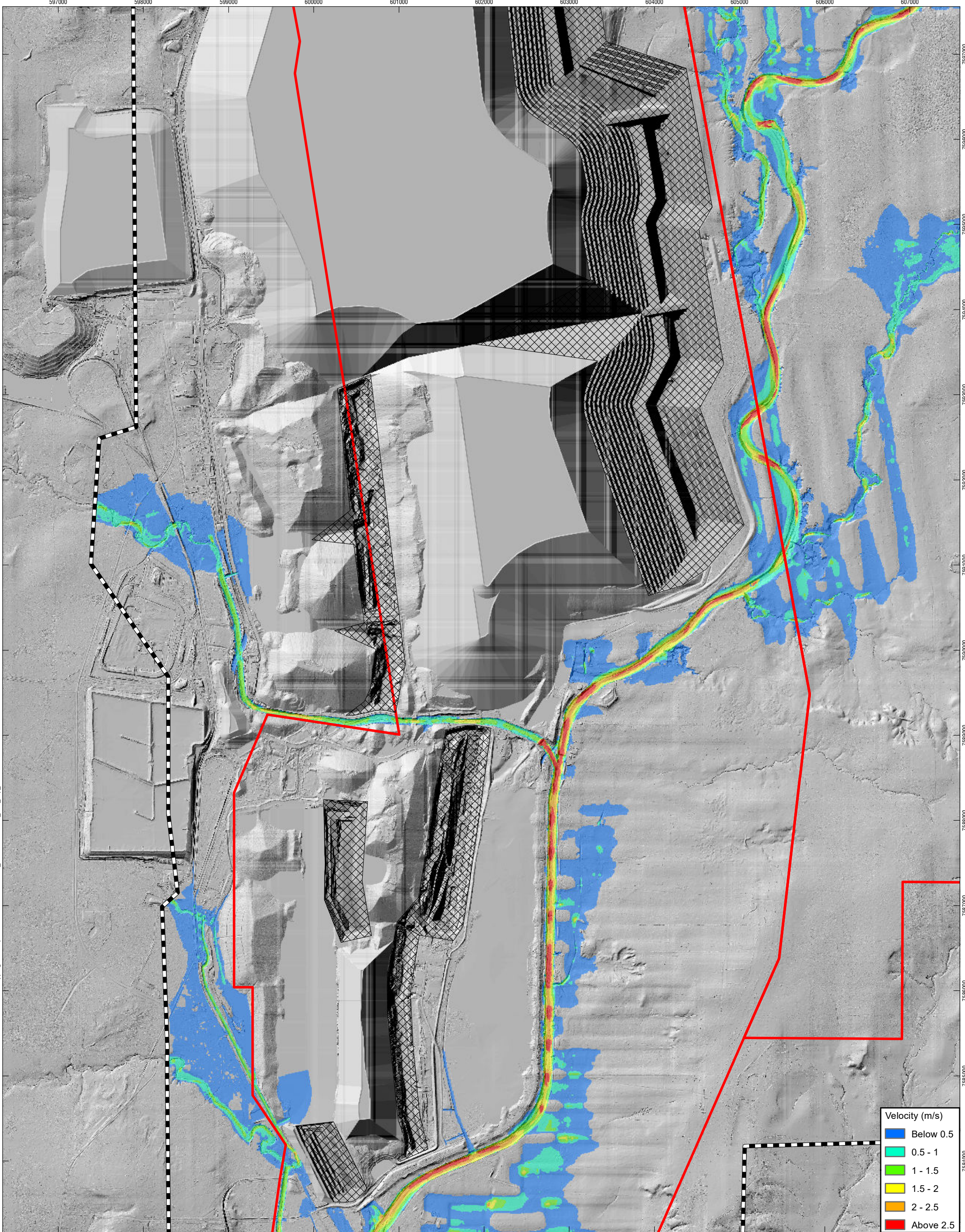
 TUFLOW Model Extent

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Velocities - 39% AEP



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0 0.325 0.65 1.3 km

Coordinate System: GDA2020 MGA Zone 55
Scale: 1:40,000 at A3
Project Number: 620.040713
Date: 23-Oct-2024
Drawn by: TS

LEGEND

- Mining Leases
- Voids
- TUFLOW Model Extent

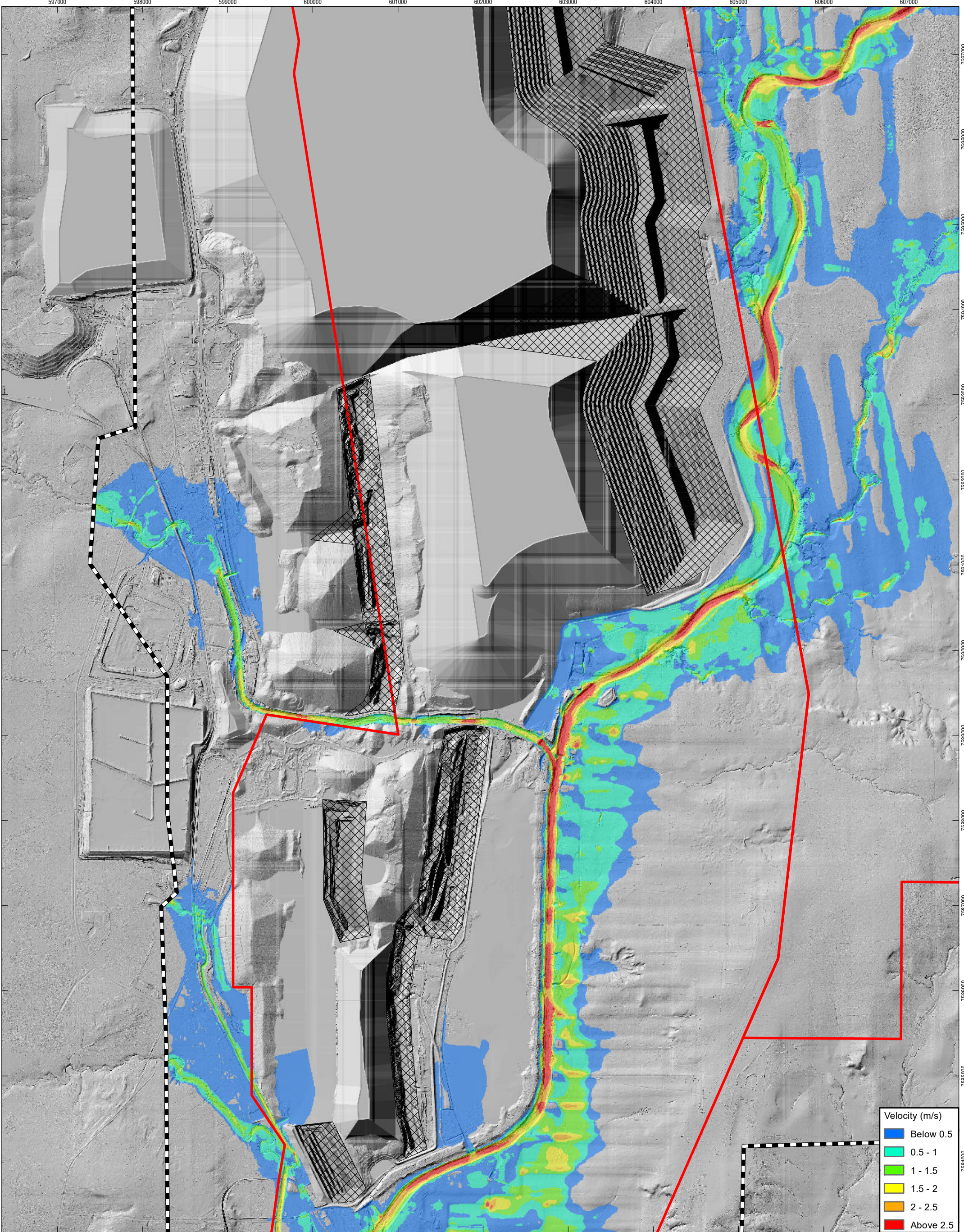
Velocity (m/s)	
	Below 0.5
	0.5 - 1
	1 - 1.5
	1.5 - 2
	2 - 2.5
	Above 2.5

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Velocities - 2% AEP



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km

Coordinate System: GDA2020 MGA Zone 55

Scale: 1:40,000 at A3

Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

LEGEND

 Mining Leases

 Voids

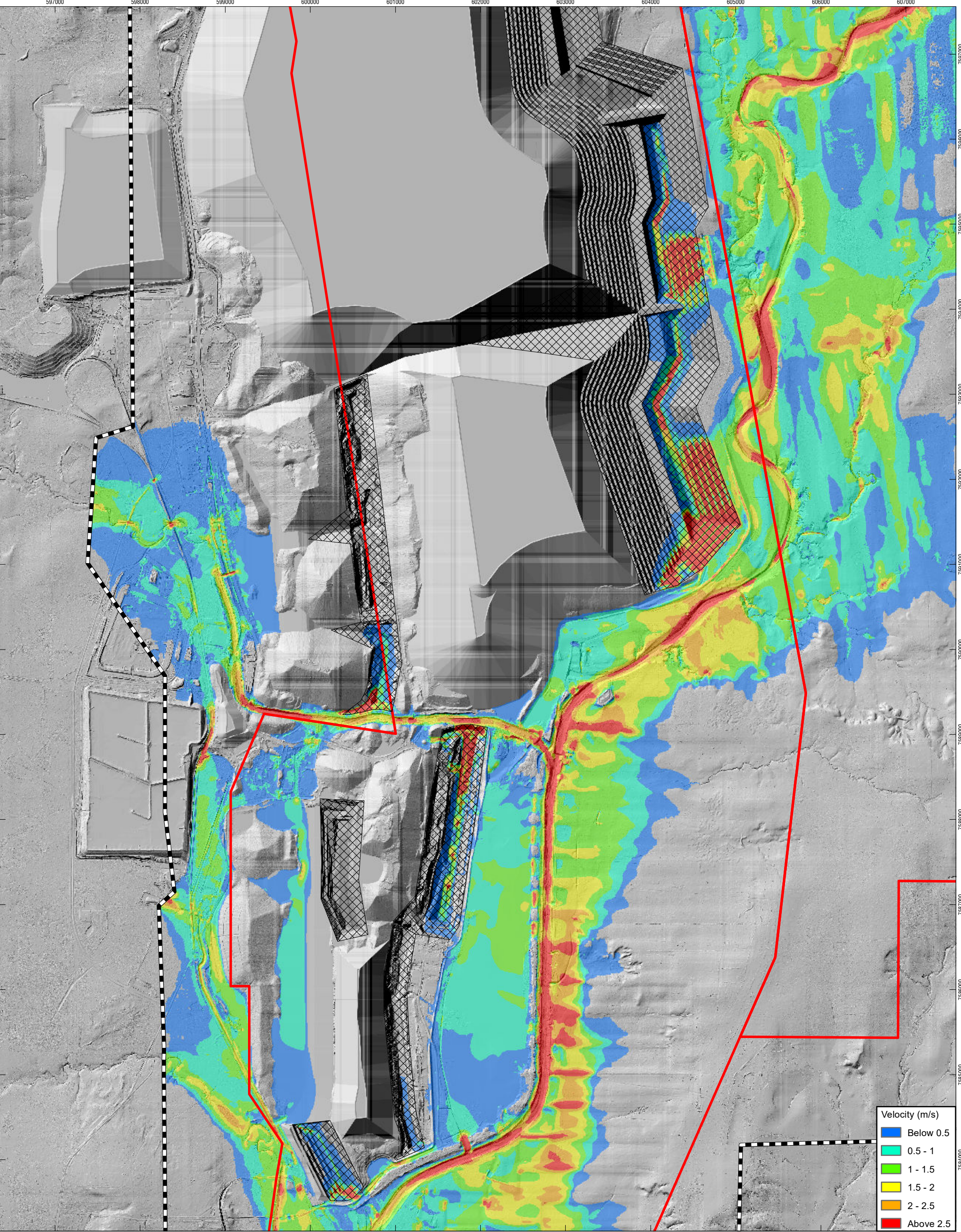
 TUFLOW Model Extent

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Velocities - 0.1% AEP



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Scale: 1:40,000 at A3

Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

LEGEND

 Mining Leases

 Voids

 TUFLOW Model Extent

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Velocities - PMF



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Scale: 1:40,000 at A3

Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

- LEGEND
-  Mining Leases

 Voids

 TUFLOW Model Extent

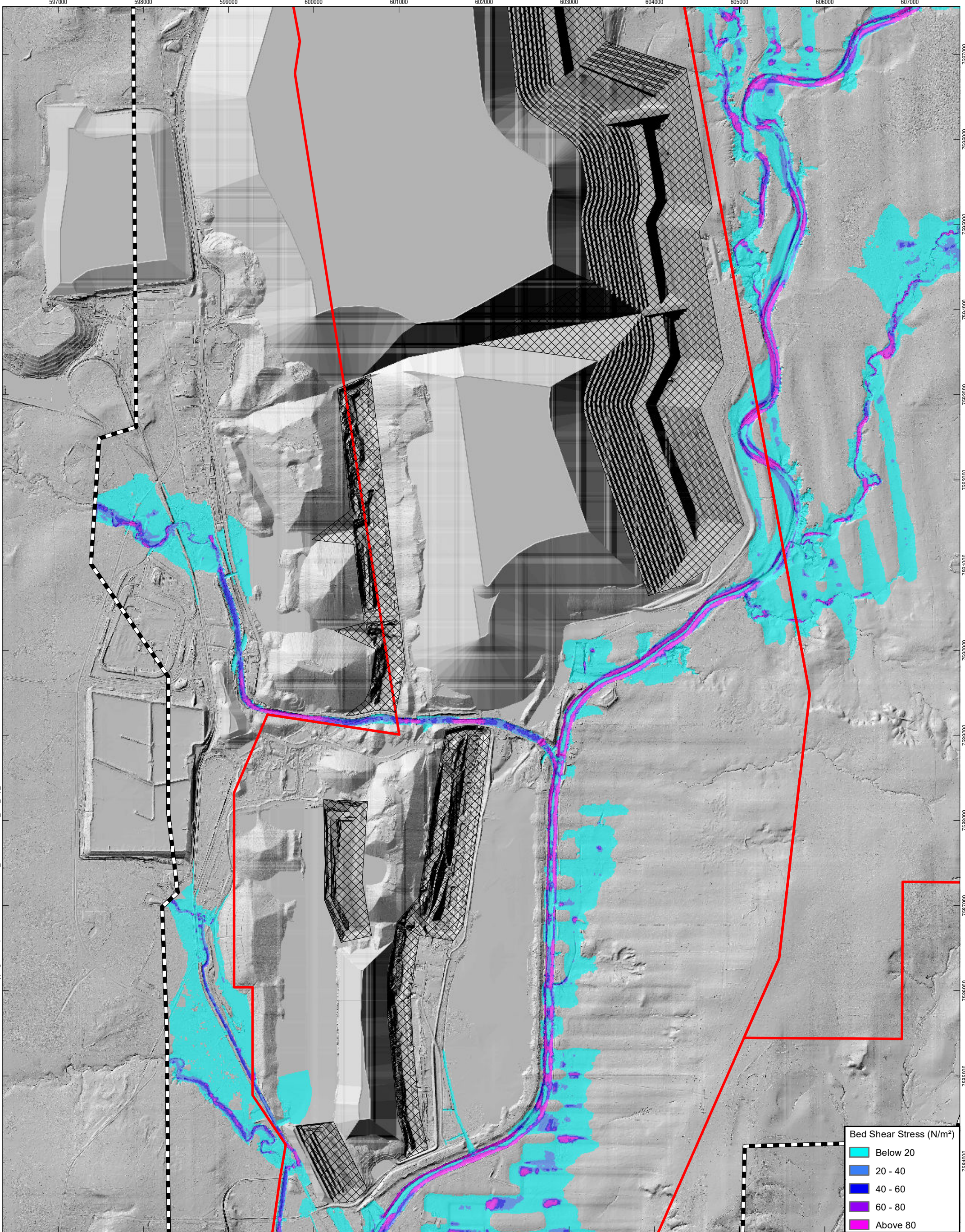
Bed Shear Stress (N/m²)	
	Below 20
	20 - 40
	40 - 60
	60 - 80
	Above 80

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Bed Shear Stress - 39% AEP



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0 0.325 0.65 1.3 km

Coordinate System: GDA2020 MGA Zone 55
Scale: 1:40,000 at A3
Project Number: 620.040713
Date: 23-Oct-2024
Drawn by: TS

LEGEND

- Mining Leases
- Voids
- TUFLOW Model Extent

Bed Shear Stress (N/m²)

- Below 20
- 20 - 40
- 40 - 60
- 60 - 80
- Above 80

Red Hill Mine PRCP Rehabilitation Flood Assessment

Isaac River PRCP Conditions Peak Bed Shear Stress - 2% AEP



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Coordinate System: GDA2020 MGA Zone 55

Scale: 1:40,000 at A3

Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

- LEGEND
-  Mining Leases

 Voids

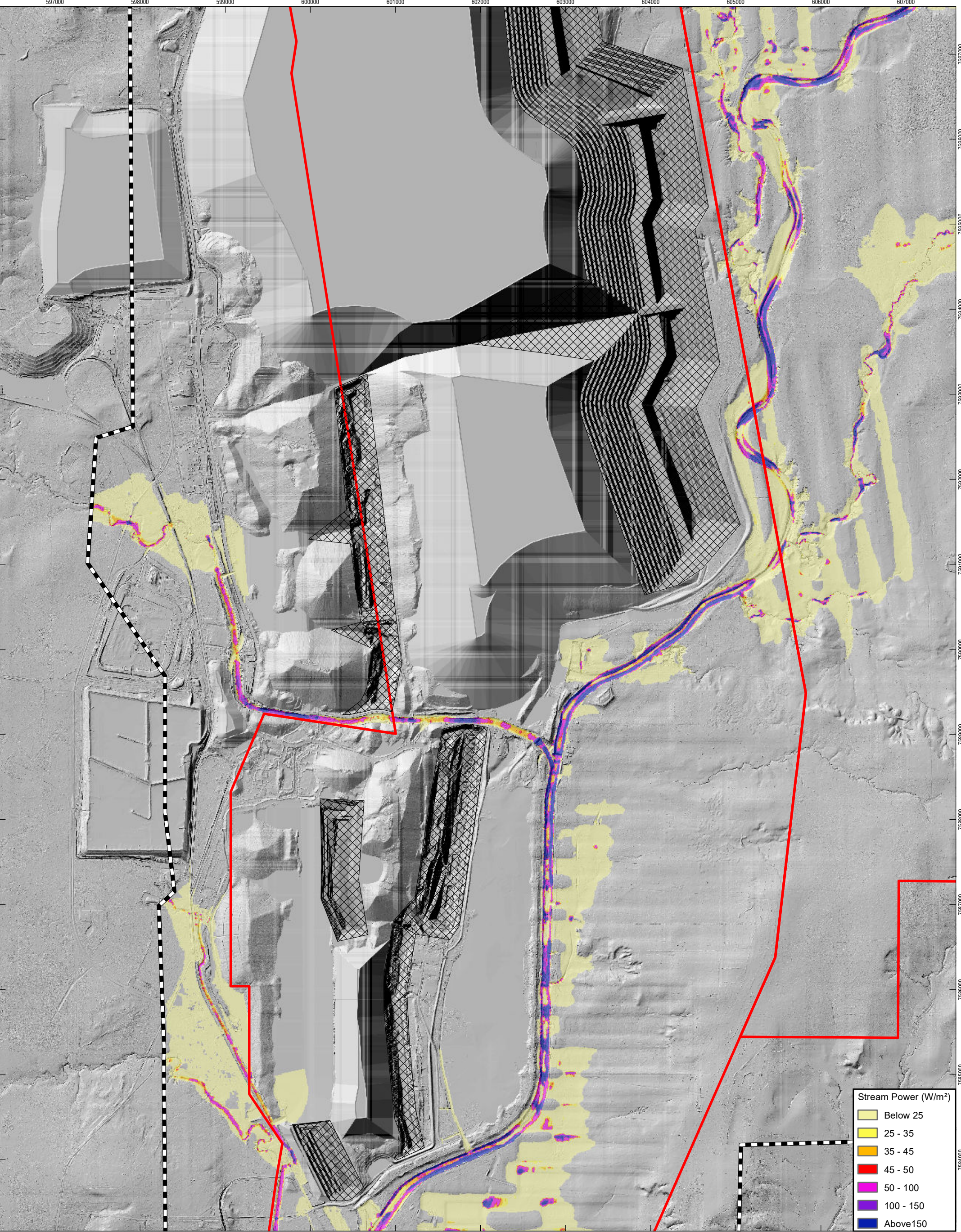
 TUFLOW Model Extent

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Stream Power - 39% AEP



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Project Number: 620.040713

Date: 23-Oct-2024

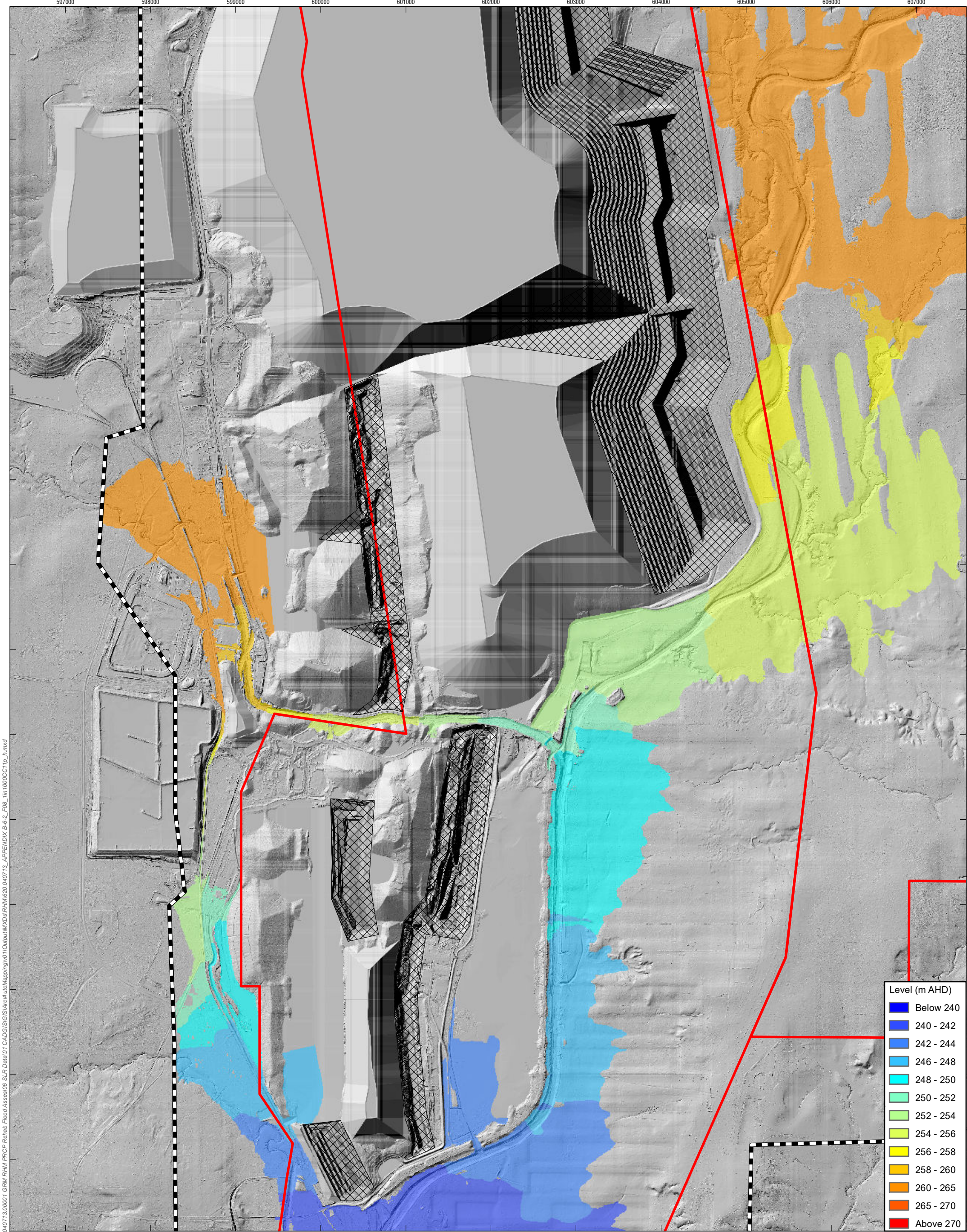
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- LEGEND
-  Mining Leases
 -  Voids
 -  TUFLOW Model Extent

**Red Hill Mine PRCP
Rehabilitation Flood Assessment**

**Isaac River PRCP Conditions
Peak Stream Power - 2% AEP**





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0

0.325

0.65

1.3

km

Coordinate System: GDA2020 MGA Zone 55

Scale: 1:40,000 at A3

Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

LEGEND

 Mining Leases

 Voids

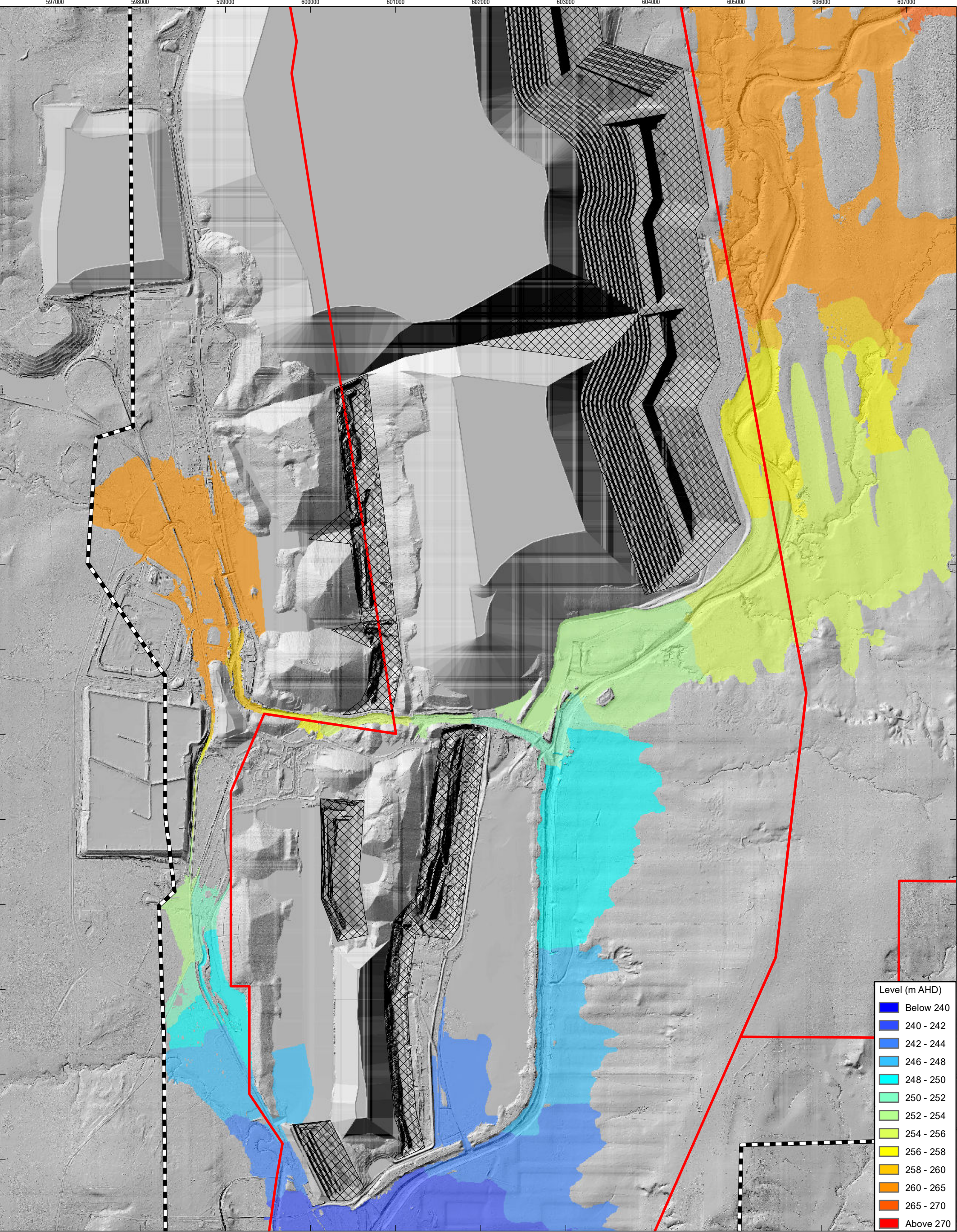
 TUFLOW Model Extent

**Red Hill Mine PRCP
Rehabilitation Flood Assessment**

**Isaac River PRCP Conditions
Peak Levels - 0.1% AEP + 11% rainfall intensity**



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Date: 23-Oct-2024

Drawn by: TS

- LEGEND
-  Mining Leases

 Voids

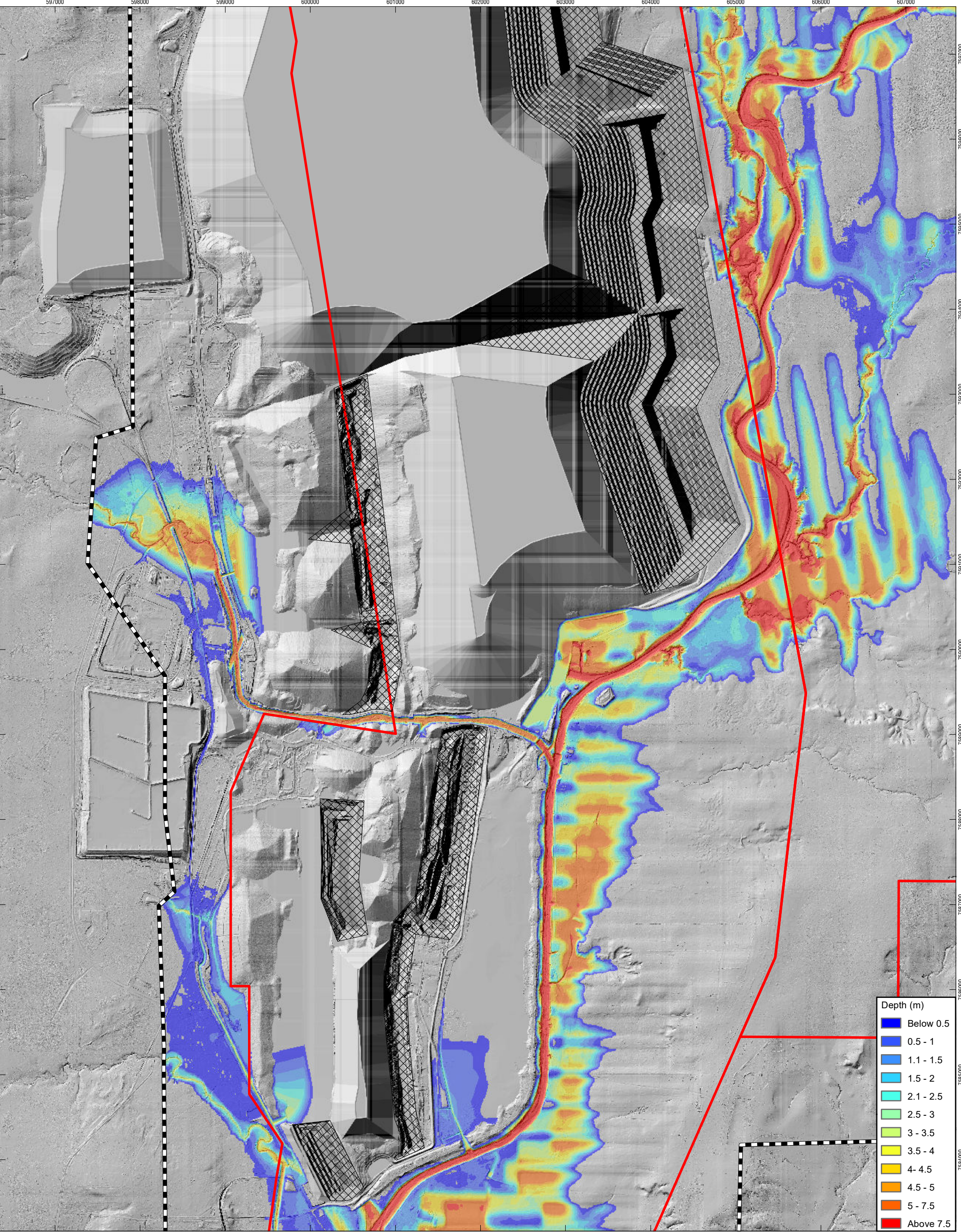
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Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Levels - 0.1% AEP + 20% rainfall intensity



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km

Coordinate System: GDA2020 MGA Zone 55

Scale: 1:40,000 at A3

Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

- LEGEND
-  Mining Leases

 Voids

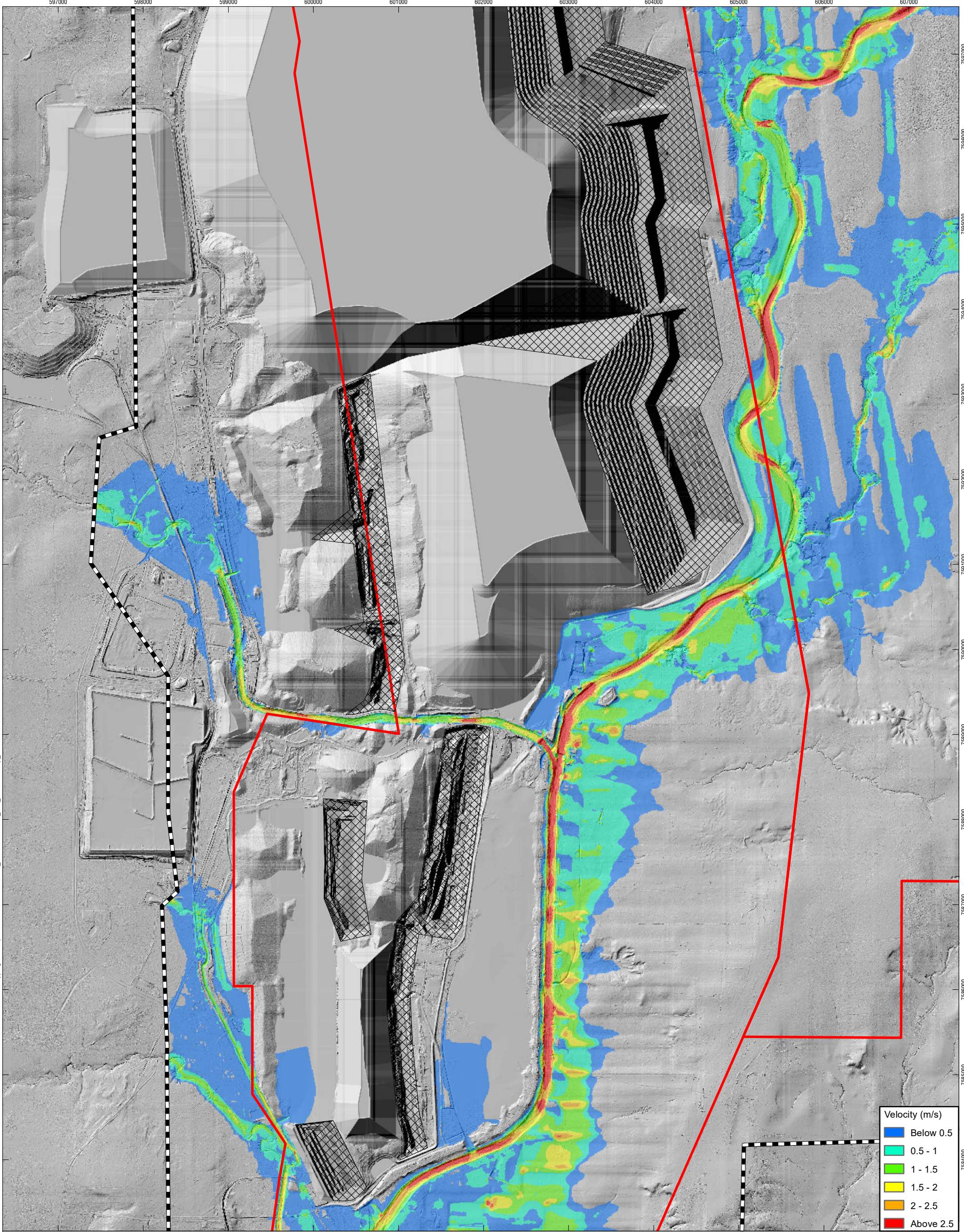
 TUFLOW Model Extent

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Depths - 0.1% AEP + 11% rainfall intensity



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Coordinate System: GDA2020 MGA Zone 55

Scale: 1:40,000 at A3

Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

LEGEND

 Mining Leases

 Voids

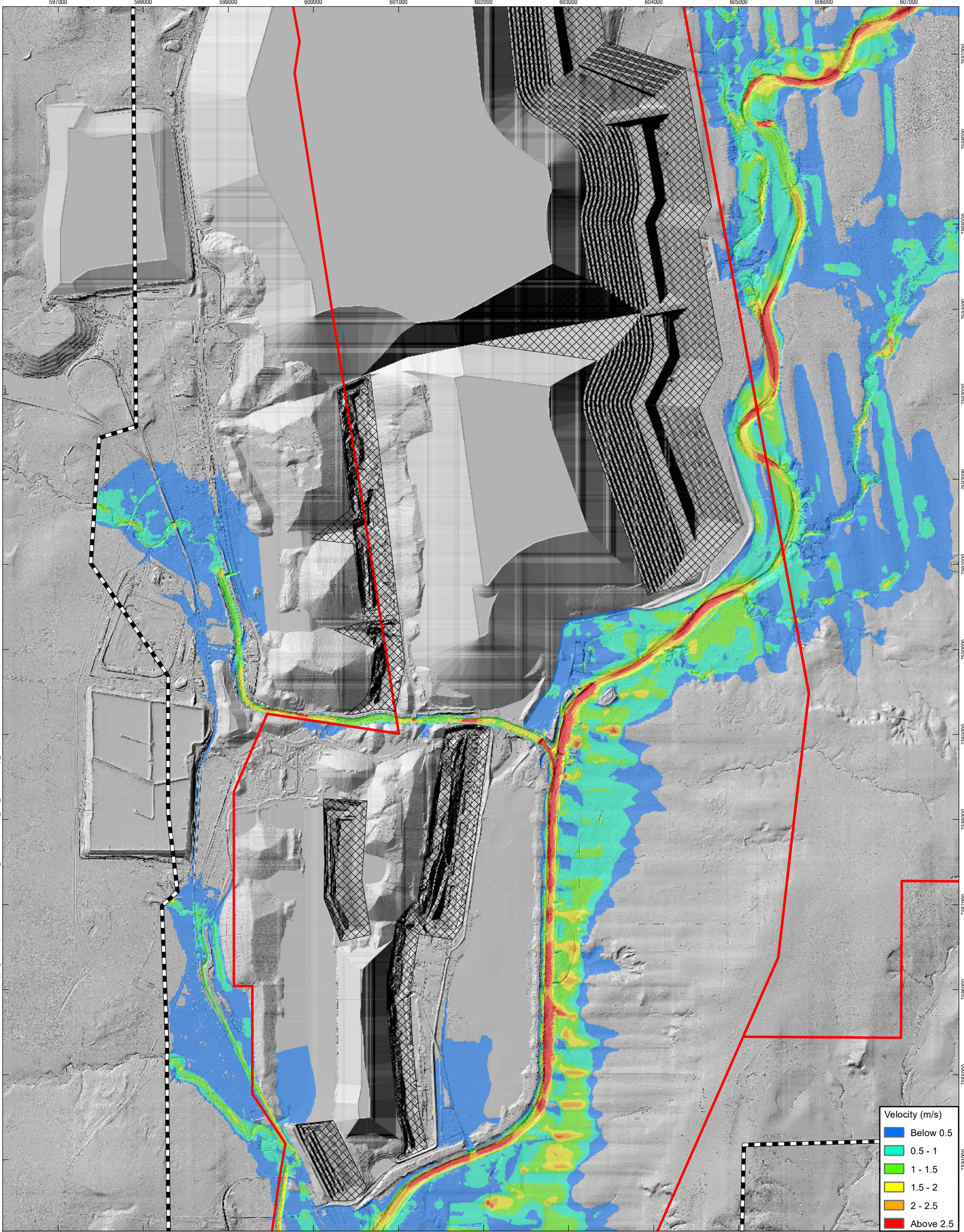
 TUFLOW Model Extent

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Velocities - 0.1% AEP + 6% rainfall intensity



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0 0.325 0.65 1.3 km

Coordinate System: GDA2020 MGA Zone 55
Scale: 1:40,000 at A3
Project Number: 620.040713
Date: 23-Oct-2024
Drawn by: TS

LEGEND

- Mining Leases
- Voids
- TUFLOW Model Extent

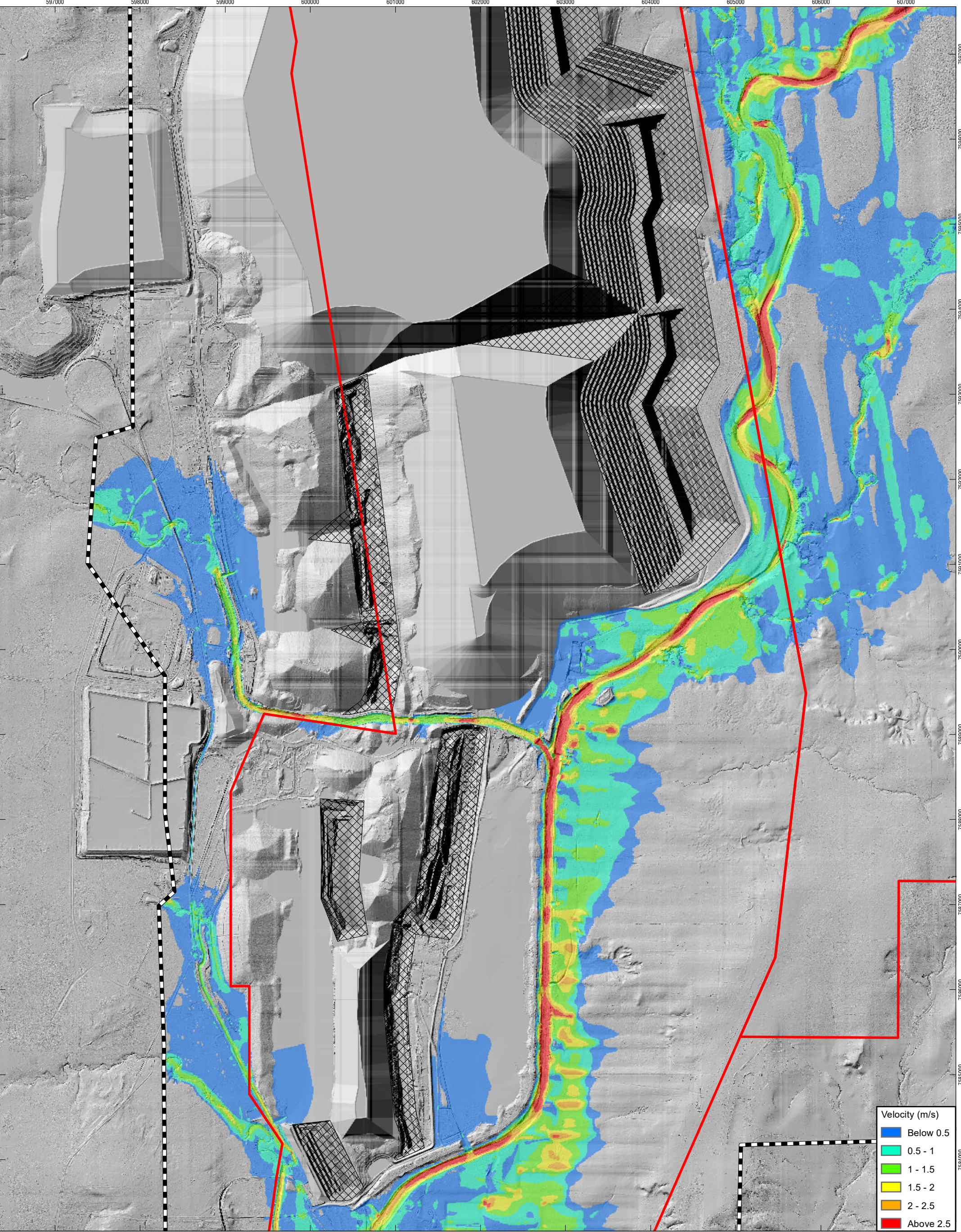
Velocity (m/s)	
	Below 0.5
	0.5 - 1
	1 - 1.5
	1.5 - 2
	2 - 2.5
	Above 2.5

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Velocities - 0.1% AEP + 11% rainfall intensity



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km

Coordinate System: GDA2020 MGA Zone 55

Scale: 1:40,000 at A3

Project Number: 620.040713

Date: 23-Oct-2024

Drawn by: TS

- LEGEND
-  Mining Leases

 Voids

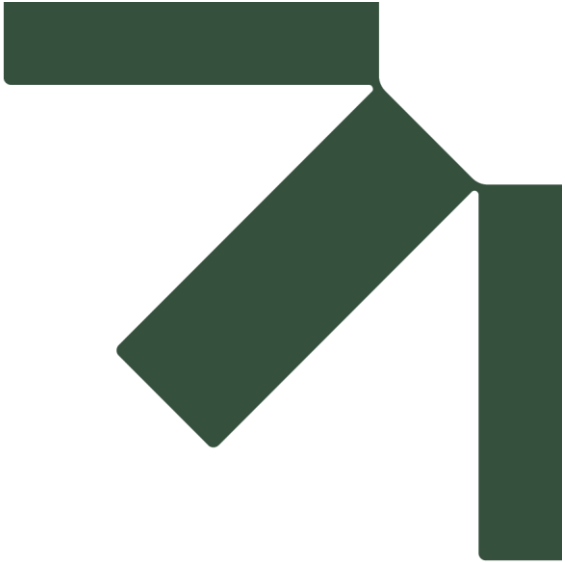
 TUFLOW Model Extent

Velocity (m/s)	
	Below 0.5
	0.5 - 1
	1 - 1.5
	1.5 - 2
	2 - 2.5
	Above 2.5

Red Hill Mine PRCP
Rehabilitation Flood Assessment

Isaac River PRCP Conditions
Peak Velocities - 0.1% AEP + 20% rainfall intensity





Appendix C Pluvial Model Results

Red Hill Mine

Progressive Rehabilitation and Closure Plan Rehabilitation Flood Assessment

BHP Mitsubishi Alliance

SLR Project No.: 620.040713.0000

27 November 2024

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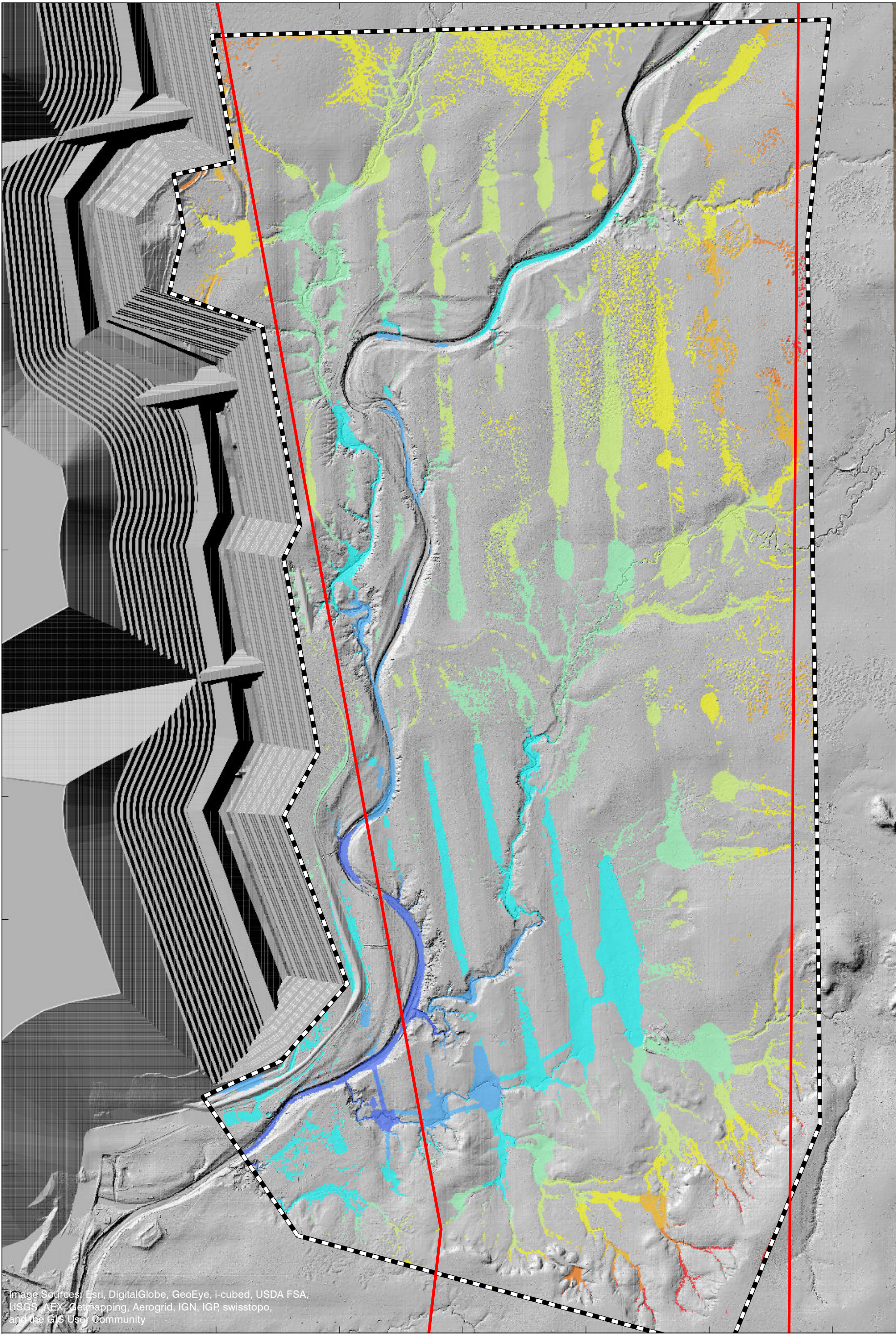


Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

 0 0.225 0.45 0.9 km
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Scale: 1:30,000 at A3
Project Number: 620.040713
Date: 03-Oct-2024
Drawn by: TS

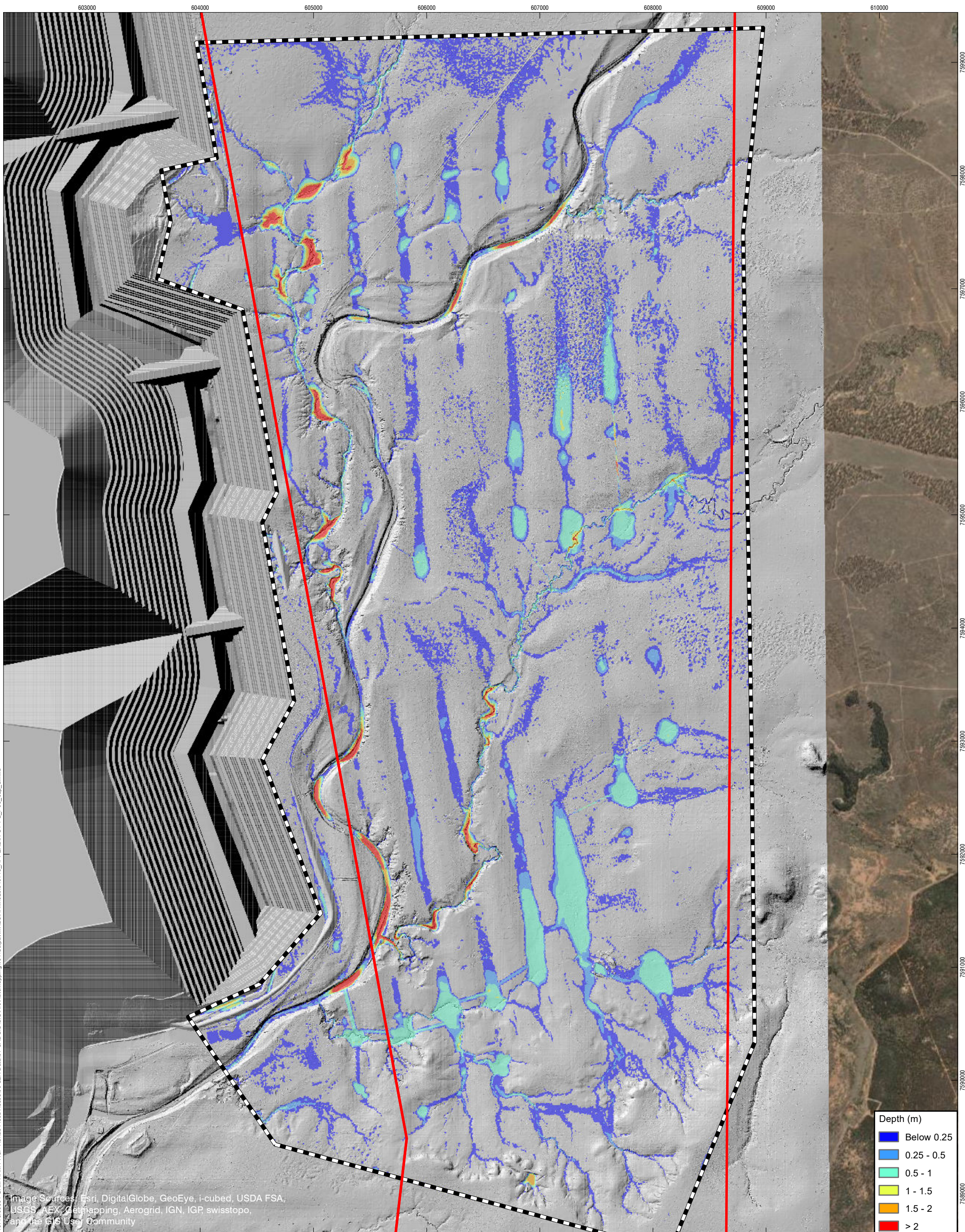
LEGEND
 Mining Leases
 TUFLOW Model Extent

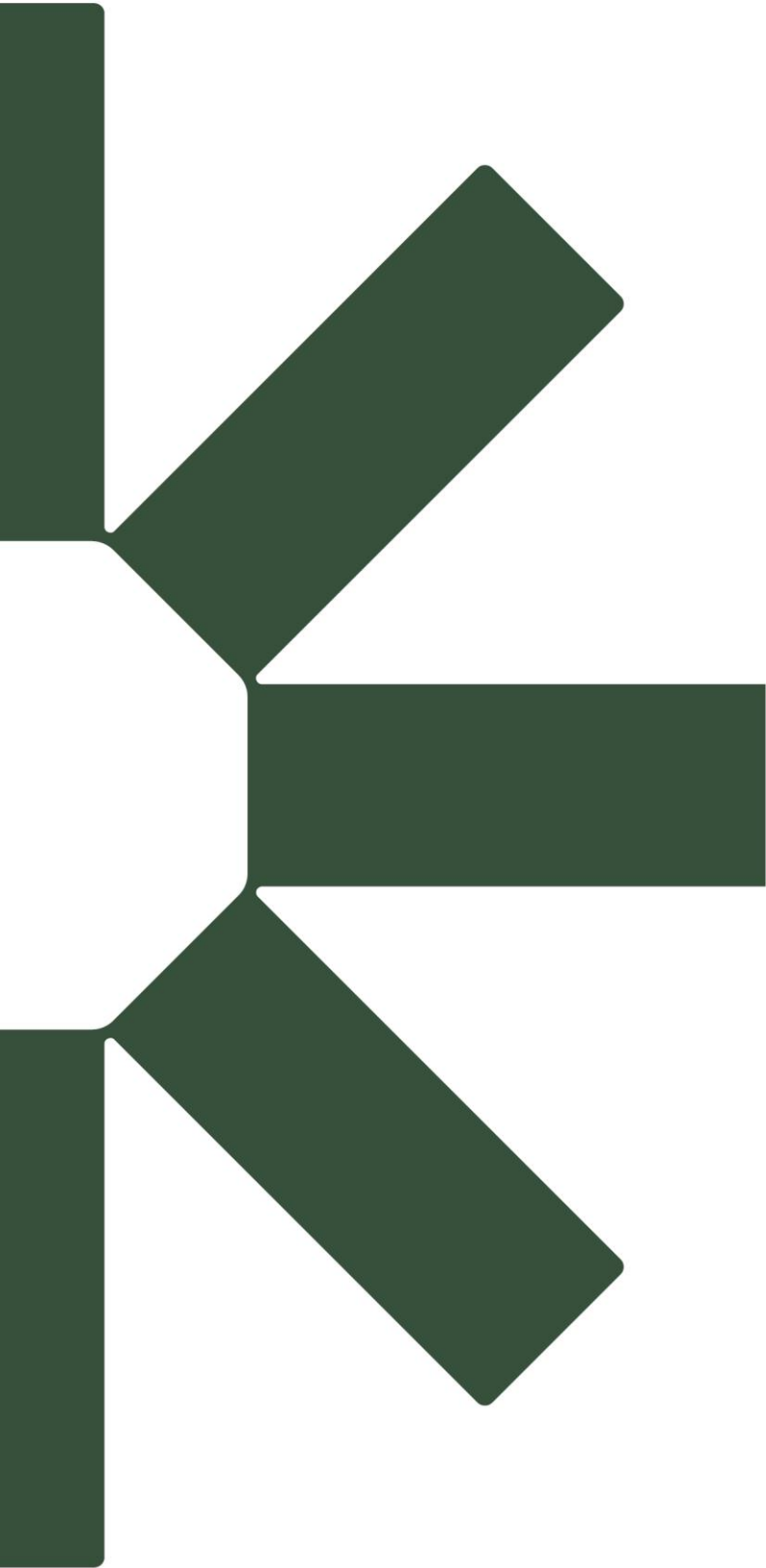
Level (m AHD)	
	Below 240
	240 - 245
	245 - 250
	250 - 255
	255 - 260
	260 - 265
	265 - 270
	270 - 275
	275 - 280
	> 280

**Red Hill Mine PRCP
Rehabilitation Flood Assessment**

**PRCP Conditions Pluvial Modelling
Peak Levels - 2% AEP**







Making Sustainability Happen

BMA TECHNICAL SERVICES

Geotechnical considerations for closure of Red Hill Mine.

REPORT: BMA-14 REDHILL

Date: 3 December 2024

Prepared by:

Dr Ross Seedsman RPEQ

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1 INTRODUCTION

Red Hill Mine will extract the Goonyella Middle Seam (GMS) immediately to the north of Broadmeadow Mine (Figure 1)¹. It is presumed that access to the mine will be highwall entry from Ramp 5 of the Goonyella Riverside open cut (Goonyella residual void). The proposed panels are typically 2-3 km in length and 320 m wide with chain pillars with widths that have ranged between 35 m and 45 m (Figure 2). The extracted thickness is to be 8 m (Figure 3) and top coal caving system will be adopted to extract this thickness.

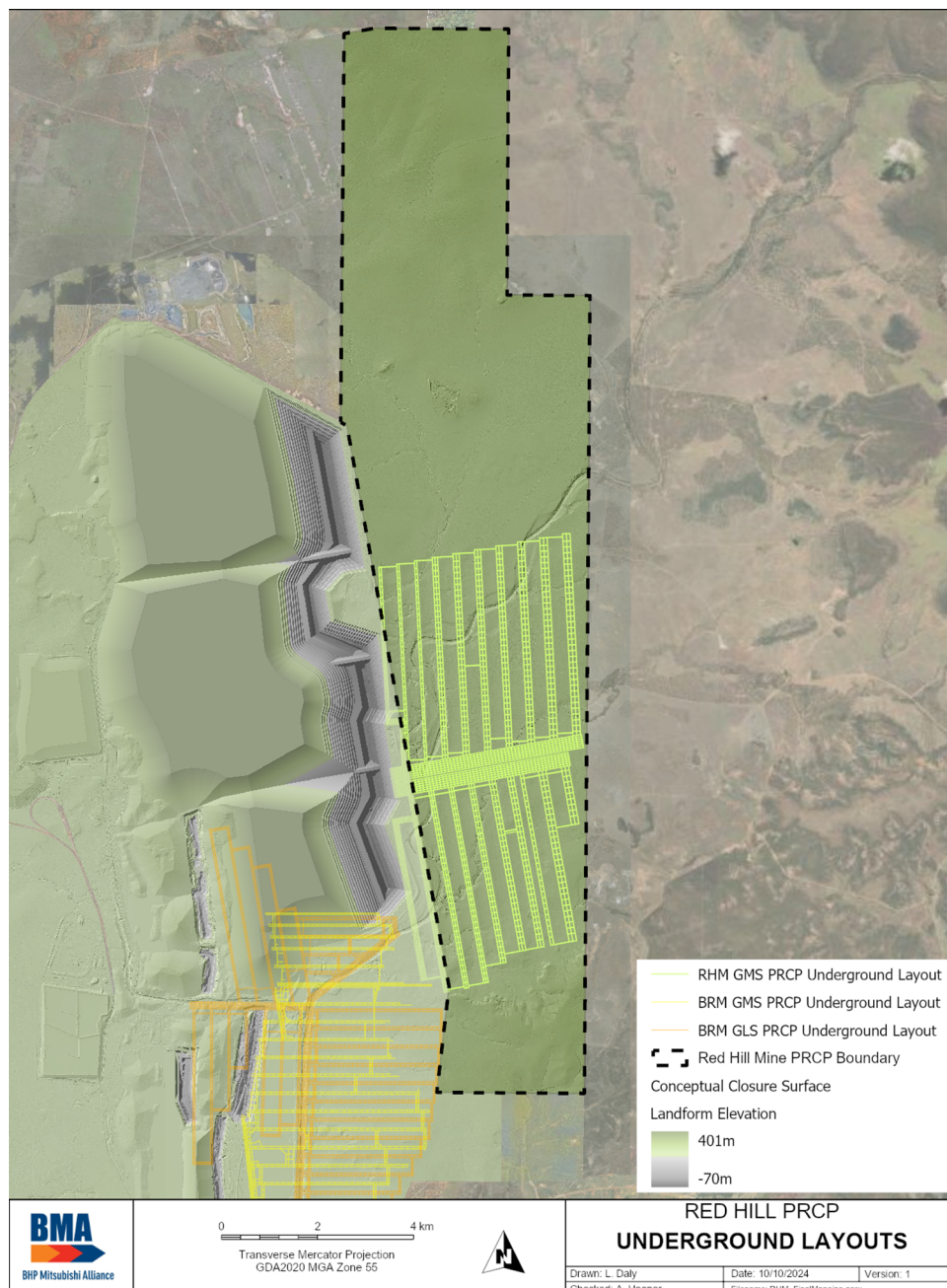


Figure 1 Location of Red Hill relative to Broadmeadow Mine

¹ The principal source for information in this report is the Red Hill Project EIS – dated 27/11/2013.

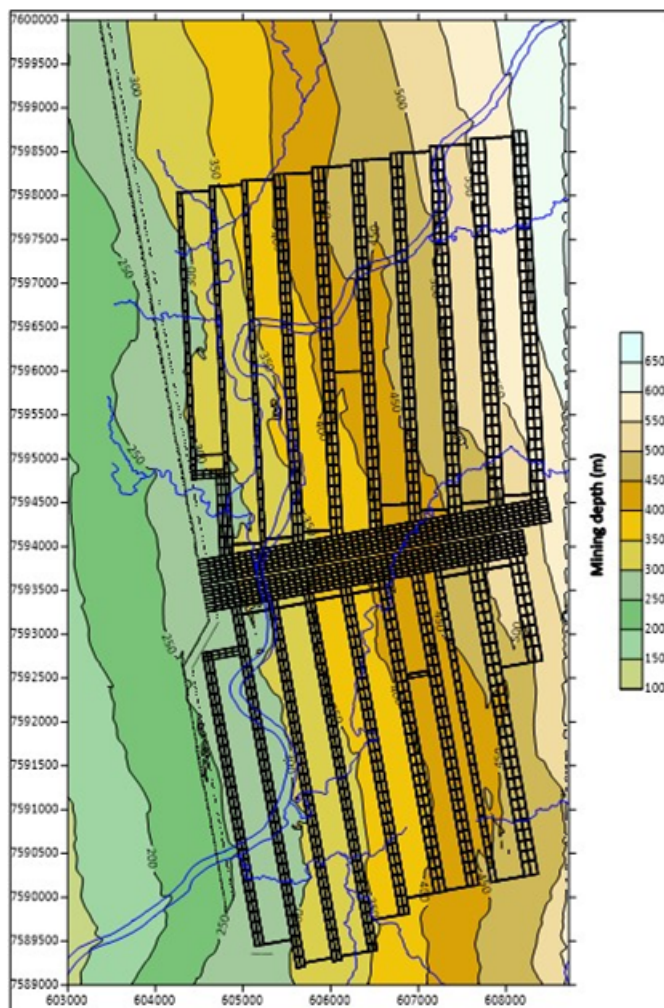


Figure 2 Depth of cover

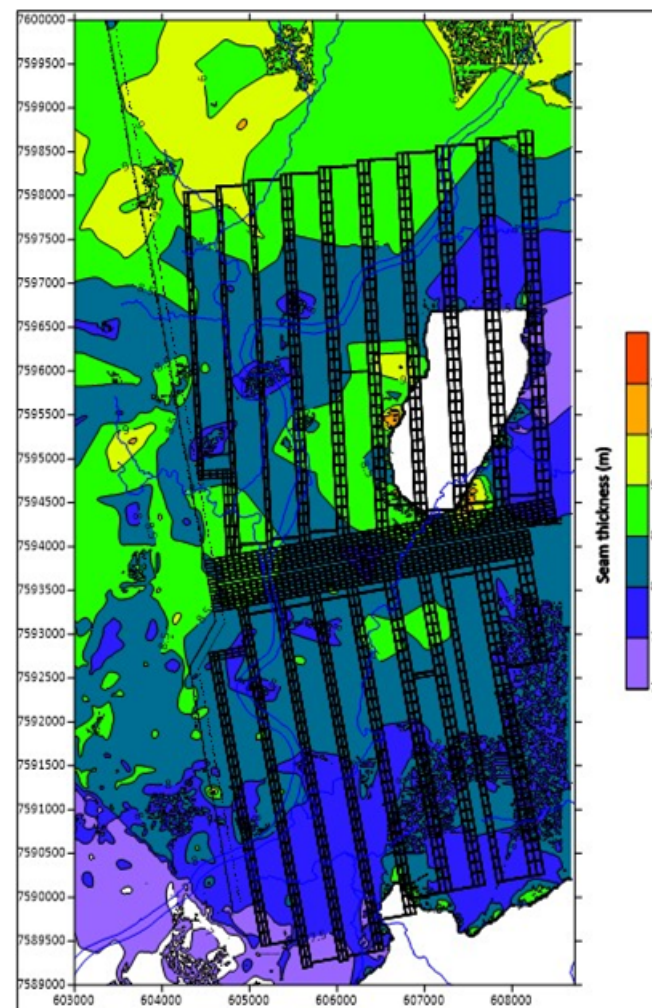


Figure 3 GMS thickness

2 ENGINEERING GEOLOGY

2.1 Regional geology

Locally, the Permo-Triassic sequence comprises, in ascending stratigraphic order: the upper part of the late Permian German Creek Formation of the marine influenced Back Creek Group; and the Moranbah Coal Measures, Fort Cooper Coal Measures and Rangal Coal Measures of the late Permian Blackwater Group (Figure 4). All units of the Permo-Triassic sequence dip from west to east at between three and five degrees in the vicinity of the Red Hill mining area. The target coal seams for mining are contained within the Moranbah Coal Measures.

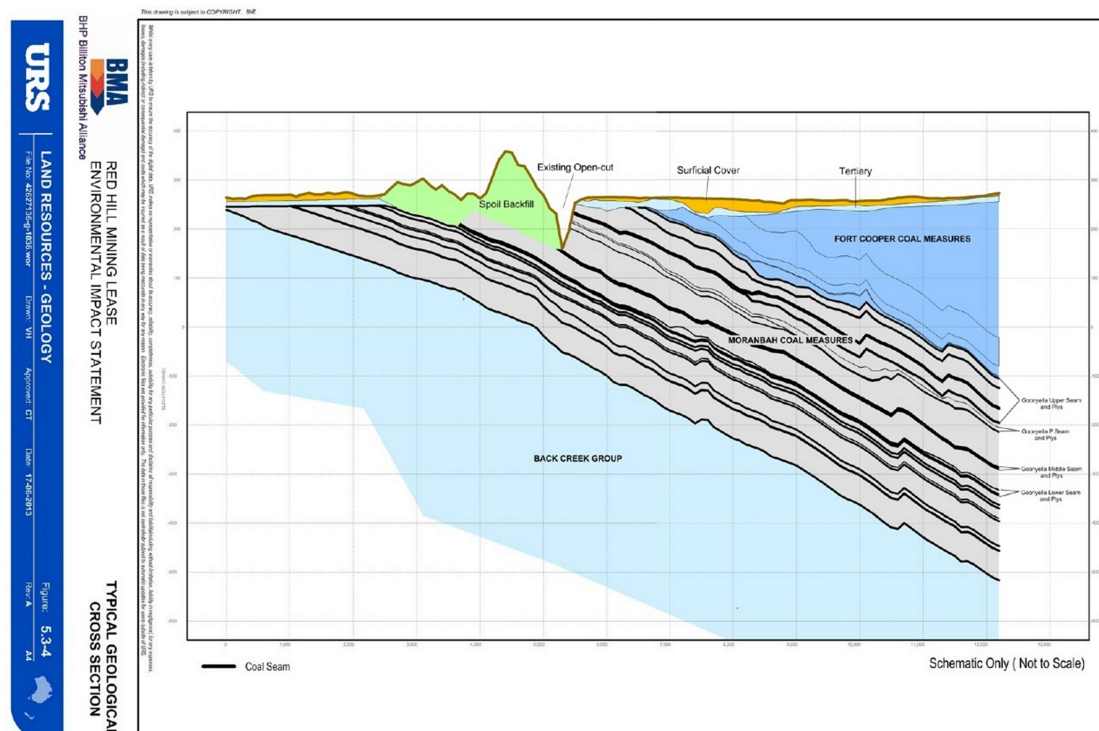


Figure 4 Stratigraphic cross section

The Moranbah Coal Measures, conformably overlie the German Creek Formation and are overlain by the Fort Cooper Coal Measures. The Moranbah Coal Measures were deposited in a predominantly fluvial flood plain environment.

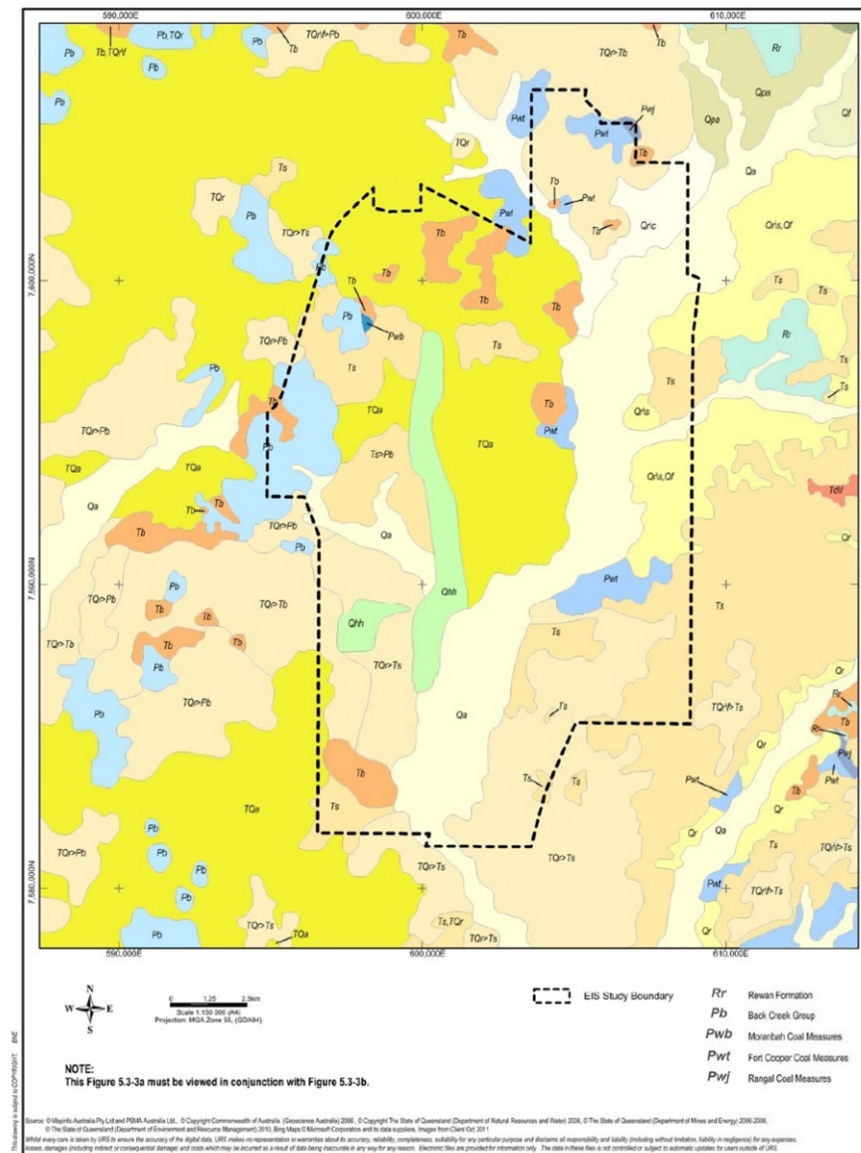
The Late Permian Fort Cooper Coal Measures conformably overlie the Moranbah Coal Measures and are present across the eastern portion of the area (Figure 4). The Fort Cooper Coal Measures consist of grey lithic sandstone, siltstone, mudstone, coal, and tuffaceous sediments. A number of coal seams are contained within the Fort Cooper Coal Measures. The seams are typically thick, highly stone-banded and contain high inherent ash coal.

2.2 Surface deposits and Tertiary geology

The Red Hill area is covered by a 0.5 to 30 m thick layer of poorly consolidated Tertiary and Quaternary sediments unconformably overlying an irregular erosion surface of Permian strata. These sediments consist of lenses of river channel gravels and sands separated by sandy silts, sandy clays and clays. The Tertiary silts and clays are densely compacted and hard. Lag deposits of sand and gravel are found directly on the Tertiary/Permian unconformity and can also be present related to recent Quaternary deposition from the Isaac River.

The following geomorphological land zones of Cainozoic age (Figure 5) have been identified:

- Quaternary Alluvium (Qa); River and Floodplain Deposits; clay, silt, sand, and gravel.
- Tertiary-Quaternary Older Alluvial Deposits (TQa); somewhat dissected high-level alluvial deposits in re-entrant valley floors and footslopes; clay, silt, sand, and gravel.
- Tertiary-Quaternary Residual Soils and Colluvium (TQr); siliceous and ferruginous gravelly residual soils and colluvium; locally occurring as (TQr\Qf) mainly siliceous gravelly alluvial fan deposits (bajadas) or (TQr\fb) highly ferruginous (lateritic) residual soils and/or colluvium.
- Tertiary Basalt Flows and Plugs (Tb); basalt.
- Tertiary Sutor Formation (Ts), fluvial and lacustrine sediments; quartz sandstone, clayey sandstone, mudstone, conglomerate and minor interbedded basalt.



BMA
BHP Billiton Mitsubishi Alliance

RED HILL MINING LEASE
ENVIRONMENTAL IMPACT STATEMENT

SURFACE GEOLOGY

URS

LAND RESOURCES - GEOLOGY

Figure: 5.3-3a

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Approved: CT

Date: 17-06-2013

Rev: A

A4

Figure 5 Surface geology

2.3 Coal measures

The lithology of the Moranbah Coal Measures is generally characterised by interbedded fine-grained lithic sandstone, siltstone, mudstone, claystone, and coal, which is uniform across the entire EIS study area. The Moranbah Coal Measures show regular grading of lithological sequences from sandstone to siltstone and mudstone to coal, then tending back to sandstone, typical of depositional flood plain / river systems.

2.3.1 Goonyella Middle Seam

The GMS is the most consistent of the major seams and is consistently 9 m to 10 m thick and only in the south do thin seams (less than 0.5 m thick) separate from the main seam (Figure 6). Firstly, the GM2 splits from the top of the GM0 to leave the GM1 and then the GM3 splits from the base of the seam in the far southern end of the lease to leave just the GM4. The average thickness of the GM1 is 6 m to 7 m.

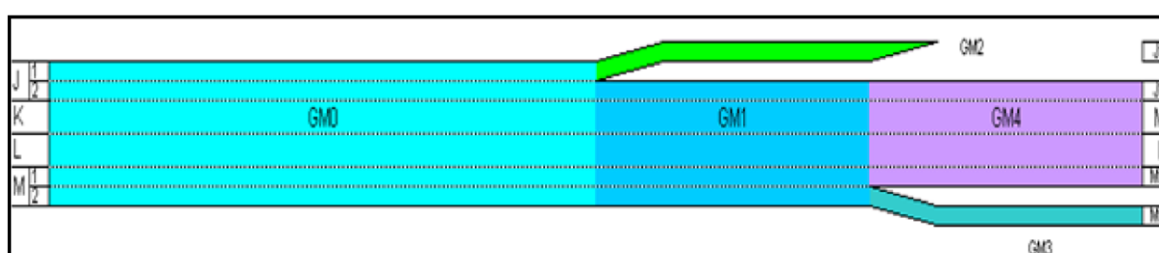


Figure 6 Plys and splits in the GMS seam.

2.3.2 Roof and floor of GMS

The roof and floor of the GMS in the Red Hill area are similar to those at Broadmeadow: fine grained rocks such as mudstones and siltstones should have a Uniaxial Compressive Strength (UCS) of about 30 MPa. Sandstones will be stronger with a UCS of about 40 MPa and with a wider range of variation (Figure 7). There should be no low strength clayey units in proximity to the GMS.

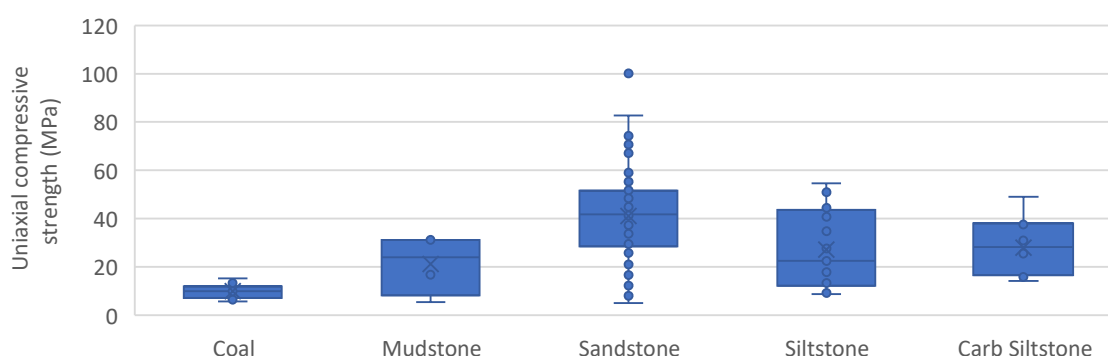


Figure 7 Range of UCS values for different lithologies (data from Broadmeadow Mine).

3 UNDERGROUND MINING

3.1 Longwalls

Inherent in safe and productive longwall mining is the collapse of the overburden rock mass above the extracted coal. The geotechnical parameters of the local and regional geology (Section 2) are critical in understanding the way in which the strata above the underground mine will collapse.

The collapse may extend to the surface if the width of the extraction relative to the depth of

mining exceeds about 0.5. The width:depth ratio for the current and legacy longwall mines in Queensland mean that vertical subsidence develops progressively as the longwall advances. The mains pillars and roadways are designed to be stable during the operations – both in terms of roof collapse in the roadways and stability of the pillars.

3.2 Deformation during Operations

Mining subsidence results in the following deformation and associated impacts at the surface:

- Downward vertical movements
- Change in surface slope angles
- Vertical steps and compression humps
- Surface cracking

The hazards presented by subsidence at closure of longwall mines need to be considered in the context of the post-mining land use and using the temporal and spatial probability method - how many humans or wild life would access the area and how often. The most problematic hazard is likely to be cracking resulting from subsidence. Remediation of vertical steps, humps, and cracking will be addressed in progressive rehabilitation and will form a part of the day-to-day operational mining rehabilitation activities.

4 SUBSIDENCE

4.1 Existing Subsidence

No subsidence exists at Red Hill Mine as it is not currently operational.

4.2 Geotechnical mechanisms

Overbuden collapse above the mined seam may extend to the surface if the width of the extraction relative to the depth of mining exceeds about 0.5. Maximum subsidence is developed above the extraction and within about 100 m of the retreating face, there would also have been a lesser amount of vertical subsidence above the chain pillars that developed independently of that above the extraction (Figure 8).

When the underground workings are flooded there may be a small amount of additional vertical subsidence related to the softening of the caved rock above the extracted coal in the presence of water. This flooding can occur as a direct result of the mine being purposefully flooded, or over time as the ground water recovers from dewatering. The subsidence above the chain pillars is unlikely to increase when the groundwater recovers.

The situation with the mains pillars and roadways is different. These are designed to be stable during the operations – both in terms of roof collapse in the roadways and stability of the pillars. The mains pillars are typically designed with high stability factors such that failure over the long term is unlikely. Flooding of the mine may temporarily reduce the stability of the pillars, but eventually their stability will be increased due to a buoyancy effect reducing the loads on the pillars.

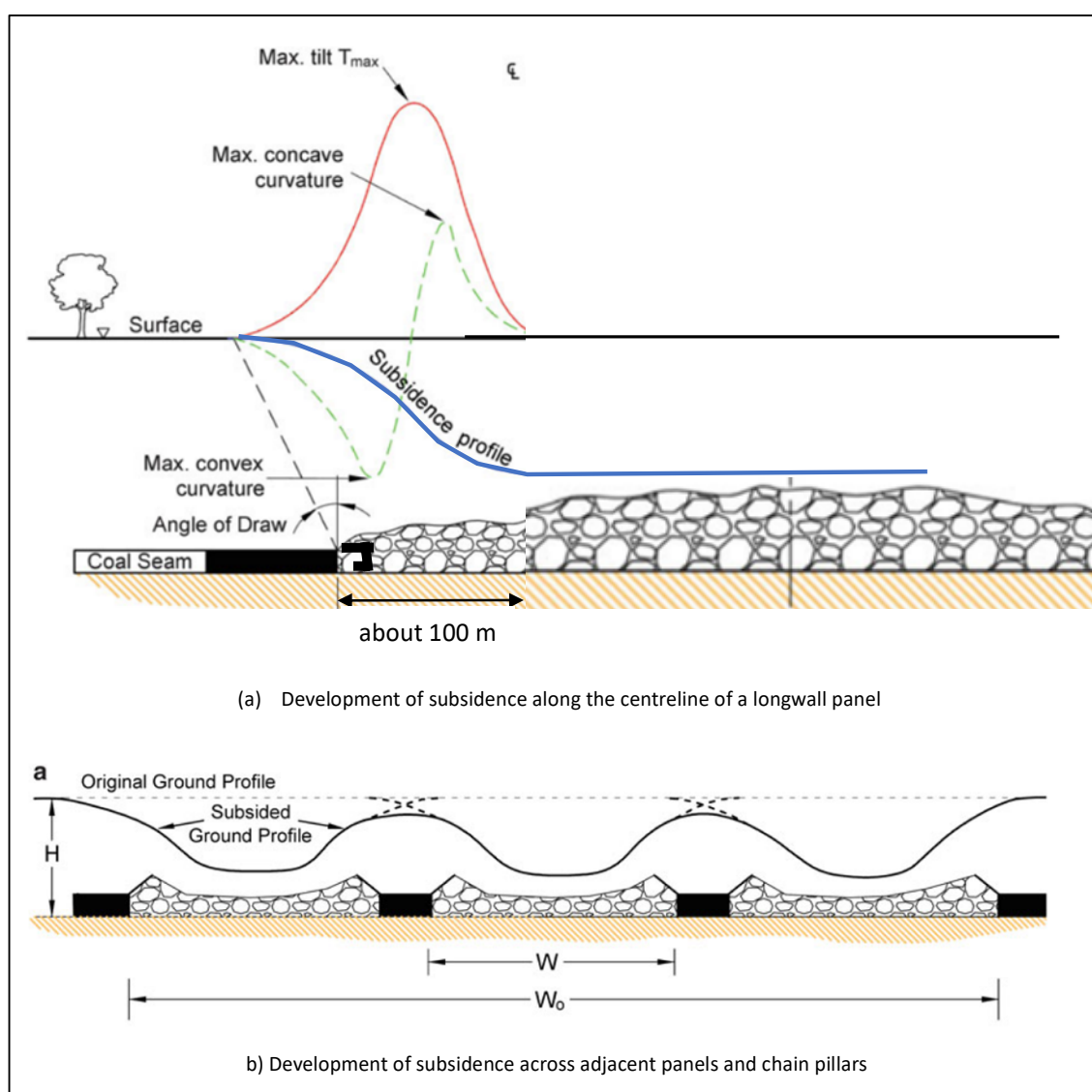


Figure 8 General nature of longwall subsidence².

4.3 Predicted Subsidence

4.3.1 Longwall extraction

The nature of subsidence deformations has been well established at Broadmeadow Mine (Table 1) and can be reliably used to predict subsidence above the extracted longwalls at Red Hill. There will be differences at Red Hill related simply to the larger extracted thickness – 8 m extraction has been assumed although it is recognised that top coal caving may not achieve such extraction and this means that subsidence is likely to be over-estimated.

Table 1 Default parameters for subsidence prediction at BMA mines

S _{max} /T	0.75
Edge-effect offset (distance from panel edge to inflexion point normalised to mining depth)	0.2
Angle of influence	63.4°
Factor to convert curvature to strain (metric system)	0.2

² Galvin JM 2016. Ground Engineering: Principles and Practices for Underground Coal Mining. Springer.

4.3.2 Pillars

Adopting a development roadway height of 3.5 m and a full seam thickness of 8 m, Figure 9 presents a prediction for the subsidence that will develop directly above the centres of the proposed chain pillars³. Pillar subsidence increases from about 350 mm at 250m depth to 1.8 m at 650 m depth.

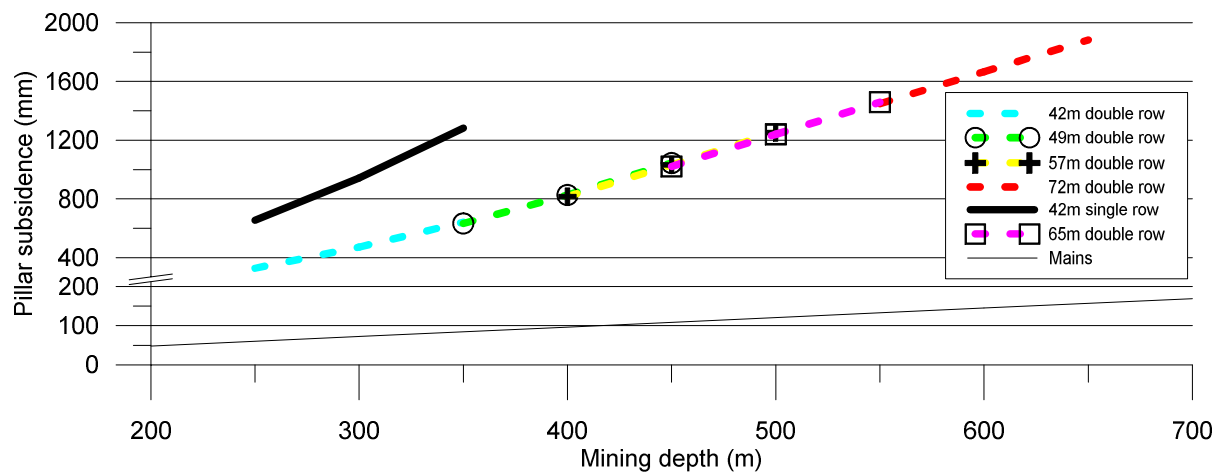


Figure 9 Chain and mains pillar subsidence as a function of depth of mining (legend relates to width of chain pillars and the number in each gate road)

4.3.3 Surface Deformation Prediction System

In this report the Surface Deformation Prediction System (SDPS) influence function method⁴ has been used. The visualisation software (SDPS) provides 2 ways of modelling subsidence above chain pillars (Figure 10):

- One way involves the simple addition of the predicted subsidence for each longwall panel. Without calibration data, the panel addition method is more applicable for deeper mines and has been adopted for Red Hill. This method tends to underestimate pillar subsidence but gives a better representation of the subsidence above the extraction. Predictions were made on 20 m centres.
- The alternative way is to assume the maximum subsidence is developed over all panels and then the chain pillars are specifically introduced. The pillar reduction method works reasonably well for longwalls at shallow depths (individual panels are supercritical) but becomes more complicated for deeper mines (individual panels are subcritical).

³ Coal UCS/modulus = 10 MPa/1.7 GPa. GSI=40, Roof and floor strength = 35MPa

⁴ Surface Deformation Prediction System (SDPS) Software | Office of Surface Mining Reclamation and Enforcement (osmre.gov)

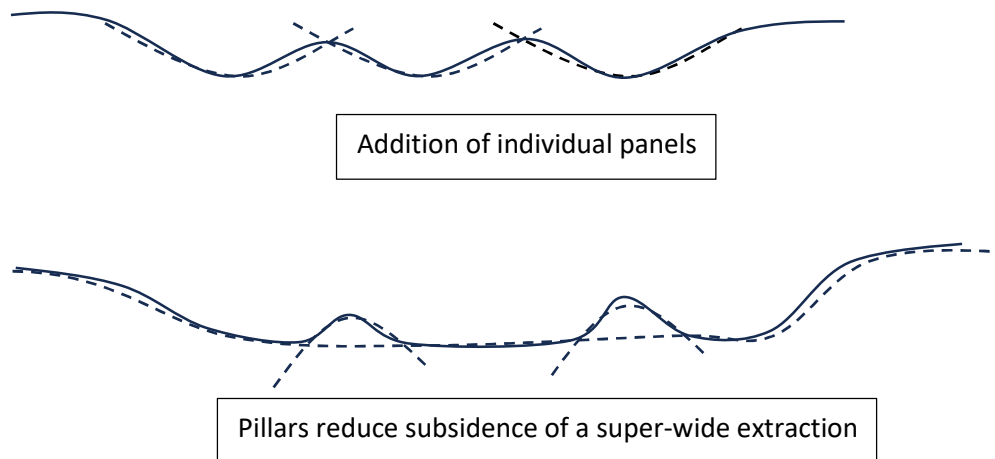


Figure 10 Two ways of modelling pillar subsidence in SDPS

4.4 Subsidence deformations

The modelled distribution of vertical subsidence, tilt and strains along 2 cross section lines are shown in Figure 1111; the location of the section lines and visualisation of subsidence, tilts, and strains in plan view are shown in Figure 12.

The maximum vertical subsidence is 5.77 m. For the vertical subsidence, a cut-off deformation of 20 mm was adopted to define the onset of displacement. Using this definition, there is an estimated area of 29 km² of impacted ground. The maximum tilt is 4.6% or 46 mm/m and horizontal strains vary between -19 mm/m (compressive) to 21 mm/m (tensile).

For horizontal strain the presented contours are those in excess of 5 mm/m in either tension or compression to give an insight into areas where visible localised surface deformations may be seen (cracking).

Figure 13 presents frequency plots of the level of vertical subsidence, change in slope, and tensile/compressive strains expressed relative to the area defined by the 20 mm vertical subsidence level. It is anticipated that about 30% of the subsided area may have tensile strains in excess of 5 mm/m.

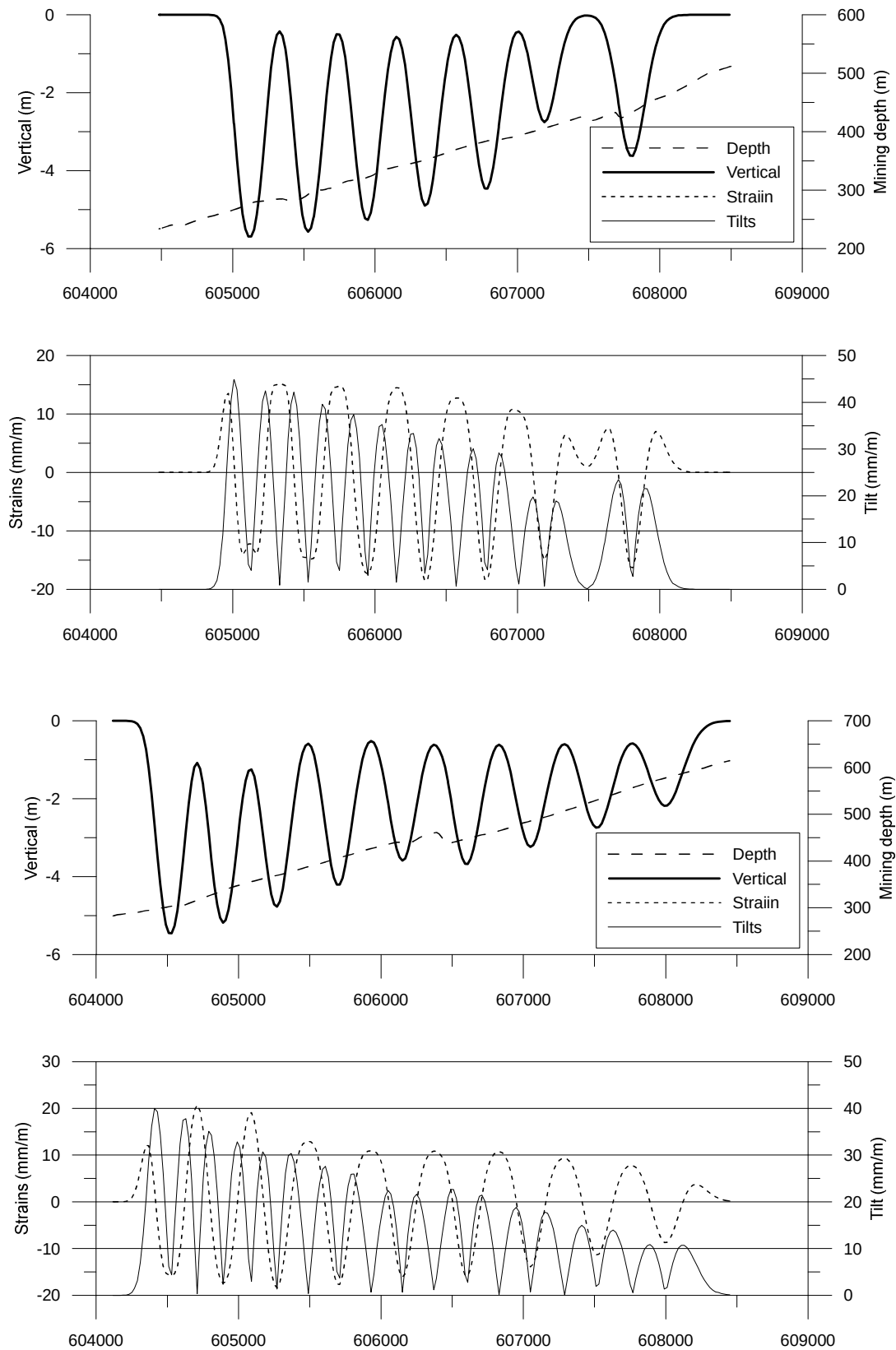


Figure 11 Subsidence parameters along Northern and Southern cross lines

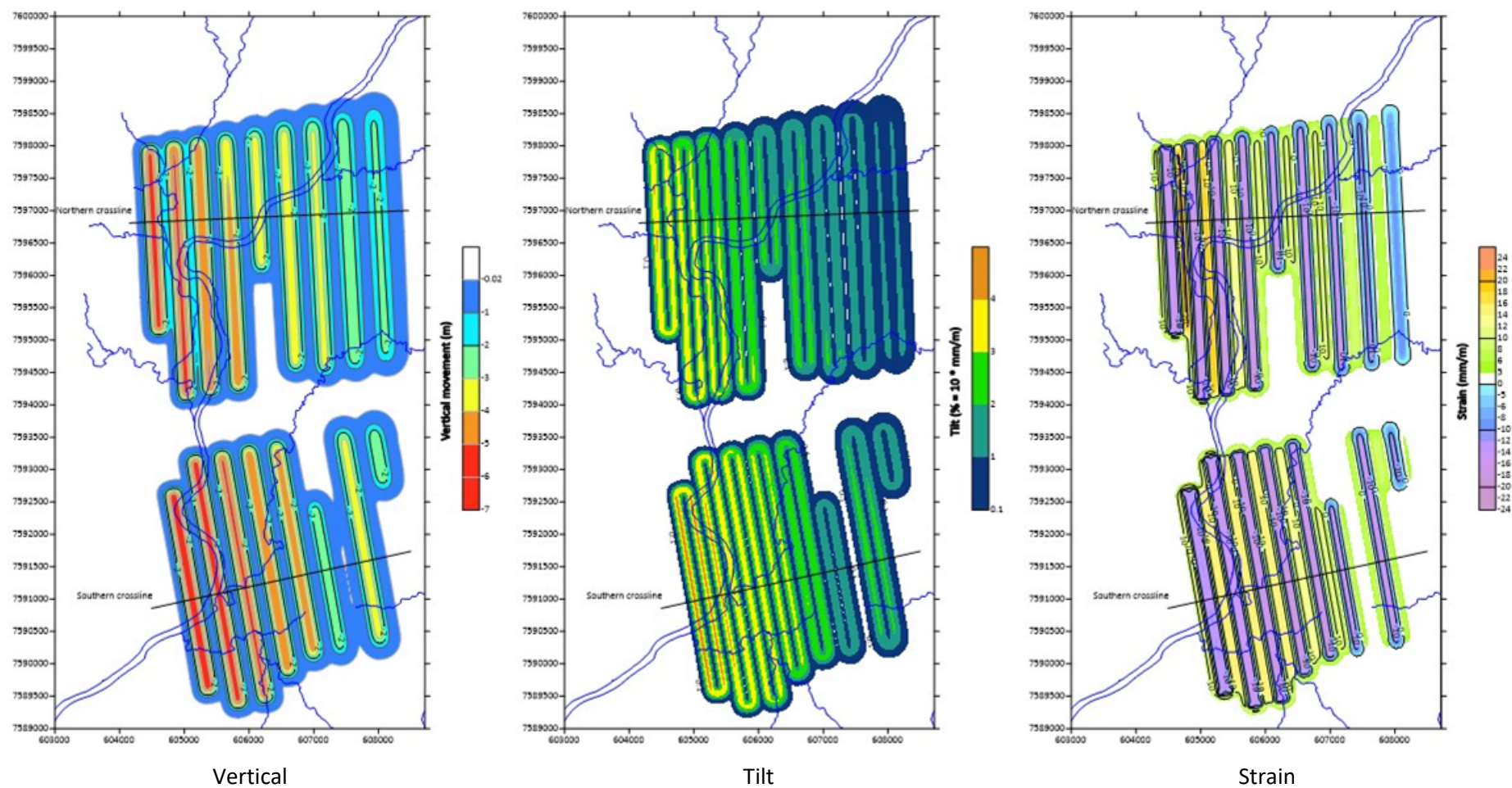


Figure 12 Visualisation of subsidence, tilts, and strains.

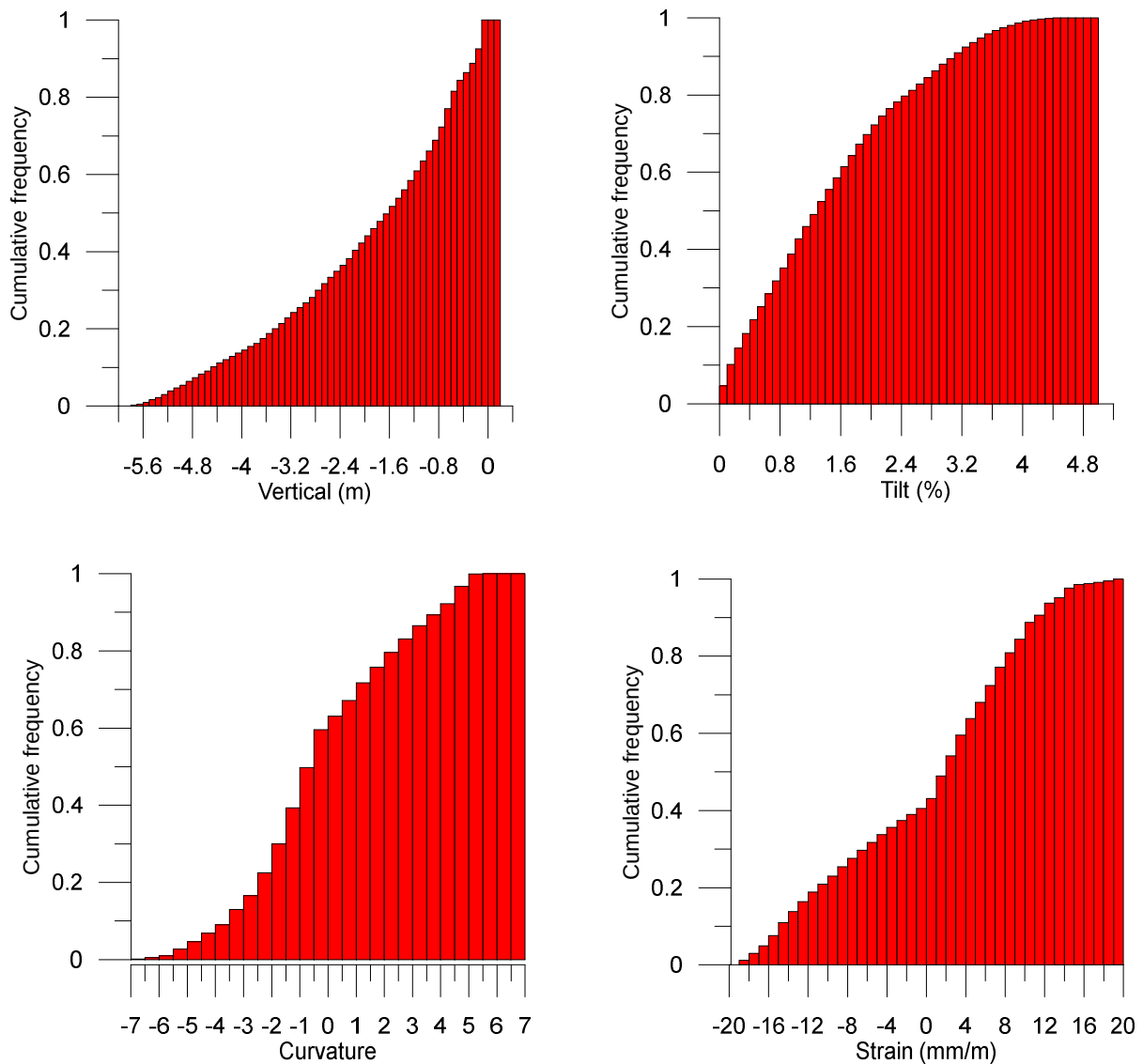


Figure 13 SDPS statistics.

5 SUBSIDENCE DAMAGE – CRACKING

5.1 Current understanding

For longwalls such as those proposed for Red Hill Mine with large width/depth ratios, cracking is to be expected at the surface (Figure 14). Open cracking may be parallel and close to the panel edges (longitudinal fracture) or parallel to the face line (arcuate fractures). There may be other longitudinal fractures distant from the panel edges.

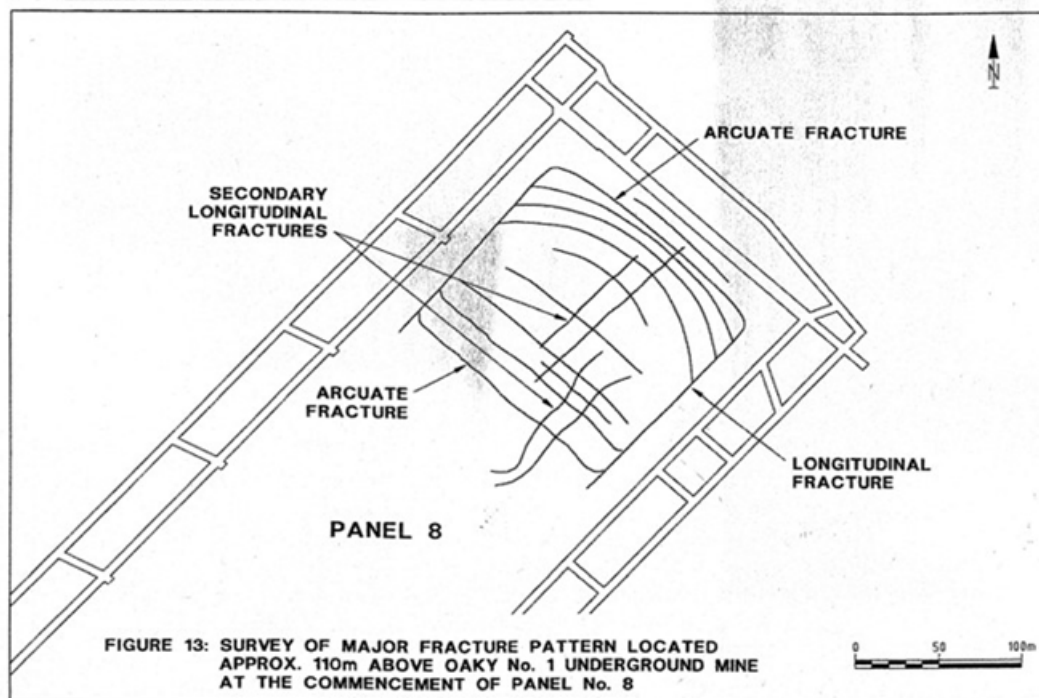
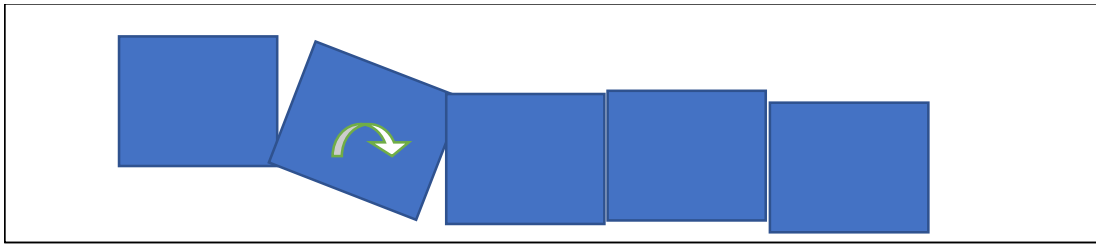


Figure 14 Longwall cracking (ACARP 2000)

The relationship between the width of the cracks and the predicted tensile strain depends on the spacing of the cracks. The predicted tensile strains are in part related to the spacing of the survey pegs (10 m) used in the calibration of SDPS. Kinematics suggests that the depth of the cracks may be 10 times the width, but could be up to 20-30 times the width in extreme cases. The recommended default assumption for the Bowen Basin at this stage is 10 m.

5.1.1 Longitudinal cracking

The longitudinal cracking is perhaps the most obvious and is typically the focus of progressive rehabilitation regimes on most mine sites. Longitudinal cracking is the result of overburden blocks' rotation at the edge of the extraction panel (Figure 15). Both a tensile opening and a compression strain associated with block rotation is experienced. The tensile opening (crack) becomes easily visible at the surface, where the compression strain is usually not clearly discernible.



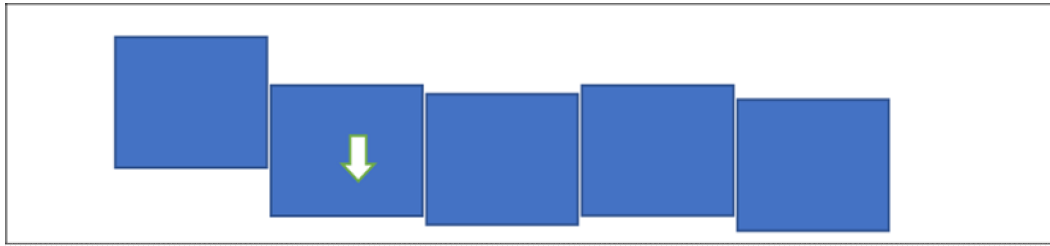
Longwall crossline – blocks near the ribside tend to rotate



Figure 15 Longitudinal cracks

5.1.2 Arcuate cracking

The arcuate deformations are related to periodic vertical collapse (Figure 16) with the collapse somewhat akin to the periodic weighting events experienced at the longwall mining face but at a much smaller scale. As the longwall face retreats the rocks near the surface may temporarily “hang up” but then collapse vertically. The roughness of the interface between the blocks will mean that the blocks will not match perfectly - hence the steps and some opening. As for the longitudinal cracks, the arcuate deformations will be apparent through the soil cover but may be ameliorated by rainfall. The mode of formation of these cracks is more by vertical shear so the result is the formation of steps with relatively little dilation.



Longwall centreline – blocks move downwards (and to a lesser degree sideways) at discrete intervals



Figure 16 arcuate cracks

5.2 Crack dimensions and rehabilitation

The relationship between the width of the cracks and the predicted tensile strain depends on the spacing of the cracks. The predicted tensile strains are in part related to the spacing of the survey pegs (20 m in the Red Hill analyses) used in the calibration of SDPS. If only 1 crack develops between consecutive pegs then the predicted tensile strains of up to 20.8 mm/m translate to cracks up to 400 mm wide.

Section 2.2 notes that the surficial deposits range in thickness between 0.5 m to 30 m. The poorly consolidated sediments are likely to collapse into cracks after rainfall at Red Hill Mine.

5.3 Pot holes

The depths of cover mitigate against the development of pothole subsidence.

6 HYDROGEOLOGICAL CHANGES

6.1 Hydraulic conductivity

Collapse or fracturing of the rock mass above the extracted coal is an intrinsic feature of pillar extraction or longwall mining, except in some specific geological environments where there is a spanning unit that stops the progression of the cave. Subsidence results in large scale fracturing of the overburden and disruption to the overburden above the mined seam. This means that groundwater systems are unlikely to be returned to pre-mining condition. Importantly, if the differential surface subsidence above any extraction panel is in excess of about 500 mm there will be

fracturing through to the surface - not as a single continuous crack but multiple shorter discontinuous cracks.

Following work done at Crinum North, a new model for longwall fracturing and hydraulic conductivity has been developed. The largest changes in hydraulic conductivity are now recognised to be in the "Enhanced Conductivity Zones" (Figure 17). The impact on the overburden above the extracted area is not homogenous in its lateral extents. An estimate of the resulting hydraulic conductivity (based on one scenario of how cracking develops in the overburden) is presented in Figure 18. The hydraulic conductivity is estimated using the crack density model, as summarised Seedsman et al (2023)⁵, in which a key parameter is an estimate of the frequency of mining induced fracturing in the overburden – the fewer the number of cracks, the wider they are and hence the higher the hydraulic conductivity. The right-hand chart in Figure 18 provides an indication of the sensitivity of the prediction to the choice of spacing. It is noted that the values should be considered as the "uniformly distributed" values at any particular horizon – in reality there may be wider crack apertures to the sides of the collapse. Note that the zone of elevated conductivities to the sides of the collapse is similar in height to the caved zone (Kendorski⁶) or Zone A (Ditton and Merrick⁷).

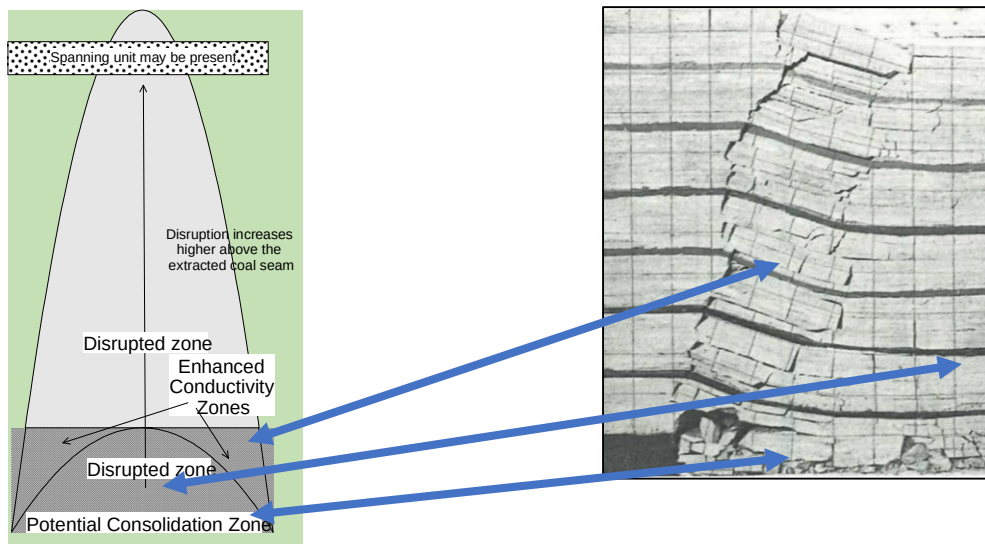


Figure 17 Framework of the geotechnical model for hydrogeological impact (Seedsman 2019,2020⁸).

The immediate roof of the GMS seam has UCS values of 40-50 MPa. In the Potential Consolidation Zone (PCZ) such material will have a high conductivity when dry but will consolidate in the presence of water and its hydraulic conductivity values will drop to about – 10^{-5} to 10^{-6} m/sec – possibly similar to the pre-mining values.

⁵ Seedsman, R.W., Fellowes, M., Thoeni, K And Fityus, S. 2023. The viability of a pumped hydro scheme using abandoned longwall mines. *Proceedings of the 14th Australia and New Zealand Conference on Geomechanics, Cairns 2023 (ANZ2023)*.

⁶ Kendorski, F.S. 1993. Effect of high-extraction coal mining on surface and ground water. *12th International Conference on Ground Control in Mining*. 412-425.

⁷ Ditton S, and Merrick, NP (2014) A new sub-surface fracture height prediction model for longwall mines in the NSW coalfields. Paper presented at the Australian Earth Science Convention, Newcastle NSW.

⁸ Seedsman, RW. 2019. Interpretations of mine water pumpout data and revisions to caving and fracturing models for longwalls. *Mine Water and the Environment*, 38,3,67-685.

Seedsman, RW. 2020. Prediction of the height of caving and fracturing above an isolated longwall extraction panel. *Mining Technology*, 129:2, 95-103.

Note that the prediction is particularly sensitive to assumptions about the spacing of cracking induced by the longwall extraction. At the time of preparation of this report, a crack spacing of 2 m is recommended.

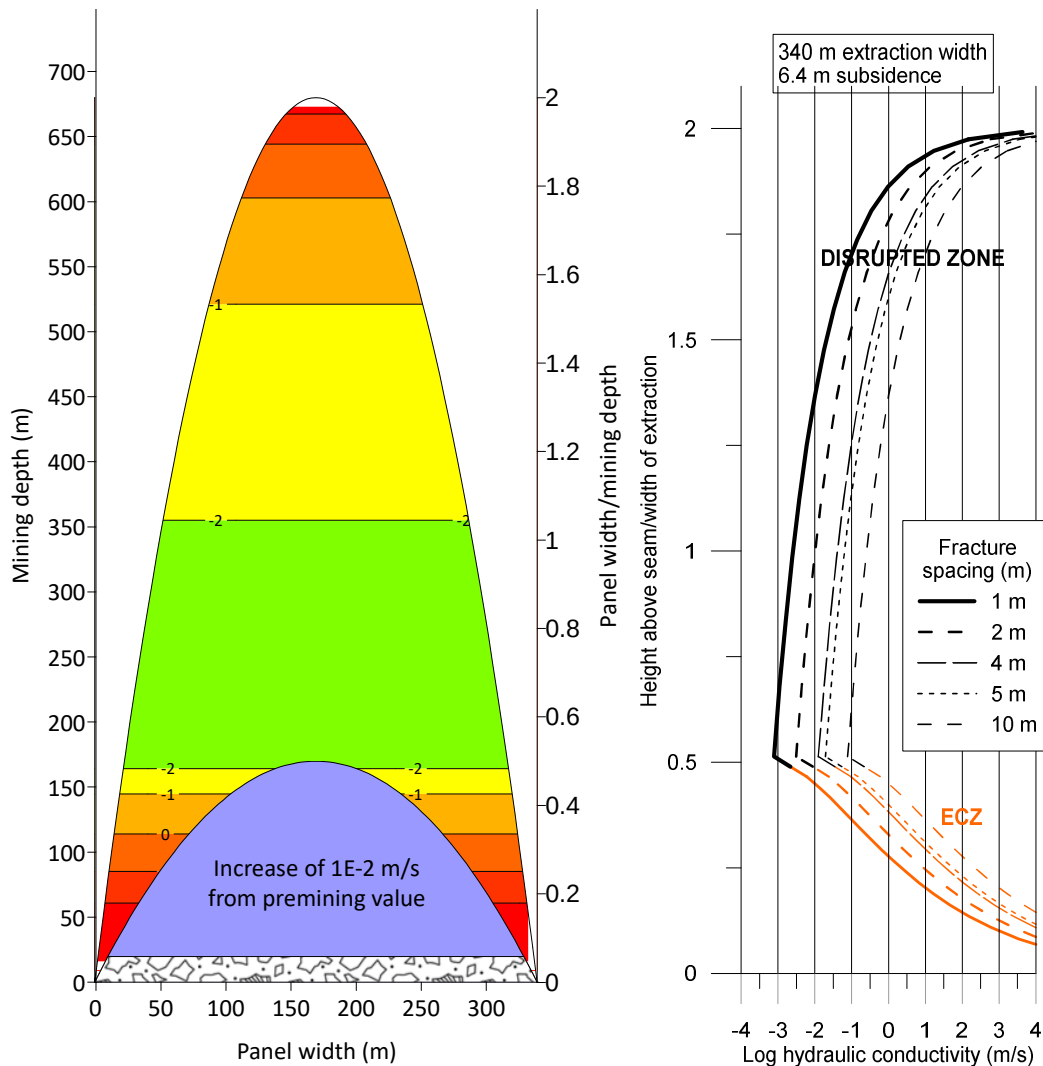


Figure 18 left - Distribution of hydraulic conductivity based on 6.4 m maximum supercritical subsidence and crack spacing of 2.0m; right - sensitivity to adopted fracture spacing, black lines represent centreline, orange lines represent sides of caved zone.

6.2 Flooding of undergrounds

6.2.1 Longwall

Flooding an underground mine will result in the saturation of the bottom of the goaf (the Potential Consolidation in Figure 17) and this will cause a softening of the fragmented immediate roof with consequent consolidation. This consolidation may be reflected in additional surface subsidence.

6.2.2 Pillars

In the laboratory there is a measurable decrease in uniaxial compressive strength on saturation of coal measure rocks (about 20%). The impact of this on the stability of narrow pillars is in the order of 11% for pillars with width to height ratios of less than four but has not been studied for wider pillars. It is assessed that this strength loss will not add materially to the consideration for the stability of the pillars at Red Hill.

There is a possibility of reduction in the floor strength of the roadways which would result in a reduction in the bearing strength of the pillar floor system (Figure 16). The reduction in roadway floor strength may be relatively small so the impact on pillar stability will be minor unless the impacted layer is very thick and initial floor stability was low. The available information on the GMS seam suggests that the floor strengths are well in excess of those that could be associated with this type of failure mechanism.

In contrast to these reductions in strength, there will be an overall trend for an increase in stability related to a buoyancy effect as the water level rises above the coal seam. The result is that any decrease in stability will be temporary while the material at or below seam level softens and the water level is such that there is no buoyancy effect. Over time as the water level rises above the coal seam level, buoyancy will dominate and stability will increase beyond that at mine closure. It is valid to include consideration of buoyancy when using the available method to estimate pillar loading.

7 STABILITY ASSESSMENT

An assessment of the current and ongoing stability of the underground workings is critical to understand the subsidence risk at closure. Specifically, the possibility of pillar collapse leading to surface subsidence or roof collapse leading to pot-hole subsidence and the impacts on the post mining land use nominated for the area.

7.1 Standing pillars

7.1.1 Mains

For operational reasons the pillars in the main access roadways (Mains pillars) were typically designed with high levels of stability and a design life in excess of 50 years. Typically, Mains pillars are dimensioned with a factor of safety in excess of 2.0 and there is a conjecture that the probability of failure is better than 1:1 000 000. It is valid to assume that these mains pillars will not collapse.

Specifically for Red Hill, the pillars in the Mains are designed a constant size of 40 m by 66.4 m with roadways of 5.6m width (45.6*72 m centres). A development height of 3.6 m has been adopted. At maximum depth of 550 m the stability factor is 2.16 (Figure 19). The associated subsidence ranges from 50 mm to 170 mm (Figure 9).

7.1.2 Chain pillars

The stability factors of the chain pillars under full goaf loading are mostly in excess of 1.0 (Figure 19). Note that the subsequent collapse of the goaf means that at mine closure the chain pillars will be laterally confined so they will have greater stability than that implied by this analysis. The prediction of associated surface subsidence is between 350 mm and 1.46 m (Figure 9).

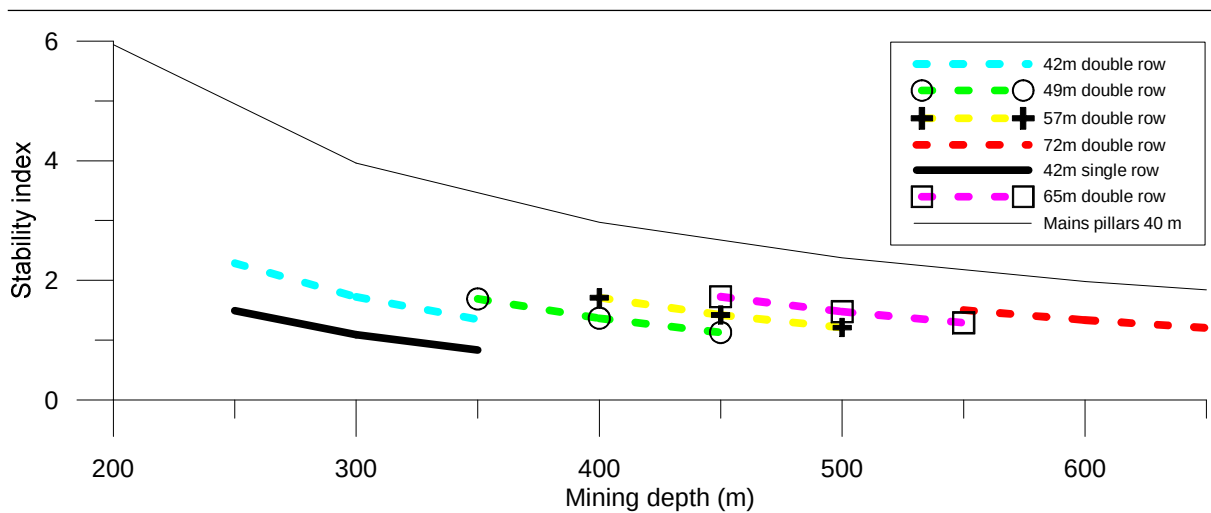


Figure 19 Pillar stability (legend relates to width of chain pillars and the number in each gate road)

7.1.3 Long-term stability

The width to height of the mains pillars assuming the full thickness of the seam, is approximately 5: 1 (4/8) which implies an internal angle of 11 °. This angle is less than the known friction angles of coal so it is assessed that such pillars cannot fail by through going shear. On this basis it is assessed that all the pillars are long-term stable.

7.2 Potholes

The depths of mining are such that there is no hazard of pothole subsidence outside of the Goonyella NUMA associated with the highwall entries of the GMS.

8 SEALING OF UNDERGROUND WORKINGS

Mine seals are used to manage or limit water and gas flows if required, as well as to control physical access to the underground mine.

Depending on their functional requirements there are three types of seals (US EPA4):

- Dry seals – prevent physical access only.
- Air seals – prevent physical access without retaining water.
- Hydraulic seals – prevent physical access and retain water.

Due to the flooding of the underground workings and void lakes establishing in the residual voids used to access the underground workings after mining, dry seals are required at Red Hill Mine to prevent physical access. Their location means there will be little or no hydrostatic pressure applied to them. A corollary of this is that they need to be permeable to water.

A suitable dry seal for portals with concrete arches or culverts (as planned at Red Hill Mine) could be constructed by backfilling the concrete section and then covering further to an equal height (Figure 20).

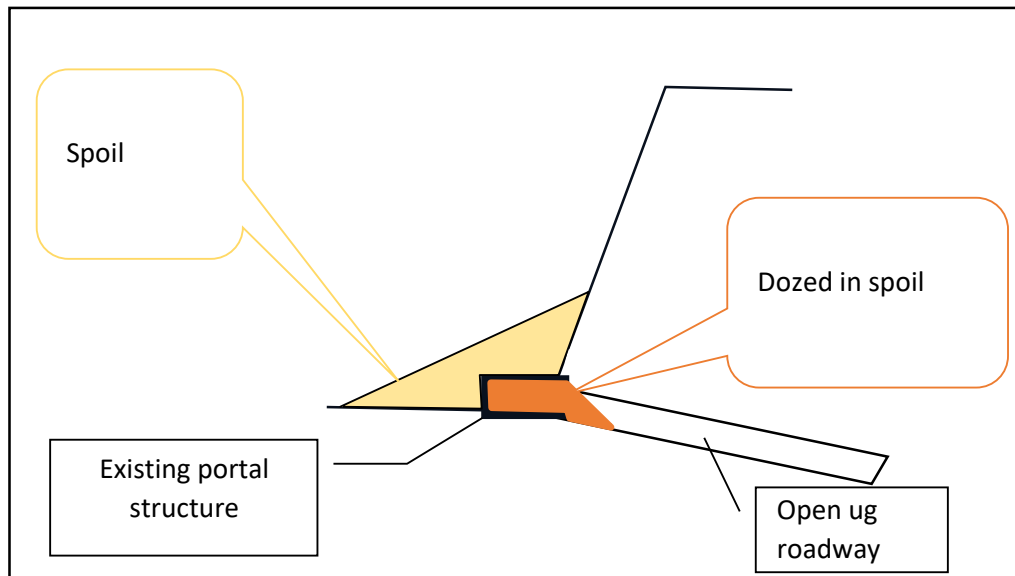


Figure 20 Concept for access (dry) seals at portals with concrete arches or culverts

9 REHABILITATION STRATEGIES

Rehabilitation of longwall cracking has been addressed above.

9.1 Shafts

Shafts should be closed according to the standards and guidelines at the time. This will likely include being fully backfilled with any locally sourced material. The shaft collar should be removed to allow removal of weathered/soil like material and then backfilled and compacted before a concrete slab is installed (Figure 21).

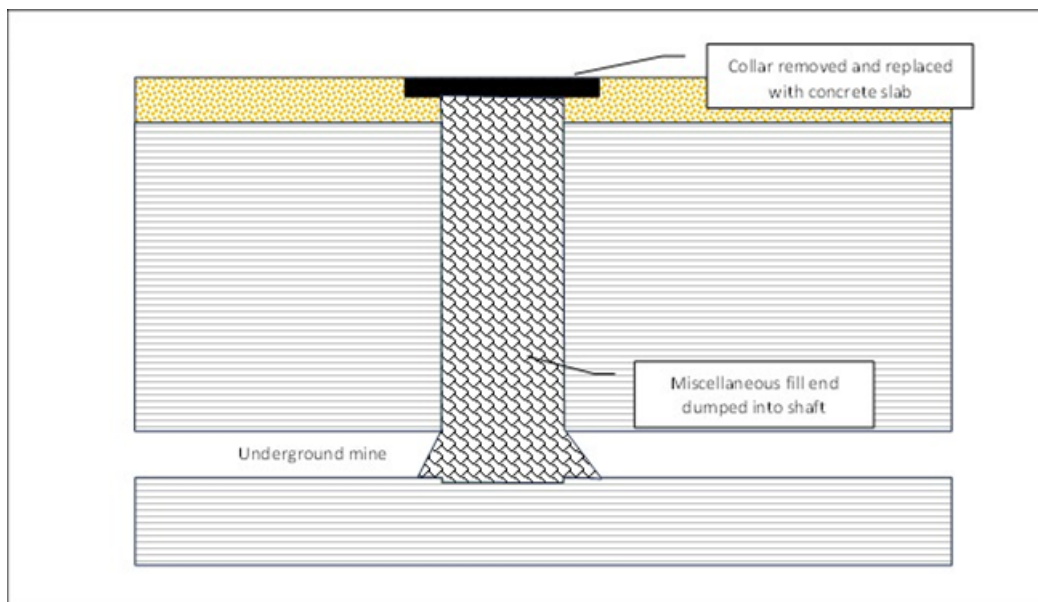


Figure 21 Filling of shafts

9.2 Underground service holes (drop holes, pump holes)

Open service holes to the surface will need to be grouted to surface and sealed. All mine plans should be reviewed for these holes to ensure that no open access to the underground workings is maintained at closure.

10 MONITORING AFTER MINE CLOSURE

Subsidence monitoring should be conducted along a limited number of subsidence lines until the groundwater level in the underground is judged to have reached close to long-term equilibrium and then continued for another 2 years to confirm that significant movements have stopped. Broad scale mapping of the surface should be conducted at the 2-year interval to confirm that additional subsidence (if developed) has not resulted in unacceptable cracking. It is anticipated that all movements will have ceased by year 5.

Red Hill Mine PRCP
Risk Assessment

Risk Event	Scenario #	Scenario	Causes (related to risk event)	Impact Description	Highest MFL Level	Mitigating Controls	Highest Severity	Preventative Controls	Likelihood Basis (<i>chance of the impact at the severity, taking into account the effectiveness of the preventative controls</i>)	Likelihood	Likelihood	RRR
Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU1	Landform failure	1. Erosional instability 2. Geotechnical instability 3. Incorrect geotechnical assessment 4. Flooding/unplanned inundation 5. Selection of inappropriate PMLU 6. Greater than modelled subsidence impacts	- Erosion - Growth media loss - Failure of vegetation - Surface cracking	3	- Monitoring of landform stability and rehabilitation success to be undertaken post rehabilitation - Subsidence monitoring - Identify requirements for rectification works. - Complete maintenance	2	- Ongoing materials characterisation - Review the topsoil and rock material balance periodically during operations to ensure sufficient volumes for the rehabilitation needs. - Groundcover including vegetation to provide erosion resistance - Compliance to plan - Growth media assessment to determine amelioration and fertiliser requirements - Progressive operational subsidence management to repair initial cracks and drainage to reduce inundation/ponding to acceptable limits after initial subsidence - Final subsidence rehabilitation to repair final cracks and drainage to reduce inundation/ponding to acceptable limits after final subsidence	With all controls in place, including ongoing monitoring and maintenance, landform failure on a large scale for this landform is unlikely	Highly Unlikely	0.1	3
Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU2	Alteration of hydrogeological conditions	1. Release of contaminants to groundwater 2. Change in groundwater flow, recharge and/or discharge characteristics resulting in changes to the hydrogeological system 3. Drawdown and alteration of groundwater flow due to off site (GRM) void lakes acting as a sink driven by evaporation from the lakes 4. Maintaining dewatered conditions within aquifers 5. Change of aquifer availability/properties resulting from resource removal and subsidence	- Groundwater chemistry altered rendering it not suitable for extraction and/or to support the PMLU, or reduction of groundwater quality within the Isaac alluvials - Groundwater quality not supporting the establishment/maintenance of Environmental Values and Water Quality Objectives for the basins in which the site is located - Unfavourable Geochemical or contaminants reporting to shallow and deep groundwater systems - Reduction of groundwater height within surrounding extraction bores - Degradation of terrestrial and aquatic groundwater dependant ecosystems (GDEs) - Dewatering of coal seams and other lithologies that have potential for AMD generation resulting in transport of contaminant of concern to ground and groundwater resources	5	- Assessment and remediation of impacted material, where appropriate - Development and approval of a Site Management Plan to assist with on-going management and restriction to future land use activities where appropriate - Implementation of management controls and monitoring programs outlined in an approved Site Management Plan - Re-establishment of impacted ecosystems - Decommissioning of impacted supply bores and re-instatement in suitable location - Regular updating of groundwater models to continue to improve the understanding of groundwater and the affects from mining operations	3	- All imported hazardous materials are to be stored and used in in accordance with relevant standards and removed from site on completion of mining - At the completion of operations, all stored hazardous materials and infrastructure within the administration areas and underground workings that have the potential to release contaminants to groundwater, will be removed from site - Contaminated land investigation to be undertaken at the completion of operations to identify contamination that has the potential to cause impacts to groundwater - Implementation of remediation and/or management plans as required to reduce potential groundwater impact risks - Mine water dams to be decommissioned (including investigation for potential contamination and groundwater impacts) - Groundwater monitoring to be undertaken in accordance with EA/PRCP conditions - Groundwater conditions to be understood well in advance of closure to allow any required rectification works - Modelling of groundwater and fate and transport to understand the impacts associated with landforms/activities - Revisiting the groundwater model on a five year turn around to include up to date information and used to inform landform design and confirm that	With all controls in place, including ongoing monitoring and maintenance, failure to attain a stable condition for land described as the post-mining land use is unlikely due to alternation of hydrogeological conditions	Unlikely	0.1	10

Red Hill Mine PRCP
Risk Assessment

Risk Event	Scenario #	Scenario	Causes (related to risk event)	Impact Description	Highest MFL Level	Mitigating Controls	Highest Severity	Preventative Controls	Likelihood Basis (<i>chance of the impact at the severity, taking into account the effectiveness of the preventative controls</i>)	Likelihood	Likelihood	RRR
Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU3	Alteration of surface water systems	1. Release of contaminants to surface water resources 2. Changes to alignments and ecosystems of drainage lines and watercourses 3. Changes to hydraulic flows 4. Changes to flood patterns/distribution 5. Alteration of surface water infiltration rates 6. Surface water flows over unvegetated/disturbed soils where rehabilitation has not re-established 7. Overland discharges from neighbouring landforms and rehabilitated areas 8. Watercourses and drainage lines not attaining successful rehabilitated state 9. Changes to surface water flows due to subsidence 10. Changes in vegetation due to ponding	- Surface water chemistry altered rendering it not suitable for PMLU - Degradation of ecosystems and land uses connected to surface water flows and floodplains on and down gradient of the mine - Sedimentation of downstream surface water drainage lines resulting in changes to their hydraulic properties and impacting ecosystems - Surface water quality not supporting the establishment/maintenance of Environmental Values and Water Quality Objectives for the basins in which the mine is located - Accelerated erosion rates from surface water flows in disturbed areas and degraded ecosystems - Reduction in rehabilitation success rates due to reduced surface water quality - Alteration of soil properties associated with contaminants/inundation, including erodibility and geotechnical qualities	4	- Surface water monitoring data to be collected in accordance with the EA. If impacts are identified, further investigations will be undertaken to determine appropriate remedial measures - Any loss of hazardous contaminants that cause contaminated land/environmental harm will be reported and investigated as appropriate - Remedial works will be undertaken where releases from site result in impacts to surface waters, which may include alteration of the landforms, implementation of a Site Management Plan, implementation of additional controls/measures that reduce the potential for surface water impacts and/or re-establishment of impacted ecosystems where appropriate - Subsidence monitoring and rectification works - Undertake maintenance of	3	- All imported hazardous materials to be stored and used in accordance with relevant standards and removed from site on completion of operations - Mine affected water dams to be decommissioned and areas rehabilitated - Surface water monitoring to be undertaken in accordance with EA conditions - Monitoring of surrounding ecosystems will be undertaken in accordance with EA conditions - A contaminated land investigation will be undertaken at the completion of operations and remediation works undertaken as appropriate - Rehabilitation and monitoring of disturbed reaches of watercourses undertaken - Progressive operational subsidence management - Final landform that limits the ponding of water within subsidence areas to enable surface water movement to Isaac River at mine closure	With all controls in place, including ongoing monitoring and maintenance, failure to attain a stable condition for land described as the post-mining land use is unlikely due to alternation of surface water conditions	Unlikely	0.1	10
Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU4	Contaminated land impacting on environmental receptors, rehabilitation and attainment of PMLUs	1.Discharges and accumulation of hazardous contaminants (including emerging contaminants) from operational activities. 2. Licensed activities such as disposal of general and other wastes. 3. Pre-existing contamination from farming activities	- Contaminants present within soil or water resulting in an unacceptable risk to the environment or PMLU - Alteration of soil chemistry that impacts on structural characteristics - Contaminants reducing the soil suitability for rehabilitation species - Requirement for on-going management and restriction of land uses	3	- Investigate and remediate contamination incidents - Implement a Site Management Plan to manage impacts, where required - Removal of primary or secondary sources - Restrict site usage - Undertake ongoing monitoring to manage contaminated land risks	3	- Cleaning up of spills upon identification - Remediation or management of residual risk - Contaminated land investigation to be undertaken prior to closure and areas of contamination remediated and/or managed as appropriate - On-going surface water and groundwater monitoring providing an indication of contamination - Management of operational activities to limit any potential contamination	Due to current state of RHM and all precautions followed for a new underground mine, and processing of coal is offsite, contamination of the land at closure is unlikely.	Unlikely	0.1	10

Red Hill Mine PRCP
Risk Assessment

Risk Event	Scenario #	Scenario	Causes (related to risk event)	Impact Description	Highest MFL Level	Mitigating Controls	Highest Severity	Preventative Controls	Likelihood Basis (<i>chance of the impact at the severity, taking into account the effectiveness of the preventative controls</i>)	Likelihood	Likelihood	RRR
Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU5	Flooding influences on rehabilitation and final landforms	1. Saturation of materials within landforms 2. Velocities of floodwaters on rehabilitated landforms 3. Inaccurate modelling 4. Surface inundation due to subsidence	- Mobilisation of any contaminants contained within the landforms and impacts to downstream water and groundwater quality - Alteration of terrestrial ecology through introduction of weeds, sedimentation, or damage to select rehabilitation species - Introduction of weeds and impacts to rehabilitation vegetation establishment - Vegetation failure in subsidence inundated areas - Reduction in land capability of PMLU in subsidence ponded areas (woodland habitat and/or grazing)	3	- Assessment of landform failure and required rectification works upon safe access to site immediately after the flood event. Assessment to include identification of measures that would limit potential for on-going impacts. - Re-engineering of landforms to mitigate future failures followed by re-construction of landforms, and rehabilitation works. - Assessment of downstream impacts and undertake remediation/rehabilitation as required to re-establish drainage line hydraulics and ecosystems in liaison with the administering authority. - Monitoring of landform stability and rehabilitation success to be undertaken	2	- Removal of infrastructure from watercourses - Decommissioning of dams - Remediation of contaminated material where required - Design of landforms within flood extents that are stable and able to withstand flooding and water velocities - Establishment of vegetation suitable for the environment and reduces erosion risks - Progressive operational subsidence management to repair initial cracks and drainage to reduce inundation/ponding to acceptable limits after initial subsidence and final subsidence rehabilitation after final subsidence - Suitable revegetation species in subsidence inundation areas - Subsidence monitoring	Flood modelling indicates post-mining landform design velocities outside of the watercourses and diversions are unlikely to impact rehabilitated landforms. Preventative controls include decommissioning of dams and culverts that could contribute to, or impact flood conditions.	Unlikely	0.1	3
Stable condition for land described as a post-mining land (reference PDM EA Table E1 - cattle grazing, woodland habitat and watercourse) is not achieved	PMLU6	Rehabilitated landforms result in alteration of flood hydrology upstream and downstream	1. Changes to drainage network hydraulics. 2. Artificial landforms and subsidence areas reducing or increasing flood extent and changing velocities/flows. 3. Changes to vegetation cover and soil type which alter runoff and infiltration rates.	- Increasing/decreasing of flood extents, frequency and severity - Degradation of ecosystems due to altered flows, flood extent, duration or frequency - Infrastructure damage - Health and safety risks to on-site and off-site land users associated with increased flood heights, velocities and frequency	3	- Due to the off-site nature of the impacts, which occur during significant flood events, available mitigating controls at the time of the impact are limited due to safety and accessibility restrictions. After flooding has reseeded, landform design and alteration could be undertaken to reduce possible future events.	3	- Removal of infrastructure that would adversely interfere with stream hydraulics (culverts) and decommissioning of dams - Establishment of landforms that are stable and provide appropriate level of flood protection to the residual voids - Undertake monitoring and maintenance works where required to maintain landforms - Rehabilitated landforms to be free draining where practical or inundation limited to acceptable limits - Monitoring of subsidence and rectification works as required	Given subsided landform, impact to upstream and down stream hydrology is probable.	Probably	0.3	30
Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU7	Insufficient or inappropriate growth media required for rehabilitation activities	1. Insufficient growth media and rock quantities of suitable quality 2. Unstable/unsuitable material (erosive, dispersive, saline materials) 3. Weed infestation (soil is already infested with weed seeds) 4. Insufficient placement depth and surface treatment 5. Incorrect growth media and rock characterisation and amelioration 6. Inappropriate topsoil and rock stockpiling and management 7. Selection of inappropriate PMLU	- Erosion - Growth media loss - Topsoil deficit - Failure of vegetation (poor vegetation growth or incorrect vegetation affecting PMLU)	3	- Monitoring of rehabilitation success to confirm stability and identify requirements for rectification works. - Repair erosion areas, retest growth media and revegetate.	2	- Topsoil surveys and mapping - Review the topsoil, growth media and rock resources periodically during operations to ensure sufficient volumes for the rehabilitation needs. - Final landform design based on available materials. - Undertake rehabilitation planning and preparation in accordance with the specific requirements for growth media, rock, seed and management for the PMLU - Management of topsoil and rock stockpiles and application during rehabilitation - Growth media assessment to determine ameliorant and fertiliser requirements - Amelioration and fertiliser applied as per assessment - Selective handling of materials for placement - Compliance to plan	With all controls in place, including ongoing monitoring and maintenance, insufficient or inappropriate growth media and rock for use on rehabilitation is unlikely	Unlikely	0.1	3

Red Hill Mine PRCP
Risk Assessment

Risk Event	Scenario #	Scenario	Causes (related to risk event)	Impact Description	Highest MFL Level	Mitigating Controls	Highest Severity	Preventative Controls	Likelihood Basis (<i>chance of the impact at the severity, taking into account the effectiveness of the preventative controls</i>)	Likelihood	Likelihood	RRR
Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU8	Inadequate and/or inappropriate revegetation	1. Unfavourable climatic conditions and/or weather events 2. Incorrect species mix 3. Poor seed quality 4. Weed contaminated seed 5. Poor quality growth media or seed bed preparation 6. Erosion 7. Land contaminants 8. Subsidence related ponding causing vegetation dieback and loss of groundcover	- Exposed soils due to poor vegetation establishment and growth, resulting in enhanced erosion rates. - Increased weed establishment and growth. - Reduction in land capability of PMLU (woodland habitat and/or grazing) - Need for ongoing corrective action - soil sampling and analysis, amelioration and re-vegetation. - Reduced fauna habitat due to loss of existing vegetation	3	- Monitoring of rehabilitation - Monitoring of subsidence areas and repair of surface cracks - Rectification works undertaken e.g. repair erosion areas or ponded areas, retest materials, review seed mix and revegetate	1	- Growth media assessment to determine ameliorant and fertiliser requirements - Management of seed selection, provenance and quality - Plant at optimal time of year - Revegetation species aligned to growth media, landforms, subsidence and PMLU - Progressive operational subsidence management to repair initial cracks and drainage to reduce ponding to acceptable limits after initial subsidence and final rehabilitation after final subsidence	With all controls in place, including revegetating with species aligned to growth media, landforms, subsidence and PMLUs, as well as ongoing monitoring and maintenance, inadequate or inappropriate revegetation is unlikely	Unlikely	0.1	1
Stable condition for land described as a post-mining land (reference PMLU table E1 - cattle grazing, woodland habitat, water course) use is not achieved	PMLU9	Deterioration of built infrastructure conditions	1. Potential soil contamination around mine industrial areas 2. Inadequate sealing of surface underground infrastructure (shaft, holes, etc)	- Reduced soil fertility to support PMLU land capability - Potential contamination of surface water runoff affecting integrity of local catchments. - Inability to achieve PMLU	2	- Undertake a preliminary contaminated land assessment prior to the completion of the approved activities, identify if any areas require a further Detailed Site Investigation and remediation plan developed if required - Conduct ongoing maintenance - Mapping of below ground infrastructure remaining at closure	1	- Clean up and remediate contamination during operational period. - Undertake contaminated land assessment and remediation/management where required post mining - Capping and sealing of surface underground infrastructure (shaft, holes etc)	With all controls in place, including ongoing monitoring and maintenance, deterioration of built infrastructure is unlikely	Unlikely	0.1	1