Appendix D

Extraction Plan for 918 Panel: Groundwater Assessment (JBS&G 2026a)

EMM
creating opportunities

Extraction Plan for 918 Panel: Groundwater Assessment

Clarence Colliery Pty Ltd

Report

JBS&G 68229 | 171726 (R01Rev1)

23 April 2026

JBS&G

We acknowledge the Traditional Custodians of Country throughout Australia and their connection to land, sea and community.

We pay our respect to Elders past, present and emerging and in the spirit of reconciliation we commit to working together for our shared future where every person is respected, valued and has strong sense of belonging.

Caring for Country The Journey of JBS&G
Artist: Patrick Caruso, Eastern Arrernte

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Nomenclature

Categorical Definitions of Magnitude:

The following nomenclature has been adopted when describing the magnitude of values (numerical) in this report.

Surface Water

Table NM-A1a: Definition of Magnitude (Numerical) – Flow (General)

Term	Definition
Negligible	<0.01m^3/s (equivalent to less than 10L/s, or 0.864ML/d)
Small	0.01 to 0.1m^3/s (equivalent to between 10 and 100L/s, or 0.864 to 8.64ML/d)
Medium	0.1 to 1m^3/s (equivalent to between 100 to 1000L/s, or 8.64 to 86.4ML/d)
Large	more than 1m^3/s (equivalent to greater than 1000L/s, or 86.4ML/d)

This table pertains to surface water flow in ephemeral and perennial watercourses. It considers everyday flow in a watercourse, as well as flows during periods of flooding.

Groundwater

Table NM-A2a: Definition of Magnitude (Numerical) – Pressure Head (General)

Term	Definition
Negligible	less than 5m
Small	5m to 20m
Medium	20 to 50m
Large	more than 50m

This table pertains to pressure (in m) in an aquifer/aquitard and is conceived with respect to the base of hydrogeologic unit. A perched water table might have negligible pressure head, but that does mean that that pressure is not significant with respect to a local environmental receptor. Conversely, a deep groundwater system might have a large pressure head, and that large pressure is important to reduce, for safety purposes, as part of development and ahead of extraction.

Table NM-A2b: Definition of Magnitude (Numerical) – Flow (General)

Term	Definition
Negligible	1L/s (equivalent to less than 0.0864ML/d)
Small	1 to 10L/s (equivalent to between 0.0864 to 0.864ML/d)
Medium	10 to 100L/s (equivalent to between 0.864 to 8.64ML/d)
Large	more than 100L/s (equivalent to greater than 8.64ML/d)

This table pertains to groundwater extraction rates in various circumstances. Whilst an extraction of 1L/s might not be significant with respect to a mine dewatering or irrigation activity, it may be significant if that extraction leads to an impact to an adjacent environmental receptor.

General

Table NM-A3: Definition of Magnitude (% Contribution) – Water Balance (General)

Term	Definition
Negligible	less than 5%
Small	5 to 20%
Medium	20 to 45%
Large	more than 45%

This table pertains to components of the groundwater system balance (and/or modelling). It is usually the case that recharge makes up most of the input to a groundwater system balance. Conversely, it is usually the case that evapotranspiration and loss to surface watercourses make up most of the output from a groundwater system balance.

Categorical Definitions of Change:

The following nomenclature has been adopted when describing the magnitude of changes (numerical) in this report.

Surface Water

Table NM-B1a: Definition of Magnitude of Change (Numerical) – Flow (General)

Term	Definition
Negligible	change is <2%, that is, no different from background levels
Small	change is 2 to 5%
Medium	change is 5 to 15%
Large	change is >15%

Notes. 1. For watercourses, the NSW River Flow Objectives (NSW DCCEEW, 2006) list characteristics such as 'protect dry pools in dry times' and 'protect natural low flows'. Those aspects were used to inform the selection of the above definitions.

This table pertains to flow in surface watercourses. It is usually analysed in the context of a flow duration curve, which is a cumulative distribution function. i.e. the percent of time specified discharges were equalled or exceeded during a given period.

Table NM-B1b: Definition of Magnitude of Change (Numerical) – Water Quality (General)

Term	Definition
Negligible	change is <2%, that is, no different from background levels
Small	change is 2 to 5%
Medium	change is 5 to 15%
Large	change is >15%

Notes. 1. For watercourses, the NSW Water Quality Objectives (NSW DCCEEW, 2006) include protection of aquatic ecosystems, visual amenity, primary and secondary contact recreation, livestock water supply, irrigation water supply, drinking water – groundwater, aquatic foods (cooked), industrial supply, as relevant to a specific catchment.

This table pertains to numerical change in individual analytes, however, mostly is with respect to salinity.

Groundwater

Table NM-B2a: Definition of Magnitude of Change (Numerical) – Flow (Mine Dewatering Rate)

Term	Definition
Negligible	change is <10%, that is, no different from background levels
Small	change is 10 to 25%
Medium	change is 25 to 50%
Large	change is >50%

This table pertains to change in mine dewatering rate. The selected categories have context to site water management as well as the resulting change in groundwater elevation (drawdown), potentially with respect to other groundwater users surrounding a particular Site or Project and/or local environmental receptors.

Table NM-B2b: Definition of Magnitude of Change (Numerical) – Flow (Groundwater Contribution to Surface Water)

Term	Definition
Negligible	change is <5%, that is, no different from background levels
Small	change is 5 to 10%
Medium	change is 10 to 25%
Large	change is >25%

This table pertains to groundwater contribution to surface water in the context of its contribution to overall surface water flow. For everyday flow, groundwater contribution to surface water is a small component to overall surface water flow, but during dry times, it can be a large component. Assessment of context (overall surface water flow) is usually presented in a Regional Surface Water Flow and Quality Model.

Table NM-B2c: Definition of Magnitude of Change (Numerical) – Groundwater Elevation (General)

Term	Definition
Negligible	change is <2m
Small	change is 2 to 10m
Medium	change is 10 to 25m
Large	change is >25m

This table pertains to a general description of change in groundwater elevation in a particular aquifer/aquitard. Changes with respect to the uppermost water table and/or at water supply works is defined further below.

Table NM-B2d: Definition of Magnitude of Change (Numerical) – Groundwater Elevation (Highest Active Node)

Term	Definition
Negligible	change is <0.5m
Small	change 0.5 to 2m
Medium	change is 2 to 5m
Large	change is >5m

This table pertains to near-surface accessibility to groundwater (depth to water).

Table NM-B2e: Definition of Magnitude of Change (Numerical) – Groundwater Elevation (Water Supply Work)

Term	Definition
Negligible	<0.5m decline
Small	0.5 to 2m decline
Medium	2 to 5m decline
Large	>5m decline

Notes. 1. The NSW Aquifer Interference Policy 'Level 1 Minimal Impact Considerations' (NSW DCCEEW, 2012) is based on a decline in groundwater elevation at a water supply work of no more than 2m, cumulative.

This table is informed by the NSW Aquifer Interference Policy (NSW DCCEEW, 2012).

Table NM-B2f: Definition of Magnitude of Change (Numerical) – Groundwater Elevation (Environmental Receptor/Groundwater Dependent Ecosystem)

Term	Definition
Negligible	change is <5% decline
Small	change is 5 to 10% decline
Medium	change is 10 to 25% decline
Large	change is >25% decline

Notes. 1. The NSW Aquifer Interference Policy 'Level 1 Minimal Impact Considerations' (NSW DCCEEW, 2012) is based on a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any high priority groundwater dependent ecosystem or high priority culturally significant site listed in the schedule of the relevant water sharing plan. For this report, environmental receptors, which are identified as potential groundwater dependent ecosystems, not just listed high priority groundwater dependent ecosystems, were assessed using the above definition.

This table is informed by the NSW Aquifer Interference Policy (NSW DCCEEW, 2012).

Table NM-B2g: Definition of Magnitude of Change (Qualitative, Numerical) – Water Quality (General)

Term	Definition
Small to Medium	change to groundwater quality does not lower the beneficial use category of groundwater beyond 40m from the activity.
Large	change to groundwater quality lowers the beneficial use category of groundwater beyond 40m from the activity.

Notes. 1. The NSW Aquifer Interference Policy 'Level 1 Minimal Impact Considerations' (NSW DCCEEW, 2012) states that any change to groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.

This table is informed by the NSW Aquifer Interference Policy (NSW DCCEEW, 2012).

Relative Parameter Uncertainty Variance Reduction:

The values presented in this table pertain to outcomes of GENLINPRED (Watermark Numerical Computing, 2024) with respect to relative parameter uncertainty variance reduction. They describe "*…the ability (or otherwise) of a history-matching dataset to reduce the uncertainty of a particular parameter.*" (Doherty, 2025).

Table NM-C: Categorisation of Relative Parameter Uncertainty Variance Reduction

Term	Definition
Negligible	value of less than 0.05
Small	value between 0.05 and 0.20
Medium	value between 0.20 and 0.40
Large	value greater than 0.40

Notes. 1. Relative parameter uncertainty variance reduction is defined in Section 10.3.2 of Doherty (2025).

Categorical Definition of Significance:

The following nomenclature has been adopted when describing the significance of impacts in this report.

It is noted that whilst a particular property may be subject to a large change, that does not mean, necessarily, that the impact of that change is significant. Conversely, a change to particular property may be numerically small, however, the impact of that change may still be significant.

Table NM-D: Definition of Significance of Impact

Term	Definition
Not Significant or Insignificant	Impact is so small or unimportant as to be not worth considering; insignificant.
Significant	Impact is sufficiently great or important to be worthy of attention; noteworthy

Notes. 1. The definition of significance can be, as appropriate, informed by statistical significance, with respect to statistical hypothesis testing; however, statistical significance does not necessarily imply importance. In this report, the definition of significance is based on importance and may, or may not, take into account statistical significance.

Categorical Definition of Salinity:

The following definitions have been adopted when describing the salinity of surface and groundwater.

"Fresh *waters are sufficiently dilute to be potable, that is less than 1,000mg/L.* Brackish *waters are too saline to be potable, but are significantly less saline than seawater; the range is approximately 1,000mg/L to 20,000mg/L TDS.* Saline *waters have salinities similar to or greater than seawater (35,000mg/L), and* brines *are waters significantly more saline than seawater.*"

[Page 13 of Drever, 1997]

Executive Summary

This report presents a Groundwater Assessment of implementation of the Extraction Plan for 918 Panel at Clarence Colliery.

Clarence Colliery is located in the Western Coalfields of NSW and the target coal seam, within the Illawarra Coal Measures is the Katoomba Seam. Mining commenced at Clarence in 1979 and has used a range of extraction methods that result in partial extraction (i.e. limited extraction ratio from the coal seam) and/or total extraction (i.e. higher extraction ratio from the coal seam).

Extraction of 918 Panel will use the panel and pillar partial extraction method (PPPE), by continuous miner and shortwall. This mining technique limits extraction and results in minimal subsidence (less than or equal to 100mm), which is consistent with contemporary mining performance at Clarence Colliery. A geotechnical and subsidence analysis of recent post-mining experience of double-sided lifting at 908-910 Panel, which has an equivalent unsupported span width to PPPE, is presented in SCT (2026) with respect to Pagoda Swamp. This is in conjunction with the subsidence contours and valley closure assessment presented in MSEC (2025).

918 Panel has three sub panels, two of which are adjacent. For the southern, adjacent sub panels, Sub Panel 918A and Sub Panel 918B2, these are separated by a solid spine of pillars, with solid coal barrier on the outside of those sub panels. For the northern sub panel, there will be a single Sub Panel, Sub Panel 918B1, with the same solid spine of pillars on one side and a solid coal barrier on outside of the sub panel.

Extraction in the 918 Panel does not occur beneath Temperate Highland Peat Swamps on Sandstone (THPSS) shrub and hanging swamps (with the exception of Paddy's Creek Hanging Swamp which is located partly above the proposed 918B2 sub-panel); however, these exist within the 26.5° Angle of Draw.

The proposed void width (unsupported span) of sub panels of 918 Panel is 75m for Sub Panel 918A and Sub Panel 918B2 (southern, two sub panels) and is 83m for Sub Panel 918B1 (northern, single sub panel).

The depth of cover with respect to the Extraction Plan for 918 Panel is 174 to 329m.

The mine schedule is provided in **Appendix A**, with further detail specified in SCT (2026) and MSEC (2026).

Modelled Scenarios

Two model simulations were prepared:

- **Approved Case** (includes existing mining at Clarence Colliery and surrounding mines)
- **Proposed Case** (includes existing mining at Clarence Colliery and surrounding mines, as well as development and extraction of 918 Panel)

The objective of the above simulations were to assess the:

- change to modelled groundwater elevation
- change to groundwater contribution to surface water
- change to mine dewatering rate.

due to the implementation of the Extraction Plan for 918 Panel.

Groundwater Model Update

As part of the Scope of Work, updates to the groundwater model (JBS&G, 2025ab) included:

- refinement to approach to represent geological lineaments
- refinement to representation of enhanced recharge
- incorporate change to storage (specific yield, Sy), applied to saturated flow ('non-Richards equation') model layers

- introduction of a General Head Boundary (GHB) to represent State Mine Complex (flooded historical workings) located to the south of Springvale Mine
- incorporate heterogeneity in implementation of Tammetta's equation, which informs the height of the top of Zone A above the top of the mined seam, via Pilot Points, including covariance matrices
- recalibration of the model
- update to Time Varying Material (TVM), and Drains (DRN), to include the mine schedule for 918 Panel, both with respect to development and extraction.

Change in Groundwater Elevation

Figure ES.1, **Figure ES.2** and **Figure ES.3** presents the layout of the sub panels of 918 Panel, as well as time-series model output (stochastic simulations) (change to groundwater elevation of the highest active node (uppermost water table)) for the Proposed Case and Approved Case at representative model cells in the vicinity of those sub panels.

Detailed model output, including output at other cells in the vicinity of the presented representative cells, is presented in the main body of this report.

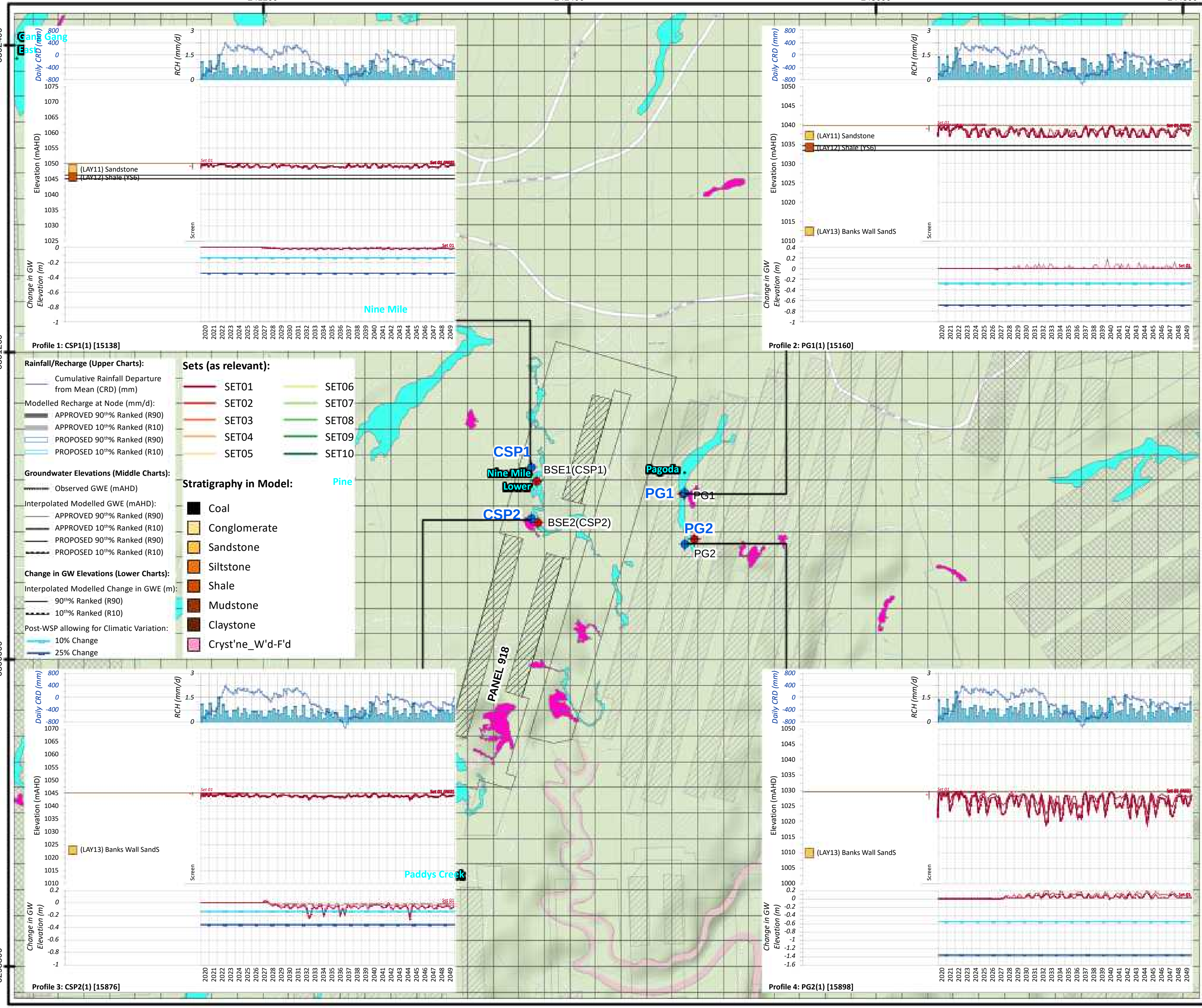
It is noted that the definition of negligible, small, medium and large is presented in the **Nomenclature**.

From **Figure ES.1** through **Figure ES.3**, the modelled change in groundwater elevation of the highest active node ranges between negligible and small and are at or below the Level 1 Minimal Impact Considerations of the NSW Aquifer Interference Policy (NSW DCCEEW, 2012). In **Figure ES.1**, for swamp piezometer CSP2, prediction model output ranges between a negligible change to a small change, with transitory changes that are medium in magnitude in the 90^{th}% ranked change, as defined in the **Nomenclature**.

It is highlighted that in **Figure ES.1** through **Figure ES.3** (and throughout this report) that model output is presented inclusive of predictive uncertainty, namely 10^{th}% ranked change and the 90^{th}% ranked change, with both these values and values in between being equally likely. i.e. model output is from stochastic simulations, not probabilistic simulations.

From **Figure ES.1**, for swamp piezometer CSP2, whilst the 10^{th}% ranked change is negligible to small throughout, the 90^{th}% ranked change has transient medium changes, but those changes are not considered to be significant as they do not persist in the medium and long term. It is further noted that the transient difference in the 90^{th}% ranked change is only 10cm beyond the 10% change threshold.

There are no non-mine dewatering groundwater users in the vicinity of 918 Panel. Accordingly, the modelled decline in groundwater elevation in the Katoomba Seam and underlying and overlying strata is not significant.



Legend:

- Groundwater Monitoring Locations

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Modelling:

- Model Grid
- Model Output Locations

Notes:
1) GWE: Groundwater Elevation.
2) 10% and 25% threshold calculated based on model output between 01/01/2011 and 31/12/2021.
3) CRD Trace dates from 01/01/2010 - 31/12/2049.

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevB	Date: 29-Jan-2026
Drawn By: DAW	Checked By: JRWB
Scale 1:20,000	

0 250 500
Meters

Coor. Sys. GDA 1994 MGA Zone 56

Groundwater Hydrographs (Prediction Period):

- CSP1
- PG1
- CSP2
- PG2

FIGURE: ES.1

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D069a_ES_UA_Hydrographs_CSP1_PG1_CSP2_PG2.mxd
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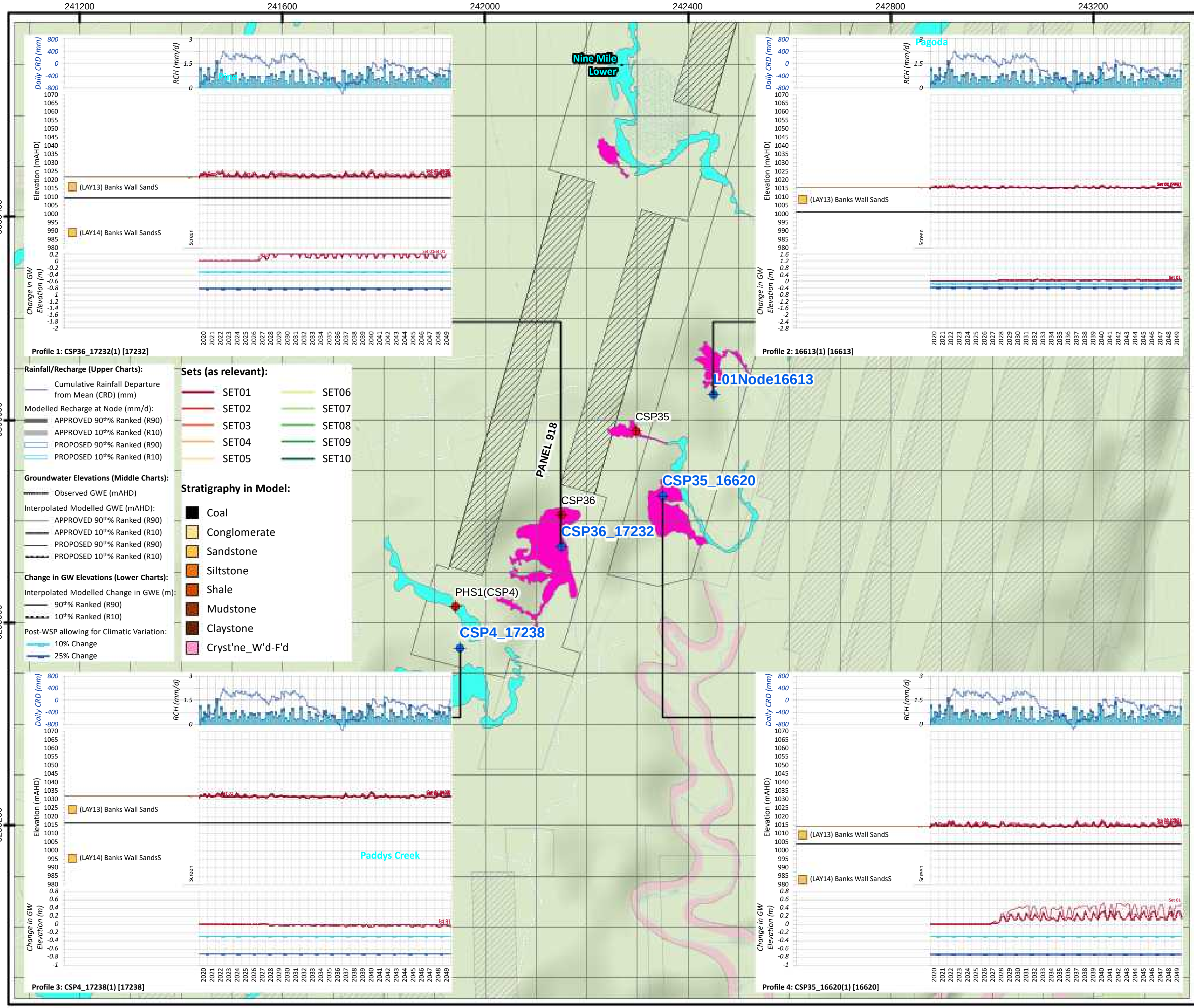

Legend:

- Groundwater Monitoring Locations

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Modelling:

- Model Grid
- Model Output Locations

Notes:
1) GWE: Groundwater Elevation.
2) 10% and 25% threshold calculated based on model output between 01/01/2011 and 31/12/2021.
3) CRD Trace dates from 01/01/2010 - 31/12/2049.
4) Observations are translated, to be representative, of the centre of each cell for purpose of comparison.

JBS&G

Job No: 68229

Client: Clarence Colliery Pty Ltd

Version: R01RevB	Date: 29-Jan-2026
Drawn By: DAW	Checked By: JRWB

Scale 1:10,000

0 200 400
Meters

Coor. Sys. GDA 1994 MGA Zone 56

Groundwater Hydrographs (Prediction Period):

- **CSP36**
- **L01Node16613**
- **CSP4**
- **CSP35**

FIGURE: ES.2

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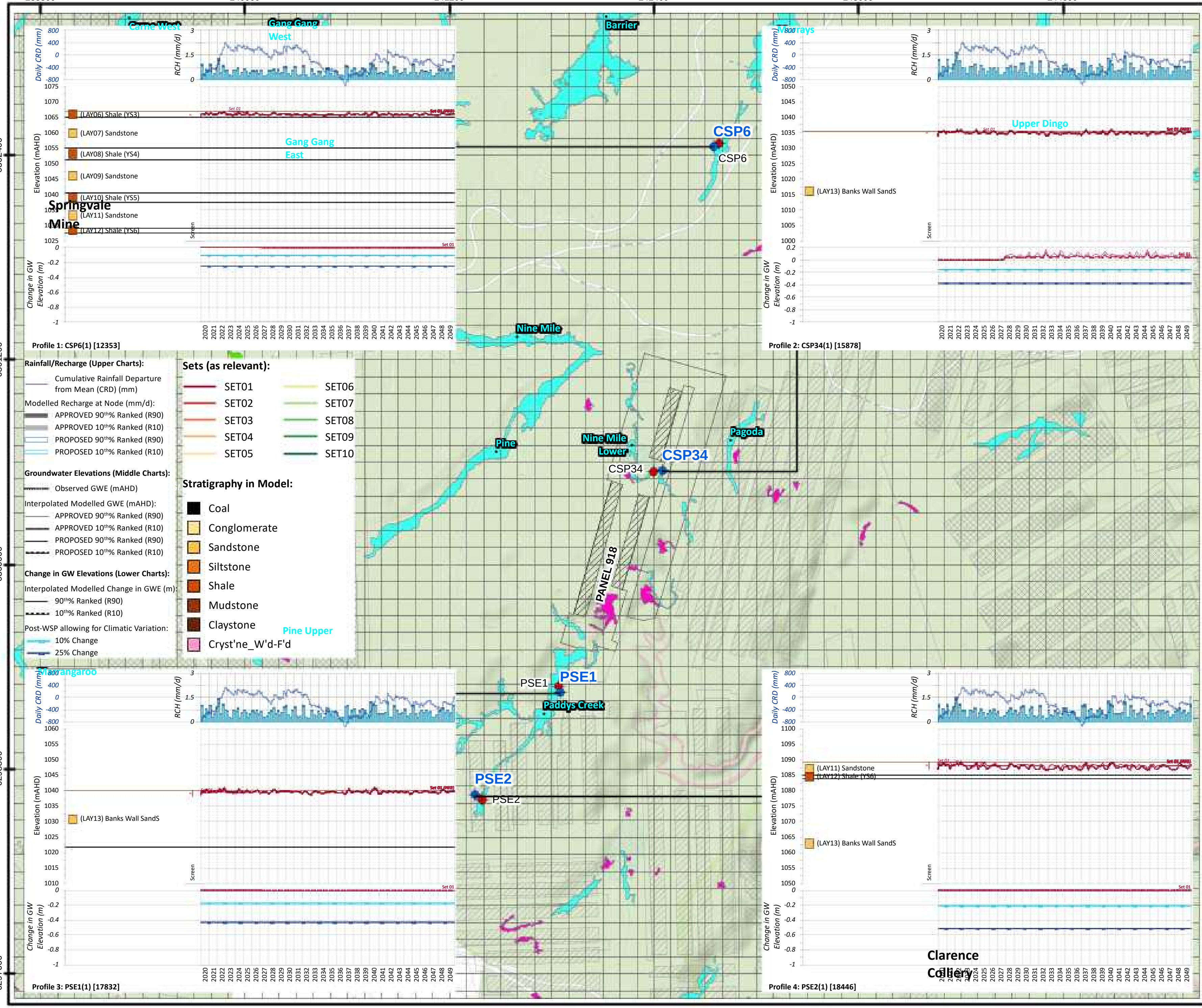

Legend:

- Groundwater Monitoring Locations

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Modelling:

- Model Grid
- Model Output Locations

Notes:
1) GWE: Groundwater Elevation.
2) 10% and 25% threshold calculated based on model output between 01/01/2011 and 31/12/2021.
3) CRD Trace dates from 01/01/2010 - 31/12/2049.

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevB	Date: 29-Jan-2026
Drawn By: DAW	Checked By: JRWB
Scale 1:30,000	

0 500 1,000
Meters

Coor. Sys. GDA 1994 MGA Zone 56

Groundwater Hydrographs (Prediction Period):

- CSP6
- CSP34
- PSE1
- PSE2

FIGURE: ES.3

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Reference: © Department of Customer Service 2020; Model Reference: 68229_R01RevA_PRO_02a_Excised_minus_68229_R01RevA_APR_03c_Excised_OUT_10TH_286.

Change in Groundwater/Surface Water Interaction

Groundwater contribution to surface water was extracted for various subcatchments in the vicinity of 918 Panel.

Model output (stochastic) indicates that the change to groundwater contribution to surface water ranges is negligible.

The modelled change to groundwater contribution to surface water is not significant, including evaluation of the change to duration of dry periods presented in the Surface Water Assessment (JBS&G, 2025c).

By way of example, output for subcatchment Node 751 (Paddys Creek Swamp) is presented in **Figure ES.4** and **Figure ES.5** presents the modelled change to groundwater contribution to surface water for that subcatchment. Output is presented in **Figure ES.5** for both the 10^{th}% and 90^{th}% contributions.

From **Figure ES.5**, there is an increase in groundwater contribution to surface water with respect to Paddys Creek Swamp in both the 10^{th}% and 90^{th}% modelled output. An increase in groundwater contribution to surface water occurs because there is a decline in the uppermost water table beneath local topographic ridgelines, which leads to additional groundwater being discharged to surface water.

Change to Mine Dewatering Rate

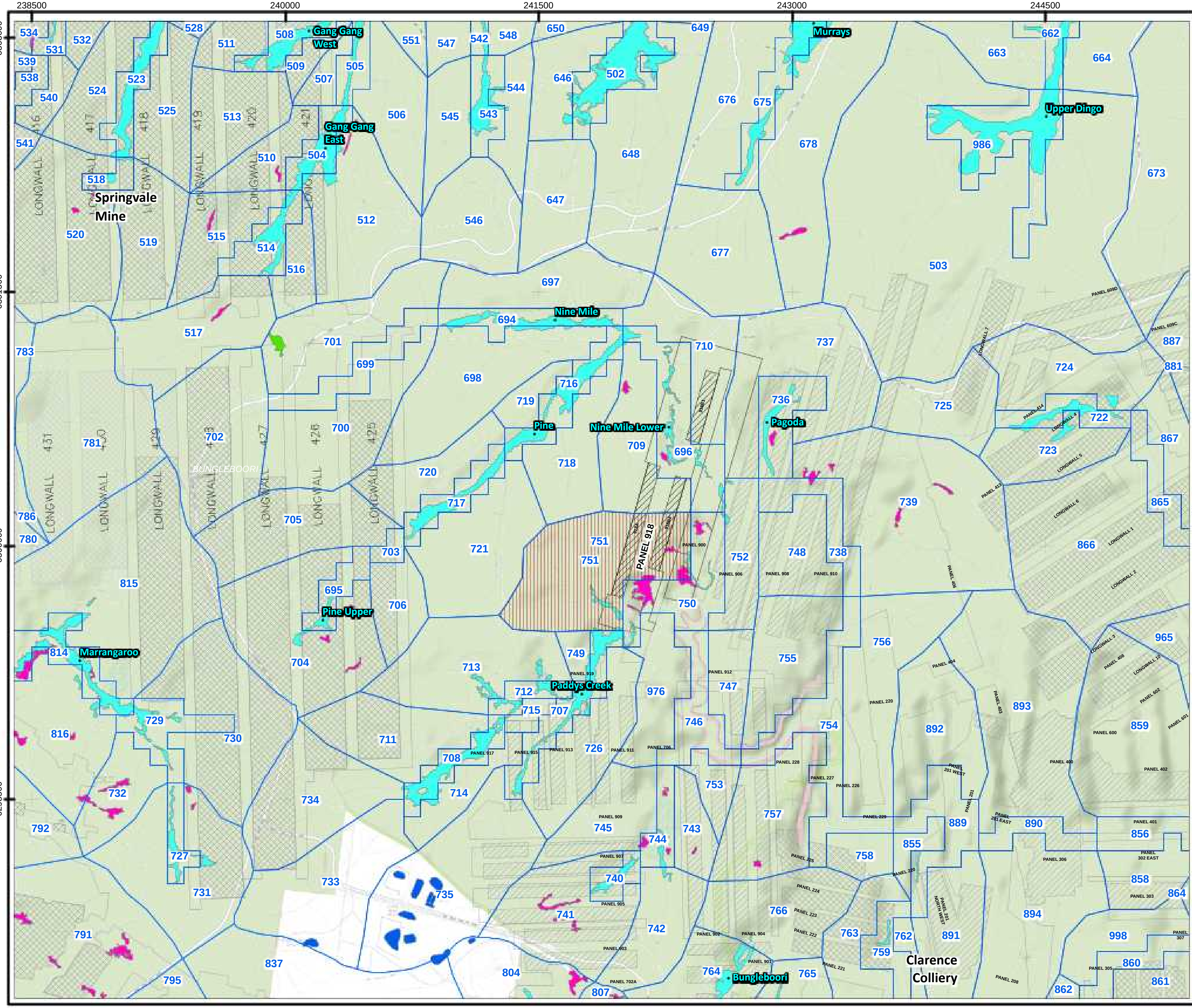
Modelling indicates that there is a negligible change (less than 10%) in modelled mine dewatering rate at Clarence due to implementation of the Extraction Plan for 918 Panel.

The modelled change is an increase of 0.9ML/d, which then declines to 0.2ML/d. The magnitude of increase is considered to be negligible.

The observed increase in mine dewatering rate for 908-910 Panel Area (double-sided lifting; Model Mining Method = 3) was an initial increase of 0.7ML/d, which then decline to near zero. This observation is consistent with that predicted for implementation of the Extraction Plan for 918 Panel.

Analysis indicates that currently held Water Access Licences (WALs) in the Sydney Basin West Groundwater Source continue to be sufficient, inclusive of indirect take from surface water, which, in accordance with Figure 7 of NSW DCCEEW (2022b), is assigned to the Sydney Basin West Groundwater Source.

The impact of the change in mine dewatering rate will also have an insignificant impact on the Site Water Balance and ‘above ground’ mine water management infrastructure, such as the Water Treatment Plant at Clarence Colliery and associated discharge via Clarence’s Environment Protection Licence (LDP002).



Legend:

Mining Methods:
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:
- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):
- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Modelling:
- Surface Water Catchments
- Selected Catchment

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 05-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:30,000	
0 0.5 1 km	
Coor. Sys. GDA 1994 MGA Zone 56	

Surface Catchments - Paddys Creek Upper (Node 751)

FIGURE: ES.4

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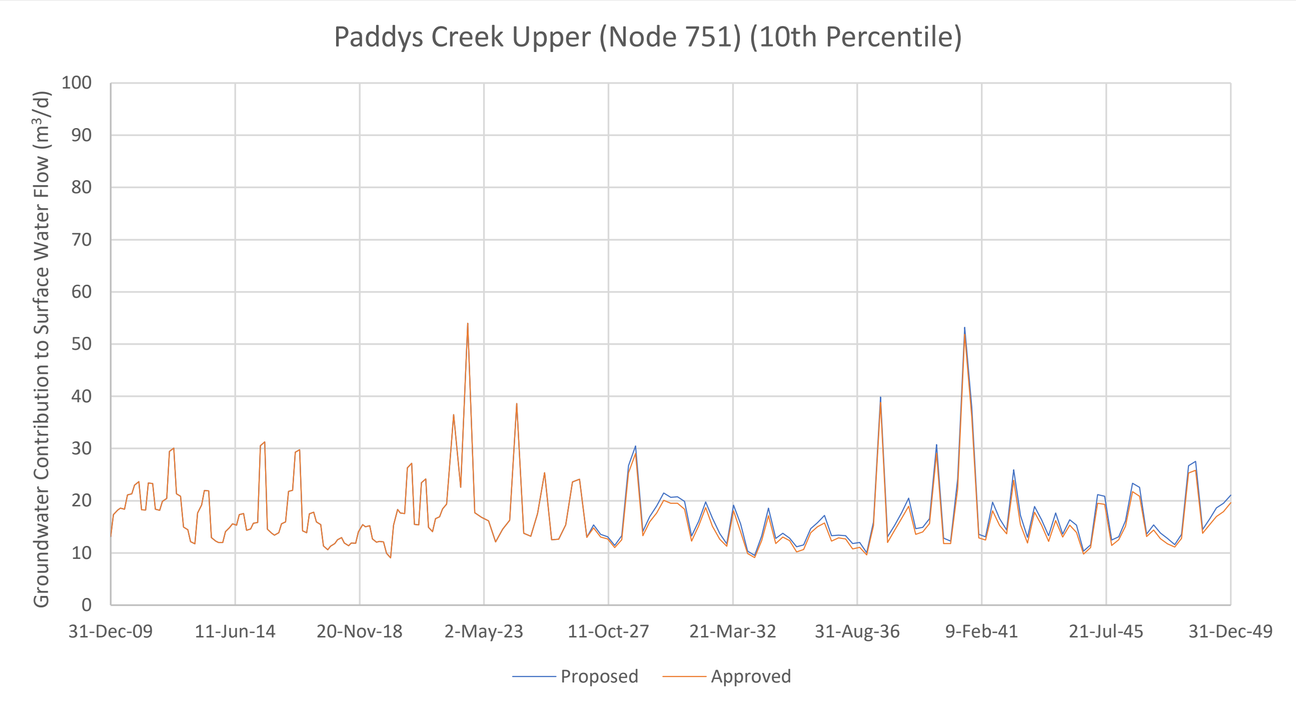

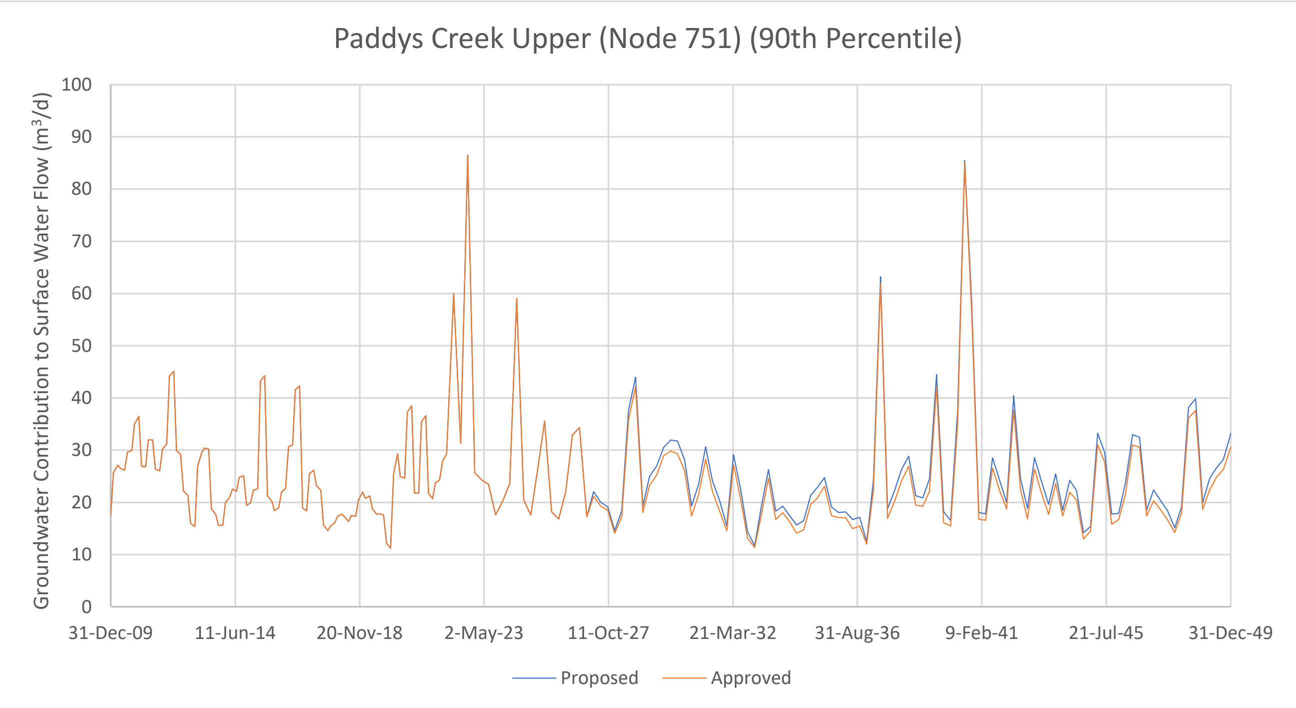

Figure ES.5: Modelled Groundwater Contribution to Surface Water – Prediction Simulation (Stochastic): Paddys Creek Upper (Node 751)

Limitations

This report has been prepared for use by the client who has commissioned the works in accordance with the Scope of Work provided by the Client only, and has been based in part on information obtained from the Client and other parties. The advice herein relates only to this Scope of Work and all results conclusions and recommendations made should be reviewed by a competent person with experience in environmental impact assessment, before being used for any other purpose.

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This report does not provide a complete assessment of the environmental status of the site, and it is limited to the scope defined herein. Should information become available regarding conditions at the site including previously unknown issues, JBS&G reserves the right to review the report in the context of the additional information.

This report, and environmental modelling associated therein, has been prepared to the standard typical of that undertaken by consultants in preparing an environmental impact assessment.

Glossary (Model Specific)

Approved Case – development (1st workings) and extraction (2nd workings, PPPE using a continuous miner and shortwall supports) of Panel 918 does not proceed.

CRD – Cumulative Rainfall Departure from Mean.

Closed Lineament – in a hydrogeological context, the lineament acts as a barrier to groundwater flow (typically, in the horizontal direction). In a hydrogeological context, both an ‘open’ and a ‘closed’ type lineament are infilled with another material and are not ‘physically open’ (not infilled, therefore ‘air’).

CTH DCCEEW – Department of Climate Change, Energy, the Environment and Water, Commonwealth of Australia

CTH IESC – Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development within the Department of Climate Change, Energy, the Environment and Water, Commonwealth of Australia.

Deterministic – ‘single’ prediction simulation (Proposed and Approved Case) based upon calibrated parameter values.

Development – “*The process of establishing areas of the mine for subsequent extraction. Mine development consists of regular bord and pillar panels mined as a series of roadway and cut-throughs to open up the mine*.” [Glossary of CTH IESC (2021)].

DRN – an abbreviation for Drain; is a MODFLOW boundary condition module that is used for mining cells, seepage faces and ephemeral surface watercourses. Originally developed in MODFLOW for agricultural drains. Flow is only one-way, out of the groundwater model.

Equivalent porous media – an assumption of MODFLOW that hydraulic properties within a cell are constant and representative of all detail within that cell through a bulk/single value.

Extraction – “*The process of mining whereby, once mine production panels have been established and blocked out during the development stage of the mine, they are then extracted using one of the mining systems for coal removal* .” [Glossary of CTH IESC (2021)].

FAO56 – an abbreviation for a standard method of calculating evapotranspiration based on the Penman-Monteith equation. The method is described in the Food and Agriculture Organisation of the United Nations Irrigation and Drainage Paper No. 56 (UN, 2006).

GENLINPRED – a PEST utility that calculates the relative parameter uncertainty variance reduction. It is similar to parameter identifiability (which examines each individual parameter in isolation) (Doherty and Hunt, 2009)); however, also takes into account the benefit of use of covariance matrices. Doherty (2015) explains that covariance matrices should be used whenever Pilot Points (‘spatial relatedness’) are used.

Goaf – a mine-subsidence related term describing post-roof collapse area in a mine (following total extraction, including longwall mining). Goafing affects the mined seam, coal is removed and void becomes filled with rubble, and several overlays geologic/hydrogeologic units.

GHB – an abbreviation for General Head Boundary; is a MODFLOW boundary condition module used to represent lateral regional flow as well as, in the case of this model, water storage in the State Mine Complex, located to the south of Springvale Mine. Flow can be into or out of the groundwater model through a GHB boundary condition, limited by an assigned conductance (the value of which is cell-size dependent).

Jacobian – a matrix filled with the sensitivity of each parameter to the observation dataset. Parameters can be added and removed from the Jacobian (‘delete columns’). Where a new parameter/s is to be added then a new, separate, small Jacobian can be created, and subsequently combined with the original, large Jacobian into a combined, large Jacobian. Observations can also be removed from the Jacobian (‘delete rows’), but if observations are to be added ('add rows'), then the combined, large Jacobian would have to be completely recalculated.

km – kilometres, where a kilometre is 1,000 metres.

Latin Hypercube Sampling – a mathematical technique, supported through a PEST utility, that generates thoroughly randomised samples of parameter values. Through use of this technique, the Calibration-Constrained Null Space Monte Carlo method of Doherty (2015) can be implemented using a practical number of simulations of Approved Case and Proposed Case (300).

ML/d – Megalitres per day, where a megalitre is 1,000,000 litres.

Model Mining Method – the groundwater model incorporates the varied and complex mining history in the Western Coalfields in respect to mining techniques, extraction ratios, goafing/non-goafing behaviour and subsidence outcomes. These have been categorised into Model Mining Methods.

MODFLOW-USG – groundwater modelling code of the United States Geological Survey (USGS); the Unstructured Grid variant (USGS, 2013), subsequently modified by GSI Environmental (2025).

NARCliM – New South Wales and Australian Capital Territory Regional Climate Modelling Project.

NSW DCCEEW – Department of Climate Change, Energy, the Environment and Water, New South Wales.

Open Lineament – in a hydrogeological context, the lineament does not act as a barrier to groundwater flow (typically, in the horizontal direction). In a hydrogeological context, both an 'open' and a 'closed' type lineament are infilled with another material and are not 'physically open' (not infilled, therefore 'air').

Panel and Pillar Partial Extraction (PPPE) – A new partial extraction technique to be deployed at Clarence Colliery. Implemented via continuous miners and shortwall supports, with extraction to around 60% of coal. Designed to be a 'low' subsidence mining method with limited goafing.

Parameter Uncertainty File – a text file that sets the 5th and 95th expected values of parameters to be included in prediction simulations incorporating predictive uncertainty.

Partial Extraction – a form of bord and pillar mining where a system of pillar panels is formed up during the development stage and then a limited percentage of the pillar coal is extracted on the retreat, to ensure the remaining pillars are still able to provide regional support to the overburden and restrict surface subsidence by minimising extraction widths, usually without inducing significant caving (CTH IESC, 2023b).

PEST – a parameter estimation and uncertainty analysis software platform (Watermark Numerical Computing, 2024), the theory behind which is presented in Doherty (2015); BEOPEST is an alternative version of PEST configured for distributed computing (used in this study to assist in calculation of the Jacobian matrix); PEST_HP was previously a commercial version of PEST, but is now public domain (Watermark Numerical Computing, 2025). PEST_HP was used for SVD-assisted calibration (inversion).

Pilot Points – Points in planar space (2D) that hold parameter data between which interpolation to the model grid is made.

PLPROC – a PEST utility (Parameter List Processor) that undertakes interpolation (via automated kriging) of Pilot Points.

PPCOV – a PEST utility that generates a covariance matrix (spatial relatedness, such that Pilot Points that are close to each other have similar values). Also has the ability to incorporate bearing and anisotropy.

Proposed Case – as per the Approved Case, however, includes development (1st workings) and extraction (2nd workings, PPPE using a continuous miner and shortwall supports) of 918 Panel.

Quadtree Refinement – A tree data structure in which each model grid cell is subdivided into four quadrants.

R10 – acronym to describe 10th percentile ranked model output.

R90 – acronym to describe 90th percentile ranked model output.

RCH – an abbreviation for Recharge; is a MODFLOW boundary condition module used to simulate the portion of rainfall that contributes to the groundwater system. This is applied using a specific flux distributed over the top of the model.

RIV – an abbreviation for River; is a MODFLOW boundary condition module used for perennial watercourses such as lakes and rivers. Flow can be into or out of the groundwater model through a RIV boundary condition.

Total Extraction – A term used in bord and pillar extraction where the intention is to extract the maximum percentage of the pillar coal formed up during development, in a safe and effective manner, with caving and goaf formation as part of the extraction mining process. Recovery rates within total extraction bord and pillar panels can reach 70% or greater but do not achieve the 95%-100% levels possible with longwall mining. The term can also be applied to longwall mining panels (CTH IECS, 2023b).

SAPSWBM – Springvale Angus Place Swamp Water Balance Model; a surface water model that uses the output of groundwater model to simulate expected change in catchment runoff.

SILO Climatic Dataset – a dataset maintained by the Queensland Department of Environment, Tourism, Science and Innovation (DETSI). The rainfall and evapotranspiration data of the SILO climatic dataset is used in this report.

Simulation0 – Proposed and Approved Case prediction model simulations (single runs) utilising parameter values, as calibrated. They are deterministic simulations.

SP – an abbreviation for Stress Period; a Stress Period is set in MODFLOW, usually months or quarters, where boundary conditions are constant for that period.

Stochastic – 'ensemble' of prediction simulations (Proposed and Approved Case) based upon 300 sets of randomised parameter values.

SVD – Singular Value Decomposition. A mathematical technique used to separate Calibration Solution Space (model parameters informed, at least partially from observation dataset) from Null Space (model parameters not informed by the observation dataset) and is fed by the Jacobian matrix.

TARGPEST3D – a custom-developed script that undertakes 3D interpolation of layer-by-layer MODFLOW groundwater elevation output to the reference point of a piezometer (whether that is a centre of a screen of a standpipe piezometer or the elevation of the sensor of a vibrating wire piezometer).

THPSS – Temperate Highland Peat Swamps on Sandstone.

TS – an abbreviation for Time Step; the number of time steps per Stress Period is set in MODFLOW, usually 4 or 5 during period of interest or usually 10 for quasi steady-state or early Stress Periods in a simulation. Model output is calculated at each time step, however, is only saved if requested.

TVM – an abbreviation for the Time-Varying Material; is a MODFLOW module that facilitates changes to hydraulic properties at specified Stress Period. Used in this report to model the subsidence-induced impact of mining, including a change in storage to represent mine void and effect of goafing.

USGS – United States Geological Survey, the authors of MODFLOW and MODFLOW-USG, which are industry-standard groundwater modelling codes

WAL – Water Access Licence

WEL – an abbreviation for Well; is a MODFLOW module that represents deep leakage from the base of the model (applied in this version of the model) as well as extraction from individual groundwater water supply works within the model (not applied in this version of the model, as they are minor to negligible in comparison to groundwater extraction due to mine dewatering).

wy – water year. A water year runs from 1 July through to 30 June of the following year.

ZonBudUSG – The MODFLOW-USG cell-by-cell budget file extraction tool published by the USGS.

1. Introduction

This chapter presents the context, objective and layout of the report.

1.1 Extraction Plan Context

The Clarence underground coal mine (Clarence Colliery), owned and operated by Clarence Colliery Pty Ltd (Clarence), currently operates as a bord and pillar partial extraction mine, extracting coal from the Katoomba coal seam using continuous miners.

Clarence Colliery has operated since 1979 utilising a range of extraction methods that result in either partial extraction (i.e. limited extraction ratio from the coal seam) and/or total extraction (i.e. higher extraction ratio from the coal seam).

To provide clarity around the differences between partial and total extraction, the following definitions are provided in CTH IESC (2023b):

"***Partial Extraction*** *is a form of bord and pillar mining where a system of pillar panels is formed up during the development stage and then a limited percentage of the pillar coal is extracted on the retreat. This is to ensure the remaining pillars can still provide regional support to the overburden and restrict surface subsidence, usually without inducing any significant caving, by minimising extraction widths. Recovery rates using this system vary considerably but are typically in the range of 45%–65%, depending on local geotechnical conditions and surface subsidence constraints.*"

"***Total extraction*** *is a form of bord and pillar extraction where the intention is to extract the maximum percentage of the pillar coal formed up during development, in a safe and effective manner, with caving and goaf formation as an inherent and essential part of the extraction mining process. Recovery rates within total extraction bord and pillar panels can reach 70% or greater but do not achieve the 95%–100% rates possible with longwall mining. (The term total extraction can also be applied to longwall mining panels.)*"

Clarence Colliery holding includes Consolidated Coal Lease (CCL) CCL 705 and Mining Leases (ML) ML 1353, ML 1354, ML 1583 and ML 1721 (Clarence, 2025a).

Clarence has approval to extract up to 3 million tonnes of coal per annum which is sold both domestically and exported internationally. Clarence proposes to extend mining to the northwest, into 918 Panel.

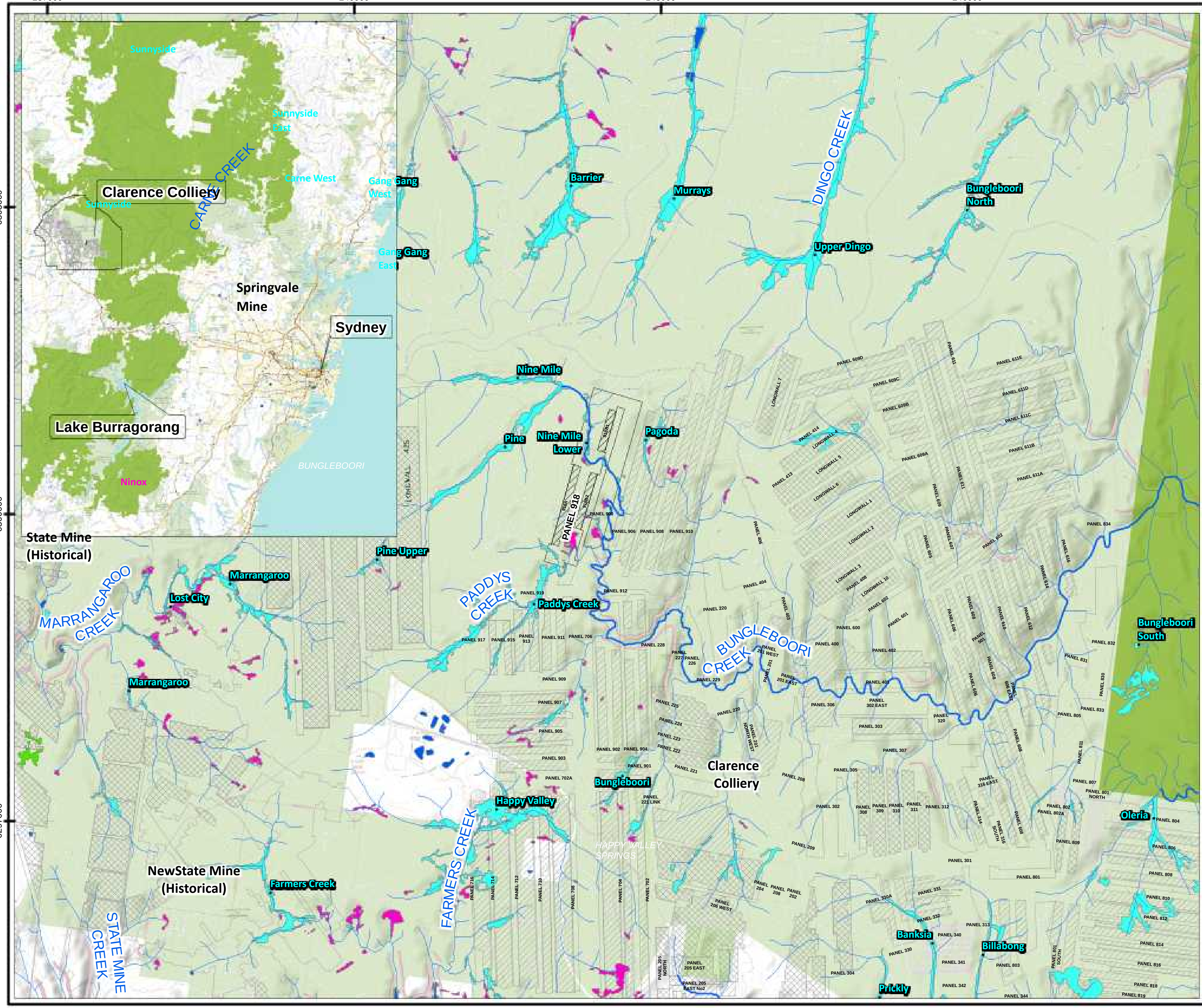
Mining of the 918 Panel, which is covered by the Extraction Plan, will be undertaken using panel and pillar partial extraction (PPPE) employing continuous miners and shortwall supports. The PPPE method constitutes a partial extraction mining method, as it restricts the proportion of coal extracted to around 60%. This type of mining has been designed to be a 'low' subsidence mining method with limited goafing, suitable for the in-situ geotechnical conditions at Clarence Colliery.

Figure 1-1a presents an overview of the region, including the location of Clarence Colliery and **Figure 1-1b** presents the regional topography.

Figure 1-1c presents the floor elevation of the Lithgow Seam, as well as the modelled steady-state groundwater elevation and at current time. Details of the numerical groundwater model is presented in **Section 4**.

From **Figure 1-1c**, the Lithgow Seam dips to the northeast. From **Figure 1-1c**, steady-state groundwater elevation in the Lithgow Seam is influenced by the topographic ridgeline (northwest to southwest) above Angus Place Colliery, Springvale Mine and Clarence Colliery, as well as outcropping of the seam into the Wolgan Valley. Flow direction is to the north, northeast and east.

From **Figure 1-1c**, at current time, Springvale Mine is active and Angus Place Colliery is being maintained dewatered state (Care and Maintenance; 800 and 805mAHD). From **Figure 1-1c**, the historical workings (State Mine Complex), located to the south of Springvale Mine are currently filled with water (895mAHD).



Legend:

Greater Blue Moutains World Heritage Area

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Modelling:

- Active Model Domain

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Hydrology:

- Waterbody
- Watercourse

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R02RevC	Date: 09-Feb-2026
Drawn By: DAW	Checked By: JRWB
Scale 1:50,000	

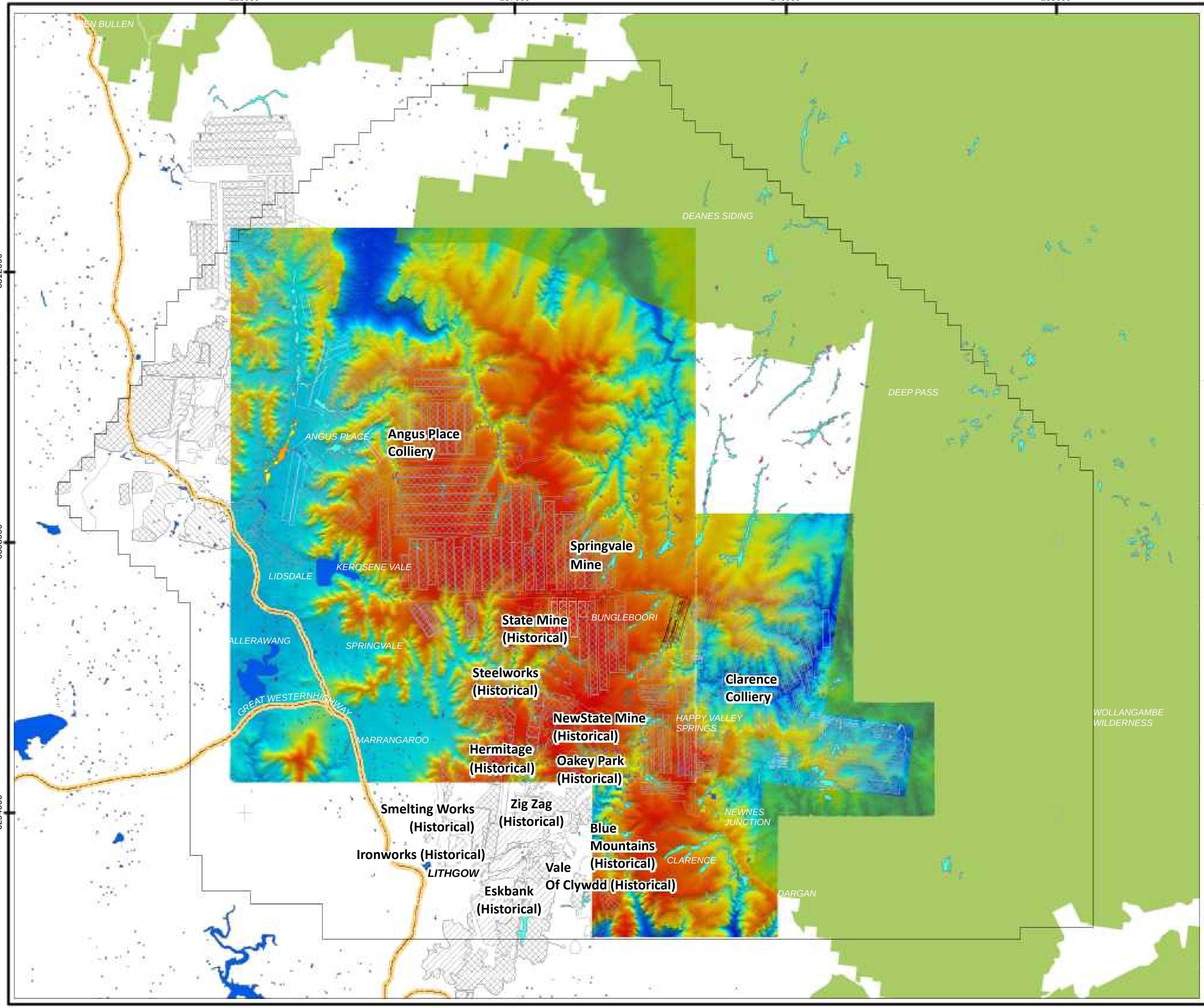
0 1 2
km

Coor. Sys. GDA 1994 MGA Zone 56

Overview of Region - Locality

FIGURE: 1.1a

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R02RevC_D001a_OverviewOfRegion.mxd
Reference: © Department of Customer Service 2020



Legend:

- Highway
- Greater Blue Moutains World Heritage Area

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Modelling:

- Active Model Domain

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Swamps by MU Name (RPS, 2018):

- 53 Mountain Hollow Grassy Fen (EEC)
- Typha orientalis Wetland

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevB	Date: 23-Jan-2026
Drawn By: DAW	Checked By: JRWB
Scale 1:170,000	

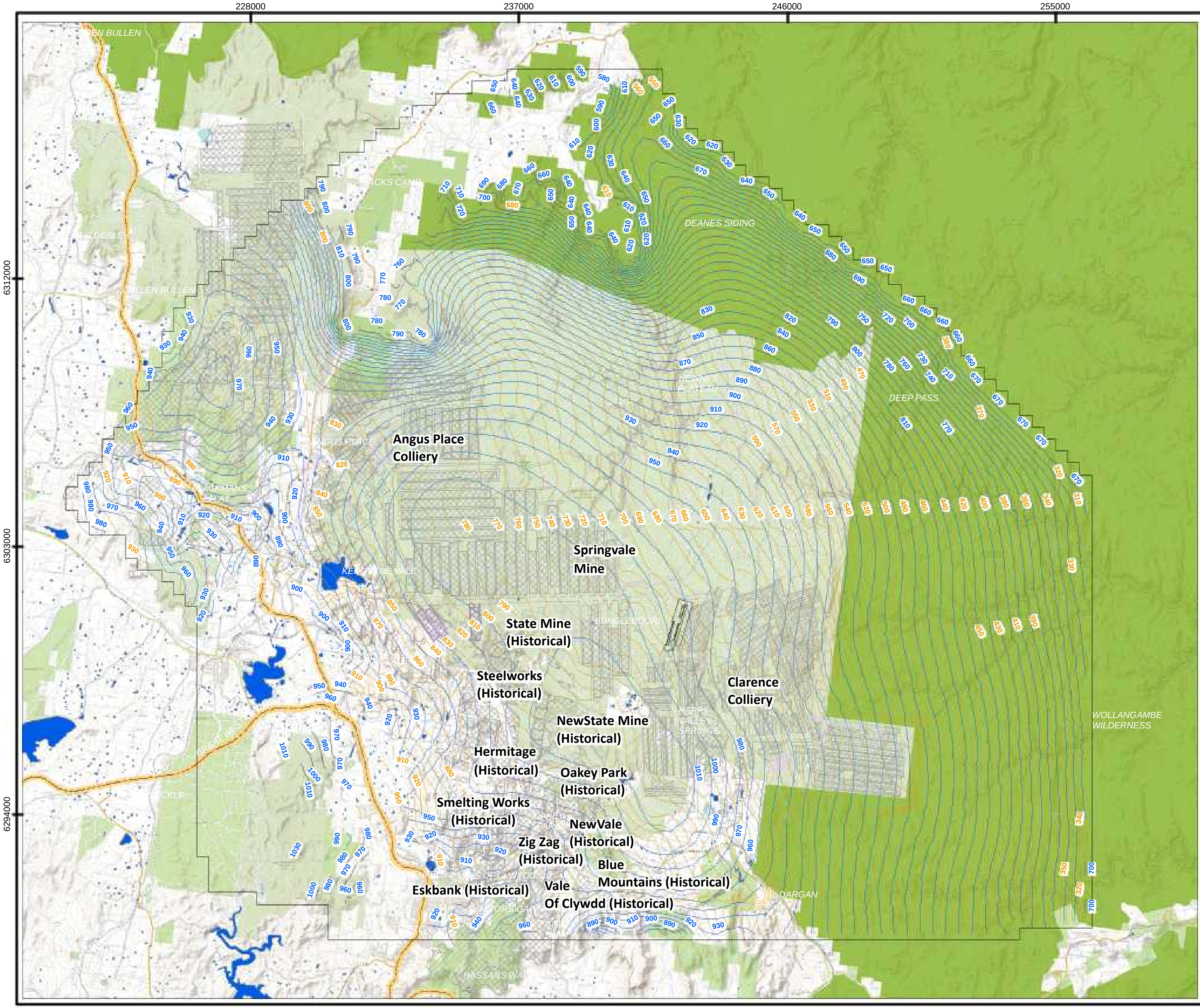
0 3 6
km

Coor. Sys. GDA 1994 MGA Zone 56

Overview Of Region - Regional Topography

FIGURE: 1.1b

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D001b_OverviewOfRegion.mxd
Reference: © Department of Customer Service 2020; Regional DEM provided by Centennial in 2016.



Legend:

- Highway
- Greater Blue Moutains World Heritage Area

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Modelling:

- Active Model Domain
- Groundwater Elevation (mAHD)[1]
- Lithgow Seam Elevation (Layer 24)[2]

Notes: 1) Groundwater elevation is extracted from the model; 2) Bottom elevation extracted from model geometry.

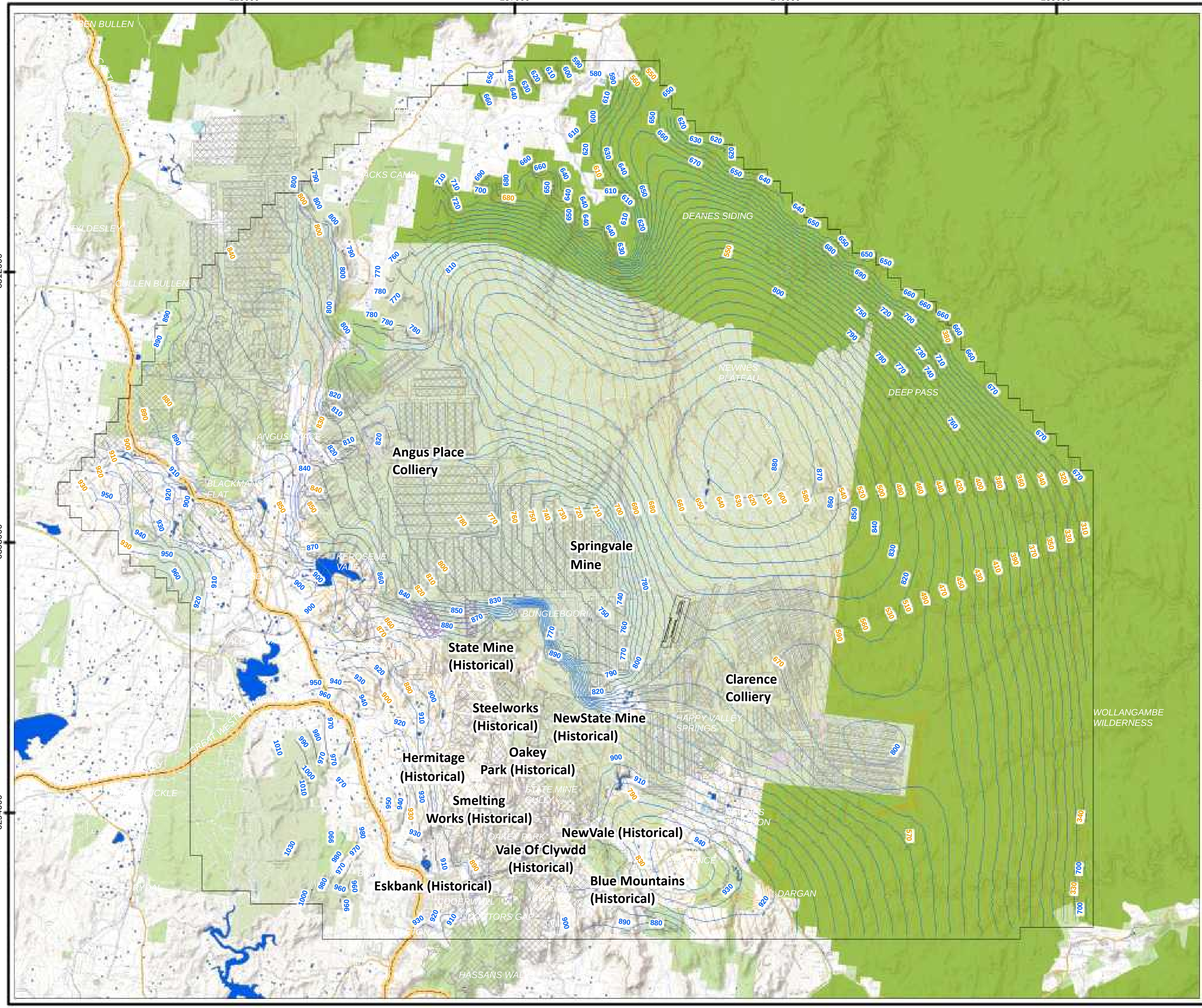
JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevB	Date: 23-Jan-2026
Drawn By: DAW	Checked By: JRWB
Scale 1:170,000	
0 3 6 km	
Coor. Sys. GDA 1994 MGA Zone 56	

Overview Of Region
- Regional Groundwater Elevation
(Lithgow Seam, Layer 24)
Steady-State (SP001)

FIGURE: 1.1c-1

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D001c-1_OverviewOfRegion_L24_SP001.mxd
Reference: © Department of Customer Service 2020; Model Reference: 68229_R01RevA_PRO_02a.



Legend:

- Highway
- Greater Blue Moutains World Heritage Area

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Modelling:

- Active Model Domain
- Groundwater Elevation (mAHD)[1]
- Lithgow Seam Elevation (Layer 24)[2]

Notes: 1) Groundwater elevation is extracted from the model; 2) Bottom elevation extracted from model geometry.

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevB	Date: 23-Jan-2026
Drawn By: DAW	Checked By: JRWB
Scale 1:170,000	
0 3 6 km	
Coor. Sys. GDA 1994 MGA Zone 56	

Overview Of Region - Regional Groundwater Elevation (Lithgow Seam, Layer 24) September 2025 (SP144)

FIGURE: 1.1c-2

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D001c-2_OverviewOfRegion_L24_SP144.mxd

Reference: © Department of Customer Service 2020; Model Reference: 68229_R01RevA_APR_03c.

Figure 1-1d presents the floor elevation of the Katoomba Seam, as well as the modelled steady-state groundwater elevation and at current time.

From **Figure 1-1d**, the Katoomba Seam does not exist above Angus Place and Springvale Mine, but the dip of the Katoomba Seam is similar to that of the Lithgow Seam.

From **Figure 1-1d**, the steady-state groundwater elevation is also influenced by the topographic ridgeline (northwest to southwest) above Angus Place Colliery, Springvale Mine and Clarence Colliery, and flow direction is to the northeast and east.

From **Figure 1-1d**, at current time, Clarence Colliery is active and includes several underground water storage areas. From **Figure 1-1d**, the influence of Clarence Colliery (at depth) extends under the Greater Blue Mountains World Heritage Area but this does not affect the perched and shallow aquifers (at surface) and there is no decline in groundwater contribution to surface water due to operations at Clarence.

From **Figure 1-1d**, at current time, there is interaction between Springvale Mine (Lithgow Seam) and Clarence Colliery (Katoomba Seam), insofar as overlap of their respective 'cones of depression'.

1.2 Extraction Plan Overview

Clarence currently operates under Consolidated Consent DA 504-00, as modified. The last modification to consent was Modification 10 and this was approved in May 2024, as DA 504-00-Mod-10 (NSW DPH&I, 2024).

Mining of 918 Panel, which is covered by the Extraction Plan, will involve:

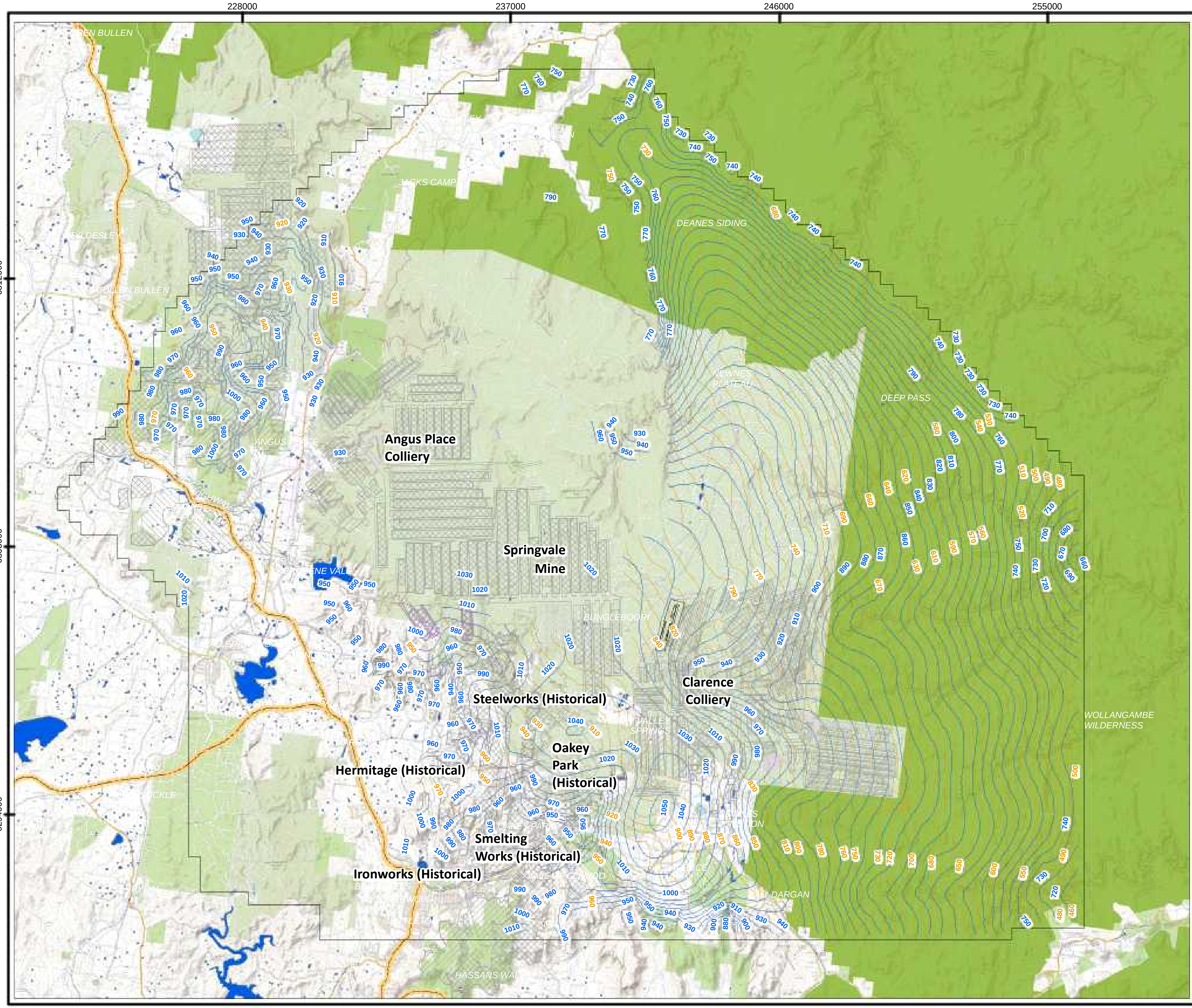
- Development (1st workings) of 918 Panel
- Extraction (2nd workings, PPPE using a continuous miner and shortwall supports) of 918 Panel.
  - Void width (unsupported span) is 75m for Sub Panel 918A and Sub Panel 918B2 (southern, two sub panels) and is 83m for Sub Panel 918B1 (northern, single sub panel).

918 Panel is located at the northwestern edge of the Clarence Colliery holdings, adjacent to 906 Panel.

Figure 1-2 presents the location of 918 Panel at Clarence and **Appendix A** presents the mining schedule.

For the purpose of modelling, it was assumed that development (1st workings) commenced on 1 January 2025 (Start of SP142) and is completed by 30 June 2027 (End of SP151). Extraction (2nd workings) was assumed to commence on 1 October 2026 (Start of SP149) and be completed by 31 December 2027 (End of SP153).

It is emphasised that assumptions presented below with respect to the numerical groundwater model are relevant to its intent, which is to calculate modelled change to groundwater elevation, change to groundwater contribution to surface water and change to mine dewatering rate. As such, some assumptions may be more conservative, such as timing of various project elements, than that presented in the Extraction Plan for 918 Panel.



Legend:

- Highway
- Greater Blue Moutains World Heritage Area

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Modelling:

- Active Model Domain
- Groundwater Elevation (mAHD)[1]
- Katoomba Elevation (Layer 18)[2]

Notes: 1) Groundwater elevation is extracted from the model; 2) Bottom elevation extracted from model geometry.

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevB	Date: 23-Jan-2026
Drawn By: DAW	Checked By: JRWB
Scale 1:170,000	

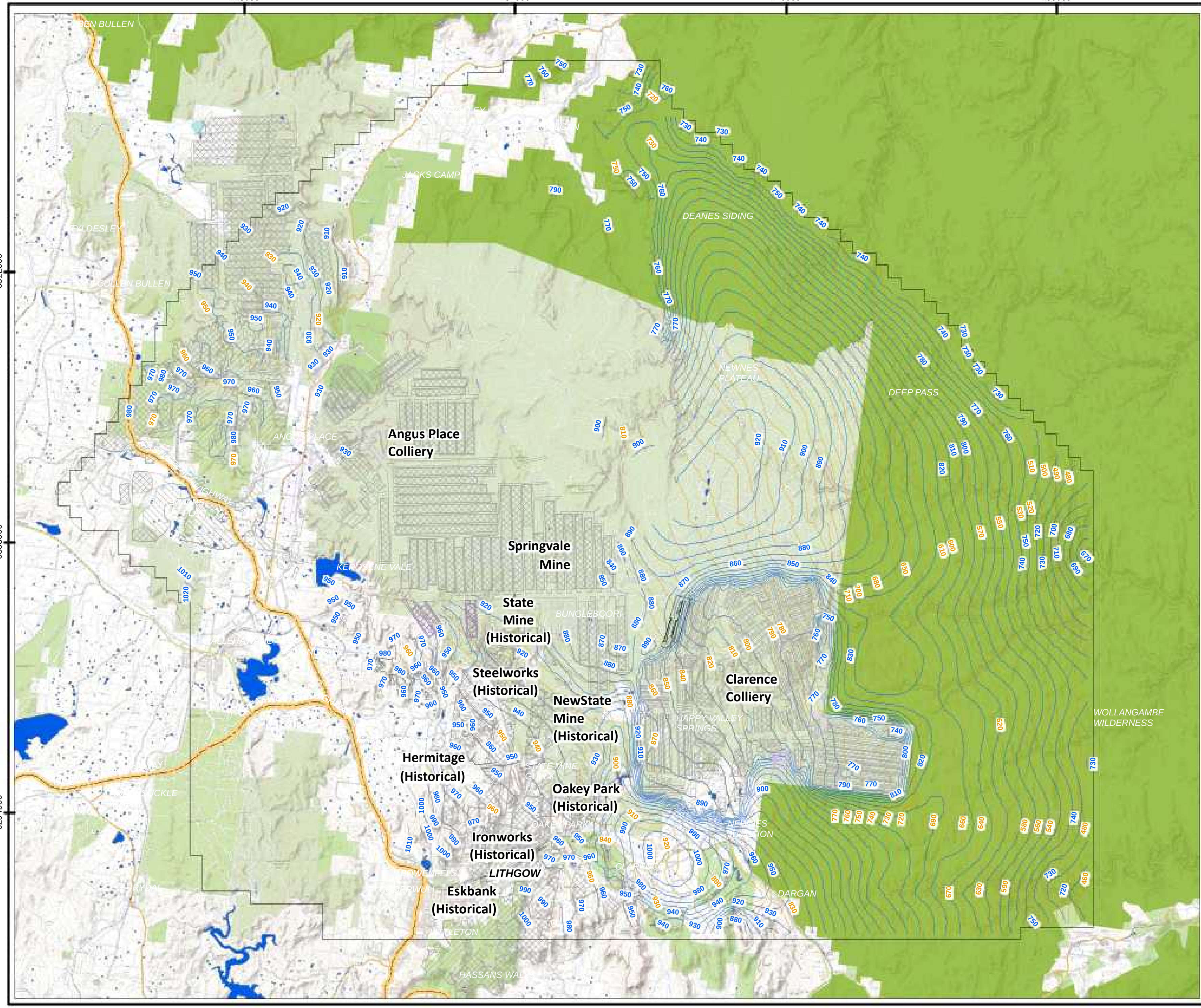
0 3 6
km

Coor. Sys. GDA 1994 MGA Zone 56

Overview Of Region
- Regional Groundwater Elevation (Katoomba Seam, Layer 18) Steady-State (SP001)

FIGURE: 1.1d-1

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D001d-1_OverviewOfRegion_L18_SP001.mxd
Reference: © Department of Customer Service 2020; Model Reference: 68229_R01RevA_PRO_02a.



Legend:

- Highway
- Greater Blue Moutains World Heritage Area

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Modelling:

- Active Model Domain
- Groundwater Elevation (mAHD)[1]
- Katoomba Elevation (Layer 18)[2]

Notes: 1) Groundwater elevation is extracted from the model; 2) Bottom elevation extracted from model geometry.

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevB	Date: 23-Jan-2026
Drawn By: DAW	Checked By: JRWB

Scale 1:170,000

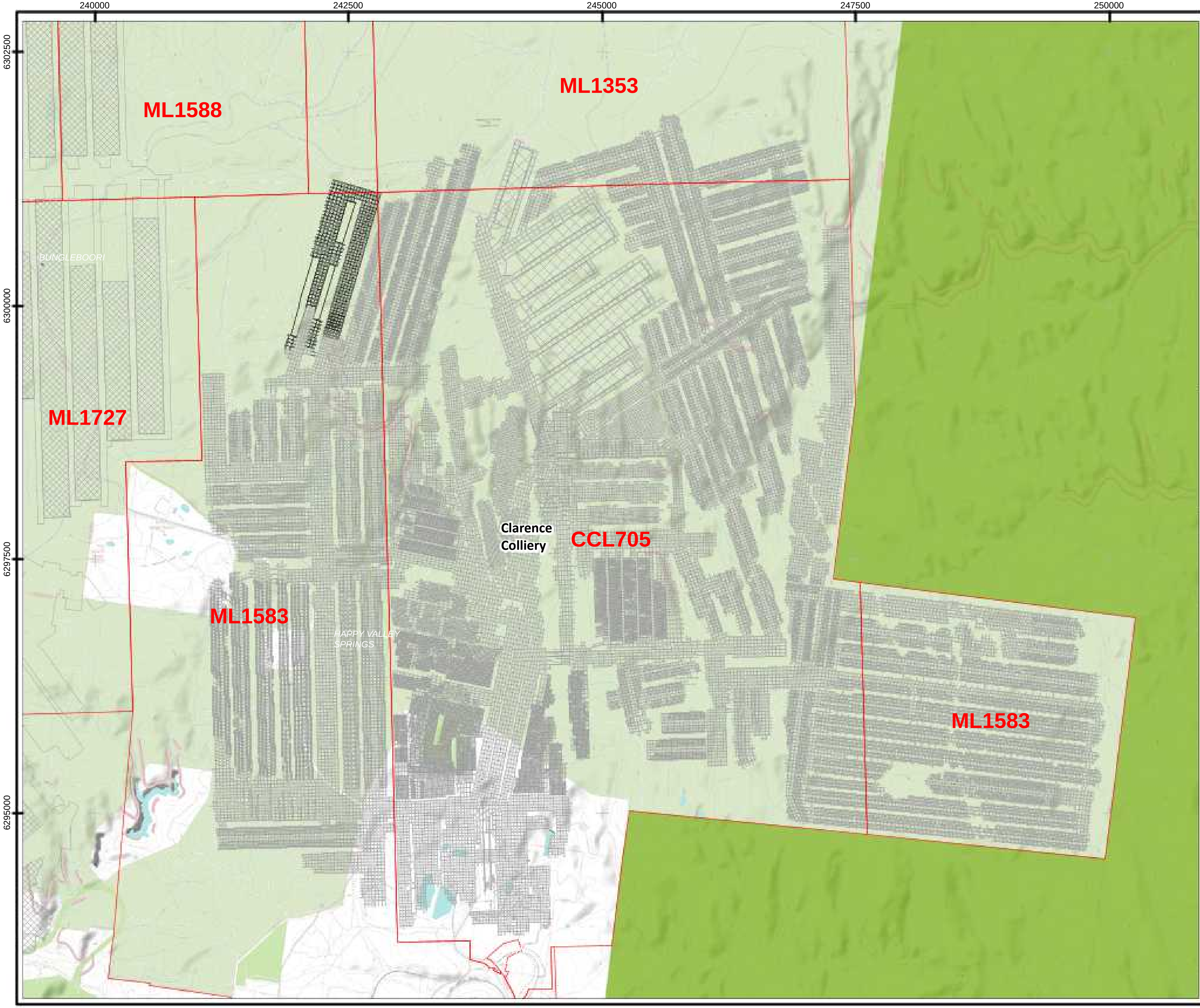
0 3 6
km

Coor. Sys. GDA 1994 MGA Zone 56

Overview Of Region
- Regional Groundwater Elevation (Katoomba Seam, Layer 18) September 2025 (SP144)

FIGURE: 1.1d-2

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D001d-2_OverviewOfRegion_L18_SP144.mxd
Reference: © Department of Customer Service 2020; Model Reference: 68229_R01RevA_APR_03c.



Legend:

Greater Blue Moutains World Heritage Area

Mining:

Mining Lease
Clarence Existing Mine Layout
Clarence Existing Total Extraction
Clarence Proposed Mine Layout

JBS&G

Job No: 68229

Client: Clarence Colliery Pty Ltd

Version: R01RevA	Date: 03-Nov-2025
Drawn By: DAW	Checked By: JRWB

Scale 1:50,000

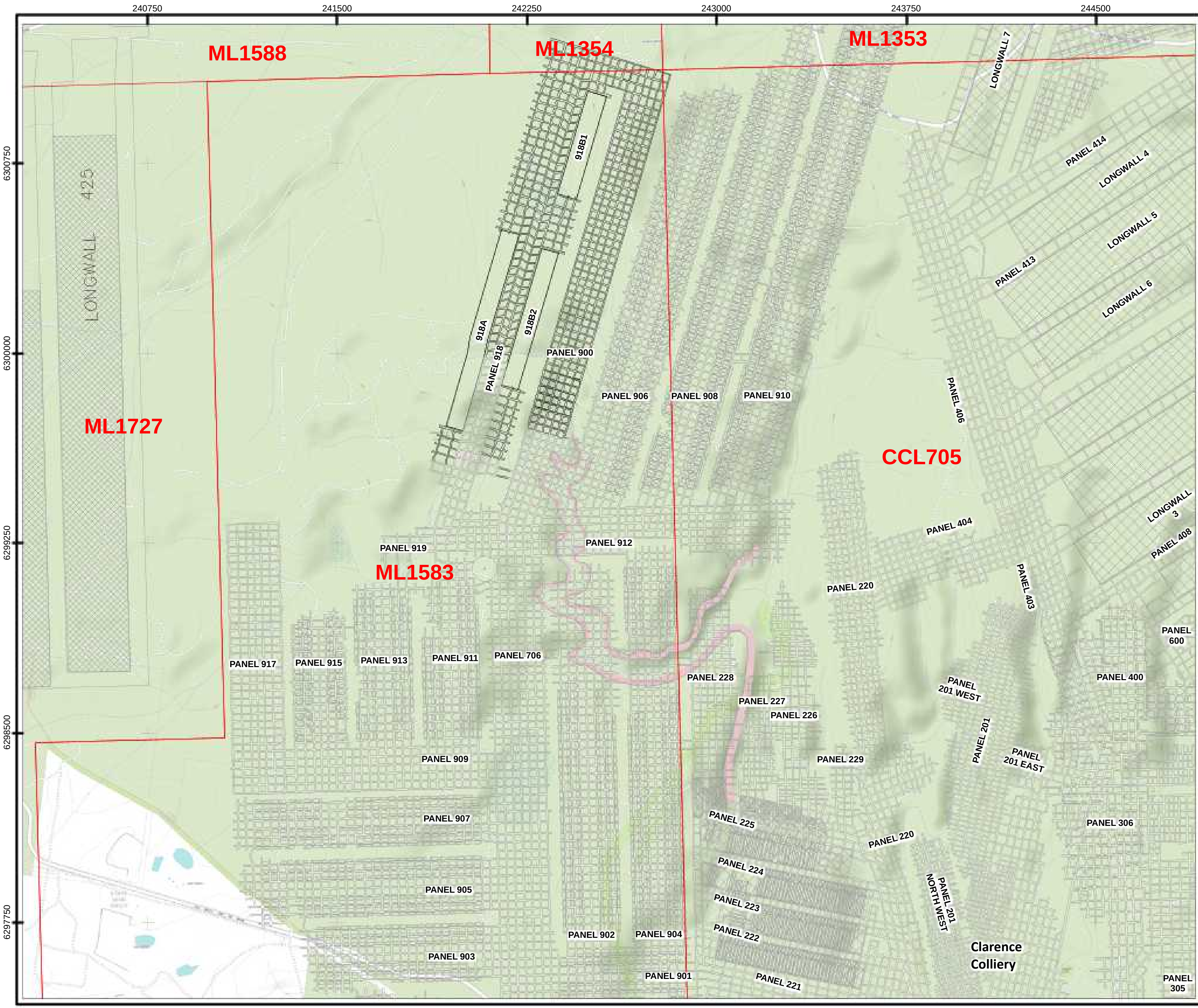
0 1 2
km

Coor. Sys. GDA 1994 MGA Zone 56

Detailed Mine Plan - Clarence Colliery

FIGURE: 1.2a

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D031a_DetailedMinePlan.mxd
Reference: © Department of Customer Service 2020



Legend:

Mining:

- Mining Lease
- Clarence Existing Mine Layout
- Clarence Existing Total Extraction
- Clarence Proposed Mine Layout

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 04-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:20,000	
0 250 500 Meters	
Coor. Sys. GDA 1994 MGA Zone 56	

Detailed Mine Plan - 900 Area

FIGURE: 1.2b

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D031b_DetailedMinePlan_900Area.mxd

Reference: © Department of Customer Service 2020

Model Mining Method used in this report are defined as follows, and illustrated in **Figure 1-3**.

- Model Mining Method 1 – development (non-goafing)
- Model Mining Method 2 – extraction (partial extraction, principally single-sided pillar lifting; non-goafing)
- Model Mining Method 3 – extraction (panel and pillar partial extraction (PPPE) and double-sided pillar lifting with extraction ratios between 55% and 65%; limited goafing)
- Model Mining Method 4 – extraction (total pillar extraction with extraction ratios greater than 80%; full goafing)
- Model Mining Method 5 – extraction (longwall extraction, with extraction ratios greater than 85%; full goafing)
- Model Mining Method 6 – extraction (backfilling of open cut)

1.3 Purpose and Objective of the Report

This technical report has been prepared to present an evaluation of groundwater impact of implementation of the Extraction Plan for 918 Panel.

The report presents the groundwater context (environmental setting and conceptual hydrogeological model), describes the numerical groundwater model that has been developed for the Western Coalfields over many years, including recent updates, as well as output from the model (including stochastic simulations).

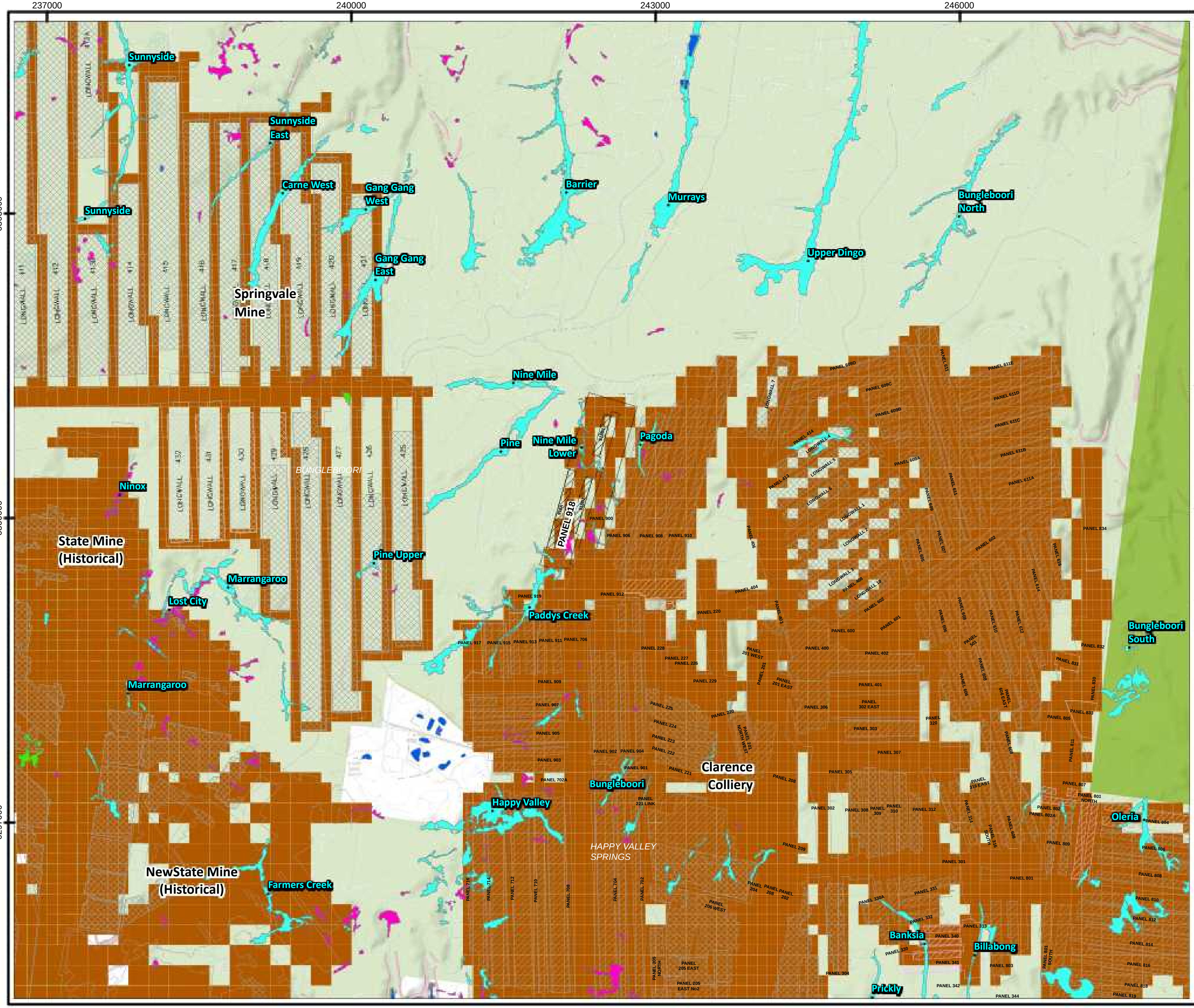
The report presents an assessment of impact of changes to groundwater elevation, groundwater contribution to surface water and mine dewatering rate at Clarence Colliery and comparison to relevant guidelines, policies and regulation.

The report also presents the expected change to licensing, management, monitoring and mitigation.

1.4 Layout of the Report

The layout of this report is as follows:

- Chapter 1 – presents the objective of this report and the layout of the report
- Chapter 2 – presents governing legislation, regulations, environmental planning instruments, guidance documents and policies relevant to the assessment
- Chapter 3 – presents a summary of the hydrogeological and environmental setting
- Chapter 4 – presents detailed discussion of the groundwater model, calibration of the model and model simulations (deterministic and stochastic)
- Chapter 5 – presents an impact assessment of the outcomes of model simulations
- Chapter 6 – presents the implication of model findings on licensing, management and monitoring due to the implementation of the Extraction Plan
- Chapter 7 – presents a conclusion from the analysis
- Chapter 8 – discusses limitations of the current version of the model and approach
- Chapter 9 – discusses recommendations for improving future versions of the model
- Chapter 10 – presents relevant references.



Legend:

Greater Blue Moutains World Heritage Area

Mining Methods:
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:
- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):
- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Model Mine Method:
- #1 - 1st (development; non-goafing)
- #2 - 2nd (partial extraction, single-sided lift; non-goafing)
- #3 - 2nd (PPPE and double-sided lifting; limited goafing)
- #4 - 2nd (total pillar extraction; limited to full goafing)
- #5 - 2nd (longwall extraction; full goafing)
- #6 - 2nd (backfilling of open cut; n/a)
- #7 - 2nd (grouting; n/a)
- #8 - 2nd (open cut; n/a)

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 04-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:50,000	

0 1 2 km

Coor. Sys. GDA 1994 MGA Zone 56

Model Mine Method - Development

FIGURE: 1.3a

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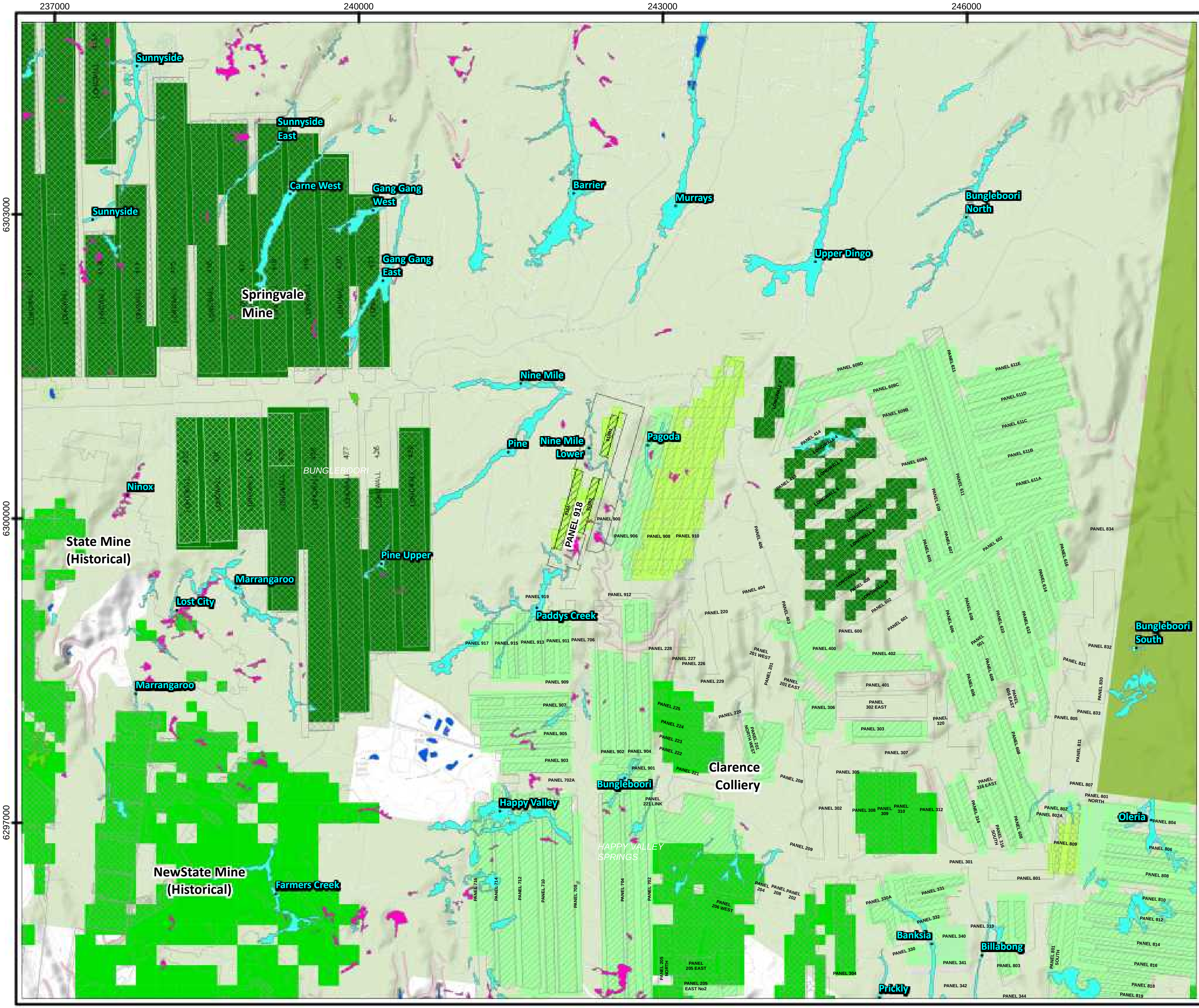


Legend:

Greater Blue Moutains World Heritage Area

Mining Methods:
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:
- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):
- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Model Mine Method:
- #1 - 1st (development; non-goafing)
- #2 - 2nd (partial extraction, single-sided lift; non-goafing)
- #3 - 2nd (PPPE and double-sided lifting; limited goafing)
- #4 - 2nd (total pillar extraction; limited to full goafing)
- #5 - 2nd (longwall extraction; full goafing)
- #6 - 2nd (backfilling of open cut; n/a)
- #7 - 2nd (grouting; n/a)
- #8 - 2nd (open cut; n/a)

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 08-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:50,000	

0 1 2
km

Coor. Sys. GDA 1994 MGA Zone 56

Model Mine Method - Extraction

FIGURE: 1.3b

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D032b_MMM_2nd.mxd
Reference: © Department of Customer Service 2020

2. Legislation, Regulation and Policy

This chapter presents the governing legislation, regulations, statutory instruments, guidance documents and policies relevant to the assessment.

2.1 Commonwealth Legislation

2.1.1 Environment Protection and Biodiversity Conservation Act 1999 (Cth)

The *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) is the main Commonwealth environmental legislation that provides the legal framework to protect and manage Matters of National Environmental Significance (MNES). Those matters include:

- World Heritage Areas
- National Heritage Places
- Wetlands of International Importance (listed under the Ramsar Convention)
- Listed Threatened Species and Ecological Communities
- Listed Migratory Species (protected under international agreements)
- Commonwealth Marine Areas
- Great Barrier Reef Marine Park
- Nuclear Actions (including uranium mines)
- Water Resources (that relate to coal seam gas development and large coal mining development).

The following matters were listed as endangered ecological communities (EECs) under the *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) (via a Protected Matters Search (https://pmst.environment.gov.au/) and are understood to be present and/or in the vicinity of Clarence Colliery:

- Temperate Highland Peat Swamps on Sandstone (THPSS) (may occur)
- Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion (may occur)
- Natural Temperate Grassland of the South Eastern Highlands (may occur)
- White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (may occur).

None of the endangered ecological communities are listed as being 'likely to occur'. Notwithstanding, swamps on the Newnes Plateau are mapped as THPSS (Clarence, 2025bc).

Review of the expected impact of the Extraction Plan on THPSS is presented in **Section 5.2.1.1**.

Water resources are also an MNES and the impact of the Extraction Plan is assessed in this report against the *Significant Impact Guidelines for Coal Seam Gas and Large Coal Mining Developments – Impacts on Water Resources*, which is published by the Commonwealth Department of Climate Change, Energy, the Environment and Water (CTH DCCEEW, 2022). These guidelines are presented in the following section.

It is noted that a Surface Water Assessment has also been prepared, as an accompaniment to this report (JBS&G, 2025c). That report presents the hydrological context for modelled changes in groundwater contribution to surface water presented in this report. As THPSS are groundwater dependent ecosystems, the modelled change to groundwater contribution to surface (this report) is a primary consideration.

2.2 Commonwealth Guidelines and Policy

2.2.1 Significant Impact Guidelines

CTH DCCEEW (2022) presents guidance on the assessment of impact on hydrological characteristics by an action under the *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) by coal seam gas and large coal mining developments with respect to water resources.

Section 4.2 of CTH DCCEEW (2022) states that consideration of these guidelines is required when an action (underground coal mining; however, it is noted that this report pertains to an Extraction Plan (for 918 Panel) within an existing consent (Consolidated Consent DA 504-00-Mod-10), and is not a modification to consent for Clarence Colliery) may result in a direct or indirect change to:

- the hydrology of a water resource
- the water quality of a water resource.

With respect to water quantity, Section 4.3 of CTH DCCEEW (2022) states the following:

"*A significant impact on the hydrological characteristics of a water resource may occur where there are, as a result of the action:*

- *changes in the water quantity, including the timing of variations in water quantity*
- *changes in the integrity of hydrological or hydrogeological connections, including structural damage (for example, large scale subsidence)*
- *changes in the area or extent of a water resource.*

where these changes are of sufficient scale or intensity as to significantly reduce the current or future utility of the water resource for third party users, including environmental and other public benefit outcomes.

The following aspects may need to be considered when assessing changes in hydrological characteristics:

- *flow regimes (volume, timing, duration and frequency of surface water flows)*
- *recharge rates to groundwater*
- *aquifer pressure or pressure relationships between aquifers*
- *groundwater table and potentiometric surface levels*
- *groundwater-surface water interactions*
- *river-floodplain connectivity*
- *inter-aquifer connectivity*
- *coastal processes including changes to sediment movement or accretion, water circulation patterns, permanent alterations in tidal patterns, or substantial changes to water flows or water quality in estuaries.*

Unless the proponent can establish otherwise, the department will assume that there is a connection between surface water and groundwater. The proponent should also consider the potential impact of drilling, excavating or hydraulic stimulation on connectivity between surface water and groundwater, and whether this is likely to impact on the hydrology of the system beyond the life of the proposed action.".

[Section 4.3 of CTH DCCEEW (2022)]

Furthermore, Section 4.3.1 of CTH DCCEEW (2022) notes:

"…

A proponent may obtain entitlements to extract water under a state water plan which has been prepared in accordance with the requirements of the NWI [National Water Initiative].

If a proponent can demonstrate that all of the water used by a proposed action is authorised through such entitlements, the action is less likely to require a referral due to significant impacts on the hydrological characteristics of a water resource.

However, there may be situations where the water used by the proponent in a particular location at a given time exceeds the environmentally sustainable level of extraction for that location, or for another hydrologically connected location. In these cases, the action is more likely to have a significant impact on a water resource.

… .".

[Section 4.3.1 of CTH DCCEEW (2022)]

The implication of Section 4.3.1 of CTH DCCEEW (2022) is that groundwater extracted for the purpose of depressurisation, ahead of development and extraction of coal, is a licensable take, and is obtained within the 'sustainable yield' of that water resource (aquifer) via the Water Sharing Plans (insofar as their setting of Long-Term Average Annual Extraction Limit (LTAAEL) with respect to each water source) established through the *Water Management Act* 2000 (NSW). Notwithstanding, at Clarence Colliery and other mining operations in the Western Coalfields, a negligible portion of groundwater inflow to underground workings is consumed for operational purposes, with, essentially all of it, being returned to the environment following treatment.

With respect to surface water, there is not an equivalent to 'sustainable yield', and take with respect to a surface water source is also licensed. That take will be assigned in accordance with NSW DCCEEW (2022b).

Assessment of the impact of the Extraction Plan on water resources (quantity) is presented in **Section 5.2.2.1**.

With respect to water quality, Section 4.4 of CTH DCCEEW (2022) states the following:

"*A significant impact on a water resource may occur where, as a result of the action:*

- *there is a risk that the ability to achieve relevant local or regional water quality objectives would be materially compromised, and as a result the action:*
    - *creates risks to human or animal health or to the condition of the natural environment as a result of the change in water quality*
    - *substantially reduces the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality*
    - *causes persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment*
    - *seriously affects the habitat or lifecycle of a native species dependent on a water resource, or*
    - *causes the establishment of an invasive species (or the spread of an existing invasive species) that is harmful to the ecosystem function of the water resource, or*
- *there is a significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives), or*
- *high quality water is released into an ecosystem which is adapted to a lower quality of water.*

For water-dependent ecosystems, a significant impact is likely if the predicted change in water quality is greater than that required for 'moderately to slightly disturbed' systems as described in the relevant local or regional water quality objectives (typically the 80% to 95% ecosystem protection guideline values listed in the Australian Water Quality Guidelines). Note that other thresholds may apply where changes in water quality may impact on other matters of national environmental significance, such as threatened species or ecological communities.

…".

[Section 4.4 of CTH DCCEEW (2022)]

Assessment of the impact of the Extraction Plan on water resources (quality) is presented in **Section 5.2.2.1**.

2.2.2 Information Guideline Explanatory Notes

There are several Explanatory Notes issued by CTH IESC.

- Assessing groundwater-dependent ecosystems (CTH IESC, 2019a)
- Deriving site-specific guideline values for physico-chemical parameters and toxicants (CTH IESC, 2019b)
- Characterisation and modelling of geological fault zones (CTH IESC, 2021)
- Uncertainty analysis for groundwater modelling (CTH IESC, 2023a)
- Subsidence associated with underground coal mining (CTH IESC, 2023b)
- Using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact assessment (CTH IESC, 2024)

The Explanatory Notes informed the approach to development of the conceptual hydrogeological model and the numerical groundwater model presented further below.

An assessment of the Extraction Plan against the Explanatory Notes is presented in **Section 5.2.2.2**.

2.2.3 Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018

Management of water quality in Australia is undertaken using the National Water Quality Management Framework (CTH WQA, 2025). That framework comprises the following steps:

- "*Examine current understanding*
- *Define community values and management goals*
- *Define relevant indicators*
- *Determine water/sediment quality guidelines values*
- *Define draft water/sediment quality objectives*
- *Assess if draft water/sediment quality objectives are met*
- *Consider additional indicators or refine water/sediment quality objectives*
- *Consider alternative management strategies*
- *Assess if water/sediment quality objectives are achievable*
- *Implement agreed management strategy.*"

[https://www.waterquality.gov.au/anz-guidelines/framework]

Typical community values include:

- "*aquatic ecosystems — the health or integrity of the waterway's ecosystem(s)*
- *cultural and spiritual values — water is particularly important for indigenous peoples*
- *drinking water — water is suitable for human consumption*
- *industrial water — water is suitable for use by industry, for example mining, manufacturing, cooling and electricity generation*

- *primary industries — water is suitable for irrigation, livestock drinking water, aquaculture and human consumers of aquatic foods*
- *recreational water and aesthetics — recreation can be undertaken without risk of sickness or disease or loss of aesthetic appeal.*"

[https://www.waterquality.gov.au/anz-guidelines/resources/key-concepts/community-values]

The National Water Quality Management Framework also helped inform the NSW approach. The selected water quality (surface water) and river flow (surface water) objectives for Clarence Colliery and the Extraction Plan for 918 Panel are presented in **Section 2.4.1**. Those objectives are relevant to both the CTH approach and the NSW approach.

As noted by CTH WQA (https://www.waterquality.gov.au/anz-guidelines/guideline-values), site-specific guideline values should be used in preference to default guideline values and for Clarence, these are documented in Clarence (2026).

As JBS&G understands it, these values were developed in accordance with CTH WQA (2024), insofar comparison to a reference to a control site. Further detail on the development of site-specific guideline values and an evaluation of consistency with CTH IESC (2019b) is presented in Clarence (2026).

An assessment against the water quality objectives (NSW) is presented in **Section 5.2.4.1.**

2.2.4 Australian Drinking Water Guidelines 6 – 2011

The guidelines are published by the National Health and Medical Research Council of the Australian Government (CTH NHMRC, 2022) and are:

"*…intended to provide a framework for good management of drinking water supplies that, if implemented, will assure safety at point of use. The Guidelines have been developed after consideration of the best available scientific evidence. They are designed to provide an authoritative reference on what defines safe, good quality water, how it can be achieved and how it can be assured. They are concerned both with safety from a health point of view and with aesthetic quality.*

The Guidelines are not mandatory standards; however, they provide a basis for determining the quality of water to be supplied to consumers in all parts of Australia. These determinations need to consider the diverse array of regional or local factors, and take into account economic, political and cultural issues, including customer expectations and willingness and ability to pay.

The Guidelines are intended for use by the Australian community and all agencies with responsibilities associated with the supply of drinking water, including catchment and water resource managers, drinking water suppliers, water regulators and health authorities."

[Page 2 of CTH NHMRC (2022)]

918 Panel does not lie within the contributing catchment to Lake Burragorang (Warragamba Dam), the primary drinking water supply dam for the Sydney metropolitan area. 918 Panel is also not within the contributing catchment to Farmers Creek Dam (Dam #2), which is a local water supply dam of Lithgow City Council.

Notwithstanding, an assessment of the change to water quality due to implementation of the Extraction Plan for 918 Panel was undertaken because there may be incidental take from surface water by recreational users (hiking). This is relevant to the Groundwater Assessment through groundwater/surface water interaction.

An assessment of the Extraction Plan against the Australian Drinking Water Guidelines is presented in **Section 5.2.2.3**.

2.3 NSW Legislation

2.3.1 Environmental Planning and Assessment Act 1979

Extraction of 918 Panel is administered under DA 504-00 (State Significant Development (SSD)). DA 504-00 has been modified eight times, with DA 504-00-Mod-10, approved on 17 May 2024, being the current version of the Consolidated Consent (NSW DPH&I, 2024).

In accordance with Schedule 3, Condition 2 Extraction Plan, Clarence Colliery is required to prepare an Extraction Plan for all second workings (extraction) not covered by an existing approved Subsidence Management Plan, to the satisfaction of the Secretary.

Schedule 3, Condition 5 presents the Water Resources Impact Assessment Criteria from NSW DPH&I (2024):

"*The Applicant must ensure that the development does not result in any:*

a) significant inflows to mine workings;

b) reduction in pumping yield in private-owned groundwater bores;

c) reduction in surface flows and ground baseflow to upload swamps (Newnes Plateau Shrub Swamps) and wetlands; and

d) reduction in surface flows and groundwater baseflow to waterbodies including Marrangaroo Creek, Farmers Creek, Dargans Creek, Wolgan River, Dumbano Creek, Bungleboori Creek, and Wollangambee River (excluding reduction in flows associated with the proposed water transfer scheme),

to the satisfaction of the Planning Secretary."

[Schedule 3 Condition 5 of NSW DPH&I (2024)]

An assessment of the Extraction Plan against the Water Resources Impact Assessment Criteria of DA 504-00-Mod-10 is presented in **Section 5.2.3.1**.

2.3.2 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act* 1997 (NSW) is administered by the NSW Environment Protection Authority (NSW EPA), which is an agency of NSW DCCEEW.

Relevant features of this legislation include:

- protection of the environment policies (PEPs)
- integrated environment protection licensing
- regulation of scheduled and non-scheduled activities.

The NSW EPA is the regulatory authority for scheduled activities (activities declared under Schedule 1 of the *Protection of the Environment Operations Act* 1997 (NSW)). The NSW EPA is also the regulatory authority for non-scheduled activities, where activities are undertaken by a public authority.

Clarence Colliery has been granted an EPL for mining of coal and associated works (EPL 726). The EPL covers the mining operation and surface water facilities at Clarence Colliery. The provisions of EPL 726 prescribe water quality and volumetric discharge limits of various surface water pollutants to designated Licensed Discharge Points (LDPs).

It is noted that LDP002 discharges into the Wollangambe River, which is a declared Wild River under the *National Parks and Wildlife Act* 1974 (NSW).

The limits presented in **Table 2-1** do not apply to LDP003 and LDP004 when the five consecutive day total rainfall exceeds 56mm (refer to L2.5 of EPL 726). The total volume discharged from LDP002 may exceed 25000kL/day on any day where greater than 10mm of rainfall is recorded at the premises, for that day.

Table 2-1: Licensed Discharge Point Conditions - Current (EPL 726)

Discharge Point[1]	LDP002, LDP003, LDP004
Function	Discharge and monitoring point
Limit of discharge (kL/d)	25000 for LDP002
Oil & Grease (mg/L)	10
pH	6-8.5
TSS (mg/L)	30
Conductivity (µS/cm)	n/a
Arsenic (dissolved) (mg/L)	0.013
Boron (mg/L)	0.1
Cadmium (dissolved) (mg/L)	0.0002
Chloride (mg/L)	25
Cobalt (dissolved) (mg/L)	0.0025
Copper (dissolved) (mg/L)	0.0014
Filterable iron (mg/L)	0.3
Fluoride (mg/L)	1
Lead (dissolved) (mg/L)	0.0034
Lithium (dissolved) (mg/L)	0.100
Manganese (dissolved) (mg/L)	0.5
Mercury (dissolved) (mg/L)	0.00006
Nickel (dissolved) (mg/L)	0.011
Nitrogen (total) (mg/L)	0.25
Phosphorus (total) (mg/L)	0.02
Selenium (total) (mg/L)	0.005
Silver (dissolved) (mg/L)	0.00005
Sulfate (mg/L)	250
Zinc (dissolved) (mg/L)	0.008

Notes: 1) 100% concentration limit.

2.3.3 Water Management Act 2000

The *Water Management Act* 2000 (NSW) presents the framework for sustainable and integrated water management in NSW and its objectives are as follows:

- *"to apply the principles of ecologically sustainable development, and*
- *to protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity and their water quality, and*
- *to recognise and foster the significant social and economic benefits to the State that result from the sustainable and efficient use of water, including:*
    - *benefits to the environment, and*

- *benefits to urban communities, agriculture, fisheries, industry and recreation, and*
- *benefits to culture and heritage, and*
- *benefits to the Aboriginal people in relation to their spiritual, social, customary and economic use of land and water,*

- *to recognise the role of the community, as a partner with government, in resolving issues relating to the management of water sources,*
- *to provide for the orderly, efficient and equitable sharing of water from water sources,*
- *to integrate the management of water sources with the management of other aspects of the environment, including the land, its soil, its native vegetation and its native fauna,*
- *to encourage the sharing of responsibility for the sustainable and efficient use of water between the Government and water users,*
- *to encourage best practice in the management and use of water."*

[Chapter 1, Section 3 of the *Water Management Act* 2000 (NSW)]

The primary instruments applied in NSW to achieve these objectives are Water Sharing Plans.

Water Sharing Plans

Water Sharing Plans provide the basis for equitable sharing of surface water and groundwater between water users, including the environment, and are regulations under the *Water Management Act* 2000 (NSW).

All of NSW is covered by Water Sharing Plans. If an activity leads to a take from a groundwater or surface water source covered by a Water Sharing Plan (excluding Basic Landholder Rights), then an approval and/or licence is required.

In general, the *Water Management Act* 2000 (NSW) requires:

- a water access licence to take water
- a water supply works approval to construct a work
- a water use approval to use the water.

Figure 2-1 presents the boundaries of groundwater sources within the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources* 2023 (NSW).

From **Figure 2-1**, Clarence Colliery is located within the boundary of the Sydney Basin West Groundwater Source underlain by the Lachlan Fold Belt Greater Metropolitan Groundwater Source.

Table 2-2 presents a summary of various water share classes in Sydney Basin West Groundwater Source and Lachlan Fold Belt Metropolitan Region Groundwater Source of the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources* 2023 (NSW).

Table 2-2: Summary of Long Term Average Annual Extraction Limits of the Sydney Basin West Groundwater Source and the Lachlan Fold Belt Metropolitan Region Groundwater Source (ML/wy)

Source	LTTAAEL (ML/wy)
Sydney Basin West Groundwater Source	36045 ML/wy
Lachlan Fold Belt Greater Metropolitan Groundwater Source	133949 ML/wy

Transfer trading of water access licences is made possible under Section 71M of the *Water Management Act* 2000 (NSW).

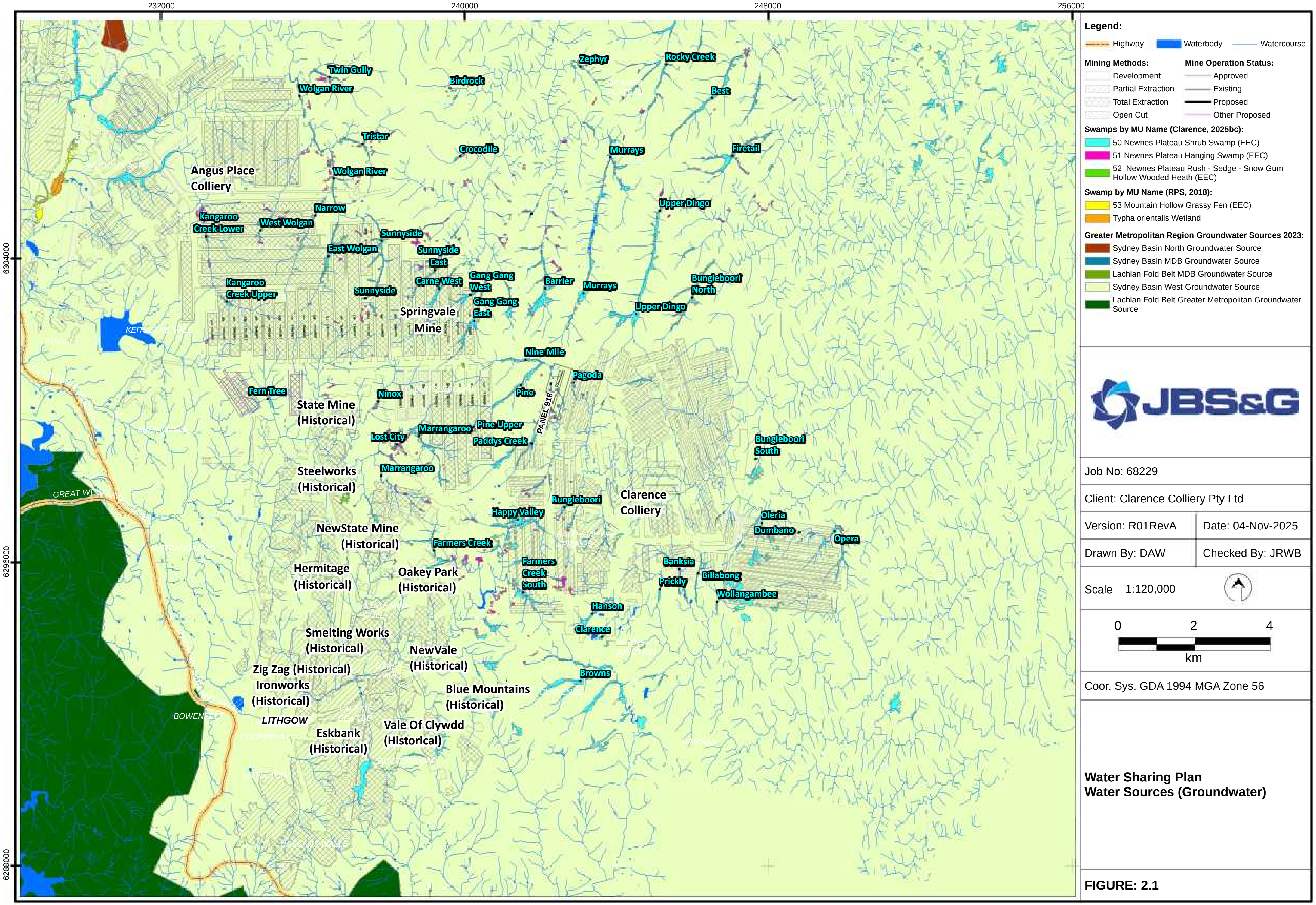
A summary of the transfer trading of water access licences in the Sydney Basin West Groundwater Source of the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources* 2023 (NSW) is presented in

Table 2-3**.** It is noted that during the presented period the available water determination (AWD) was 1.0ML per share.

Table 2-3: Summary of Trading in the Sydney Basin West Groundwater Source

WAL	Category	Transferred	Share (Units or ML)	Price Paid '$ per Unit'
30148	Aquifer	06/02/2013	15	$0.07
36354	Aquifer	17/06/2014	20	$0.00
24406	Aquifer	28/08/2014	3	$0.00
24418	Aquifer	26/09/2014	18	$0.00
24417	Aquifer	17/10/2014	15	$0.00
24431	Aquifer	05/12/2014	14	$0.00
24365	Aquifer	23/04/2015	19	$0.00
36485	Aquifer	05/01/2016	120	$0.00
24439	Aquifer	06/03/2017	25	$0.00
30970	Aquifer	16/05/2017	49	$0.00
30134	Aquifer	06/06/2017	16.5	$0.00
24445	Aquifer	30/06/2017	5	$0.00
24363	Aquifer	16/04/2018	18	$0.00
35522	Aquifer	19/06/2018	20	$0.00
24444	Aquifer	20/09/2018	10	$0.00
24410	Aquifer	09/04/2019	8	$0.00
24412	Aquifer	24/06/2019	4	$0.00
24394	Aquifer	16/10/2019	4	$0.00
30148	Aquifer	17/12/2019	15	$1,000.00
27447	Aquifer	17/12/2019	18	$944.44
24414	Aquifer	18/05/2020	30	$0.00
36443	Aquifer	05/06/2020	585	$0.00
24444	Aquifer	30/06/2020	10	$0.00
24431	Aquifer	19/08/2020	14	$0.00
24443	Aquifer	30/12/2020	1	$0.00
24357	Aquifer	04/05/2021	10	$0.00
24357	Aquifer	04/05/2021	10	$0.00
24363	Aquifer	21/09/2021	18	$0.00
24363	Aquifer	03/12/2021	18	$55,555.56
27447	Aquifer	14/03/2022	18	$0.00
27449	Aquifer	11/04/2022	38	$0.00
27449	Aquifer	11/04/2022	38	$0.00
35674	Aquifer	24/05/2022	40	$0.00
35674	Aquifer	24/05/2022	40	$0.00
24402	Aquifer	02/08/2022	19	$2,200.00
24421	Aquifer	05/09/2022	12	$0.00

WAL	Category	Transferred	Share (Units or ML)	Price Paid '$ per Unit'
24428	Aquifer	06/01/2023	6	$0.00
24421	Aquifer	07/09/2023	12	$1,000.00



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Reference: © NSW Department of Planning and Environment (2023).

A summary of the trading of water access licences in the Lachlan Fold Belt Greater Metropolitan Groundwater Source of the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Water Sources* 2023 (NSW) is presented in **Table 2-4**. It is noted that during the presented period, the available water determination (AWD) was 1.0ML per share.

Table 2-4: Summary of Trading in the Lachlan Fold Belt Greater Metropolitan Groundwater Source

WAL	Category	Transferred	Share (Units or ML)	Price Paid '$ per Unit'
24648	Aquifer	02/12/2014	19	$0.00
24695	Aquifer	05/02/2015	10	$0.00
24648	Aquifer	30/04/2015	19	$0.00
30986	Aquifer	29/05/2015	30	$0.00
24710	Aquifer	29/05/2015	52	$0.00
24640	Aquifer	06/08/2015	28	$0.00
24126	Aquifer	25/09/2015	8	$0.00
37296	Aquifer	25/09/2015	22	$0.00
37325	Aquifer	03/11/2015	100	$0.00
24705	Aquifer	22/01/2016	25	$0.00
24666	Aquifer	12/02/2016	7.5	$0.00
36011	Aquifer	21/03/2016	100	$0.00
36031	Aquifer	21/03/2016	50	$0.00
24624	Aquifer	06/04/2016	4	$0.00
24691	Aquifer	06/07/2016	20	$0.00
24703	Aquifer	08/08/2016	10	$0.00
37817	Aquifer	01/10/2016	70	$0.00
24693	Aquifer	20/02/2017	2	$0.00
24658	Aquifer	11/05/2017	5	$0.00
24125	Aquifer	01/08/2017	4	$0.00
24694	Aquifer	08/11/2017	5	$0.00
24631	Aquifer	01/02/2018	10	$0.00
24635	Aquifer	16/02/2018	60	$0.00
24620	Aquifer	05/06/2018	10	$0.00
35523	Aquifer	27/08/2018	20	$0.00
24708	Aquifer	24/01/2019	15	$0.00
24719	Aquifer	29/01/2019	10	$0.00
24719	Aquifer	29/01/2019	10	$0.00
24661	Aquifer	05/06/2019	152	$0.00
24709	Aquifer	06/08/2019	7	$0.00
24624	Aquifer	16/12/2019	4	$0.00
30981	Aquifer	01/04/2020	100	$0.00
24679	Aquifer	07/05/2020	70	$0.00
24704	Aquifer	21/09/2020	15	$0.00
24691	Aquifer	27/10/2020	20	$0.00

WAL	Category	Transferred	Share (Units or ML)	Price Paid '$ per Unit'
24625	Aquifer	19/07/2021	40	$0.00
42007	Aquifer	21/07/2021	10	$0.00
42006	Aquifer	27/07/2021	50	$0.00
31047	Aquifer	17/08/2021	10	$0.00
24666	Aquifer	04/02/2022	7.5	$0.00
24640	Aquifer	16/03/2022	28	$0.00
24712	Aquifer	28/05/2022	52	$0.00
24649	Aquifer	28/05/2022	50	$0.00
24723	Aquifer	28/05/2022	76	$0.00
24666	Aquifer	01/11/2022	7.5	$0.00
42006	Aquifer	21/11/2022	50	$0.00
24639	Aquifer	15/12/2022	2	$0.00
24711	Aquifer	28/02/2023	100	$5,226.48
24622	Aquifer	14/03/2023	12	$0.00
43073	Aquifer	26/04/2023	42	$180.00
24716	Aquifer	16/05/2023	80	$0.00
24693	Aquifer	18/05/2023	2	$0.00
24654	Aquifer	31/05/2023	20	$0.00
30093	Aquifer	17/06/2023	19	$0.00
24619	Aquifer	05/01/2024	20	$0.00
30986	Aquifer	04/03/2024	0	$0.00
24710	Aquifer	04/03/2024	52	$0.00
30986	Aquifer	04/03/2024	30	$0.00
24710	Aquifer	04/03/2024	0	$0.00
24716	Aquifer	05/03/2024	80	$0.00
24716	Aquifer	05/03/2024	0	$0.00
24654	Aquifer	18/03/2024	20	$0.00
24641	Aquifer	17/12/2024	10	$30,000.00
24618	Aquifer	18/12/2024	3	$0.00
24702	Aquifer	22/01/2025	2	$0.00
44506	Aquifer	03/02/2025	70	$655.00
44505	Aquifer	03/02/2025	60	$655.00

The distribution of WALs in each of the relevant water sources is summarised in **Table 2-5** below.

Table 2-5: Distribution of Water Access Licences (WALs) in Water Sources

Access Licence Category	No. of WALs[1]	Total Share Component[2]	Reported Usage (ML/wy)[3]
Sydney Basin West Groundwater Source			
Aquifer	115	26706.7	22628.1
Stock and Domestic (Town Water Supply)	2	29	0
Lachlan Fold Belt Greater Metropolitan Groundwater Source			
Aquifer	174	7998.5	153.2
Aquifer (Town Water Supply)	2	100	0

Notes 1. Water Access Licence (WAL).; 2. Available Water Determination (AWD) is, generally, 100% of share component. i.e. 1 share equates to 1ML/wy, if AWD = 100%; 3) for Water Year (wy) = 2023/24.

Clarence Colliery holds two WALs for the Sydney Basin West Groundwater Source presented in **Table 2-6**. The total entitlement for Clarence Colliery is 7,718ML/wy.

Table 2-6: Clarence Colliery Water Access Licences (WALs)

WAL	Category	Water Source	Share Components (units or ML)	Nominated Work Approval(s)
WAL36479	Aquifer	Sydney Basin West Groundwater Source	6623.0	10WA118719 10WA118750 10WA118758
WAL41882	Aquifer	Sydney Basin West Groundwater Source	1095.0	10WA123214
n/a (currently)	Aquifer	Lachlan Fold Belt Greater Metropolitan Groundwater Source	0 (currently)	aquifer interference activity

Review of the *High Priority Groundwater-Dependent Ecosystem Map (GDE037_Version 1)* (approximately 1:400,000 scale) from the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Water Sources* 2023 (NSW) indicates that listed high priority groundwater dependent ecosystems and generally consistent with the mapped location of Temperate Highland Peat Swamps on Sandstone (Clarence, 2025bc).

The locations of the Temperate Highland Peat Swamps on Sandstone (THPSS) comprising of Newnes Plateau Shrub Swamps and Hanging Swamps have been mapped (Clarence, 2025bc). The THPSS is a high priority groundwater dependent ecosystem. The location of the THPSS are presented in **Section 3.5.9**.

Lower Nine Mile Swamp (located along Bungleboori Creek) and Paddys Creek Swamp (located along Paddys Creek) are in the immediate vicinity of 918 Panel and are shrub swamps. Extraction does not occur beneath these swamps.

Under the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Water Sources* 2023 (NSW):

"(1) A water supply work must not be constructed on land within the following areas—

(a) waterfront land for a lagoon, third order stream or higher order stream,

(b) waterfront land for a first or second order stream, unless—

(i) the water supply work is drilled into the underlying parent material and the slotted intervals of the work commence deeper than 30m, or

(ii) the applicant submits a hydrogeological study that, in the Minister's opinion, adequately demonstrates that the water supply work will have no more than minimal impact on base flows in the stream,

(c) 100m of the top of an escarpment,

(d) 200m of a high priority groundwater-dependent ecosystem listed in Schedule 4, Part 1,

(e) 200m of a high priority groundwater-dependent ecosystem identified on the High Priority Groundwater Dependent Ecosystem Map unless, in the Minister's opinion, there is not a high probability of groundwater dependence for the relevant ecosystem,

(f) 200m of a coastal wetland,

(g) 500m of a high priority groundwater-dependent ecosystem listed in Schedule 4, Part 2.

(2) Subsection (1) does not apply if—

(a) the water supply work is used only for basic landholder rights, or

(b) the water supply work is a replacement groundwater work, or

(c) the water supply work is for the purpose of monitoring, environmental remediation activities or emergency services, or

(d) in the Minister's opinion, the location of the water supply work is likely to cause no more than minimal harm to the water source and its associated ecosystems and ecological processes, high priority groundwater dependent ecosystem, wetland, karst or spring concerned."

[Subsection 1-2, Section 33, Part 7 of *Water Sharing Plan for the Greater Metropolitan Region Groundwater Water Sources* 2023 (NSW)]

An assessment of the Extraction Plan against rules for granting access licences, managing access licences, water supply works approvals and access licence dealings is presented in **Section 5.2.3.2**.

2.3.4 Biodiversity Conservation Act 2016

Biodiversity Conservation Act 2016 (NSW) is NSW state legislation that is intended to maintain a healthy, productive and resilient environment for the greater well-being of the community, now and into the future, consistent with the principles of ecologically sustainable development.

In the vicinity of Clarence Colliery, following are listed as Critically Endangered Ecological Communities under Schedule 2, Part 1 of the Act:

- "Natural Temperate Grassland of the South Eastern Highlands"
- "White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland"

In the vicinity of Clarence Colliery, following are listed as Endangered Ecological Communities under Schedule 2, Part 1 of the Act:

- "Temperate Highland Peat Swamps on Sandstone"
- "Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion"

The Temperate Highland Peat Swamps on Sandstone (THPSS) comprise of Newnes Plateau Shrub Swamps (Mapping Unit MU50, NSW DCCEEW (2006a)) and Hanging Swamps (Mapping Unit MU51, NSW DCCEEW (2006a)) listed under the *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) as Endangered Ecological Communities (EECs) reside on the Newnes Plateau.

The Natural Temperate Grassland of the South Eastern Highlands, White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland and Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion ecological communities are not designated as groundwater dependent ecosystems.

The Ecological Communities in the vicinity of Clarence Colliery are classified as ‘may occur’ and are not ‘likely to occur’.

The only relevant critically endangered ecological communities to this groundwater assessment are the THPSS.

An assessment of the impact of the Extraction Plan on groundwater dependent ecosystems is presented in **Section 5.2.3.3**.

2.4 NSW Guidelines and Policy

2.4.1 NSW Water Quality and River Flow Objectives 2006

Environmental values have been identified for various catchments within NSW (NSW DCCEEW, 2006b).

There are no specific environmental values set for the Hawkesbury-Nepean river catchment due to the transition at that time from the Healthy Rivers Commission to the Natural Resources Commission.

However, catchments in the vicinity have identified water quality and river flow objectives that are appropriate for the purpose of presenting the impact of the Extraction Plan these are presented below.

It is noted that the environmental values identified in the NSW Water Quality and River Flow Objectives are consistent with the National Water Quality Management Framework (CTH WQA, 2024).

Table 2-7 presents the adopted Water Quality and River Flow Objectives for the various water sources.

Table 2-7: NSW Water Quality and River Flow Objectives – Clarence Colliery

Objective Type	Objective

Water Quality	• Aquatic ecosystems
	• Visual amenity
	• Drinking water at point of supply – Disinfection only (n/a)
	    o Incidental take from recreational users only, as Extraction Plan for 918 Panel is outside of drinking water supply catchments.
	• Drinking water at point of supply – Clarification and disinfection only (n/a)
	    o Incidental take from recreational users only, as Extraction Plan for 918 Panel is outside of drinking water supply catchments.
	• Aquatic foods (cooked) (n/a)
	• Industrial water supply (not listed, but relevant to Clarence Colliery)

River Flow	• Protect natural pools in dry times • Protect natural low flows • Maintain wetland and floodplain inundation (not listed, but relevant to Clarence Colliery) • Maintain natural flow variability (not listed, but relevant to Clarence Colliery) • Minimise effects of weirs and other structures • Maintain groundwater for ecosystems (not listed, but relevant to Clarence Colliery)

An assessment of the impact of the Extraction Plan against the NSW Water Quality and River Flow Objectives is presented in **Section 5.2.4.1**.

2.4.2 NSW Groundwater Quality Protection Policy 1998

The objectives of the NSW Groundwater Quality Protection Policy (NSW DCCEEW, 1998) are the basis of the objectives of the *Water Management Act* 2000 (NSW).

The NSW Groundwater Quality Protection Policy encourages ecologically sustainable management of groundwater resources to:

- *"slow and halt, or reverse any degradation of groundwater resources*
- *ensure sustainability of groundwater dependent ecosystems*
- *maintain the full range of beneficial uses of these resources*
- *maximize economic benefit to the Region, State and Nation."*

[Page 7 of NSW DCCEEW (1998)]

NSW DCCEEW (1998) state that the objectives of the NSW Groundwater Quality Protection Policy will be met through the following management principles:

1. *"All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained.*
2. *Town water supplies should be afforded special protection against contamination.*
3. *Groundwater pollution should be prevented so that future remediation is not required.*
4. *For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource.*
5. *A groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwaters that are incompatible with soil, vegetation or receiving waters.*
6. *Groundwater dependent ecosystems will be afforded protection.*
7. *Groundwater quality protection should be integrated with the management of groundwater quantity.*
8. *The cumulative impacts of developments on groundwater quality should be recognized by all those who manage, use, or impact on the resource.*
9. *Where possible and practical, environmentally degraded areas should be rehabilitated, and their ecosystem support functions restored."*.

[Chapter 5 of NSW DCCEEW (1998)]

An assessment of the impact of the Extraction Plan against the NSW Groundwater Quality Protection Policy 1998 is presented in **Section 5.2.4.2**.

2.4.3 NSW Aquifer Interference Policy 2012

The NSW Aquifer Interference Policy (NSW DCCEEW, 2012) presents the requirements for assessment of aquifer interference activities administered under the *Water Management Act* 2000 (NSW).

The key components of the policy are:

- all water must be properly accounted for
- the activity must address minimal impact considerations with respect to water table, water pressure (if relevant) and water quality
- planning measures are to be presented to manage the circumstance that actual impacts are greater than predicted and, accordingly, that sufficient monitoring is in place to identify this circumstance.

Table 2-8 presents the Level 1 Minimal Impact Considerations from NSW Aquifer Interference Policy (NSW DCCEEW, 2012). For the purposes of this assessment, it has been assumed that the Lachlan Fold Belt Greater Metropolitan Groundwater Source and Sydney Basin West Groundwater Source of the *Water Sharing Plan of the Greater Metropolitan Regional Groundwater Sources* 2023 (NSW) are Highly Productive Porous Rock groundwater sources.

Table 2-8: Level 1 Minimal Impact Considerations – Highly Productive Porous Rock (NSW DCCEEW, 2012)

Objective Type	Objective
Water table	
	less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40m from any: • high priority groundwater dependent ecosystems • high priority culturally significant site listed in the Schedule of the relevant water sharing plan. OR a maximum of a 2m water table decline cumulatively at any water supply work.
Water pressure	
	a cumulative pressure head decline of not more than a 2m decline, at any water supply work.
Water quality	
	any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.

An assessment of the Extraction Plan against the NSW Aquifer Interference Policy is presented in **Section 5.2.4.3**.

2.4.4 NSW Groundwater Assessment Toolbox

The Groundwater Assessment Toolbox (GAT) for Significant Development and State Significant Infrastructure (SSD/SSI) Projects provides a suite of technical guidance documents that clarify NSW Government expectations for groundwater assessment, modelling, cumulative impact assessment and documentation.

Whist the Extraction Plan for 918 Panel is not a SSD, since does not comprise a modification to consent, the Toolbox has been used to facilitate review by NSW DCCEEW.

The GAT comprises five elements:

- Element 1 - Groundwater assessment toolbox for major projects in NSW – Overview Document
- Element 2 - Guidelines for Groundwater Documentation for SSD/SSI projects
- Element 3 - Minimum Groundwater Modelling Requirements for SSD/SSI Projects
- Element 4 – Cumulative Groundwater Impact Assessment Approaches
- Element 5 – NSW Aquifer Interference Policy.

For this Extraction Plan, the GAT has been applied in a scaled and fit-for-purpose manner to support the identification of groundwater impact pathways, assessment of potential impacts, consideration of cumulative effects and definition of monitoring, modelling, and management measures. The Toolbox informs the structure, transparency and technical robustness of the groundwater assessment, while recognising that the scope, level of detail and analytical methods are proportionate to the nature and risk profile of the proposed extraction.

Application of the GAT ensures that groundwater considerations addressed in this Extraction Plan are consistent with NSW Government expectations, aligned with the NSW Aquifer Interference Policy (NSW DCCEEW, 2012) and capable of supporting regulatory review and compliance under the *Water Management Act* 2000 (NSW).

Element 1 - Groundwater assessment toolbox for major projects in NSW – Overview Document (NSW DCCEEW, 2022a) (technical guideline)

Relevance

- Establishes the overarching framework for groundwater assessment for SSD and SSI projects in NSW
- Explains how groundwater assessment fits within the NSW planning, approvals and water licensing systems
- Sets expectations for transparency, proportionality, early engagement and technical defensibility
- Defines the role of supporting technical guidelines within the Toolbox and how they are intended to be applied based on project risk and complexity.

What needs to be demonstrated

- Adequate description of baseline groundwater conditions, including hydrogeology, groundwater levels, pressures and quality
- Identification of groundwater-dependent receptors, including water users, ecosystems and surface water features
- Clear explanation of impact mechanisms associated with construction and operation
- Assessment of predicted groundwater impacts against relevant criteria and policy thresholds
- Defined mitigation, management and monitoring measures, including triggers and response actions
- Logical integration of groundwater assessment with broader environmental documentation.

Element 2 - Guidelines for Groundwater Documentation for SSD/SSI projects (NSW DCCEEW, 2022b)

Relevance

- Defines NSW Government expectations for how groundwater information is structured and documented in SSD applications
- Provides a consistent framework for presenting baseline conditions, impact assessment, mitigation and monitoring
- Ensures groundwater assessments are auditable, transparent and reviewable by regulators and stakeholders.

What needs to be demonstrated

- Adequate description of baseline groundwater conditions, including hydrogeology, groundwater levels, pressures and quality
- Identification of groundwater-dependent receptors, including water users, ecosystems and surface water features
- Clear explanation of impact mechanisms associated with construction and operation
- Assessment of predicted groundwater impacts against relevant criteria and policy thresholds
- Defined mitigation, management and monitoring measures, including triggers and response actions
- Logical integration of groundwater assessment with broader environmental documentation.

Element 3 - Minimum Groundwater Modelling Requirements for SSD/SSI Projects (NSW DCCEEW, 2022c) (technical guideline)

Relevance

- Sets minimum technical standards for groundwater modelling used to support SSD and SSI assessments

- Ensures models are scientifically robust, transparent and suitable for predicting groundwater impacts
- Aligns NSW groundwater modelling expectations with national best practice.

What needs to be demonstrated

- A clear modelling objective linked directly to decision-making requirements
- Development of a defensible conceptual hydrogeological model informed by site data and regional context
- Model complexity appropriate to environmental sensitivity and risk
- Calibration against observed data using accepted quantitative and qualitative criteria
- Prediction of groundwater impacts over relevant spatial and temporal scales, including recovery
- Consideration of uncertainty and sensitivity, with transparent reporting of limitations
- Independent review where required by risk or regulatory conditions.

Element 4 – Cumulative Groundwater Impact Assessment Approaches (NSW DCCEEW, 2022d) (information paper)

Relevance

- Provides guidance on assessing cumulative groundwater impacts at the water source scale
- Clarifies how past, present and reasonably foreseeable future activities should be considered together
- Supports consistent interpretation of cumulative impact requirements under NSW water policy.

What needs to be demonstrated

- Identification of the relevant groundwater source(s) and spatial extent for cumulative assessment
- Consideration of other existing and approved projects affecting the same groundwater resources
- Assessment of cumulative impacts on groundwater levels, pressures, quality and connected surface water
- Evaluation of cumulative impacts against Aquifer Interference Policy minimal impact considerations.
- Use of qualitative or quantitative methods appropriate to risk and data availability
- Clear explanation of assumptions regarding future activities and regional development.

Element 5 – Aquifer Interference Policy (NSW DCCEEW, 2012) (policy)

Relevance

- Primary NSW policy governing assessment and licensing of aquifer interference activities
- Establishes the “no more than minimal harm” principle for groundwater impacts
- Defines specific quantitative impact criteria for groundwater levels, pressures and quality.

What needs to be demonstrated

- Identification of all aquifer interference activities associated with the project
- Assessment of groundwater impacts against minimal impact considerations
- Demonstration that impacts to water supply works, GDEs and other sensitive receptors remain within acceptable limits
- Consideration of cumulative impacts from all post-water sharing plan activities

- Mitigation and management measures where minimal impact criteria may be approached or exceeded
- Monitoring and adaptive management framework capable of validating predictions and responding to impacts.

As noted above, the Extraction Plan for 918 Panel is not a modification to consent. Notwithstanding, an assessment of the Extraction Plan against the GAT is presented in **Section 5.2.4.4**.

3. Hydrogeological Setting

This chapter presents the environmental and hydrogeological setting of Clarence Colliery.

3.1 Overview

Clarence Colliery is located in the Western Coalfields of NSW, 2km northeast of the township of Clarence and 15km east of Lithgow.

The mining lease resides within the Newnes Plateau. The Newnes Plateau is a topographically high sandstone feature (1200m AHD) that divides the surface water catchments into the Coxs River (west, southwest), Wolgan River (north) and Bungleboori Creek (east). The Wolgan Valley lies to the north of the Newnes Plateau, where surface elevation is 690mAHD. The Wolgan River, within the Wolgan Valley, flows in a northerly and then easterly direction. The Newnes Plateau hosts the Gardens of Stone State Conservation Area (GoS SCA) and a range of endangered ecological communities, including the Newnes Plateau Shrub Swamps and the Newnes Plateau Hanging Swamps. These communities form part of the federally and state listed Temperate Highland Peat Swamps on Sandstone (THPSS).

Clarence Colliery extracts coal from the Katoomba Seam and has approval to extract up to 3 million tonnes of coal per year. The Katoomba Seam, like the Lithgow Seam, is higher in the southwest and dips towards the northeast. The extracted coal (thermal coal) is predominantly exported via Port Kembla to the global market.

3.2 Climate Data

The Western Coalfields receive a temperate climate, with warm summers, cool winters and fairly uniform rainfall throughout the year.

Rainfall and evapotranspiration (FAO56) (UN, 2006) for the groundwater model domain was obtained from the SILO climate dataset of the Queensland Department of Environment, Tourism, Science and Innovation (QLD DETSI).

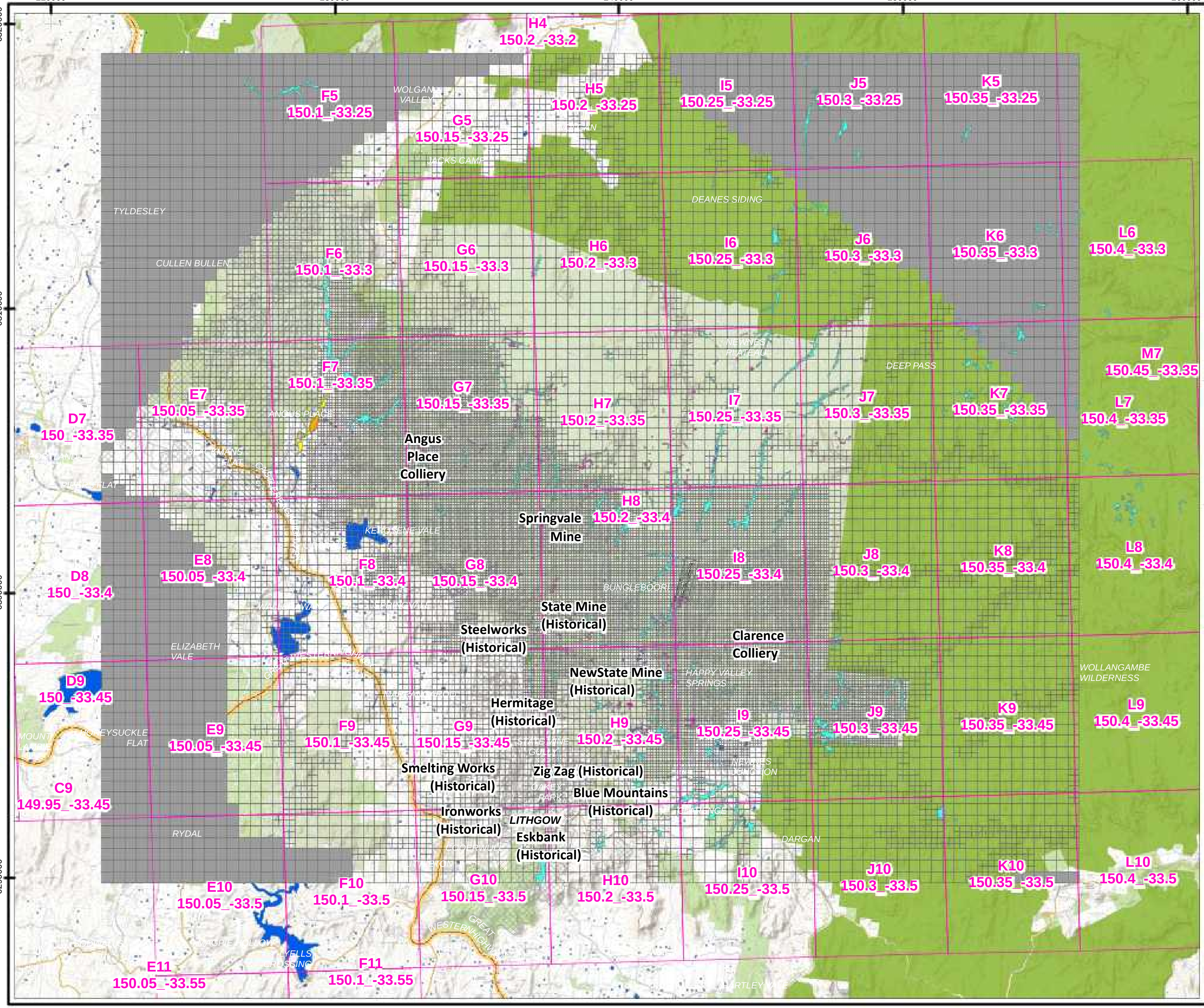
Monthly average rainfall and evapotranspiration (FAO56) above Panel 918 at Clarence Colliery is presented in **Table 3-1** as well as annual average rainfall and evapotranspiration.

Table 3-1: Climatic Summary at Clarence Colliery (150.25°, -33.4°; Grid I8)

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave. Daily Temperature (Minimum)	13.0	12.7	10.9	7.9	5.0	2.8	1.8	2.4	4.6	6.9	9.2	11.2	-
Ave. Daily Temperature (Maximum)	24.8	23.6	21.2	17.7	13.8	10.5	9.9	11.6	15.1	18.1	20.8	23.4	-
Average Rainfall (mm)	109	112	111	74.1	65.8	65.7	61.8	71.6	59.3	70.7	101	90.6	991
Average FAO56 (mm)	141	109	94.0	65.1	43.0	30.6	35.4	52.9	78.6	106	120	144	1020

Gridded data from the SILO dataset (0.05 degree) was used in the groundwater model. Daily data was extracted from the SILO database from 1 January 1979 through 31 May 2025.

Figure 3-1 presents the layout of the SILO grid.



Legend:

Highway

Greater Blue Moutains World Heritage Area

Mining Methods:
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:
- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):
- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Swamp by MU Name (RPS, 2018):
- 53 Mountain Hollow Grassy Fen (EEC)
- Typha orientalis Wetland

Climate Data:
- Distribution of SILO Gridded Data

Modelling:
- No Flow Boundary
- Model Grid

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 04-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:180,000	

0 2 4 km

Coor. Sys. GDA 1994 MGA Zone 56

Model Grid and Climate Data Grid

FIGURE: 3.1

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D034_ModelGridClimateGrid.mxd
Reference: © Department of Customer Service 2020

For future predictions using the numerical groundwater model, data from the New South Wales and Australian Capital Territory Regional Climate Modelling Project (NARCliM) was accessed (NSW DCCEEW, 2025).

Of the climate models available, after adaptation to the SILO grid presented above, historical climate data was amended to reflect long-term trends. It noted that NARCliM Version 1.0 was used for this assessment:

- 'Average' Climate conditions were represented by the ECHAM5_R3 model.

It is noted that the evapotranspiration outcomes were derived based on mean near-surface temperature derived from NARCliM and all climate model outputs were found to be similar. The largest divergence between climate models was with respect to cumulative rainfall, with the adopted average climate model being halfway between the lowest and highest.

As noted in the documentation issued in support of NARCliM, the selection of climate model to use needs to take into account the context of use, with respect to risk. For this study, that is the potential reduction in groundwater recharge, hence the focus on cumulative rainfall and evapotranspiration (via consideration of mean near-surface temperature). Furthermore, extraction of climate model output needs to be internally consistent, which means that output from different climate models should not be used, rather pick one of the climate models and use that one, single climate model.

3.3 Hydrology

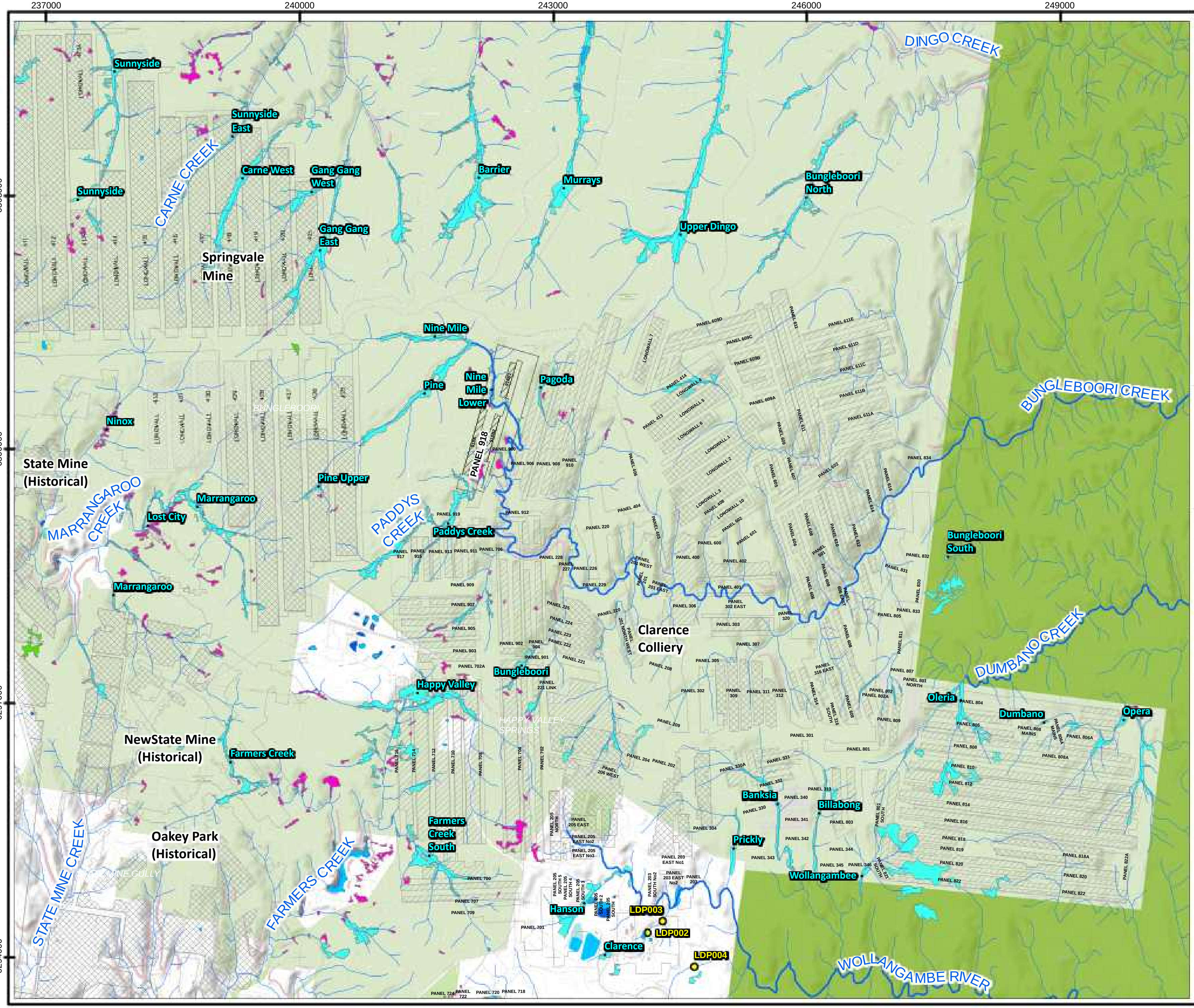
The Newnes Plateau largely influences the hydrology of the Western Coalfields. It divides surface flow into three major directions. The topographic divide between the catchments is orientated in a northwest-southeast direction.

Clarence Colliery spans across two water sources of the *Water Sharing Plan for the Greater Metropolitan Unregulated River Water Sources* 2023 (NSW). Namely, the Wywandy Water Source and the Colo River Water Source. The northern portion of Clarence sits within the Hawkesbury / Lower Nepean surface water catchment (Colo River Water Source), whereas the southern portion of Clarence falls within the Upper Nepean / Upstream Warragamba (Wywandy Water Source) surface water catchment. 918 Panel lies within the Hawkesbury / Lower Nepean surface water catchment (Colo River Water Source).

The major surface water feature in the vicinity of the 918 Panel is Bungleboori Creek, which drains from west to east through 918 Panel.

Figure 3-2 presents relevant hydrological features in the vicinity of Clarence Colliery.

Figure 3-3 presents the boundaries of the respective water sources in the Water Sharing Plan (Surface Water).



Legend:

Greater Blue Moutains World Heritage Area

Mining Methods:	Mine Operation Status:
Development	Approved
Partial Extraction	Existing
Total Extraction	Proposed
Open Cut	Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Hydrology:

- Waterbody
- Watercourse
- Licenced Discharge Points

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevB	Date: 23-Jan-2026
Drawn By: DAW	Checked By: JRWB
Scale 1:60,000	

0 1 2
km

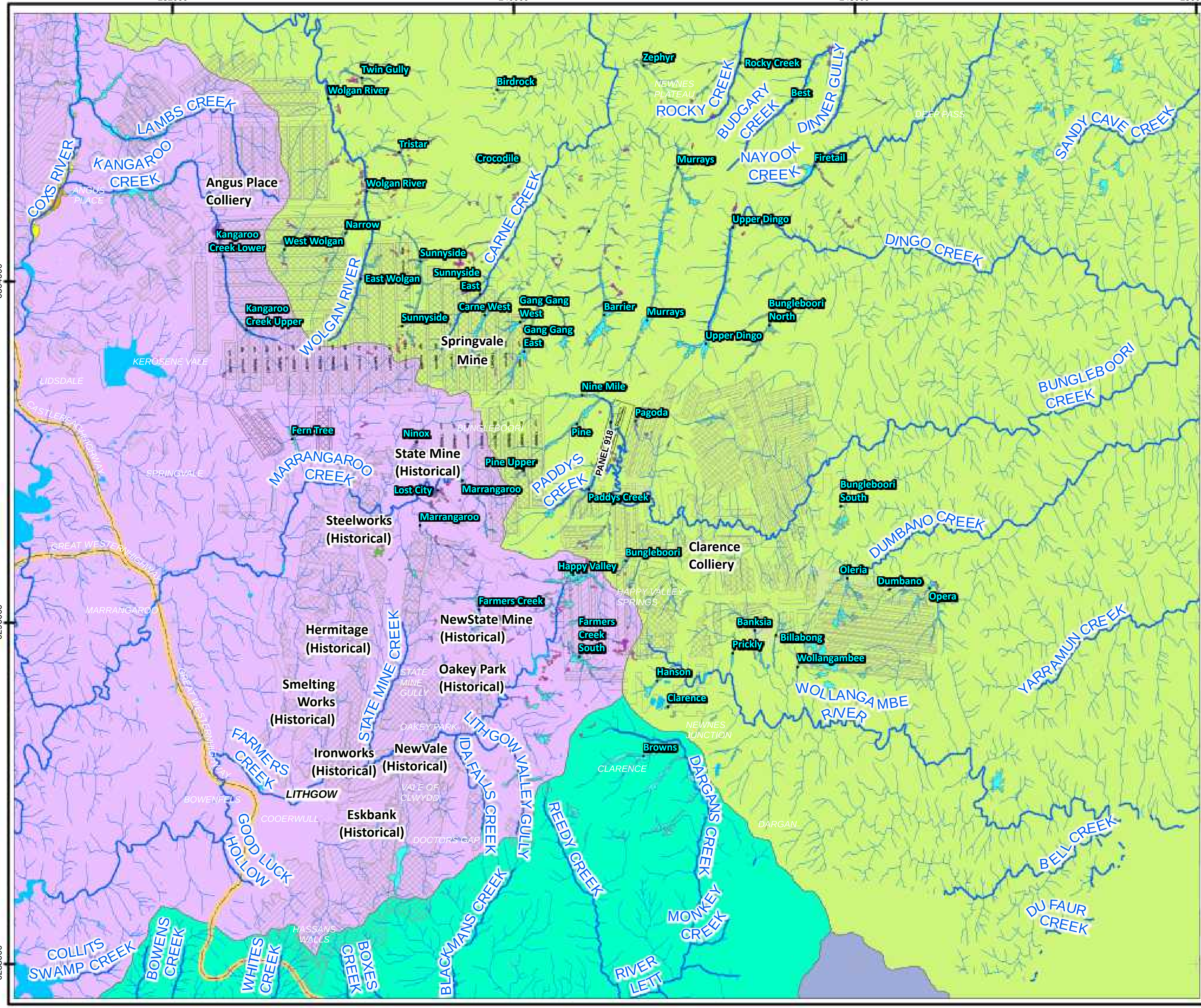
Coor. Sys. GDA 1994 MGA Zone 56

Surface Water Features

FIGURE: 3.2

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D035_SurfaceWaterFeatures.mxd

Reference: © Department of Customer Service 2020



Legend:

Highway | Waterbody | Watercourse

Mining Methods:
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:
- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):
- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Swamp by MU Name (RPS, 2018):
- 53 Mountain Hollow Grassy Fen (EEC)
- Typha orientalis Wetland

Water Sources in WSP Greater Metropolitan Region Unregulated River Sources 2023:
- Colo River Water Source
- Dharabuladh Water Source
- Fish River Water Source
- Grose River Water Source
- Turon Crudine River Water Source
- Wywandy Water Source

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 04-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:120,000	
0 2 4 km	
Coor. Sys. GDA 1994 MGA Zone 56	

Water Sharing Plan Water Sources (Surface Water)

FIGURE: 3.3

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D033b_WSP_SW.mxd
Reference: © NSW Department of Planning and Environment (2023).

3.4 Geology

Clarence Colliery is located in the Western Coalfields of NSW. The geologic sequence at Clarence Colliery is Palaeozoic (Carboniferous) through to Mesozoic (Triassic).

The Illawarra Coal Measures (coal seams, sandstones, siltstones and conglomerates) (Permian) are overlain by the Narrabeen Group (sandstones, shales, claystones, siltstones) (Triassic).

3.4.1 Geological Units

Narrabeen Group (Triassic)

The highest geologic unit of the Narrabeen Group present at Clarence Colliery is the Burralow Formation. This comprises alternating sandstones and shales, referred to locally as the "YS aquitard plies".

The Banks Wall Sandstone underlies the Burralow Formation. It is a weaker, friable sandstone unit and is up to 50m thick in the vicinity of Clarence.

The Mt York Claystone is a regionally significant claystone and is about 22m thick. It underlies the Banks Wall Sandstone. The Mt York Claystone comprises rich claystone bands interbedded with bands of siltstone and sandstone.

The Burra-Moko Head Sandstone is a strong, competent sandstone and underlies the Mt York Claystone.

The Caley Formation underlies the Burra-Moko Head Sandstone.

Illawarra Coal Measures (Permian)

Within the Illawarra Coal Measures, the Katoomba Seam, which is the uppermost economically viable seam within the coal measures, is mined at Clarence Colliery.

Figure 3-4a presents the stratigraphic sequence at Clarence Colliery after Figure 16 of McHugh (2016), with **Figure 3-4b** presenting surface geology in the vicinity of 918 Panel and **Figure 3-4c** presenting the representation of surface geology used in the numerical groundwater model.

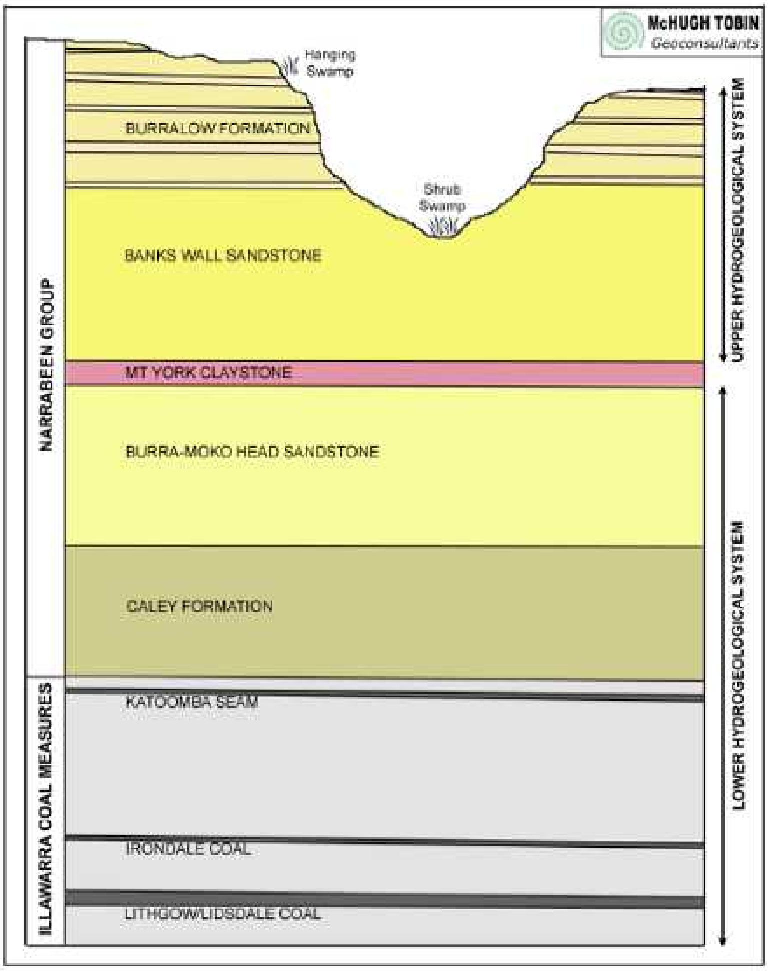


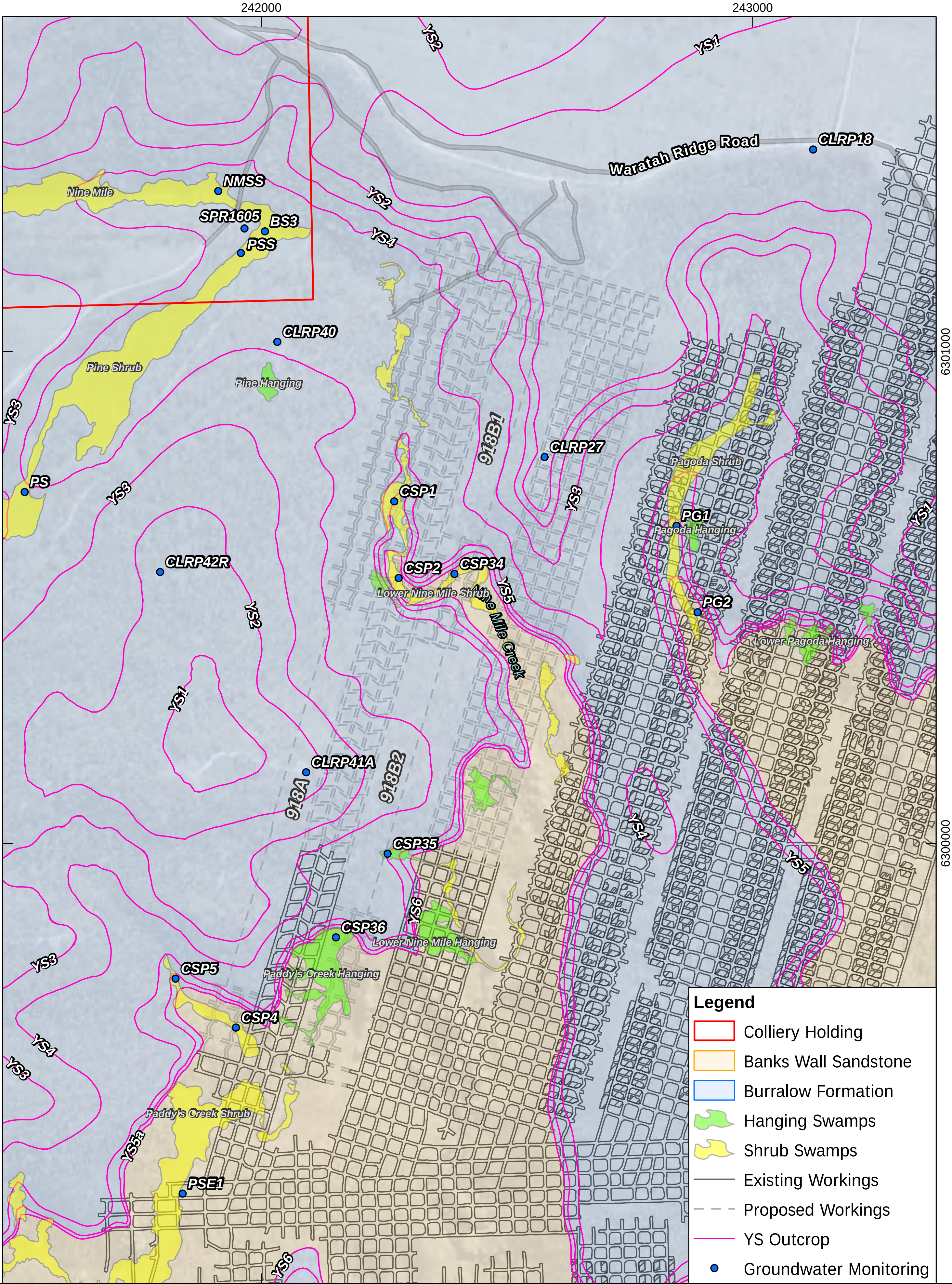
Figure 3-4: Stratigraphic Sequence beneath the Newnes Plateau (after Figure 16 of McHugh (2016))

3.5 Hydrogeology

3.5.1 Hydrogeological Units

The following geologic units were considered:

- Narrabeen Group
  - Burralow Formation (interbedded shales and sandstones)
  - Banks Wall Sandstone (sandstone)
  - Mount York Claystone (claystone)
  - Burra-Moko Head Sandstone (sandstone)
  - Caley Formation (siltstone).
- Illawarra Coal Measures
  - Katoomba Seam (coal)
  - Farmers Creek Formation (siltstone)
  - Gap Sandstone (sandstone)
  - Denman Formation (mudstone)
  - Glen Davis/Long Swamp Formation (siltstone)



N

0 250 500
meters

Coordinate System: GDA2020 MGA Zone 56

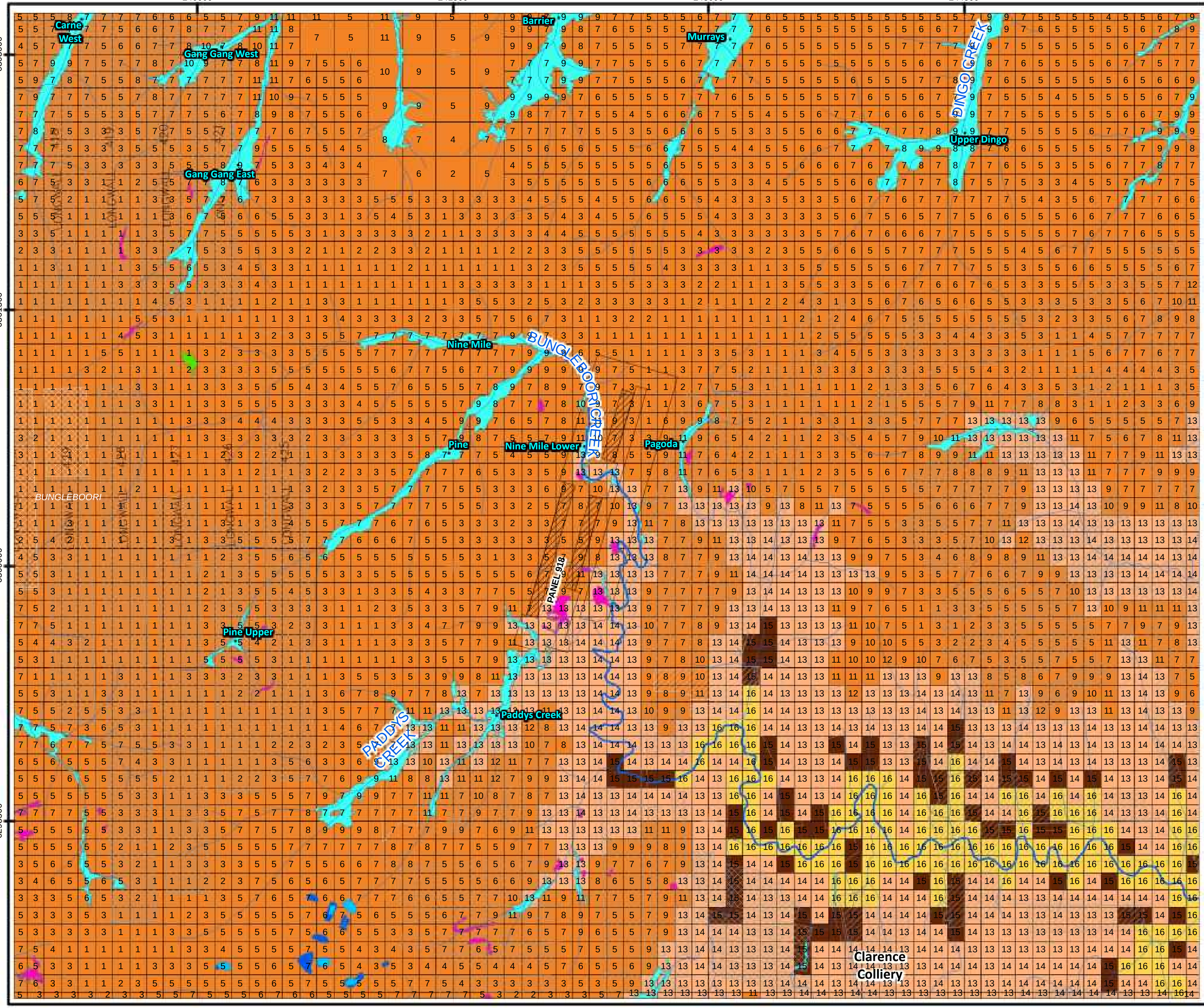
Drawn	N.Lloyd
Checked	A.Moore
Approved	A.Moore
Scale	1:10,000 @ A4
Revision	1

Clarence Colliery
Geological Surface Mapping

CENTENNIAL CLARENCE

Date: 21/07/2025 Plan No. FASS10923

Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, Maxar



Legend:

Mining Methods:
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:
- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):
- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Hydrology:
- Waterbody
- Watercourse

Hydrogeological Unit:
- Burralow Formation (L01-L12)
- Banks Wall Sandstone (L13-L14)
- Mt York Claystone (L15)
- Burra-Moko Head Sandstone (L16)

Notes: Highest Active Model Layer in the Groundwater Model is displayed for each cell.

JBS&G

Job No: 68229

Client: Clarence Colliery Pty Ltd

Version: R01RevB | Date: 18-Dec-2025

Drawn By: DAW | Checked By: JRWB

Scale 1:30,000

0 0.5 1 km

Coor. Sys. GDA 1994 MGA Zone 56

Surface Geology (Highest Active Layer)

FIGURE: 3.4c

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D001_HAL.mxd

- Blackmans Flat Conglomerate (conglomerate)
- Lithgow Seam (coal)
- Marrangaroo Conglomerate (conglomerate)
- Nile Subgroup (sandstone)
- Shoalhaven Group (siltstone).

- Carboniferous Basement (igneous/metamorphic).

The abovementioned geologic units were compilated into the following groundwater systems:

- Perched Groundwater System
  - Burralow Formation (interbedded shales and sandstones)
- Shallow Groundwater System
  - Banks Wall Sandstone (sandstone)
  - Mount York Claystone (claystone)
- Deep Groundwater System
  - Burra-Moko Head Sandstone (sandstone)
  - Caley Formation (siltstone)
  - Katoomba Seam (coal)
  - Farmers Creek Formation (siltstone)
  - Gap Sandstone (sandstone)
  - Denman Formation (mudstone)
  - Glen Davis/Long Swamp Formation (siltstone)
  - Blackmans Flat Conglomerate (conglomerate)
  - Lithgow Seam (coal)
  - Marrangaroo Conglomerate (conglomerate)
  - Nile Subgroup (sandstone)
  - Shoalhaven Group (siltstone).
  - Carboniferous Basement (igneous/metamorphic).

3.5.2 Groundwater Sources

Clarence Colliery is situated within the Sydney Basin West Groundwater Source of the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources* 2023 (NSW).

The location of the boundaries between the above groundwater sources is presented in **Figure 2-1**.

3.5.3 Conceptual Model

The conceptual model for 918 Panel is as follows:

- There are three groundwater systems:
  - a perched system upon which most THPSS shrub and hanging swamps reside, including Nine Mile Swamp, Pine Swamp and the upstream portion of Paddys Creek Swamp and Pagoda Swamp

- a shallow groundwater system variably exists within the Banks Wall Sandstone, maintained by the Mt York Claystone, which exists below the Banks Wall Sandstone and acts as a regionally significant aquitard
  - Some THPSS shrub and hanging swamps reside on this system, including the mid and lower portion of Paddys Creek Swamp, Lower Nine Mile Swamp and downstream portion of Pagoda Swamp.
- a deep system within the Illawarra Coal Measures, below the Mt York Claystone.
  - This system is subject to depressurisation ahead of mining. At Clarence, this occurs in the Katoomba Seam.

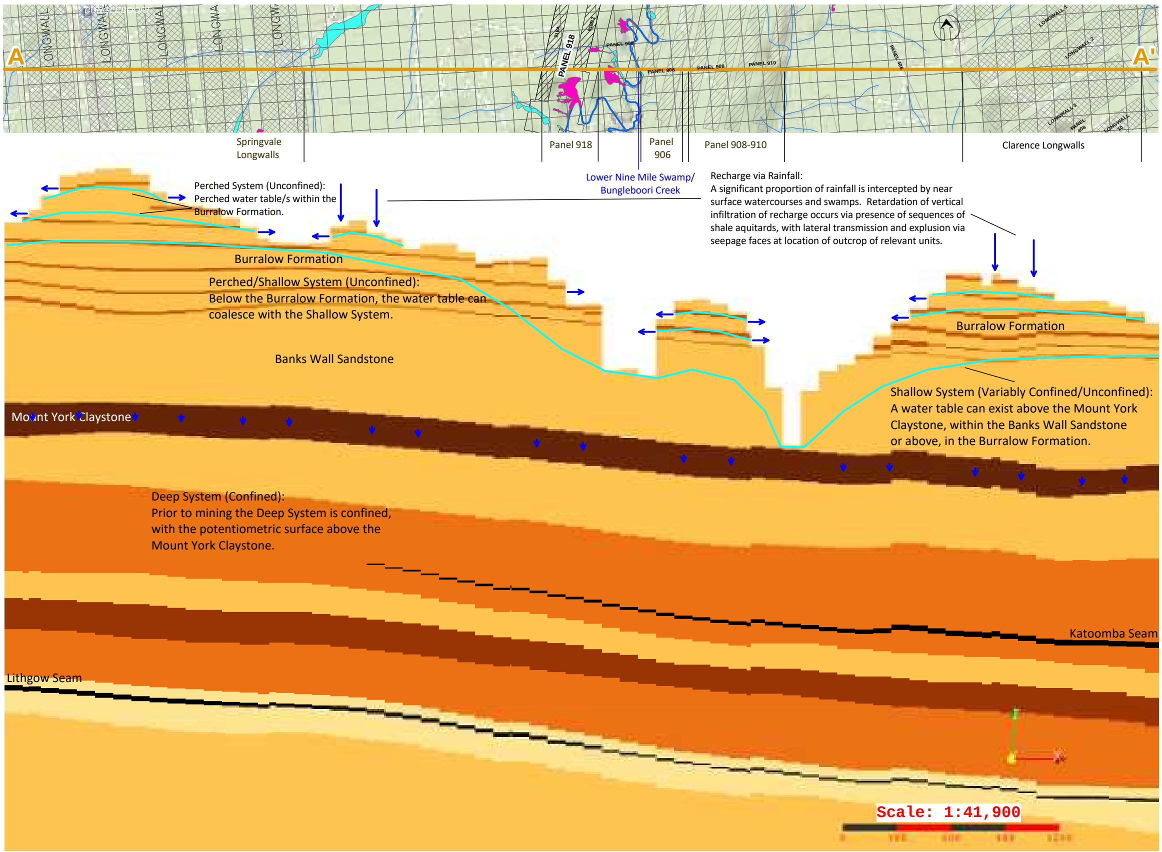
- Rainfall recharge is received to ground surface on the Newnes Plateau above Clarence's mine workings, and percolates vertically downward
- Lateral groundwater flow direction in the perched groundwater system is a subdued reflection of surface topography, as is expected. Vertical groundwater flow direction in the perched groundwater system is vertically downward towards the shallow groundwater system; however, that vertical percolation is retarded by the presence of sequences of aquitard plies (shale) of the Burralow Formation. That retardation leads to lateral transmission of most groundwater toward outcrop (as seepage faces)
- Lateral groundwater flow direction in the shallow groundwater system is a combination of the influence of surface topography, particularly where the Banks Wall Sandstone is present at ground surface, and the underlying southwest to northeast and west southwest to east northeast lateral flow direction of the deep groundwater system. Vertical groundwater flow is vertically downward below topographic ridgelines, but is vertically upward along valleys, where ground surface has cut through the Burralow Formation and the Banks Wall Sandstone is the highest hydrogeologic unit
- Lateral groundwater flow direction in the deep groundwater system is towards the northeast. This is due to the influence of the Colo River at significant distance to the north and east of Clarence Colliery. Vertical groundwater flow direction in the deep groundwater system is vertically downward, albeit the vertical hydraulic gradient is small, due to the influence of the low permeability Carboniferous basement. At Clarence, with depressurisation due to mining, a localised upward vertical hydraulic gradient from the hydrogeologic units below the Katoomba Seam can occur
- To the far northwest of Clarence, the lateral groundwater flow direction in the deep groundwater system is influenced, regionally, by outcropping of the Illawarra Coal Measures, at cliff faces, in the Wolgan Valley
- To the west of Clarence Colliery is Springvale Mine. The target coal seam at Springvale is the Lithgow Seam, which occurs at a lower elevation in the Illawarra Coal Measures than the Katoomba Seam. Depressurisation at Springvale has an influence on the deep groundwater system, both laterally and vertically. That influence extends below Clarence Colliery.
- At Springvale Mine, historical workings to the south (collectively referred to as the State Mine Complex in this report) are flooded, to a groundwater elevation of 895mAHD. The groundwater elevation of 895mAHD is hydraulically controlled by an adit in the former Vale of Clywdd colliery, located to the far southeast of the Lithgow township, where groundwater freely discharges into a creek and flows away to the southeast.
- Of the geologic units within the deep groundwater system, the coal seams are considered to possess the highest hydraulic conductivity
- The vertical hydraulic gradient is, in general, vertically downward from ground surface through to the Carboniferous basement. The Carboniferous basement is assumed to be relatively impermeable

- Almost all THPSS reside along geological lineaments (refer **Figure 3-9**). If it were the case that geological lineaments were 'surface to basement' and highly conductive, the same hydrological niche that leads to a standing water level in these swamps, and the soil moisture profile that they are dependent on, could not be maintained. Instead, geological lineaments are conceptualised as being infilled with detritus and lithified over time (not to the point of being barriers to flow), but susceptible to reactivation when applying Model Mining Methods 4 and 5, due to the higher extraction ratio and subsequent subsidence (ground movement)
- "Minimum resultant hydraulic conductivity" pertains to disturbance of low hydraulic conductivity hydrogeologic units by high subsidence mining methods.
  - Those low hydraulic conductivity units, usually function as aquitards and often act as a groundwater 'hydraulic control'. i.e. downward percolation of groundwater from the shallow groundwater system into the deep groundwater system is retarded by presence of that aquitard
  - The effect of subsidence-induced change to hydraulic properties by a high subsidence mining method is significant for an aquitard (such as a claystone) and needs to be taken into account
  - The proposed mining method for 918 Panel, PPPE, is a low subsidence mining method (Model Mining Method 3).

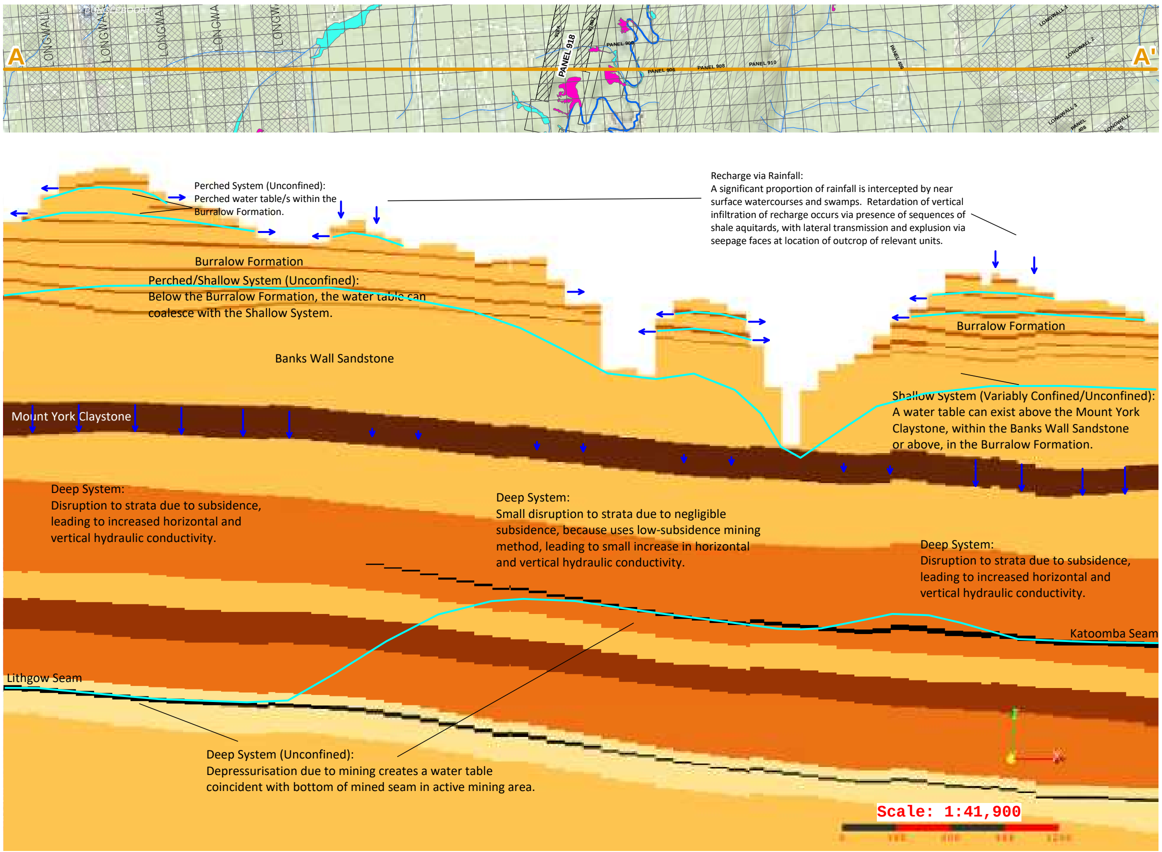
Figure 3-5 presents a graphical representation of the Conceptual Model illustrating both pre-mining and during mining conditions respectively. The location of the cross-section is presented in **Figure 4-1**.

The generalised groundwater water balance of the area is as follows:

- Recharge is the primary source of water to the perched and shallow groundwater system
- Recharge to the deep groundwater system is via vertical percolation of groundwater from the shallow system into the deep system, as well as lateral inflow (from southwest to northeast) through outcropping Illawarra Coal Measures along the Upper Coxs River (western edge of the study area)
- Groundwater is mostly lost to evapotranspiration and groundwater/surface water interaction from the perched and shallow groundwater system
- Groundwater is mostly lost from the deep groundwater system through seepage faces of the cliff faces of the Wolgan Valley as well as regional throughflow (to the northeast and east)
- All watercourses on the Newnes Plateau and in the Wolgan Valley are gaining watercourses, but the magnitude of groundwater contribution to surface water is small. Along the Upper Coxs River, the influence of historical mining (depressurisation) has led to a decline in the elevation of the uppermost water table
- Regional throughflow (generally from southwest to the northeast and east) in the deep groundwater system is small
- Vertical leakage into the Carboniferous basement from the deep groundwater system is negligible to small
- Due to the separation of the shallow and deep groundwater system by the presence of the regionally significant Mount York Claystone aquitard, depressurisation of the deep groundwater system during mining does not, in general, lead to a decline in groundwater contribution to surface water, since that occurs in the perched and shallow groundwater system only. Disruption of strata overlying the target coal seams, as well as increased vertical hydraulic gradient, can lead to a decline in groundwater elevation in the shallow groundwater system. Where the thickness of the perched system (Burralow Formation) is small, a decline in groundwater elevation can also occur.



Pre-Mining:



End of Mining:

Legend

Hydrogeological Interpretation:

- Water Flow
- Water Table

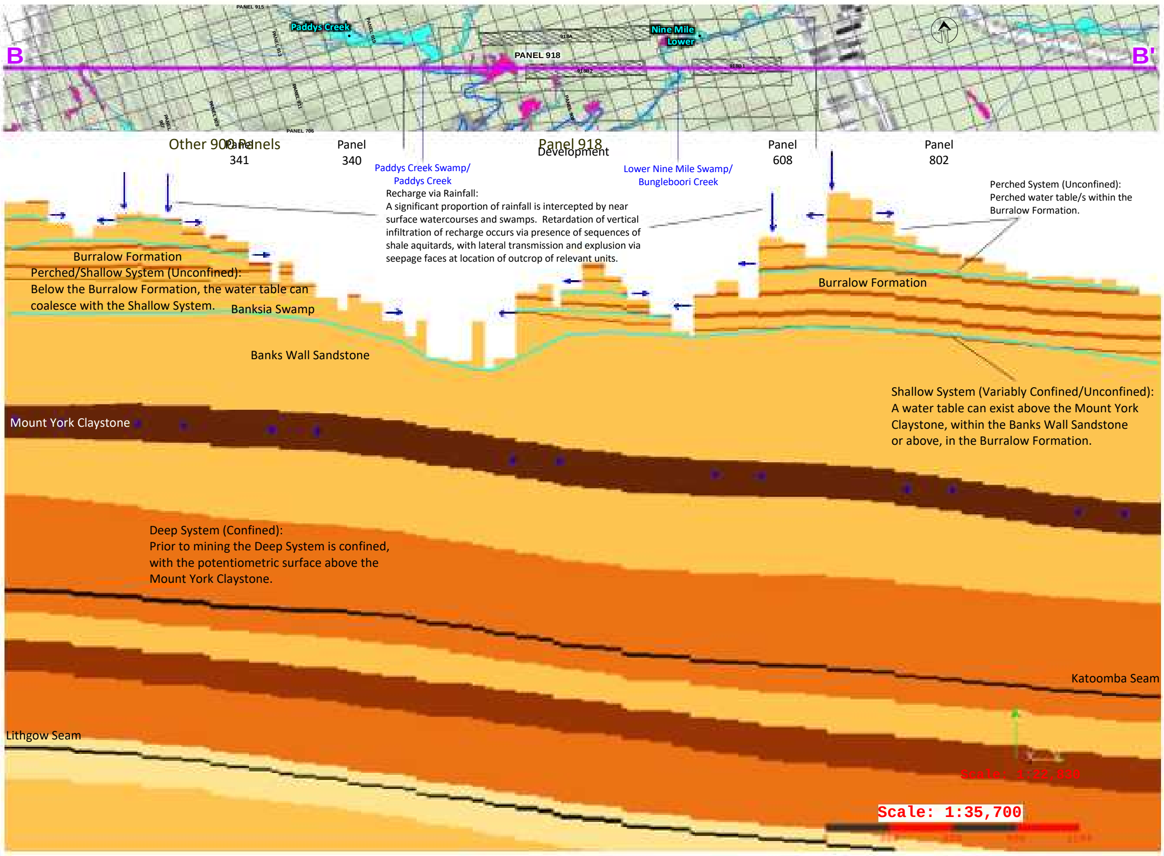
Geological Units:

- Sandstone (Regolith at Ground Surface)
- Shale (Regolith at Ground Surface)
- Claystone/Shale
- Siltstone
- Coal
- Mudstone
- Conglomerate
- Cryst'ne_W'd-F'd

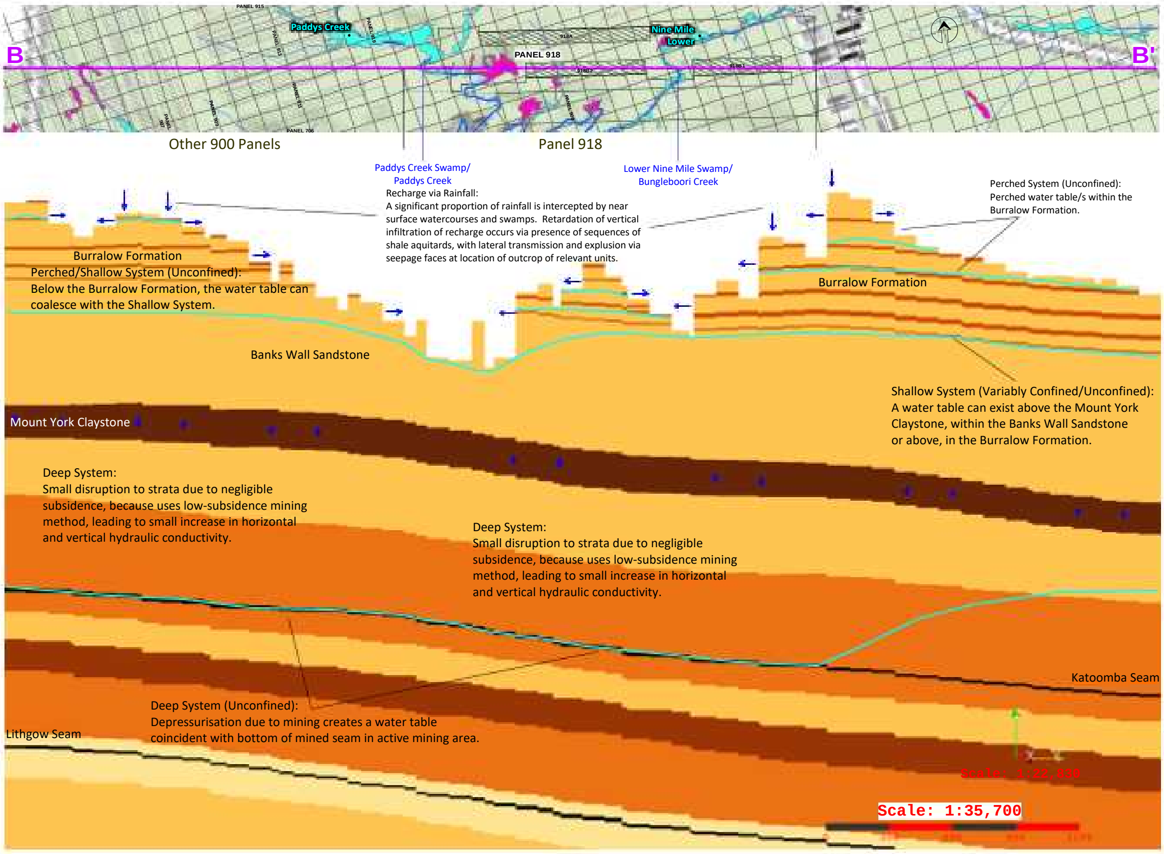
Job No.: 68229		Conceptual Hydrogeological Model (Section A - A')
Client: Clarence Colliery Pty Ltd		
Version: R01RevD	Date: 12/02/2026	
Drawn By: JRWB	Checked By: JRWB	**Figure 3.5a**

File Path: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\Grapher\68229_R01RevD_D001_ConceptualModel\68229_R01RevD_D001a_ConceptualModel_XS_A.grf

Reference: 68229_R01RevA_APR_03c



Pre-Mining:



End of Mining:

Legend

Hydrogeological Interpretation:

- Water Flow
- Water Table

Geological Units:

- Sandstone (Regolith at Ground Surface)
- Shale (Regolith at Ground Surface)
- Claystone/Shale
- Siltstone
- Coal
- Mudstone
- Conglomerate
- Cryst'ne_W'd-F'd

Job No.: 68229		Conceptual Hydrogeological Model (Section B - B')
Client: Clarence Colliery Pty Ltd		
Version: R01RevD	Date: 12/02/2026	
Drawn By: JRWB	Checked By: JRWB	**Figure 3.5b** JBS&G

File Path: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\Grapher\68229_R01RevD_D001_ConceptualModel\68229_R01RevD_D001b_ConceptualModel_XS_B.grf

Reference: 68229_R01RevA_APR_03c

3.5.4 Impact Pathway Diagram

In accordance with CTH IESC (2024), the ecohydrological model summaries the pathway of change to potential impact, in this case on TPHSS, which are groundwater dependent ecosystems, by definition.

The magnitude of these changes are dependent on the magnitude of disruption to the hydrogeological environment, with high-subsidence mining methods, such as Model Mining Method 4 and 5, being much more significant than low-subsidence mining methods, such as Model Mining Method 3, which is proposed to be used for 918 Panel.

Relevant changes are:

- subsidence-induced disturbance near ground surface (limited), that may change near surface groundwater quality due to increased groundwater/rock interaction
    - negligible due to being a low subsidence mining method.
- decline in elevation of uppermost water table along watercourses in which THPSS (shrub) exist
    - negligible within THPSS.
- increase in groundwater contribution to surface water through seepage faces, due to dilation of horizontal piles under topographic ridgelines
    - negligible due to use of a low subsidence mining method for 918 Panel.
- reduction in groundwater contribution to surface water along watercourses, due to changes to groundwater elevation of perched and shallow groundwater system
    - negligible.
- increase in tortuosity of flowpath of runoff from seepage faces to THPSS.
    - negligible due to use of a low subsidence mining method for 918 Panel.

Figure 3-6 presents the Impact Pathway Diagram for 918 Panel at Clarence Colliery. **Figure 3-6** uses the same cross-sections as used in **Figure 3-5a** and **Figure 3-5b**. It is noted that the water table and water flowpaths presented in **Figure 3-6** are as at end of mining of 918 Panel.

From **Figure 3-6**, as discussed in text above, the impact pathway pertains to:

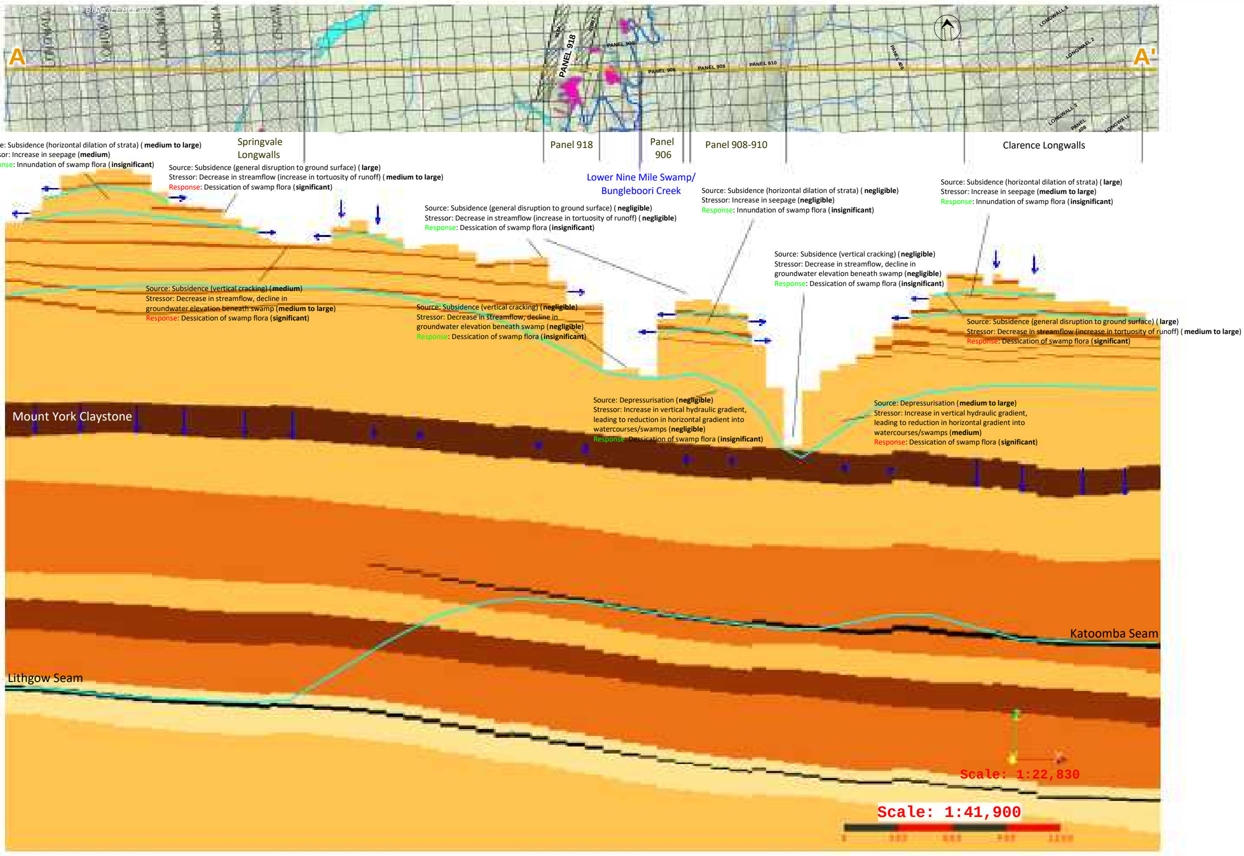
- changes to swamp water level
    - negligible within THPSS.
- changes to groundwater contribution to surface water.
    - negligible.

3.5.5 Literature Values of Hydraulic Properties

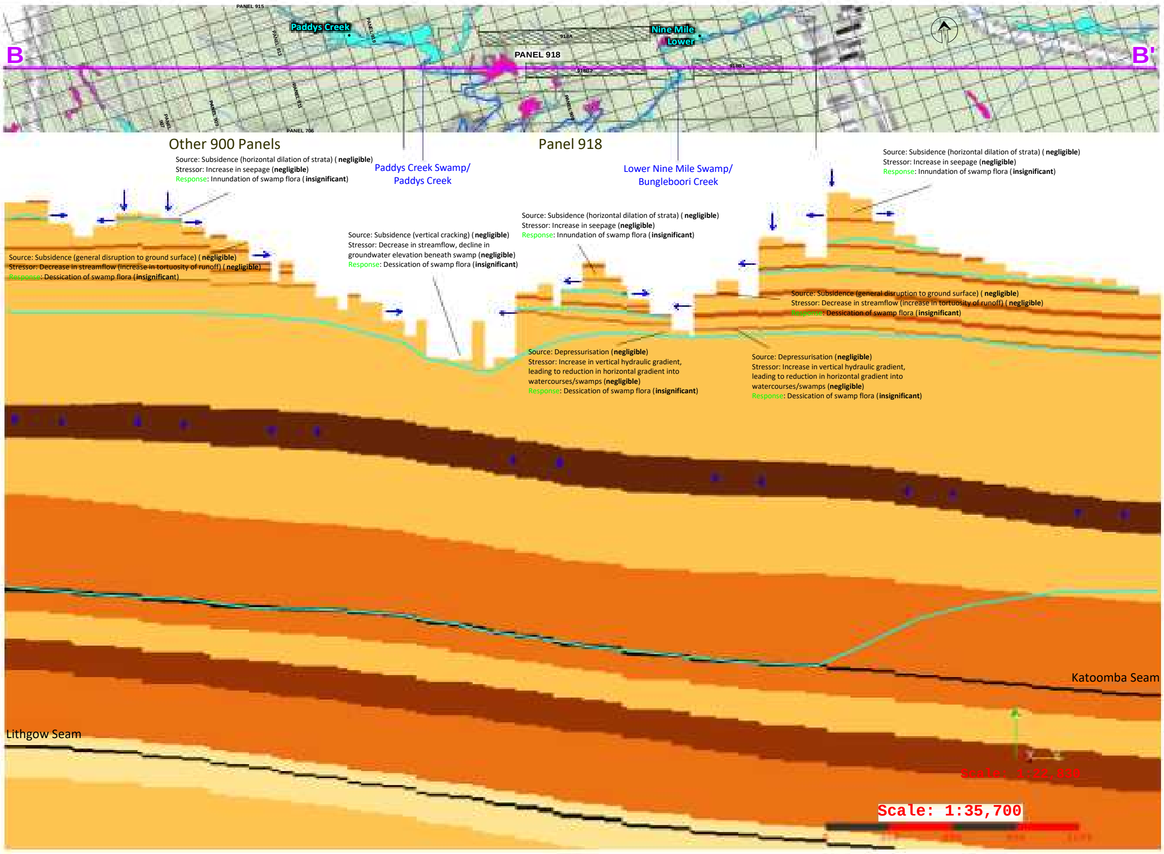
Figure 3-7 presents the adopted values for hydraulic properties, both saturated and unsaturated parameters, including their range. The 'centre' values presented in **Figure 3-7** were used as the initial values in the groundwater model, prior to model calibration. The 'range' of values presented in **Figure 3-7** were used as the lower and upper bounds during model calibration. This meant that the value of the relevant parameter could not exceed the bounds.

The values presented in **Figure 3-7** were based on Domenico and Schwarz (1997), Fetter (1994), USGS (2002), with input from JBS&G's Senior Principal Environmental Engineer. It is noted that the values presented in **Figure 3-7** were also cognisant of diagenesis with respect to sedimentary rock.

As will be presented in detail in **Section 4.7**, heterogeneity of values of hydraulic properties for each hydrogeologic unit were included in the groundwater model, as well as changes due to the presence of



Section A - A' (End of Mining):



Section B-B' (End of Mining):

Legend

Hydrogeological Interpretation:

- Water Flow
- Water Table

Geological Units:

- Sandstone (Regolith at Ground Surface)
- Shale (Regolith at Ground Surface)
- Claystone/Shale
- Siltstone
- Coal
- Mudstone
- Conglomerate
- Cryst'ne_W'd-F'd

Job No.: 68229		Impact Pathway Diagram (Section A - A' and B - B')
Client: Clarence Colliery Pty Ltd		
Version: R01RevD	Date: 12/02/2026	
Drawn By: JRWB	Checked By: JRWB	Figure 3.6

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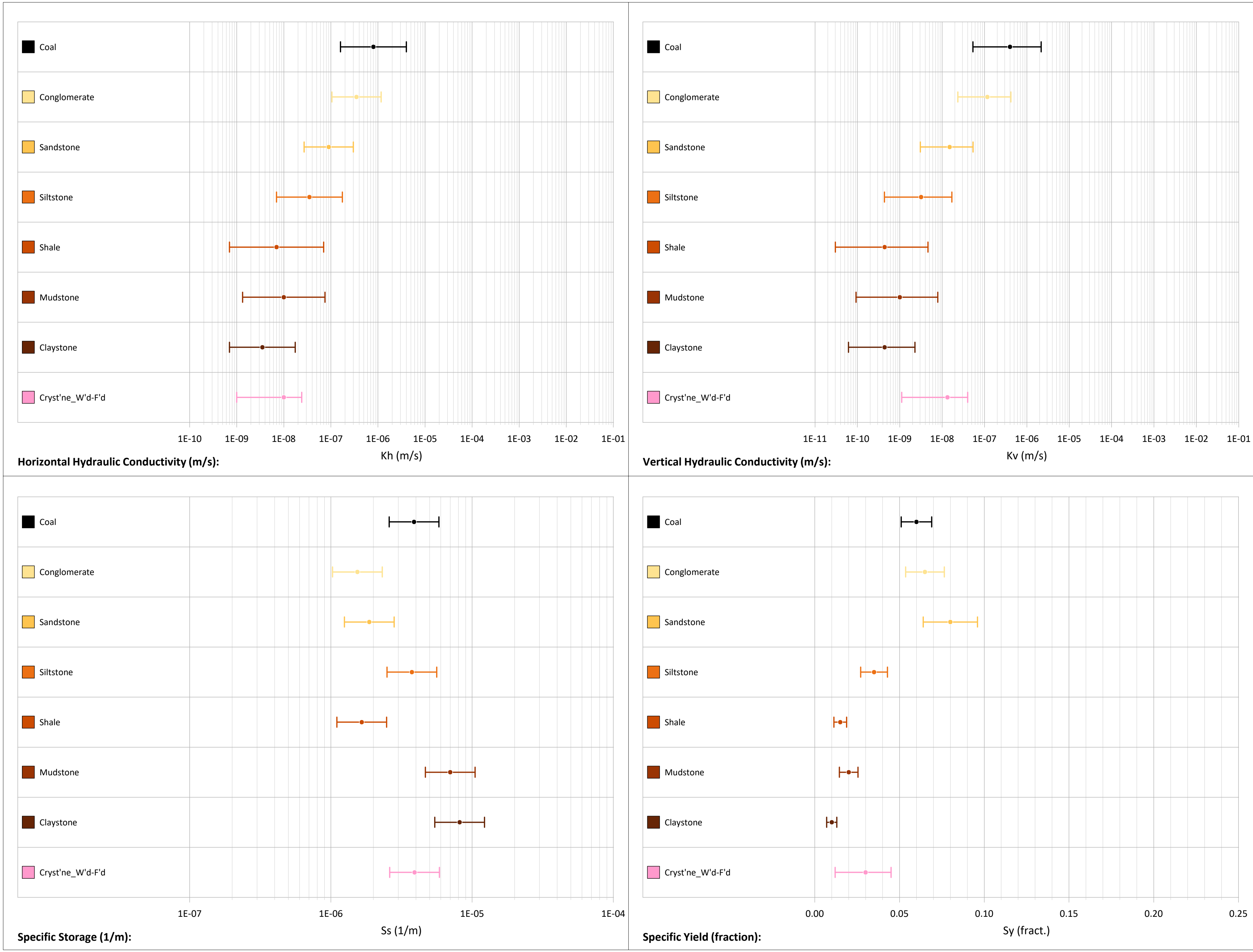
Reference: 68229_R01RevA_APR_03c



Legend

Stratigraphy in Model:

- Coal
- Conglomerate
- Sandstone
- Siltstone
- Shale
- Mudstone
- Claystone
- Cryst'ne_W'd-F'd

Notes:

Project No: 68229

Client:
Clarence Colliery Pty Ltd

Version: R01RevA

Date: 04/11/2025

Drawn By: DAW

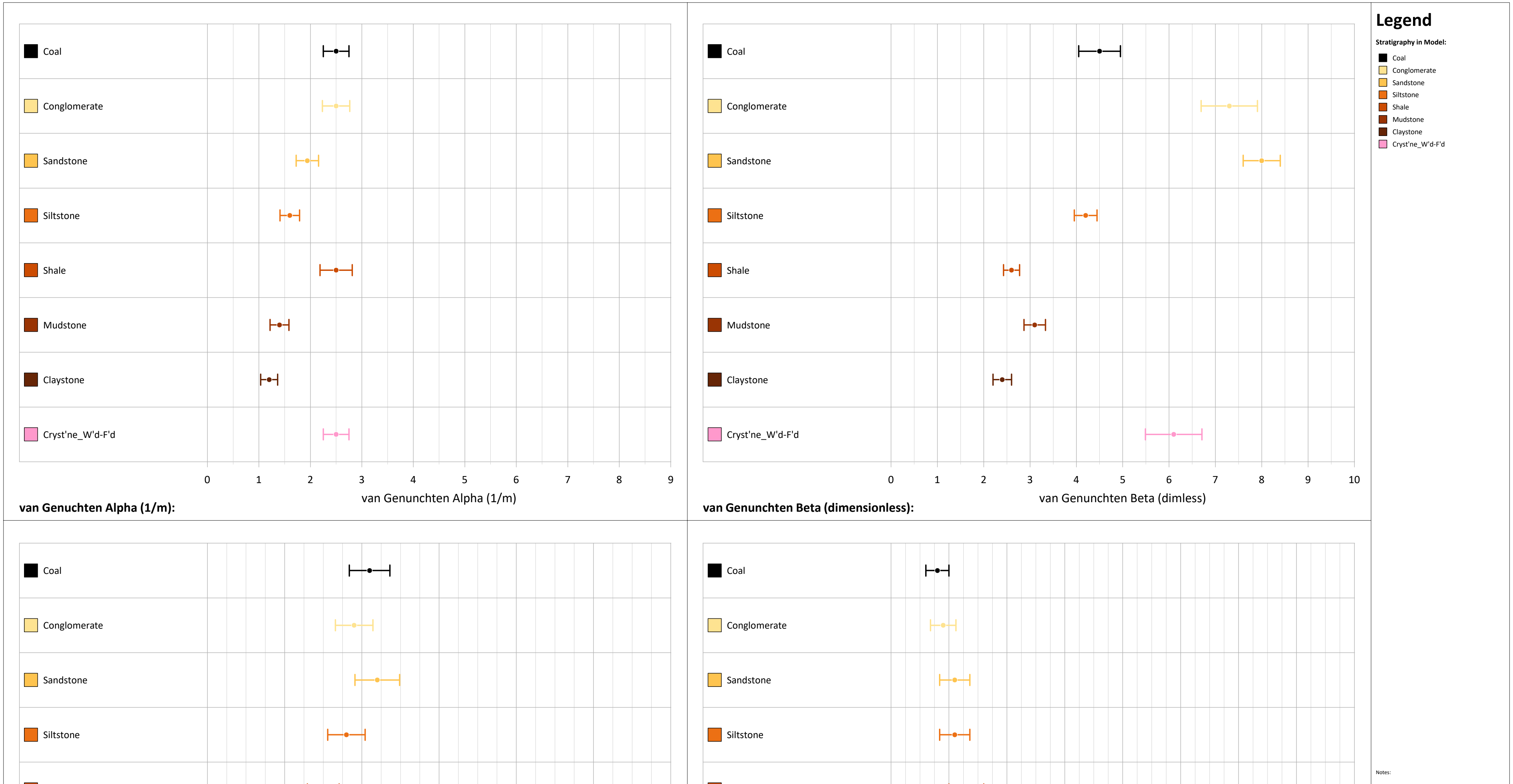
Checked By: JRWB

JBS&G

Figure 3.7a: Literature Values of Hydraulic Properties (Saturated)

File Path: N: Projects CentennialCoal ClarenceColliery 68229_UpdateTo918EP Figures Grapher 68229_R01RevA_D035_HydraulicProperties 68229_R01RevA_D035a_HydraulicPropertiesLiteratureValues_Saturated.grf

Reference: 68229_R01RevA_APR_03c.nam



Project No: 68229

Client:
Clarence Colliery Pty Ltd

Version: R01RevA

Date: 04/11/2025

Drawn By: DAW

Checked By: JRWB

Figure 3.7b: Literature Values of Hydraulic Properties (Unsaturated)

File Path: N: Projects CentennialCoal ClarenceColliery 68229_UpdateTo918EP Figures Grapher 68229_R01RevA_D035_HydraulicProperties 68229_R01RevA_D035b_HydraulicPropertiesLiteratureValues_Unsaturated.grf

Reference: 68229_R01RevA_APR_03c.nam

lineaments and also proximity to ground surface (depth-dependent modification to hydraulic properties). These latter two processes could lead to a value of hydraulic properties in excess of that presented in **Figure 3-7**. i.e. values presented in **Figure 3-7** were used to control the 'layer-based' (inclusive of heterogeneity via Pilot Points) values of hydraulic parameters, prior to alteration by the presence of lineaments and/or proximity to ground surface (depth-dependent modification).

3.5.6 Influence of Geological Lineaments on Hydrogeology

Geological lineaments are present at Clarence Colliery. These have been incorporated in recent versions of the numerical groundwater model, with structural mapping of lineaments supplied to JBS&G by Springvale, based on the study by Palaris (2013abc). Some of that mapping was interpreted, insofar as relative significance was stated, and some was raw data without interpretation.

CTH IESC (2021) presents suggested investigation pathways with respect to the location and hydrogeological type that lineaments (geological fault zones) may take. For the Western Coalfields, information provided by Springvale Mine and Clarence Colliery indicate that the lineaments (refer **Figure 3-9**) usually contain a fine grained mudstone, which is infilled post-fracturing (at time of faulting) and then lithified over time. At Clarence Colliery, there can be, occasionally, 'washouts', which contain unconsolidated poorly sorted sediment, including iron staining, but these are rare and are exceptional cases.

Figure 3-8 presents a photograph of an example of the Deanes Creek Lineament, when encountered in the Lithgow Seam at Springvale Mine (supplied by Springvale Mine).

Figure 3-8: Deanes Creek Lineament – Lithgow Seam at Springvale Mine (supplied by Springvale Mine)

From **Figure 3-8**, whilst the lineament is infilled with a fine grained mudstone, it is not considered to be substantive enough, nor continuous enough, to form a barrier to horizontal groundwater flow.

Geological lineaments are considered to be hydrogeologically ‘open’ (insofar not being a barrier to horizontal groundwater flow) and not hydrogeologically ‘closed’ (insofar as being a barrier to horizontal groundwater flow); although they are infilled with detritus prior to reactivation. The hydrogeological conceptual explanation is that if the lineaments were high hydraulic vertical conductivity zones (not filled with detritus), given the location of THPSS (shrub) along watercourses that align with these lineaments, then maintaining a standing water level in THPSS (shrub) would otherwise be infeasible.

An updated geological lineament dataset was provided to JBS&G by Clarence and implemented in the immediately recent groundwater model version (JBS&G, 2025ab). The lineament types provided include:

- Type 1
  - Type 1a – projected fault structure zones 3.0m or greater width with basement to surface connectivity
  - Type 1b – projected faults associated with major washout infill with seam to surface connectivity.
- Type 2
  - Type 2a – projected fault structure 2.0 to 3.0m width with basement to surface connectivity
  - Type 2b – projected fault structure zones 1.0 - 2.0m width or associated with ‘seam level’ intrusion with potential surface connection.
- Type 3.
  - Type 3a – projected faults associated with minor washout infill with seam to surface connectivity
  - Type 3b – projected fault structure zones projected, severity unknown seam to surface connectivity.

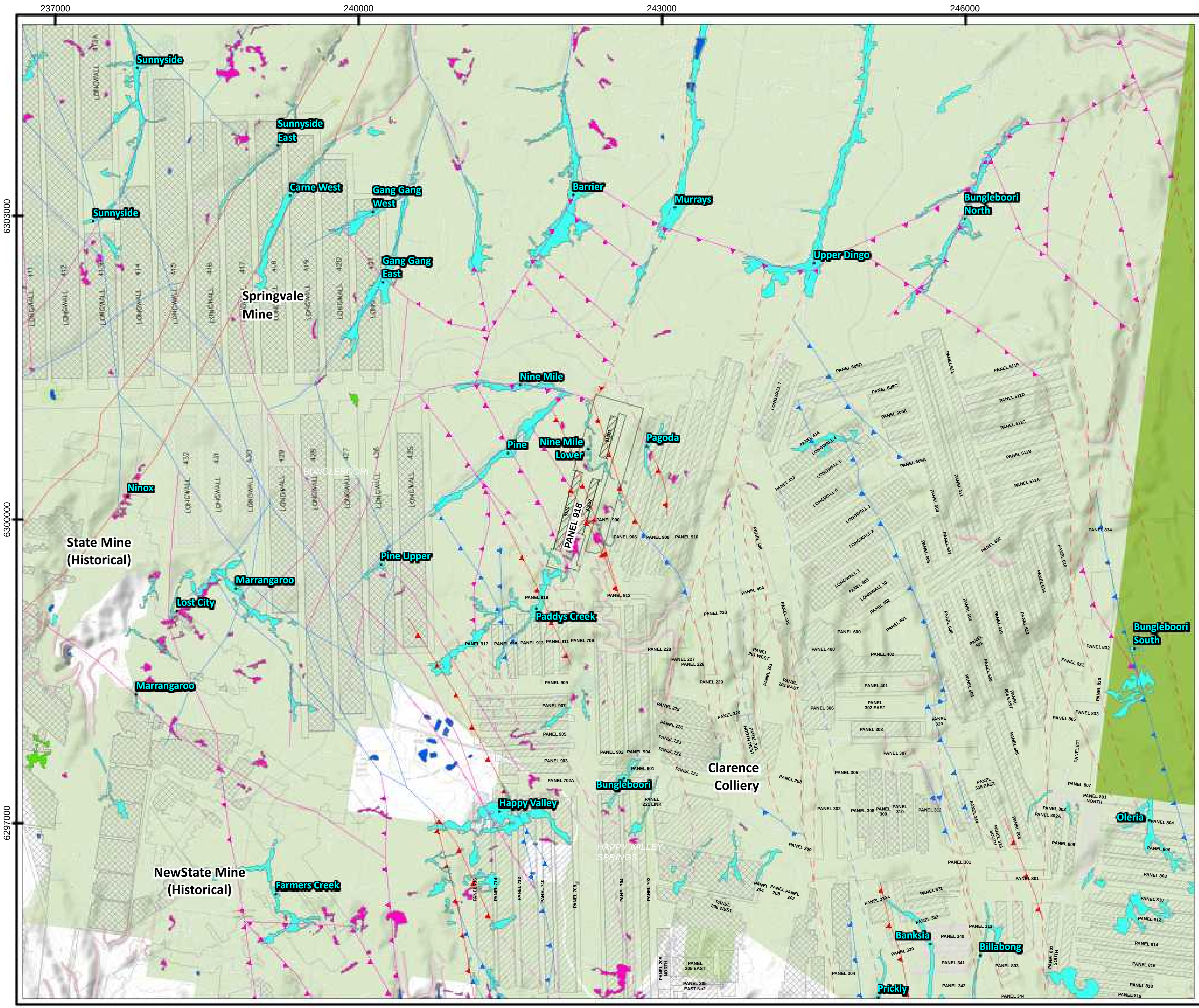
These geological lineaments were included in the model as above and adopted the following widths:

- Type 1 – projected fault structure 10.0m width
- Type 2 – projected fault structure 5.0m width
- Type 3 – projected fault structure 5.0m width.

Figure 3-9 presents the location of lineaments, including their assigned type, in the vicinity of the 918 Panel.

It was assumed that all lineaments presented in **Figure 3-9** increased local hydraulic properties (hydraulic conductivity and storage) and were not of a ‘closed’ or ‘barrier’ type geological feature.

As presented in **Section 4.7**, a ‘composite value’ approach to the representation of the influence of geological lineaments on hydraulic properties in the groundwater model was adopted (based on the methodology of Freeze and Cherry, 1979).



Legend:

Greater Blue Moutains World Heritage Area

Mining Methods:	Mine Operation Status:
Development	Approved
Partial Extraction	Existing
Total Extraction	Proposed
Open Cut	Other Proposed

Lineament Type:

Type 1	Type 2	Type 3
Type 1a	Type 2a	Type 3a
Type 1b	Type 2b	Type 3b

Swamps by MU Name (Clarence, 2025bc):

50 Newnes Plateau Shrub Swamp (EEC)
51 Newnes Plateau Hanging Swamp (EEC)
52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Note: Geological lineaments are interpreted based on dataset provided by Clarence (2024).

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 04-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:50,000	
0 1 2 km	
Coor. Sys. GDA 1994 MGA Zone 56	

Types of Lineaments in Region

FIGURE: 3.9

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D037_TypesOfLineaments.mxd
Reference: © Department of Customer Service 2020

3.5.7 Groundwater Use at Clarence Colliery

Extracted groundwater is currently treated at the Water Treatment Plant on-site at Clarence prior to being discharged to the Wollangambe River via Licenced Discharge Point 2 (LDP002).

Discharge water quality monitoring and discharge volume monitoring is undertaken in accordance with the requirements of EPL726 (Clarence, 2025a).

Further details of surface water flow and quality are presented in the Surface Water Assessment for 918 Panel (JBS&G, 2025c).

3.5.8 Groundwater Investigation and Field Testing

Groundwater Monitoring Network

There is an extensive groundwater monitoring network at Clarence Colliery and at neighbouring operations at Springvale Mine and Angus Place Colliery.

The network comprises:

- standpipe piezometer data (ridgeline, swamp and shallow aquifer piezometers)
- vibrating wire piezometers.

Figure 3-10 presents the distribution of the monitoring network.

Figure 3-11 presents observed standing water level (mBGL) in swamp piezometers pertinent to implementation of the Extraction Plan for 918 Panel.

Further observation hydrographs of all relevant monitoring locations (spatially, and vertically) at Clarence Colliery are presented in **Section 4.12.4.4**, alongside model calibration simulation results.

Hydraulic Testing

Limited hydraulic testing, via packer testing, has been undertaken at Angus Place Colliery, Springvale Mine and Clarence Colliery, although it is highlighted that mining has been on-going for more than 40 years and could reasonably be considered a large-scale 'hydraulic test'.

Testing locations include:

- Springvale Mine (SPR1101, SPR1401 and SPR1402) – LW415/416 Aquifer Disturbance Study (DGS, 2015)
- Angus Place Colliery (AP1PR and AP1109)
- Clarence Colliery (CLRP15 and CLRP40).

The testing locations are illustrated in **Figure 3-10**.

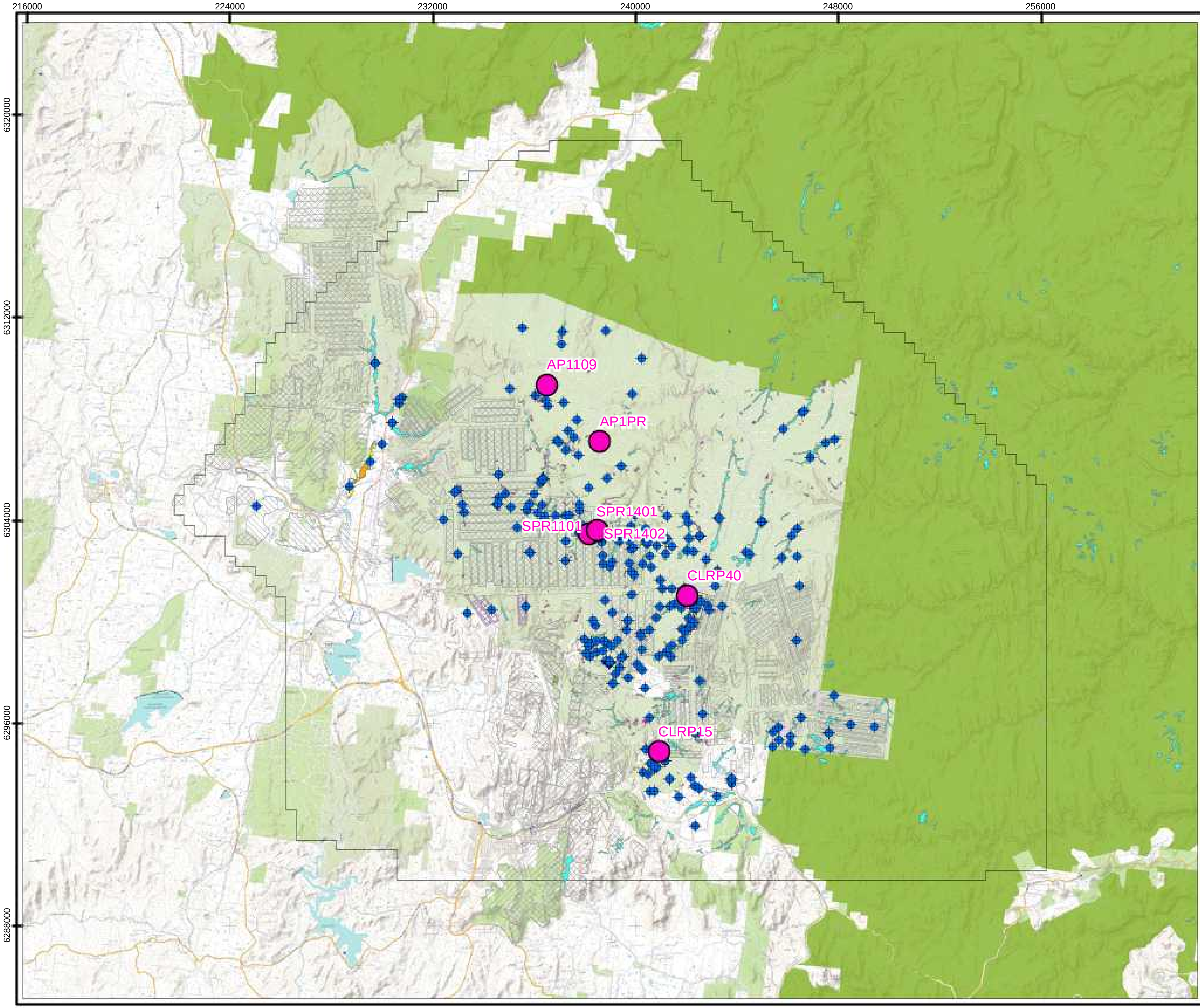
The measurement error of these observations was considered to be half an order of magnitude.

<u>Springvale Mine</u>

DGS (2015) oversaw drilling of two cored boreholes at LW415 (SPR1402) to 90mBGL and at LW416 (SPR1401) to 120mBGL, as an extension to work presented in DGS (2014). Those boreholes were installed as part of an investigation into a disruption to ridge piezometer SPR1101. Boreholes SPR1402 and SPR1401 were post-longwall-mining boreholes, whereas borehole SPR1101 was a pre-mining borehole.

Table 3-2 presents a summary of the outcomes of analysis of packer testing (after Table 5A and 5B of DGS (2015)) undertaken at each borehole.

From **Table 3-2** analysis indicates that hydraulic conductivity increases from a range of 1E-08 to 1E-07m/s, pre-mining, to a range of 5E-07 to 3E-06m/s, post- longwall-mining. That increase is consistent with the review by



Legend:

Greater Blue Moutains World Heritage Area

Mining Methods:
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:
- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):
- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Swamp by MU Name (RPS, 2018):
- 53 Mountain Hollow Grassy Fen (EEC)
- Typha orientalis Wetland

Hydrogeology:
- Groundwater Monitoring Locations
- Hydraulic Testing Locations

Modelling:
- Active Model Domain

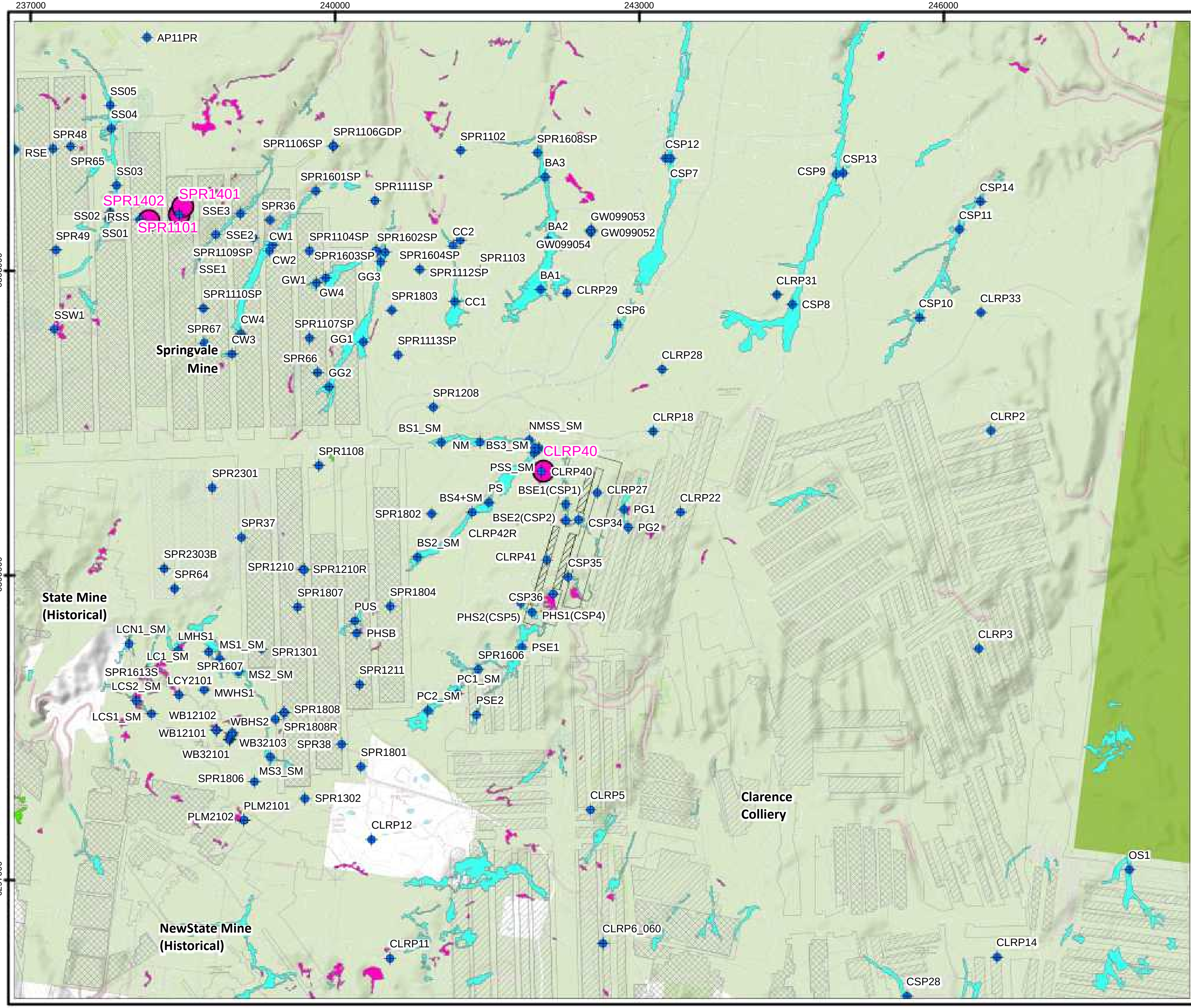
JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 04-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:200,000	
0 4 8 km	
Coor. Sys. GDA 1994 MGA Zone 56	

Groundwater Monitoring Network and Location of Hydraulic Testing

FIGURE: 3.10a

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D038a_MonitoringAndTestingNetwork.mxd
Reference: © Department of Customer Service 2020



Legend:

Greater Blue Moutains World Heritage Area

Mining Methods:
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:
- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):
- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Swamp by MU Name (RPS, 2018):
- 53 Mountain Hollow Grassy Fen (EEC)
- Typha orientalis Wetland

Hydrogeology:
- Groundwater Monitoring Locations
- Hydraulic Testing Locations

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 04-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:50,000	

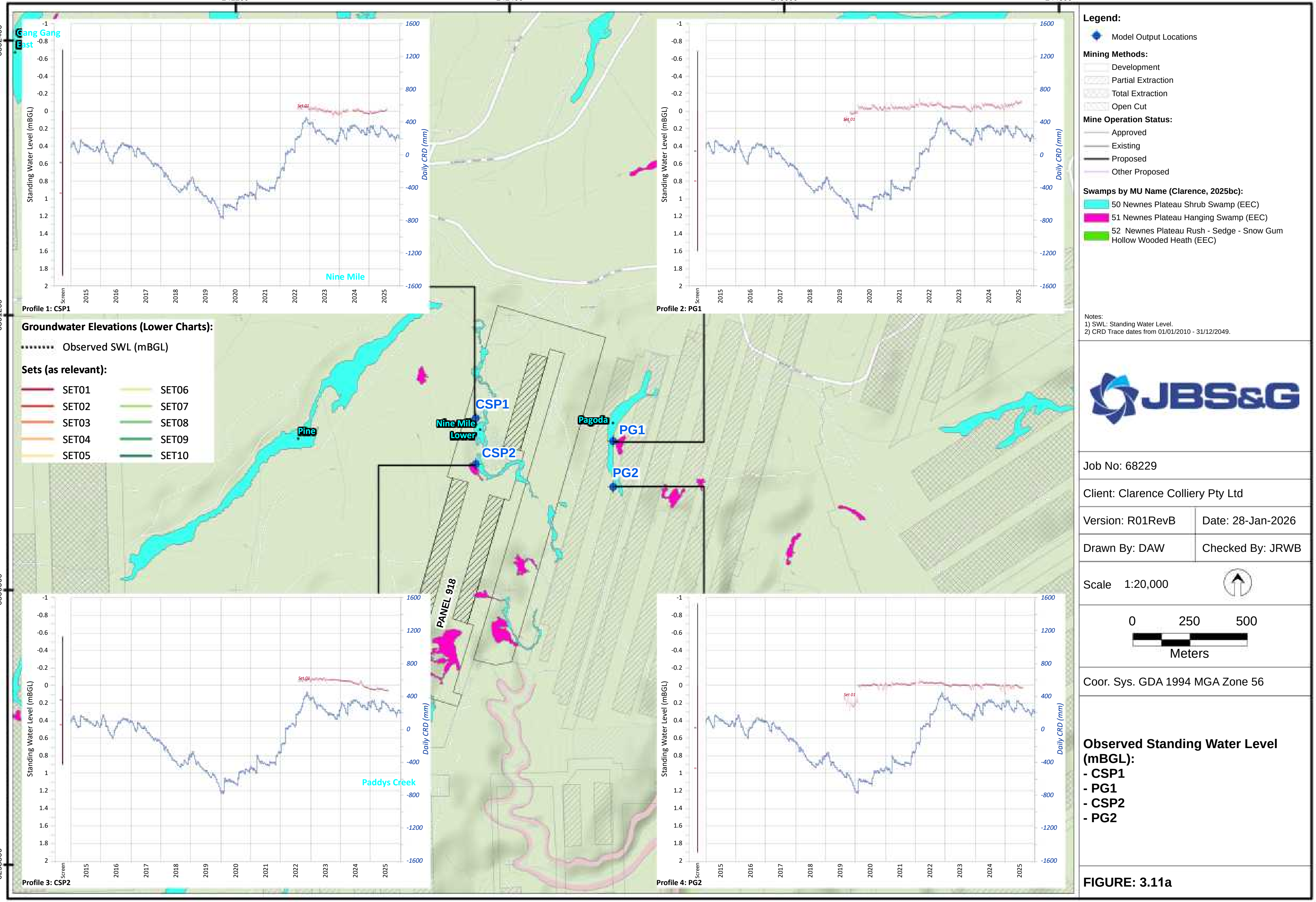
0 1 2
km

Coor. Sys. GDA 1994 MGA Zone 56

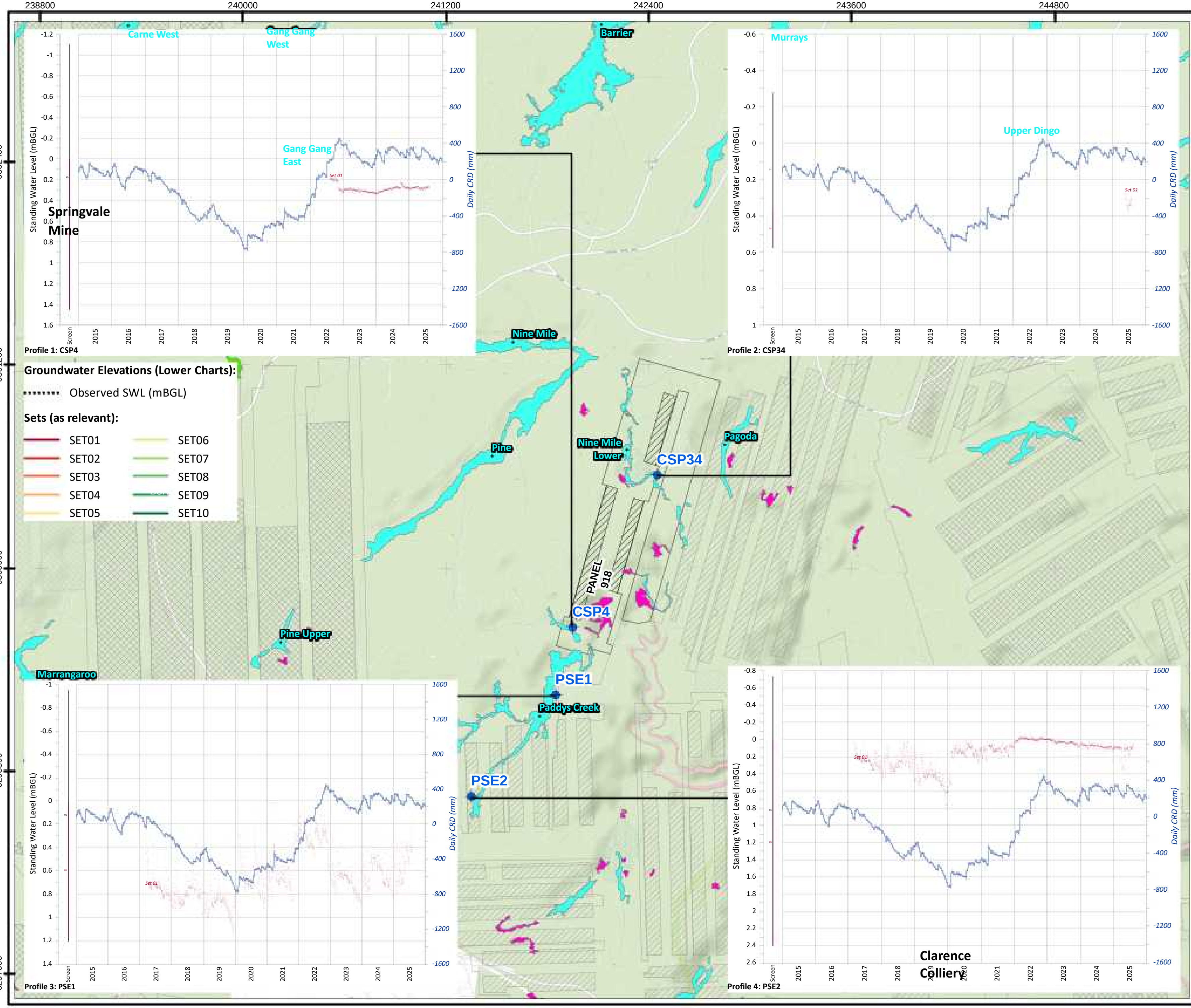
Groundwater Monitoring Network and Location of Hydraulic Testing - Vicinity of Panel 918

FIGURE: 3.10b

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D038b_MonitoringAndTestingNetwork_ClarenceZoom.mxd
Reference: © Department of Customer Service 2020



File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D067a_SWL_CSP1_PG1_CSP2_PG2.mxd
Reference: © Department of Customer Service 2020



Legend:

- Model Output Locations

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Notes:
1) SWL: Standing Water Level.
2) CRD Trace dates from 01/01/2010 - 31/12/2049.

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevB	Date: 28-Jan-2026
Drawn By: DAW	Checked By: JRWB
Scale 1:30,000	

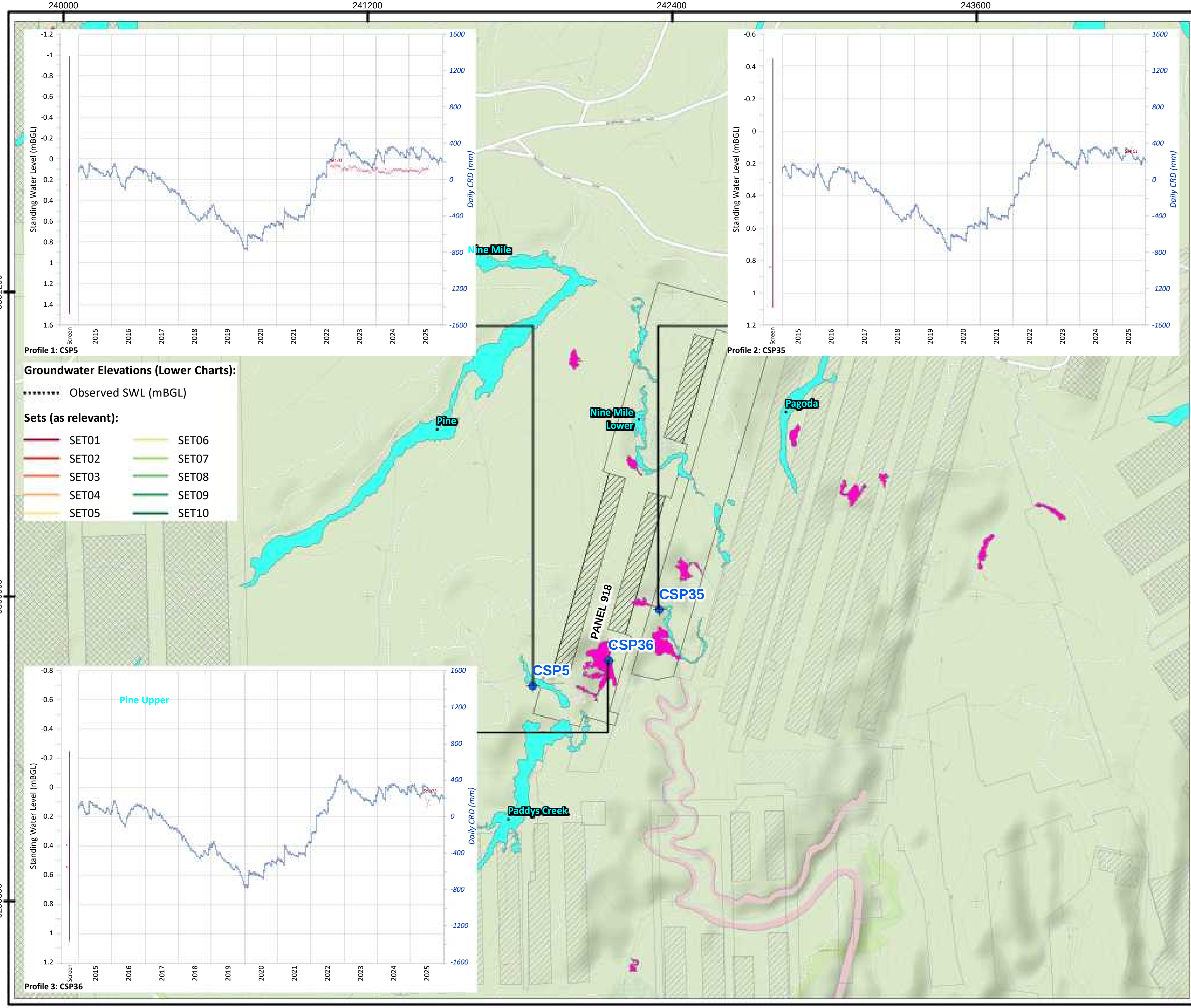
0 500 1,000
Meters

Coor. Sys. GDA 1994 MGA Zone 56

Observed Standing Water Level (mBGL):
- CSP4
- CSP34
- PSE1
- PSE2

FIGURE: 3.11b

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D067b_SWL_CSP6_CSP34_PSE1_PSE2.mxd
Reference: © Department of Customer Service 2020



Legend:

Model Output Locations

Mining Methods:
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:
- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):
- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Notes:
1) SWL: Standing Water Level.
2) CRD Trace dates from 01/01/2010 - 31/12/2049.

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevB	Date: 28-Jan-2026
Drawn By: DAW	Checked By: JRWB
Scale 1:20,000	

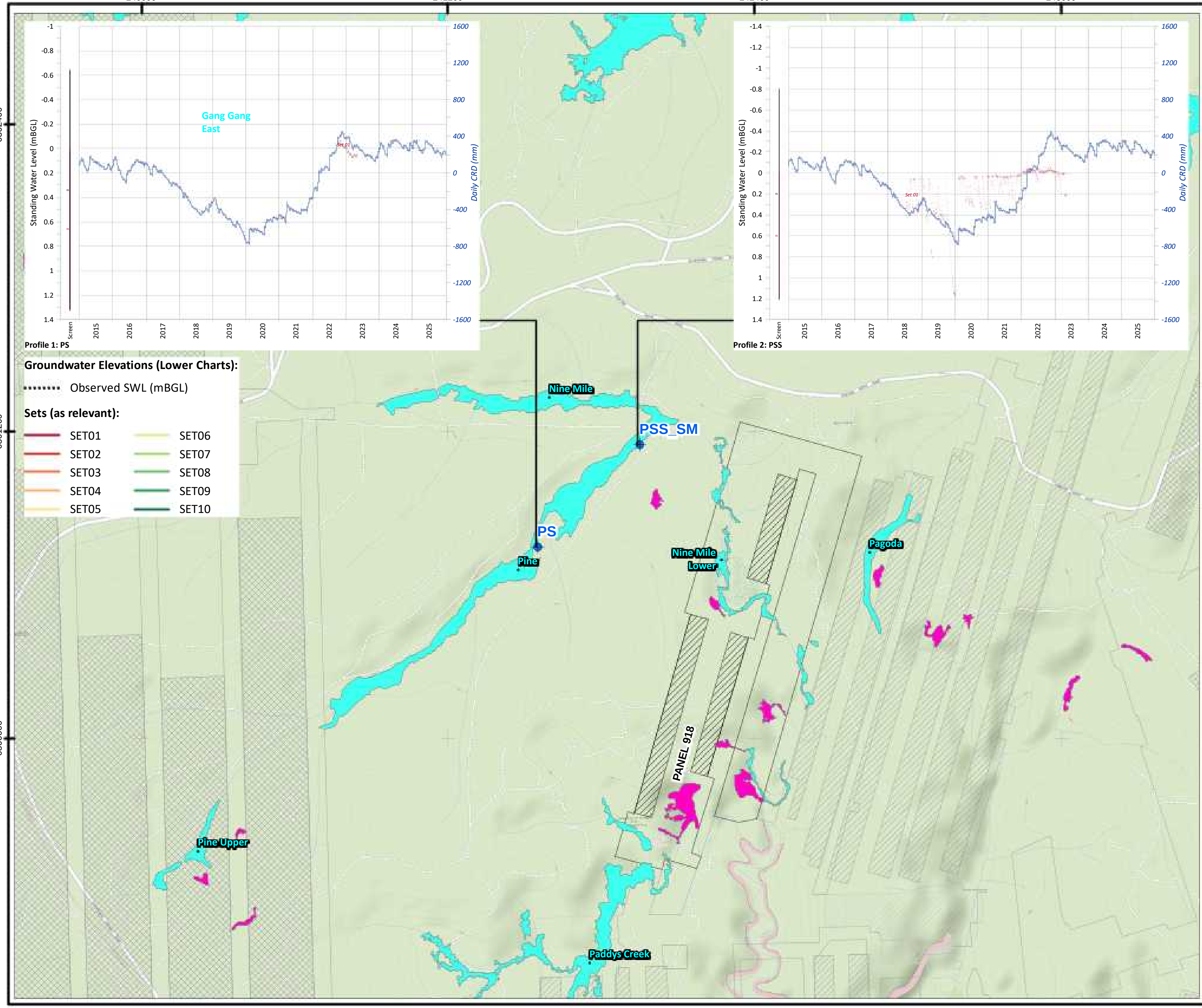
0 250 500
Meters

Coor. Sys. GDA 1994 MGA Zone 56

Observed Standing Water Level (mBGL):
- CSP5
- CSP35
- CSP36

FIGURE: 3.11c

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D067c_SWL_CSP5_CSP35_CSP36.mxd
Reference: © Department of Customer Service 2020



Legend:

Model Output Locations

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Notes:
1) SWL: Standing Water Level.
2) CRD Trace dates from 01/01/2010 - 31/12/2049.

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevB	Date: 28-Jan-2026
Drawn By: DAW	Checked By: JRWB
Scale 1:20,000	

0 250 500
Meters

Coor. Sys. GDA 1994 MGA Zone 56

Observed Standing Water Level (mBGL):
- PS
- PSS

FIGURE: 3.11d

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D067d_SWL_PS_PSS.mxd
Reference: © Department of Customer Service 2020

Table 3-2: Comparison of Pre-Mining (SPR1101(LW415 and LW416)) and Post-Mining (SPR1401(LW416) and SPR1402(LW415)) Average Hydraulic Conductivity (Km, average of isotropic equations) (after Table 5A and 5B of DGS (2015))

Table 5A - Pre and Post-Mining Rock Mass Permeability for LW416

Pre-Mining Averages					Post-Mining Averages					R
RL (m)	Depth (m)	K_m (m/s)	k_m (md)	Lugeons (uL)	RL (m)	Depth (m)	K_m (m/s)	k_m (md)	Lugeons (uL)	(K_{mpost}/K_{mpre})
1143	15	5.8E-08	6	0.3	-	-	-	-	-	-
1137	21	1.2E-07	13	0.6	-	-	-	-	-	-
1131	27	9.0E-08	9	0.4	-	-	-	-	-	-
1122	36	5.3E-08	5	0.3	-	-	-	-	-	-
1110	53	1.4E-07	14	0.7	1115	47	1.59E-06	165	10.2	11
1090	68	2.4E-08	2	0.1	1110	52	1.20E-06	125	5.3	9
1080	78	2.0E-08	2	0.1	1090	72	2.09E-06	218	12.4	87
1068	90	9.4E-09	1	0.0	1081	81	2.18E-07	23	1.1	11
1058	99.5	2.2E-08	2	0.1	-	-	-	-	-	-

Table 5B - Pre and Post-Mining Rock Mass Permeabilities for LW415

Pre-Mining Averages (SPR1101)					Post-Mining Averages (SPR1402)					R
RL (m)	Depth (m)	K_m (m/s)	k_m (md)	Lugeons (uL)	RL (m)	Depth (m)	K_m (m/s)	k_m (md)	Lugeons (uL)	(K_{mpost}/K_{mpre})
1143	15	5.8E-08	6	0.3	-	-	-	-	-	-
1137	21	1.2E-07	13	0.6	-	-	-	-	-	-
1131	27	9.0E-08	9	0.4	-	-	-	-	-	-
1122	36	5.3E-08	5	0.3	-	-	-	-	-	-
1110	53	1.4E-07	14	0.7	1098	62	2.4E-06	252	12.8	52
1090	68	2.4E-08	2	0.1	1093	67	2.6E-06	271	9.9	39
1080	78	2.0E-08	2	0.1	1086	74	8.8E-07	91	3.2	37
1068	90	9.4E-09	1	0.0	1080	80	7.6E-07	79	4.7	109
1058	99.5	2.2E-08	2	0.1	1072	89	4.9E-07	5	0.2	100

Tammetta (2015), insofar as the R value (where R is ratio of hydraulic conductivity post-mining compared to that pre-mining).

Table 3-3 through **Table 3-5** present the estimated hydraulic conductivity, including the corresponding hydrogeologic unit and layer number of the numerical groundwater model, which is described in detail further below. Literature values presented in **Table 3-3** through **Table 3-5** are obtained from **Figure 3-7**.

From **Table 3-3** through **Table 3-5**, the tests conducted at LW415 and LW416 targeted the Burralow Formation. That formation comprises Layer 12 and above in the groundwater model.

Table 3-3: Estimated Hydraulic Conductivity – Packer Test (SPR1101; Pre-Mining)

Test Interval (mBGL)	Estimated Hydraulic Conductivity (m/s)	Layer (ID)[a]	Unit	Literature Values of Hydraulic Conductivity (m/s)
15	5.8E-08	5 (12)	Sandstone (between YS2 and YS3)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
21	1.2E-07	5 (12)	Sandstone (between YS2 and YS3)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
27	9.0E-08	7 (12)	Sandstone (between YS3 and YS4)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
36	5.3E-08	7 (12)	Sandstone (between YS3 and YS4)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
53	1.4E-07	9 (12)	Sandstone (between YS4 and YS5)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)

Test Interval (mBGL)	Estimated Hydraulic Conductivity (m/s)	Layer (ID)[a]	Unit	Literature Values of Hydraulic Conductivity (m/s)
68	2.4E-08	9 (12)	Sandstone (between YS4 and YS5)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
78	2.0E-08	11 (12)	Sandstone (between YS5 and YS6)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
90	9.4E-09	11 (12)	Sandstone (between YS5 and YS6)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
99.5	2.2E-08	12 (14)	Shale (YS6)	7.0E-10 to 7.0E-08 (hor.) 3.0E-11 to 4.6E-09 (vert.)

Notes: a) ID is IDNum presented in **Table 4-2**.

Table 3-4: Estimated Hydraulic Conductivity – Packer Test (LW416 (SPR1401); Post-Mining)

Test Interval (mBGL)	Estimated Hydraulic Conductivity (m/s)	Layer	Unit	Literature Values of Hydraulic Conductivity (m/s)
47	1.6E-06	8 (14)	Shale (YS4)	7.0E-10 to 7.0E-08 (hor.) 3.0E-11 to 4.6E-09 (vert.)
52	1.2E-06	8 (14)	Shale (YS4)	7.0E-10 to 7.0E-08 (hor.) 3.0E-11 to 4.6E-09 (vert.)
72	2.1E-06	9 (12)	Sandstone (between YS4 and YS5)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
81	2.2E-07	11 (12)	Sandstone (between YS5 and YS6)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)

Notes: a) ID is IDNum presented in **Table 4-2**.

Table 3-5: Estimated Hydraulic Conductivity – Packer Test (LW415 (SPR1402); Post-Mining)

Test Interval (mBGL)	Estimated Hydraulic Conductivity (m/s)	Layer (ID)[a]	Unit	Literature Values of Hydraulic Conductivity (m/s)
62	2.4E-06	9 (12)	Sandstone (between YS4 and YS5)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
67	2.6E-06	9 (12)	Sandstone (between YS4 and YS5)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
74	8.8E-07	10 (14)	Shale (YS5)	7.0E-10 to 7.0E-08 (hor.) 3.0E-11 to 4.6E-09 (vert.)
80	7.6E-07	11 (12)	Sandstone (between YS5 and YS6)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
89	4.9E-07	11 (12)	Sandstone (between YS5 and YS6)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)

Notes: a) ID is IDNum presented in **Table 4-2**.

Angus Place Colliery

There are two hydraulic tests available at Angus Place Colliery. Both of these tests were located within the footprint of the Angus Place Mine Extension Project (1000 Panel Area). It is highlighted that the Angus Place Mine Extension Project has now been withdrawn.

Table 3-6 presents the estimated values of hydraulic conductivity at location AP1PR.

From **Table 3-6** the tested intervals include the Burralow Formation (Layer 12 and above in the groundwater model) and Banks Wall Sandstone (Layer 13 and Layer 14 in the model).

From **Table 3-6**, estimated hydraulic conductivity at the bottom of the Burralow Formation ranged between 2.0E-07 and 6.0E7m/s for sandstone and about 6.3E-08m/s for the shale. From **Table 3-6**, the estimated hydraulic conductivity in the Banks Wall Sandstone ranges between 3.4E-08 and 8.5E-07m/s. Literature values are also presented in **Table 3-6** and were obtained from **Figure 3-7**.

Table 3-6: Estimated Hydraulic Conductivity – Packer Test (AP1PR; Pre-Mining)

Test Interval (mBGL)	Estimated Hydraulic Conductivity (m/s)	Layer (ID)[a]	Unit	Literature Values of Hydraulic Conductivity (m/s)
73.1 to 84.2	3.8E-07 to 6.0E-07	11 (12)	Sandstone (between YS5 and YS6)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
85.1 to 96.2	2.0E-07 to 5.1E-07	11 (12)	Sandstone (between YS5 and YS6)	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
96.2 to 108.2	5.6E-08 to 7.6E-08	12 (14)	Sandstone/Shale (YS6)	7.0E-10 to 7.0E-08 (hor.) 3.0E-11 to 4.6E-09 (vert.)
108.2 to 120.2	1.1E-07 to 8.5E-07	13 (12)	Banks Walls Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
120.2 to 132.2	9.5E-08 to 1.1E-07	13 (12)	Banks Walls Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
132.2 to 144.2	6.9E-08 to 8.6E-08	13 (12)	Banks Walls Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
144.2 to 156.2	5.4E-08 to 6.9E-08	14 (12)	Banks Walls Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
156.2 to 168.2	3.4E-08 to 5.1E-08	14 (12)	Banks Walls Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
168.2 to 180.2	3.8E-08 to 4.5E-08	14 (12)	Banks Walls Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
180.2 to 186.2	5.9E-07 to 7.7E-07	14 (12)	Banks Walls Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)

Notes: a) ID is IDNum presented **Table 4-2**.

Table 3-7 presents the estimated values at location AP1109 (which is adjacent to vibrating wire piezometer, AP1204). It is noted that the depth to groundwater (in the open borehole) at AP1109 was not obtained during the test at the time and that JBS&G has attempted to derive an appropriate estimate. The results of analysis at AP1109 should therefore be treated with caution.

From **Table 3-7**, testing was undertaken in the Banks Wall Sandstone, Mt York Claystone, Burra-Moko Head Sandstone as well as the Glen Davis/Long Swamp Formation.

From **Table 3-7**, the estimated hydraulic conductivity at the bottom of the Banks Wall Sandstone is lower than that presented in **Table 3-6**, being about 2.0E-09m/s compared to 6.0E-08m/s (excluding the higher value presented in **Table 3-6** at the contact between the Banks Wall Sandstone (Layer 13 and 14) and the Mt York Claystone (Layer 15).

From **Table 3-7**, the estimated hydraulic conductivity of the Mt York Claystone range between 5.6E-09 and 1.2E-08m/s.

From **Table 3-7**, the estimated hydraulic conductivity is about 7E-09m/s for the Burra-Moko Head Sandstone and is about 8E-09m/s for the Glen Davis/Long Swamp Formation.

Table 3-7: Estimated Hydraulic Conductivity – Packer Test (AP1109; Pre-Mining)[a]

Test Interval (mBGL)	Estimated Hydraulic Conductivity (m/s)	Layer (ID)[b]	Unit	Literature Values of Hydraulic Conductivity (m/s)
103.1 to 115.1	1.4E-09 to 3.8E-09 (DTW assumed to be 50m)	14 (12)	Banks Walls Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
131.8 to 143.8	8.4E-09 to 1.2E-08 (DTW assumed to be 84m)	15 (16)	Mount York Claystone	7.0E-10 to 5.0E-08 (hor.) 6.1E-11 to 6.5E-09 (vert.)
143.5 to 155.5	5.6E-09 to 7.0E-09 (DTW assumed to be 84m)	15 (16)	Mount York Claystone	7.0E-10 to 5.0E-08 (hor.) 6.1E-11 to 6.5E-09 (vert.)
166.4 to 178.4	6.6E-09 to 7.8E-09 (DTW assumed to be 84m)	16 (12)	Burra-Moko Head Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
302.6 to 314.6	5.6E-09 to 1.6E-08 (DTW assumed to be 84m)	22 (13)	Glen Davis/Long Swamp Formation	7.0E-09 to 1.8E-07 (hor.) 4.3E-10 to 1.7E-08 (vert.)

Notes: a) The depth to groundwater in the borehole was not recorded during testing at the time. JBS&G have assumed the values noted in the table. Those assumptions were based on review of groundwater elevations in the vibrating wire piezometer, AP1204, whilst allowing for the 'composite nature' of what that depth to groundwater level would have been. It is emphasised that the assumption is important as to resultant calculation, therefore the interpreted values should be treated with caution.; b) ID is IDNum presented in **Table 4-2**.

Clarence Colliery

Hydraulic testing at Clarence Colliery was conducted at location CLRP15 and CLRP40 (EMM, 2023).

Table 3-8 presents the estimated hydraulic conductivity undertaken on test intervals from the Banks Wall Sandstone through to the Caley Formation at CLRP15.

From **Table 3-8**, the estimated hydraulic conductivity in the Banks Wall Sandstone ranges between 3.9E-08 and 1.4E-07m/s. From **Table 3-8**, estimated hydraulic conductivity of the Mt York Claystone ranges between 7E-08m/s and 2.3E-07m/s. This is higher than that found at AP1109, presented above. From **Table 3-8**, the estimated hydraulic conductivity in the Burra-Moko Head Sandstone ranges between 1.3E-07m/s and 5.8E-07m/s. The estimated hydraulic conductivity in the Caley Formation is about 1.0E-07m/s in **Table 3-8**.

Table 3-8: Estimated Hydraulic Conductivity – Packer Test (CLRP15; Pre-Mining)

Test Interval (mBGL)	Estimated Hydraulic Conductivity (m/s)	Layer (ID)[a]	Unit	Literature Values of Hydraulic Conductivity (m/s)
57.0 to 63.0	3.9E-08	14 (12)	Banks Wall Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
63.0 to 69.0	1.1E-07	14 (12)	Banks Wall Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
69.0 to 75.0	6.4E-08	14 (12)	Banks Wall Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
75.0 to 81.0	3.9E-07	14 (12)	Banks Wall Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
81.0 to 87.0	1.7E-07	14 (12)	Banks Wall Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
87.0 to 93.0	1.4E-07	14 (12)	Banks Wall Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
93.0 to 99.0	9.0E-08	15 (16)	Mount York Claystone	7.0E-10 to 5.0E-08 (hor.) 6.1E-11 to 6.5E-09 (vert.)

Test Interval (mBGL)	Estimated Hydraulic Conductivity (m/s)	Layer (ID)[a]	Unit	Literature Values of Hydraulic Conductivity (m/s)
99.0 to 105.0	7.0E-08	15 (16)	Mount York Claystone	7.0E-10 to 5.0E-08 (hor.) 6.1E-11 to 6.5E-09 (vert.)
105.0 to 111.0	9.3E-08	15 (16)	Mount York Claystone	7.0E-10 to 5.0E-08 (hor.) 6.1E-11 to 6.5E-09 (vert.)
111.0 to 117.0	1.7E-07	15 (16)	Mount York Claystone	7.0E-10 to 5.0E-08 (hor.) 6.1E-11 to 6.5E-09 (vert.)
117.0 to 123.0	2.3E-07	15 (16)	Mount York Claystone	7.0E-10 to 5.0E-08 (hor.) 6.1E-11 to 6.5E-09 (vert.)
123.0 to 129.0	1.3E-07	16 (12)	Burra-Moko Head Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
129.0 to 135.0	5.8E-07	16 (12)	Burra-Moko Head Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
135.0 to 141.0	3.3E-07	16 (12)	Burra-Moko Head Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
141.0 to 147.0	2.1E-07	16 (12)	Burra-Moko Head Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
147.0 to 153.0	1.8E-07	16 (12)	Burra-Moko Head Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
153.0 to 159.0	1.1E-07	17 (13)	Caley Formation	7.0E-09 to 1.8E-07 (hor.) 4.3E-10 to 1.7E-08 (vert.)
159.0 to 165.0	9.9E-08	17 (13)	Caley Formation	7.0E-09 to 1.8E-07 (hor.) 4.3E-10 to 1.7E-08 (vert.)

Notes: a) ID is IDNum presented in **Table 4-2**.

Table 3-9 presents the estimated hydraulic conductivity undertaken on test intervals from Banks Wall Sandstone through to Caley Formation.

From **Table 3-9**, the estimated hydraulic conductivity of the Banks Wall Sandstone ranges between 1.2E-08 and 1.2E-09m/s. This is lower than the outcome of testing at CLRP15 by about one order of magnitude. From **Table 3-9**, the estimated hydraulic conductivity of the Mount York Claystone is 2.3E-08m/s. At CLRP15, the estimated hydraulic conductivity of the Mount York Claystone was about one order of magnitude higher, in comparison. From **Table 3-9**, the hydraulic conductivity of the Burra-Moko Head Sandstone is between 6.9E-09 and 1.2E-08m/s. At CLRP15, the estimated hydraulic conductivity of the Burra-Moko Head Sandstone is one order of magnitude higher. From **Table 3-9**, the estimated hydraulic conductivity is 1.2E-08 to 2.3E-08m/s. At CLRP15, the estimated hydraulic conductivity is one order of magnitude higher.

Table 3-9: Estimated Hydraulic Conductivity – Packer Test (CLRP40; Pre-Mining)

Test Interval (mBGL)	Estimated Hydraulic Conductivity (m/s)	Layer (ID)[a]	Unit	Literature Values of Hydraulic Conductivity (m/s)
70.5 to 79.9	1.2E-09	14 (12)	Banks Wall Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
110.0 to 120.1	1.2E-08	14 (12)	Banks Wall Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
125.0 to 140.1	2.3E-08	15 (16)	Mount York Claystone	7.0E-10 to 5.0E-08 (hor.) 6.1E-11 to 6.5E-09 (vert.)

Test Interval (mBGL)	Estimated Hydraulic Conductivity (m/s)	Layer (ID)[a]	Unit	Literature Values of Hydraulic Conductivity (m/s)
149.5 to 160.0	6.9E-09	16 (12)	Burra-Moko Head Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
170.0 to 180.1	1.2E-08	16 (12)	Burra-Moko Head Sandstone	1.3E-08 to 6.4E-07 (hor.) 1.4E-09 to 1.1E-07 (vert.)
212.5 to 220.1	2.3E-08	17 (13)	Caley Formation	7.0E-09 to 1.8E-07 (hor.) 4.3E-10 to 1.7E-08 (vert.)
232.5 to 249.1	1.2E-08	17 (13)	Caley Formation	7.0E-09 to 1.8E-07 (hor.) 4.3E-10 to 1.7E-08 (vert.)

Notes: a) ID is IDNum presented in **Table 4-2**.

Summary of Findings

Testing indicates that the estimated hydraulic conductivity in the Burralow Formation ranges between 9E-09m/s and 1E-07m/s. Given the quite thin nature of the shale layers, specific testing of the properties of shale compared to that of sandstone was not available.

Analysis by DgS (2015) indicates that mine-subsidence (as a result of longwall mining (Model Mining Method 5)) at Springvale Mine led to an increase in estimated hydraulic conductivity. The post-mining test results range between 4.9E-07 and 2.6E-06m/s.

In the Banks Wall Sandstone, there is a range of estimated hydraulic conductivity, from between ~1E-09m/s and 9E-07m/s.

In the Mt York Claystone, the estimated hydraulic conductivity ranges between 5E-09m/s and 2E-07m/s. This is a tighter range of values than that found for the Banks Wall Sandstone. The values at CLRP15 are higher than would be initially expected for a geologic unit described as a claystone.

Hydraulic testing indicates that the hydraulic conductivity in the Burra-Moko Head Sandstone ranges between 7E-09 to 6E-07m/s, with the Caley Formation being between 1E-08 and 1E-07m/s.

Groundwater Quality

Groundwater monitoring undertaken at Clarence and at neighbouring operations included groundwater quality monitoring. Groundwater quality monitoring occurs at Clarence on a quarterly basis.

The groundwater quality monitoring locations include:

- CLRP04 (standpipe piezometer was blocked)
- CLRP05
- CLRP07
- CLRP08

Figure 3-10 presents the groundwater quality monitoring locations.

Table 3-10 and **Table 3-11** presents the groundwater quality analytical results obtained from the above locations over two time periods including March 2024 and December 2024.

Table 3-10: Representative Groundwater Quality Results (14/03/2024)

Parameter	Units	CLRP05	CLRP07	CLRP08
Range of samples		14/03/2024	14/03/2024	14/03/2024
pH		5.5	6.0	5.6
EC	µS/cm	60	45	89

Aluminium	mg/L	0.09	0.07	0.11
Barium	mg/L	0.005	0.005	0.02
Cobalt	mg/L	<0.001	<0.001	0.026
Manganese	mg/L	0.084	0.085	0.046
Strontium	mg/L	0.015	0.016	0.006
Zinc	mg/L	0.029	0.028	0.176

Table 3-11: Representative Groundwater Quality Results (11/12/2024)

Parameter	Units	CLRP05	CLRP07	CLRP08
Range of samples		11/12/2024	11/12/2024	11/12/2024
pH		4.6	5.9	4.6
EC	µS/cm	31	58	35
Aluminium	mg/L	0.03	0.1	0.03
Barium	mg/L	0.009	0.004	0.018
Cobalt	mg/L	<0.001	0.004	0.004
Manganese	mg/L	0.029	0.101	0.012
Strontium	mg/L	0.002	0.017	0.003
Zinc	mg/L	0.019	0.047	0.117

Groundwater quality for these standpipe piezometers have been given trigger values as presented in Table 6.5 of the Water Management Plan (WMP) (Clarence, 2026).

<u>CLRP05, CLRP07 and CLRP08</u>

Groundwater monitoring piezometers CLRP05, CLRP07 and CLRP08 are screened in the Banks Wall Sandstone above the Mount York Claystone. All three piezometers in March 2024 have pH ranging between 5.5 and 6.0 and in December 2024 the pH ranges between 4.6 and 5.9, which indicates that the groundwater is moderately acidic. This is between the trigger value range of 4.5 and 6.0 as presented in Table 6.5 of the WMP (Clarence, 2026).

Groundwater obtained from the three groundwater piezometers is considered fresh, with an Electrical Conductivity (EC, expressed as µS/cm, being micro-Siemens per centimetre) between 31 and 89µS/cm over the two periods. This is less than the trigger value of 190µS/cm as presented in Table 6.5 of the WMP (Clarence, 2026).

Dissolved metals recorded at the three groundwater monitoring locations over the two periods are generally maintained beneath the groundwater quality trigger values presented in the WMP. Note that earlier data is presented in the WMP (Clarence, 2026).

The groundwater quality is not expected to change due to extraction of 918 Panel.

Surface Water Quality

Surface water quality is presented in the Surface Water Assessment (JBS&G, 2025c).

3.5.9 Groundwater Dependent Ecosystems

The Newnes Plateau Shrub Swamps and the Newnes Plateau Hanging Shrub Swamps are groundwater dependent ecosystems and form part of the Temperate Highland Peat Swamp on Sandstone (THPSS). The THPSS are listed under the federal *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) and the state *Biodiversity Conservation Act* 2016 (NSW).

THPSS are also listed as high priority groundwater dependent ecosystems in the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources* 2023 (NSW).

Newnes Plateau Shrub Swamps primarily occur in narrow eroded valleys of the Burralow Formation or Banks Wall Sandstone.

Newnes Plateau Hanging Shrub Swamps tend to occur on side slopes of valleys and are reliant on seepage from geologic contacts of the Burralow Formation or within the Banks Wall Sandstone.

Newnes Plateau Shrub Swamps of relevance to 918 Panel include:

- Nine Mile Lower Swamp
- Paddys Creek Swamp Hanging Swamp.

The location of Newnes Plateau Shrub Swamps and Newnes Plateau Hanging Swamps with respect to 918 Panel are presented in **Figure 3-2**.

It is noted that the mapped extent of THPSS is based on Clarence (2025bc). The mapped extent of THPSS has been progressively updated from the initial desktop mapping undertaken by NSW DCCEEW (2006a). The mapped extent of THPSS, as associated Ecological Studies that underpin that mapping, is consistent with the intent of CTH IESC (2019), being the Explanatory Note outlining an approach to the identification and assessment of groundwater dependent ecosystems.

3.6 Groundwater/Surface Water Interaction

There is potential for groundwater/surface water interaction along Newnes Plateau Shrub Swamps including Pine Swamp, Nine Mile Swamp, Paddys Creek Swamp and Nine Mile Lower Swamp. This is expected since these swamps are designated as groundwater dependent ecosystems.

Seepage faces, where groundwater is discharged to atmosphere at outcrop of hydrogeological units, are an important contribution to surface water flow.

Geological lineaments exist in the vicinity of 918 Panel, namely Nine Mile Lower Swamp with respect to Bungleboori Creek. Nine Mile Swamp and Pine Swamp, located to the west of 918 Panel are also underlain by lineaments. Due to PPPE (Model Mining Method 3) being a ‘low’ subsidence mining method, lineament reactivation will not occur during extraction of 918 Panel.

This is supported by the analysis presented in SCT (2026) which undertook a review of subsidence-related change at Pagoda Swamp, which was undermined by 906 Panel, and is immediately adjacent to the 908-910 Panel Area. From **Figure 3-7**, there are mapped lineaments connecting 906 Panel to 908-910 Panel Area.

From Section 5.3.1 of SCT (2026), the maximum surface subsidence above 918 Panel will be 76 +/- 20mm.

From Section 9.1.1 of SCT (2026), “*The secondary extraction of 906 Panel after 910 and 908 Panels has increased the maximum subsidence along D Line from 147mm to 193mm. The maximum subsidence is now located above the centre of all three panels above the central spine pillar system of 908 Panel.*”.

Review of the observation dataset for Pagoda Swamp does not indicate adverse decline due to development and extraction of 906 Panel and 908-910 Panel Area, despite the presence of lineaments.

Subsidence contours and valley closure assessment is presented in MSEC (2026).

3.7 Mining

3.7.1 Subsidence-Induced Change to Hydraulic Properties

Underground mining leads to subsidence at ground surface, the magnitude of which depends on the selected mining method. The process of subsidence also leads to changes to the hydraulic properties of overlying strata above the top of the mined seam.

There are considered to be four zones, in terms of subsidence-induced change to hydraulic properties:

- Surface Zone (Zone D)
- Elastic Zone (Zone C)
- Constrained Zone (Zone B)
- Continuous Cracking (Zone A)
- Caved Zone (Zone A).

'Ramp' functions are used to represent the relative magnitude of change to hydraulic properties with height above the top of mined seam. A 'ramp' function is a mathematical term to describe an unary (single argument) function that is not continuously differentiable (or 'smooth'). i.e. the function has sharp 'points'.

A detailed discussion of the 'ramp' functions used in this study is presented in **Section 4.11**.

The "minimum resultant hydraulic conductivity" hypothesis acknowledges that higher subsidence mining methods can rupture hydrogeologic units that are acting as aquitards, which would otherwise prevent vertical migration of groundwater from ground surface through the overlying strata and into the underground workings.

3.7.2 Influence of the former State Mine on Springvale Mine

In a previous groundwater model update (JBS&G, 2024), the conceptual understanding of State Mine, immediately south of the Springvale Mine, was reviewed. Conceptually, the State Mine 'Complex' has been filling with water (normal vertical percolation of groundwater from the shallow system into the deep system, recovery of groundwater elevation from historical mining operations and inflow from additional recharge via Lithgow township due to connectedness of the extensive network of historical workings) for an extended period, with 'pressure relief'/'hydraulic control' being provided by the adit at the historical Vale of Cywydd mine located to the south of the township of Lithgow, NSW. The new understanding from available data indicated that the State Mine 'Complex' had filled to the elevation, underground, of the entrance to the Fernbrook Colliery workings and then 'spilled into it'.

Recharge to workings underneath the township of Lithgow NSW is facilitated by the influence of urban processes (stormwater runoff (leaky pipes), irrigation of playing fields, watering of gardens).

3.7.3 Mine Dewatering

Mine dewatering occurs at Clarence Colliery ahead of extraction (2^{nd} workings). Dewatering is achieved via down-gradient sumps with a network of transfer pumps between the various mine water storages underground.

Extracted groundwater is currently discharged via LDP002 to the Wollangambee River following treatment.

The observed dewatering rate at Clarence Colliery, and at Springvale Mine and Angus Place Colliery, is presented in **Section 4.12.4**.

The observed dewatering rate was interpolated where required as well as being converted into cumulative dewatering volume. The expected measurement error in flow rate is +/- 1ML/d.

3.7.4 Mine Water Storage

Mine water storage entails recovery of groundwater in previously mined (sometimes inclusive of goaf) districts/sections of the underground workings. The groundwater level is maintained by pumping, where the intake is set at a particular coal seam floor elevation.

Mine water storage in the region comprises the following:

- Lithgow Seam

- State Mine Complex (located to the south of Springvale Mine)
  - controlled at 895mAHD, by an adit located to the far southeast of State Mine Complex
  - groundwater level is such that multiple historical mining operations are considered to be 'flooded' (confirmed by groundwater level observation of previous ventilation shafts in State Mine).
- Angus Place Colliery – District 700/800
  - 805mAHD.
- Angus Place Colliery – District 900
  - 800mAHD.
- Springvale Mine – Northern Longwalls.
  - 730mAHD.

- Katoomba Seam.
  - Clarence Colliery – 800 Area
    - 768mAHD.
  - Clarence Colliery – 300 Area.
    - 800mAHD.

Figure 3-12 presents where water is being stored underground.

3.8 Groundwater Users

Figure 3-13 presents the location of proximal groundwater works in the vicinity of 918 Panel. These locations were obtained from WaterNSW (PINNEENA database).

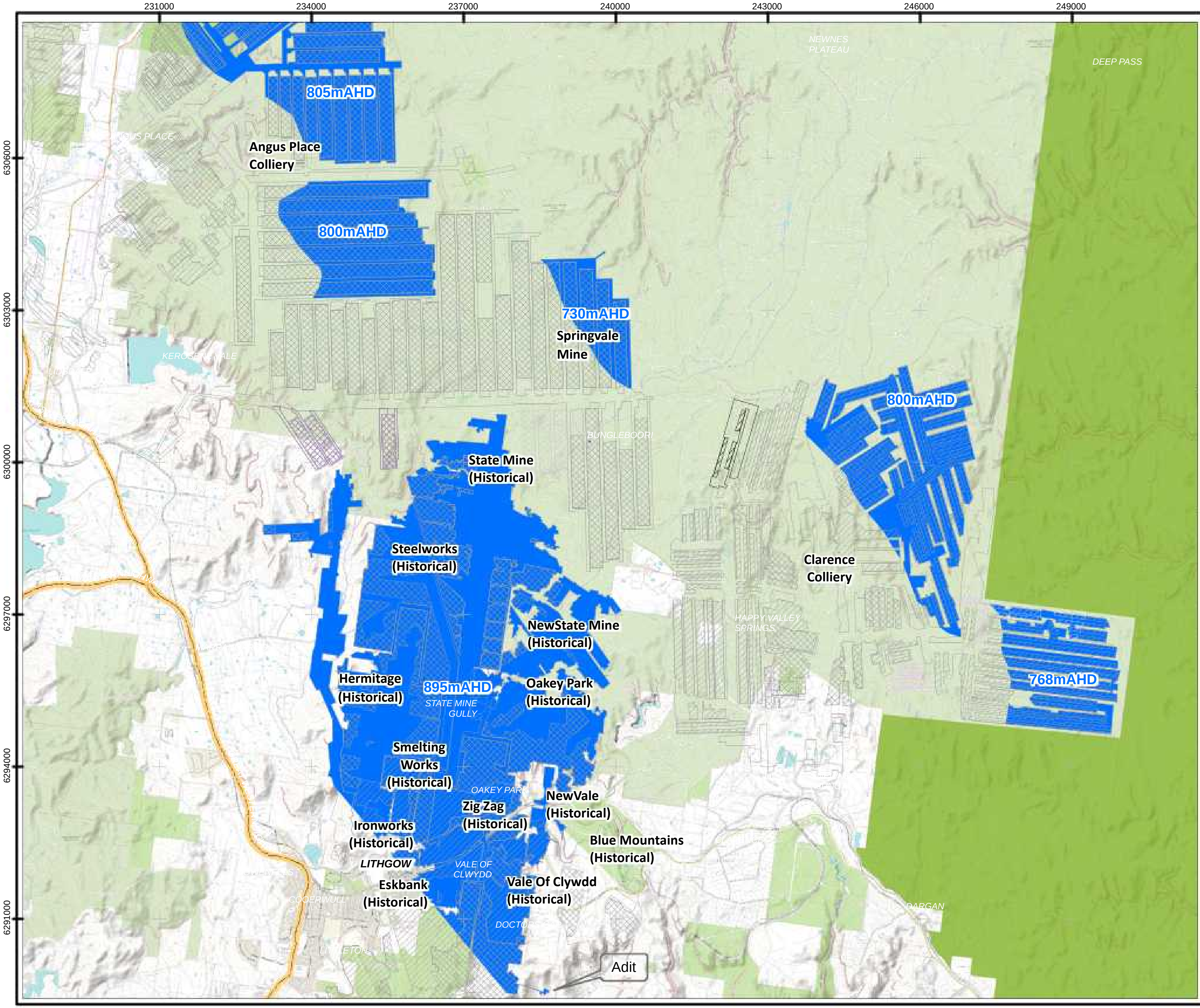
From **Figure 3-13**, there are no groundwater works in a 2km vicinity of 918 Panel, other than observation and dewatering works owned and operated by Clarence Colliery or Springvale Mine.

The NSW Water Register (https://waterregister.waternsw.com.au/water-register-frame) was reviewed and Water Access Licences (WAL) in the vicinity of Clarence Colliery identified. The location of WALs taking from groundwater sources are indicated in **Figure 3-13**.

3.9 Surrounding Land-Uses

Land-use above Clarence Colliery is predominantly the Garden of Stone Reserves, which is managed by the NSW National Parks and Wildlife Service. In the past, the Forestry Corporation of NSW (formerly NSW State Forests) operated the Newnes State Forest, for timber production. JBS&G understands that the Newnes State Forest is in the process of being transferred into the Garden of Stone Reserves. Surrounding Clarence Colliery to the north, east and south is the Greater Blue Mountains World Heritage Area.

There are multiple mines, both historical and existing (these extract or have extracted from the Lithgow Seam), in the vicinity of Clarence Colliery (extracts from the Katoomba Seam). These include:



Legend:

- Highway
- Greater Blue Moutains World Heritage Area

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Hydrogeology:

- Mine Water Storage

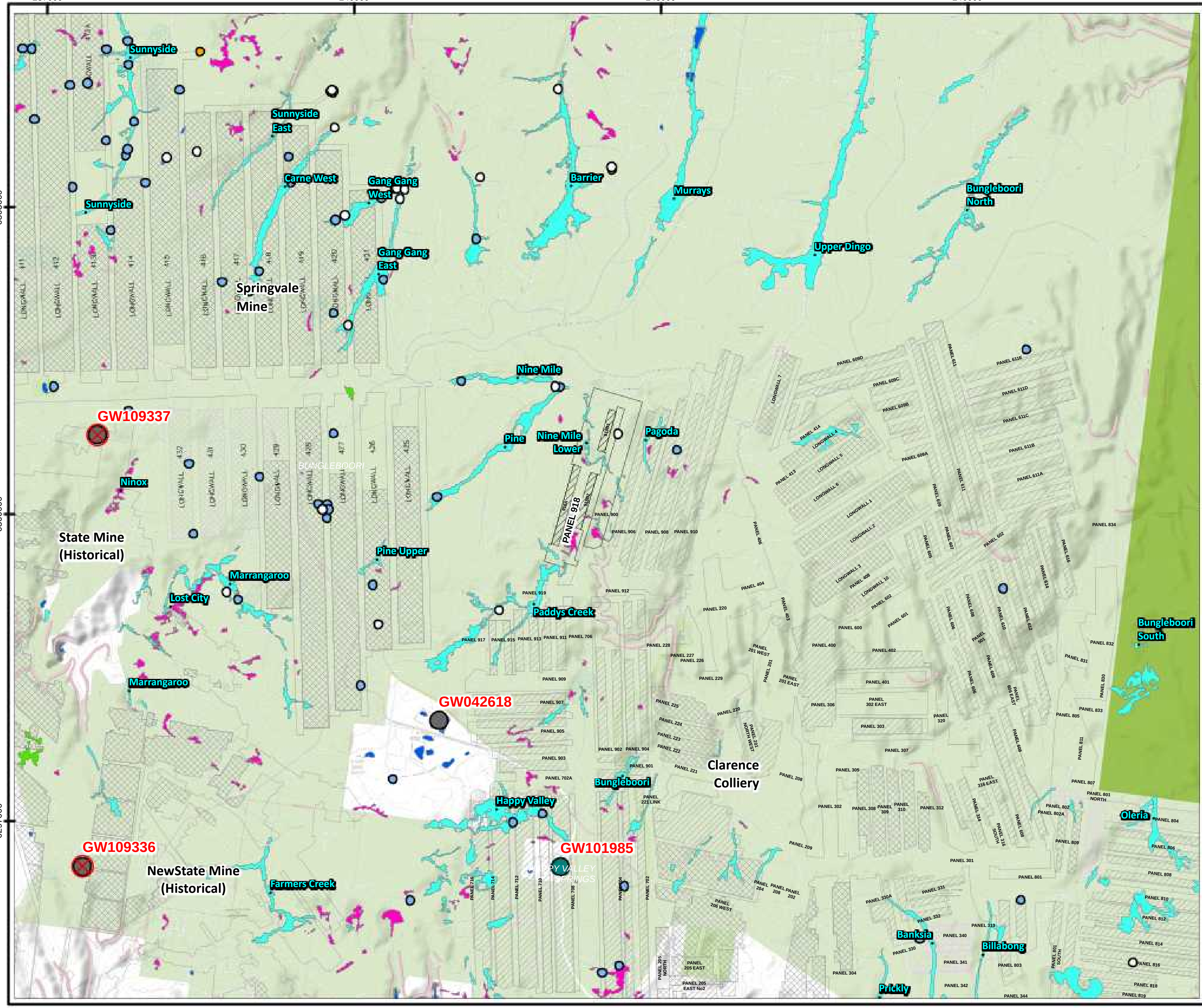
Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevB	Date: 22-Jan-2026
Drawn By: DAW	Checked By: JRWB
Scale 1:100,000	
0 1 2 km	
Coor. Sys. GDA 1994 MGA Zone 56	

Mine Water Storage

FIGURE: 3.12

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D053_MineWaterStorage.mxd

Reference: © Department of Customer Service 2020



Legend:

Greater Blue Moutains World Heritage Area

Mining Methods:	Mine Operation Status:
Development	Approved
Partial Extraction	Existing
Total Extraction	Proposed
Open Cut	Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Groundwater Work Type:

- Decomissioned
- WALs
- Industrial
- Irrigation
- Stock and Domestic
- Dewatering
- Monitoring
- No data

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 04-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:50,000	

0 1 2
km

Coor. Sys. GDA 1994 MGA Zone 56

Location of Proximal Groundwater Works

FIGURE: 3.13

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D039_GWWorks.mxd
Reference: © Department of Customer Service 2020

- Springvale Mine is located directly west and northwest of Clarence
  - Springvale is currently operational and extraction is via the longwall method (Model Mining Method 5).
- Historical mines (New State Mine and Oakey Park) border the westernmost panels of Clarence Colliery
  - Oakey Park Colliery was established in 1888 and was operational until 1941
  - New State Mine was assumed to operate between 1928 and 1941.
- Angus Place Colliery to the north and northwest of Springvale Mine
- Other historical mines (all included in the groundwater model)
  - State Mine
  - Steelworks Colliery
  - New State Mine
  - Fernbrook Colliery
  - Hermitage Colliery
  - Oakey Park Colliery
  - Smelting Works Colliery
  - Zig Zag Colliery.

The location of current and historical works in the vicinity of Clarence Colliery is presented in **Figure 1-1**.

4. Numerical Modelling

This chapter presents model history, model objectives, model setup (model geometry and boundary conditions), model calibration, sensitivity analysis as well as model simulations incorporating predictive uncertainty.

4.1 Model History

Groundwater modelling at Springvale Mine and Angus Place Colliery was commenced by the CSIRO, using their COSFLOW modelling platform, through an ACARP project (ACARP, 2007, 2012) and then extended (CSIRO, 2013, 2015 and 2016) as part of the Springvale Mine Extension Project (RPS, 2014) and Angus Place Mine Extension Project. JBS&G's modeller was one of the main authors of Groundwater Impact Assessment of these projects and was the main author of the Surface Water Impact Assessment of these projects, whilst he was working for RPS Aquaterra Pty Ltd (RPS). The COSFLOW model comprised mechanical deformation (stress/strain) and variably saturated flow, but, subsequently was reduced to variably saturated flow only (CSIRO, 2013, 2015 and 2016).

As extraction of the northern longwalls at Springvale Mine progressed, differences between the predicted change to groundwater elevation and groundwater contribution to surface water flow were identified with respect to THPSS shrub swamps. These differences triggered a request by the Independent Monitoring Panel (IMP), appointed to Springvale Mine as part of Conditions of Approval of the Springvale Mine Extension Project, to update the groundwater model to account for these differences. At the time, changes to the COSFLOW model, in order to incorporate the role of geological lineaments (thought to be part of the explanation of the differences between observed and predicted change to the groundwater system), would have required reconstruction of the model grid and the decision was made to seek an alternative.

A replacement groundwater model, based on the United States Geological Survey (USGS) modelling code, MODFLOW-USG (Unstructured Grid), commenced development in 2017, whilst JBS&G's modeller was working at Jacobs Group (Australia) Pty Ltd (Jacobs), and then has continued through to the present day.

A benefit of MODFLOW-USG is that hydrogeologic units that are not continuous can be 'pinched out', thereby saving, computationally, on needing to compute redundant model cells. Use of variably saturated flow was also continued.

During the period 2017-2019, two versions of the replacement groundwater model were attempted.

The first was a regionally extensive irregular grid, via AlgoMesh, that incorporated a 'relative' grid cell size of 30m along geological lineament zones and all major regional surface watercourses to the far north, south and east of Springvale Mine. It was found that the Graphical User Interface (GUI), Groundwater Vistas, required to view model input and output, was not sufficiently operational (with respect to irregular grids) at that time; but, nonetheless, the density of model grid was such that it was computationally intractable.

The second version of the model used a regular grid and a reduced regional extent. It deployed quadtree refinement along all major surface watercourses, as well as two levels of refinement in the area of interest, with the resultant model grid being 100m, 200m and 400m across 28 layers, vertically.

The initial approach to calibration of second version of the model comprised constant values of hydraulic properties in each layer, with segments along geological lineaments (100m cells) being assigned different values of hydraulic properties. As per the typical approach in MODFLOW, the 'relative effect' of a thin, usually higher hydraulic conductivity, feature, such as a geological lineament, was applied by adjusting the bulk properties of the relevant model cell. The approach to representing the effect of change to hydraulic properties due to mine subsidence was consistent with the approach adopted by the CSIRO, namely, that a drain (DRN) cell was applied at the mined seam, with changes to hydraulic properties above (in this case, only hydraulic conductivity, as it was identified that there was a model instability issue when attempting to also change storage properties). Calibration of the groundwater model proved elusive; however, through that calibration process, JBS&G identified that heterogeneity (different values of hydraulic properties throughout each layer) as well as 'Stacked Drains' (to the top of Zone A) were necessary assumption to match groundwater elevation and observed dewatering rate. As part of amendment of the calibration model, the 'segmental' approach to geological lineaments was dropped, and, instead, Pilot Points (Doherty, 2025) were used to represent heterogeneity. Another assumption was that 'Stacked Drains' were 'turned on and stayed on'.

Since the 2017-2019 period, model development has continued and comprised:

- Refinement of model extent, with respect to the northeast region, benefiting from known groundwater elevation (from the earlier version of the model) along that boundary (so as reduce the number of cells being modelled)
- Increase the number of model layers from 28 to 30, in order to allow subdivision of the Nile Subgroup (which variably outcrops along the Upper Coxs River)
- 'Stacked Drains' being applied for a single SP, prior to being turned off, with Time Varying Material (TVM) then being applied
- Development of a cosimulation approach to 'layer-based' hydraulic properties, whereby horizontal hydraulic conductivity was modelled using Pilot Points (including covariance matrices), and sympathetic values for vertical hydraulic conductivity, specific storage and specific yield (as well as other parameters, with respect to variably saturated flow) derived
    - The intent was to introduce dependence (via relativeness), rather than independence with respect to these hydraulic properties; however, without 'locking in' a fixed horizontal to vertical anisotropy
        - By way of example, for sedimentary rock, a Pilot Point in a model layer that has been categorised as a sandstone, might calibrate towards the lower end of the expected range of horizontal hydraulic conductivity. Using the cosimulation approach, the derived value of vertical hydraulic conductivity, specific storage, specific yield and other parameters at that location (Pilot Point) is cognisant of the geomorphological circumstance (prior to diagenesis) that would explain the sandstone being towards the lower end of the range. i.e. should the horizontal to vertical anisotropy used to devise the vertical hydraulic conductivity be higher or lower compared to a calibrated value of horizontal hydraulic conductivity in a sandstone being at the 'higher end' of expected range, and likewise for other hydraulic parameters.
    - The derived values were then subject to a warping field (via Pilot Points).
- Inclusion of geological lineaments throughout the model
- Application of updated rainfall rates above urban areas (e.g. Lithgow township)
- Application of enhanced recharge above areas of extraction
- Lineament reactivation in areas of total extraction (Model Mining Method = 4 and 5)
- Updated stress periods to activate TVM based on mine schedules at Springvale Mine and Clarence Colliery

Recent updates (this study) included:

- update to approach to lineaments to be based on composite hydraulic properties (using the methodology of Freeze and Cherry (1979)) via a calibrated vertical hydraulic conductivity, with a non-linear, dependent relationship to horizontal hydraulic conductivity, specific storage and specific yield
    - reconfigured such that variants could be surface-to-basement, basement-to-seam or surface-to-seam

- dropped the previous JBS&G Type 4 above Springvale Mine and Angus Place Colliery, but retained implementation of Type 1 through Type 3. The implementation was based on structural geological interpretation provided by Angus Place and Springvale at the time
  - updated implementation of Type 1 through Type 3 above Clarence Colliery, which was provided by Clarence.
- update to approach to enhanced recharge to be additive to recharge factor, rather than a 'wholesale' multiplier of recharge rate
  - this reduced the magnitude of increase in recharge due to ground disturbance.
- apply steady-state to SP001, rather than long-duration quasi steady-state to SP001
  - this existed previously due to a quirk in the numerical engine of MODFLOW-USG when using steady-state with variably saturated flow (Richard's Equation), with MODFLOW-USG crashing.
- implementation of change to storage (specific yield), in order to represent mine void and goaf
  - required amendment of LAYTYP to 4 (saturated flow, with upstream weighting) from 5 (variably saturated flow) for Layer 17 through Layer 19 (Katoomba Seam is Layer 18) and for Layer 23 to Layer 25 (Lithgow Seam is Layer 24)
    - Layers 17 to 19 (either side of Katoomba Seam (mined at Clarence Colliery)) and Layers 23 to 25 (either side of Lithgow Seam (mined at Springvale Mine and Angus Place Colliery) set to LAYTYP = 4
    - continued to use LAYTYP = 4 (saturated flow, with upstream weighting) for Layer 26 through Layer 30, as per previous versions of the model
    - all other layers continued to use LAYTYP = 5 (variably saturated flow (Richard's Equation).
- continued to treat Banks Wall Sandstone (upper (Layer 13) and lower (Layer 14) as two distinct hydrogeological units, namely continued to use LAYTYP = 5 for Layer 13
  - due to the thickness of the Banks Wall Sandstone, it was necessary, regardless, to split the Banks Wall Sandstone for vertical discretisation in the numerical groundwater model.
- switch Caley Formation (Layer 17) and Farmers Creek Formation (Layer 19) from shale (CoSimID = 14) to siltstone (CoSimID = 13)
  - as presented in previous reports on the model, a concern was that designation of the layers as shale, because the vertical hydraulic conductivity is generally lower in shale than a siltstone (although not significantly so), could be influencing model behaviour, namely the response to depressurisation of the mined seam in the overlying shallow groundwater system.
- broadened range of horizontal and vertical hydraulic conductivity of all hydrogeologic types (via cosimulation)
  - continue to use Pilot Points of horizontal hydraulic conductivity, including covariance matrices
  - continue to derive vertical hydraulic conductivity, specific storage, specific yield and parameters of variably saturated flow (Richard's Equation) via a non-linear dependent relationship to horizontal hydraulic conductivity.
- introduced heterogeneity in the derived height of the top of Zone A from Tammetta's equation (via use of Pilot Points, including covariance matrices)
  - an equivalent process was also developed for the Ditton & Merrick equations, but the Tammetta version was used in the numerical groundwater model presented in this report.

- applied a General Head Boundary (GHB) to represent the significant observed mine water storage in the State Mine Complex (this is a generalised term describing the historical workings to the south of Springvale Mine; consisting State Mine, New State Mine, Oakey Park and many others)
    - this was applied several Stress Periods after cessation of mine dewatering (depressurisation)
    - the value of observed groundwater elevation in the State Mine Complex is 895mAHD and is being hydraulically controlled by an adit located to the far southeast of the historical workings. The location of this adit with respect to the historical workings is illustrated in **Figure 3-12**.
- update to Time Varying Material (TVM) to present the mine schedule of 918 Panel at Clarence (the Extraction Plan)
- update to model observation datasets
- recalibration of the model
    - the immediately previous version of the model considered 10,846 parameters and 31,948 observations (JBS&G, 2025ab)
    - the current version of the model (this report) considered 11,354 parameters and 26,712 observations
        - new parameters consisted of the Tammetta Pilot Points (two sets) and amendment to the Drain (DRN) conductance scaling factors (removal and addition depending on definition of reach numbers etc.)
        - removed observations were 'pressure profile' observations, which were redundant with change to 3D interpolation of modelled groundwater elevation (using a custom-developed script called TARGPEST3D).
        - amended observations (steady-state heads) comprised revisit of the assumption that observed groundwater elevation in the Angus Place Mine Extension Project Area (vibrating wire piezometers) could be used to represent pre-mining levels. Those steady-state observations (there were both an assumed steady-state observation and transient observation) were transformed into transient only observations.
            - as noted in Watermark Numerical Computing (2024) whilst you can add and remove parameters ('columns') in a Jacobian matrix, it is not possible to add observation ('rows')
    - recalibration (inversion) used singular value decomposition (SVD), as per the approach used previously in model calibration.

4.2 Model Objectives and Model Class

4.2.1 Model Objectives

The objectives of the groundwater model (MODFLOW-USG, with variably saturated flow) were as follows:

- Continue to quantify the regional spatial and temporal change to groundwater elevation
- Resolve the influence of refilling of the historical State Mine, and all others, on regional groundwater level and flow
- Account for large observed inflows into Clarence Colliery, ~13-17ML/d, relative to its small extraction (longwall, historical) footprint
- Incorporate influence of geological lineaments (basement to surface, seam to surface and basement to seam) as well as reactivation by 'high' subsidence mining methods (Model Mining Method 4 and 5)

- quantify the spatially and temporally varying change to the groundwater system due to the development and extraction of 918 Panel, with particular focus on changes to surface watercourses and potentially impacted swamps.

Tasks undertaken to achieve the objectives included:

- continue to use a variably saturated flow approach to groundwater modelling, so that it can represent the perched, shallow and deep groundwater system in the same model
    - use saturated flow for select layers, to enable change in storage (Specific Yield; mine void and goafing) to be included
- continue to use the 'pinched-out' layers in MODFLOW-USG
- continue to use an optimised model grid to encompass Springvale Mine/Angus Place Colliery and Clarence Colliery
- continue to use a quadtree methodology for grid discretisation due to development of custom-scripts for writing, calibration and simulation of every MODFLOW module
- continue to use covariance matrices when using Pilot Points, in 2D
- continue to calibrate horizontal hydraulic conductivity using Pilot Points
- continue to use soil water characteristic curve methodology such that calibration of the variably saturated flow parameters is feasible
- continue to use Tabulated Richards (TABRICH) in the Layer Property Flow (LPF) module, so as to manage very low relative hydraulic conductivity at large capillary heads
- continue to use cosimulation methodology, such that hydraulic properties are consistent with respect to hydrogeologic unit and not calibrated independently
- continue to use a 'warping field' methodology, including Pilot Points for spatially-distributed parameters, to modify the cosimulated property values
- incorporate geological lineaments by including their relative influence on bulk properties of varying width cells
    - approach was to calibrate vertical hydraulic conductivity, and derive other hydraulic properties using a non-linear dependent relationship.
- continue to use depth-dependent modification to hydraulic properties to account for where layers are close to outcrop and hence subject to weathering/increase in hydraulic conductivity and increase in porosity (little change to specific storage)
- continue to use Pilot Points, rather than SILO Grid-based approach, to represent recharge factor. Continue to use SILO-Grid (spatially distributed) rainfall input
    - amended range of recharge factor to be more conservative (reduced upper limit).
- Continue to use 'enhanced recharge' above Model Mining Method 3, 4, 5 and 6, informed by W/H ratio as to magnitude of disruption at ground surface (limited to 100% of rainfall)
    - reduced magnitude of change during 'enhanced recharge'
- continue to use 'non rainfall' source recharge above township of Lithgow, NSW
- continue to use Pilot Points, rather than SILO Grid-based approach, to represent evapotranspiration factor and extinction depth. Continue to use SILO-Grid (spatially distributed) for FAO56
- continue to use 'significance-based' categorisation of river (RIV) boundary condition conductance

- not critical to this model as river boundary conditions are located from the area of interest.
- continue to use tailored bottom elevations for river (RIV) boundary condition
- continue to use general head boundary conditions (GHB) on the northeastern, eastern and southeastern model domain boundaries to optimise grid size
  - add State Mine Complex water storage, located to the south of Springvale Mine, as a GHB.
- continue to use a small, constant 'deep' leakage through the base of the model into the lower Carboniferous
- continue to include reactivation of geological lineaments for Model Mining Method 4 and 5, tied to 'Tammetta equation-based' change to hydraulic properties via a 'ramp function'
- continue to include tiny, 'Stacked Drain' boundary conditions for development (Model Mining Method 1)
- incorporate void space (change in storage; Specific Yield, Sy) into development (Model Mining Method 1) and partial extraction (Model Mining Method 2) and change in storage (Specific Yield, Sy) with respect to goafing (Model Mining Method 3 through 5)
- continue to include all historical mines in the Western Coalfields, including within the township of Lithgow, NSW
  - depressurisation represented using drain (DRN) boundary conditions, via 'Stacked Drains'
  - developed ability to use 'return flow' in drain boundary condition with return flow (DRT), but disabled this being running final simulations as lead to minor, localised 'groundwater mounding' in layer below mined seam. Future revision will reduce the volume of water being returned.
- continue to use 'Strahler Order-based' categorisation of drain (DRN) boundary condition conductances
- continue to use seepage faces at 'pinched-out' layers
- continue to use surface overland flow drain (DRN) boundary condition, including error checking for 'double-up' of boundary conditions in an individual cell
- recalibrated the model (with respect to historical mine dewatering rate, spatial and temporal change to vibrating wire and standpipe piezometers, including those installed in Temperate Highland Peat Swamps on Sandstone)
- run the model considering 918 Panel to determine the effect of proposed development and extraction on the groundwater system.

4.2.2 Model Class

In accordance with the Australian Groundwater Modelling Guidelines (AGMG) (Barnett et. al., 2012), the intended model confidence level classification for the groundwater model is Class 2.

Table 4-1 presents the characteristics and indicators of a Class 2 model, together with a summary of the responses to each of those characteristics and indicators, with detail presented further below.

Table 4-1: Model Confidence Level Classification – characteristics and indicators (Class 2) (after Barnett et. al., 2012)

Data	Calibration	Prediction	Key Indicator
• Groundwater head observations and bore logs are available but may not provide adequate coverage throughout the model domain. *Consistent: There is a significant groundwater monitoring network available encompassing Angus Place Colliery, Springvale Mine and Clarence Colliery. Far-field monitoring not included, but outside of area of interest.* • Metered groundwater- extraction data may be available but spatial and temporal coverage may not be extensive. *Consistent: Detailed mine dewatering data is available at Angus Place Colliery, Springvale Mine and at Clarence Colliery.* • Streamflow data and baseflow estimates available at a few points. *Consistent: On-the-ground monitoring (THPSS and within the Coxs River) occurs at Springvale Mine, Angus Place Colliery and Clarence Colliery. Whilst not presented in this report, these data informed the development of the approach to modelling re: groundwater/surface water interaction.* • Reliable irrigation-application data available in part of the area or for part of the model duration. *N/A: No comment needed.*	• Validation* is either not undertaken or is not demonstrated for the full model domain. *Consistent: This report presents improvement to an existing model, recalibration of a previously calibrated model as well as validation (via assessment against recent observation).* • Calibration statistics are generally reasonable but may suggest significant errors in parts of the model domain(s). *Consistent: Calibration statistics for various piezometer types is presented in **Section 4.12.4.3**, with detailed groundwater hydrographs presented in **Section 4.12.4.4**. **Appendix F** presents spatially and vertically distributed calibration residuals.* • Long-term trends not replicated in all parts of the model domain. *Consistent: Long-term trends are met. Mine dewatering rate matched at Springvale Mine, Angus Place Colliery and at Clarence Colliery. Some differences due to mining-induced depressurisation in some vibrating wire piezometers earlier than what is observed.* • Transient calibration to historic data but not extending to the present day. *Consistent: Calibration simulation from 1867 through to end of September 2025*	• Transient calibration over a short time frame compared to that of prediction. *Consistent: Calibration period was 1867 through to end of September 2025. Prediction period is from start of October 2025 through to end of December 2049.* • Temporal discretisation used in the predictive model is different from that used in transient calibration. *Consistent: Same discretisation used in calibration and prediction models.* • Level and type of stresses included in the predictive model are outside the range of those used in the transient calibration. *Exceeded: Mining has been on-going within the model domain since 1867. Magnitude of stresses in calibration model are the same as those in the prediction model.* • Validation* suggests relatively poor match to observations when calibration data is extended in time and/or space. *Consistent: Validation presented in this report indicates satisfactory performance.*	• Key calibration statistics suggest poor calibration in parts of the model domain. *Exceeded: 1.00% sRMS for steady-state and 6.23% sRMS for transient head. Fit to mine dewatering rate and cumulative inflow at Springvale Mine, Angus Place Colliery and Clarence Colliery achieved.* • Model predictive time frame is between 3 and 10 times the duration of transient calibration. *Consistent: Calibration period was 1867 through to end of September 2025. Prediction period was from start of October 2025 through to end of December 2049, therefore of comparable magnitude.* • Stresses are between 2 and 5 times greater than those included in calibration. *Exceeded: Mining has been on-going within the model domain since 1867. Magnitude of stresses, in the period 1979 through to 2025, in the calibration model are the same as those in the prediction model.* • Temporal discretisation in predictive model is not the same as that used in calibration. *Consistent: Same discretisation used in calibration and prediction models.* • Mass balance closure error is less than 1% of total.

Data	Calibration	Prediction	Key Indicator
	(data between start of January 2022 to present has been added and serves as validation). • Seasonal fluctuations not adequately replicated in all parts of the model domain. *N/A: Whilst model included seasonal variation, through quarterly stress periods, the model domain is dominated by mining, rather than irrigation, therefore this characteristic is not relevant. Notwithstanding, regional fluctuation in groundwater elevation due to historical mining, including transition between dewatering and mine water storage is considered to be reasonable matched.* • Observations of the key modelling outcome data set are not used in calibration. *Consistent: All observation data were used during calibration (observed groundwater level elevation, change to change elevation, packer test analysis (pre- and post-mining), mine dewatering rate, including cumulative volume.*		*Consistent: Cumulative mass balance closure error was less than 0.1% for the calibration model and for the prediction simulation.* • Not all model parameters consistent with conceptualisation. *Consistent: Through use of cosimulation, hydraulic properties are maintained within their bounds. Aspects such as depth-dependent modification and lineaments provide opportunity for the calibration to adjust to account for processes necessary to meet observed data (groundwater elevation and mine dewatering rate).* *Residual issues with parameterisation overcome through comparison of a Proposed Case and Approved Case, rather than use of a forecast methodology.* • Spatial refinement too coarse in key parts of the model domain. *Exceeded: Quad-tree refinement used to optimise grid resolution in area of interest.* • The model has been reviewed and deemed fit for purpose by an independent hydrogeologist. *Consistent: refer to **Section 4.3**.*

4.3 Groundwater Monitoring and Modelling Plan

NSW DCCEEW (2022c) states that the NSW Aquifer Interference Policy (NSW DCCEEW, 2012) requires a Groundwater Monitoring and Modelling Plan (GMMP) be prepared and submitted to NSW DCCEEW prior to the start of a modelling project.

Review of the NSW Aquifer Interference Policy (NSW DCCEEW, 2012) by JBS&G qualifies that requirement, as stated by NSW DCCEEW (2012):

"*An additional process – a gateway process - will apply to State significant development applications for mining or coal seam gas extraction on strategic agricultural land as defined in a relevant Strategic Regional Land Use Plan. The gateway process will involve a panel which is intended to provide a tailored mechanism to assess the potential impacts of these proposals on strategic agricultural land and resources. The panel will deliver greater rigor to the scientific assessment process.*

…

Under the State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007 the Minister for Primary Industries will be required to provide advice to the gateway panel, which will be made public, on aquifer impacts either:

(a) at the gateway stage (for example, relevant State significant mining and coal seam gas proposals on Strategic Agricultural Land); and

(b) during the assessment of the relevant development application.

This advice will be based on the considerations specified in section 3.2 of this Policy.".

[Section 3.1 of NSW DCCEEW, 2012]

and further, NSW DCCEEW (2014):

"*Purpose and scope*

This document assists in the development of Groundwater Monitoring and Modelling Plans (GMMPs). These plans are required as a standard condition of licence for exploration (drilling) under the Mining Act 1992 and Petroleum (Onshore) Act 1991.

This document also provides industry users with information about the NSW Aquifer Interference Policy (AIP) and other regulatory requirements under the Water Act 1912 and the Water Management Act 2000, as they relate to mineral and petroleum prospecting.

The purpose is to provide information that will assist with the design of a groundwater (and associated surface water) monitoring programs that ensure the required data and information for:

- *hydrogeological conceptualisation*
- *assessment of baseline and regional conditions*
- *time series data for any future groundwater model calibration.*

Specifically, exploration involving the construction and use of boreholes under an exploration licence issued under the Mining Act 1992 and Petroleum (Onshore) Act 1991, where it is required as a condition of that licence.

This document is designed to be used for the ongoing development of groundwater monitoring operations and groundwater modelling as a project matures beyond the exploration phase, to mining or petroleum production and beyond the life of the activity.

While there is a strong focus on groundwater monitoring and modelling required for assessing proposals against the requirements of the AIP through the stages of approval, groundwater monitoring and modelling *beyond project approval is required to identify trends and deviations from modelled predictions and initiate response and mitigation prior to exceeding defined thresholds.*".

[page 1 of NSW DCCEEW, 2014]

Clarence Colliery operates under a Mining Lease, rather than an Exploration Lease. Mining commenced at Clarence commenced in 1979. Exploration (drilling) within the Mining Lease is ongoing at Clarence and is governed under *Mining Act* 1992 (NSW). The current version of the GMMP at Clarence is from 2019 and JBS&G understands that it will be updated in the future, following the recent model development phase (this report).

4.4 Groundwater Model Peer Review

The Extraction Plan for 918 Panel is not a modification to consent. Notwithstanding, in accordance with the NSW Aquifer Interference Policy (NSW DCCEEW, 2012), with Clarence being a large coal mine development, the groundwater model has been subject to external peer review previously and also with respect to this current iteration of the model.

Meetings with the current external reviewer, Mr James Dowdeswell of GHD Pty Ltd, under the supervision of Alyssa Barron of GHD Pty Ltd, were held on:

- 20 March 2025 (Alyssa)
- 7 October 2025 (James)
- 16 October 2025 (James)
- 21 October 2025 (James)
- 6 February 2026 (James).

JBS&G has been advised that the external reviewer, Mr James Dowdeswell of GHD Pty Ltd, under the supervision of Alyssa Barron of GHD Pty Ltd, has determined that the model used in this study is 'fit for purpose', in accordance with Australian Groundwater Modelling Guidelines (Barnett et. al., 2012), thereby satisfying the requirements of the NSW Aquifer Interference Policy (NSW DCCEEW, 2012) and NSW DCCEEW (2022c).

JBS&G understands that a copy of that letter of review will be provided separately as part of the Extraction Plan documentation package.

4.5 Model Approach and Code

USG-Transport, Version 2.5.0.2, was used in this report. MODFLOW-USG is a variant of the industry-standard groundwater flow model MODFLOW. MODFLOW-USG was first published in 2013 (USGS, 2013) and has continued to be improved since that time by the main author of MODFLOW-USG as part of his work at a consulting firm (GSI Environmental, 2025), with the current version of that model referred to as USG-Transport. MODFLOW-USG and USG-Transport uses single precision output.

The model developed in this study uses quadtree refinement as well as the 'pinched-out' layer feature of MODFLOW-USG and USG-Transport.

USG-Transport implements a solution to Richards Equation (variably saturated flow) via van Genuchten (1980) for the relationship between capillary head (matrix suction) and volumetric water content (water saturation) and via Brooks and Corey (1966) for the relationship between volumetric water content (water saturation) and relative hydraulic conductivity. The approach undertaken for variably saturated flow in USG-Transport is equivalent to that used in a previous version of MODFLOW, MODFLOW-Surfact (HGL, 1996), which was developed by the same author whilst with a different consulting firm.

Groundwater Vistas, V8.30, Build 299 was used as the primary Graphical User Interface (GUI), with Groundwater Desktop, V4.1.060 used for illustration of some model inputs and outputs.

PEST_HP, Version 18.46, was used for recalibration of the model, taking advantage of singular value decomposition (SVD). BEOPEST, Version 18.27, a subvariant of PEST (also Version 18.27), was used to undertake 'serial' runs (Simulation0 and stochastic model predictions), as well as populate the Jacobian (for the new parameters pertaining to heterogeneity of Tammetta's equations, and update to Reach Numbers of scaling factors to conductance of Drain (DRN) boundary conditions).

The number of model parameters was 11,354 and the number of observations was 26,712. Four of the parameters were fixed and all other parameters were log-transformed (log10).

Post-processing of the composite Jacobian matrix (combining the large Jacobian matrix from previous calibration (with redundant parameters and observations excised), with the new small Jacobian matrix (new parameters)), using PEST's SUPCALC utility indicated the division between calibration solution space and null space was 940 dimensions.

Calibration and prediction simulations were conducted on a Commodity Cluster of 75 PCs, each being Intel 3rd and 4th generation Quad-Core i7s, each with 8MB of DDR3 RAM and a 256GB Kingston SSD. i.e. number of available PEST 'Agents' was 299, with 1 reserved to be the PEST 'Manager'.

4.6 Model Grid and Domain

The regional model grid is 400m by 400m and is oriented south-north, west-east.

The model extends 34.4km west-east and 29.2km south-north.

The coordinates of the lower left 221800mEast and 6289800mNorth. The coordinate projection of the model is Map Grid of Australia 1994, Zone 56.

One level of quadtree refinement was used along all watercourses, with the resultant grid being 200m by 200m. Quadtree refinement is where a model grid cell is divided into four quadrants. Two levels of quadtree refinement were used in active mining areas, including Springvale Mine, Angus Place Colliery and Clarence Colliery, with the resultant grid in those areas being 100m by 100m.

There are 30 layers in the model.

The number of original nodes is 789900, therefore 26330 original nodes per model layer.

'Pinched out' nodes were excluded from the model, as well as No Flow boundaries. The number of nodes (reduced) was 427833.

Figure 3-1 presents the model grid and extents. The model grid in the vicinity of 918 Panel at Clarence Colliery is presented in **Figure 4-1**. The location of a model output cross-sections is also presented in **Figure 4-1**.

4.7 Model Geometry and Hydraulic Properties

4.7.1 Model Layers and Geometry

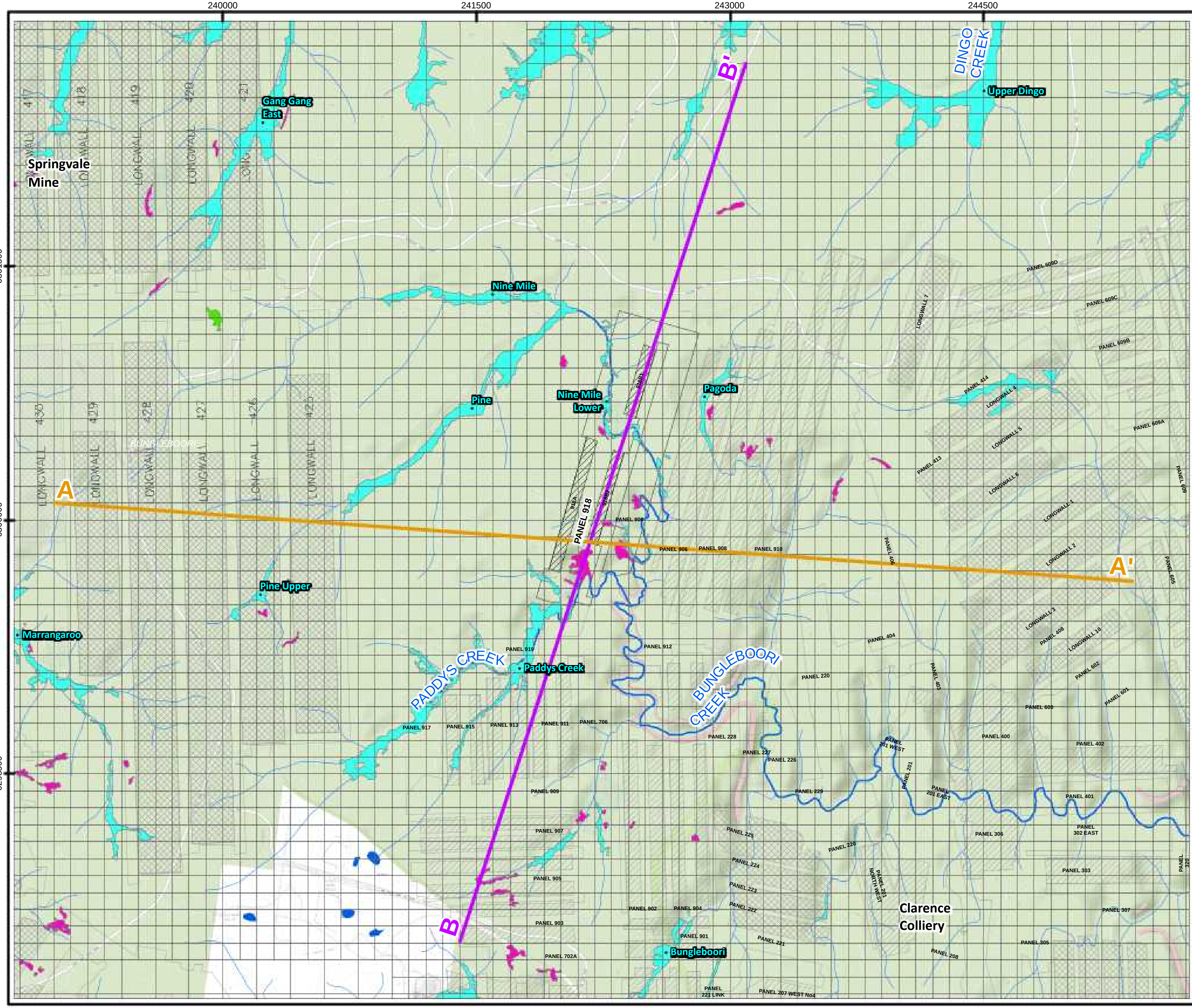
Top Elevation

The elevation of ground surface was assigned to the model grid from a composite of regional and local Digital Elevation Models (DEMs). Local DEMs were provided from Centennial. The order of priority of assignment of the top elevation to the model grid was to use the local DEM first, and the regional DEM second.

The approach to transferring consisted sampling of the relevant DEM at the centre of each model cell. Along identified watercourses and topographic ridgelines, the lowest or highest elevation in the DEM (subsampled at a 20m resolution) within a particular model cell was obtained and applied to the model grid.

Regional and Local Geological Model

The local geological model for Springvale Mine and Angus Place Colliery was developed by McHugh (2016). The same dataset was also available for Clarence Colliery, without interpretation. JBS&G used the



Legend:

Modelling:
- Cross Section A
- Cross Section B
- Model Grid

Mining Methods:
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:
- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):
- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Hydrology:
- Watercourse
- Waterbody

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 03-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:30,000	

0 0.5 1
Kilometers

Coor. Sys. GDA 1994 MGA Zone 56

Location of Model Output Cross-Sections

FIGURE: 4.1

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D021_ModelGrid_Transect.mxd
Reference: © Department of Customer Service 2020

interpretation of McHugh (2016) at Springvale Mine and Angus Place Colliery to extrapolate across to the Clarence Colliery mine area.

Outside of where the local geological model existed, regional data from *Western Coalfield Geological Modelling Project* (NSW Regional NSW, 2016) was used.

Layer Thicknesses and Layer Number Assignment

Table 4-2 presents the vertical discretisation adopted for the groundwater model, including the average thickness of each layer. The minimum model layer thickness is 1m.

It is noted that Layer 17 and Layer 19 have been changed from shale to siltstone, and is therefore different to that used in the previous version of the numerical groundwater model JBS&G (2025ab). These changes were consistent with the Model Recommendations presented in JBS&G (2025ab) and were applied to explore the potential that those categorisations were exerting a 'larger-than-intended' control on vertical groundwater flow into the Katoomba Seam (Layer 18) at Clarence.

The location of model output cross-sections is presented in **Figure 4-1**.

LAYTYP

Layers 1 through 16, and Layers 20 through 22, were set to be LAYTYP = 5. This meant that Richards Equation (variably saturated flow) was applied. In USG-Transport this was implemented through van Genuchten (1980) for the relationship between capillary head (matrix suction) and water saturation (volumetric water content), and Brooks and Corey (1966) for the relationship between water saturation (volumetric water content) and relative hydraulic conductivity, K_{rw}. Relative hydraulic conductivity refers to a multiplier of the saturated hydraulic conductivity, K. LAYTYP = 5 will switch between unconfined (groundwater elevation is below the top of the respective model layer) hydrogeologic response and confined (groundwater elevation is above the top of the respective model layer) hydrogeologic response automatically, as required.

Layers 17 to 19 and Layers 23 to 30 were set to be LAYTYP = 4. LAYTYP = 4 considers saturated flow. LAYTYP = 4 will switch between unconfined and confined hydrogeologic response as required. Note that it was attempted to set Layer 13 (Banks Wall Sandstone) to LAYTYP = 4. However, the model was unable to converge due to discretisation in the model geometry and thus, Layer 13 was returned to LAYTYP = 5.

Of the above layers set to LAYTYP = 4, Layers 17 to 19 and Layers 23 to 25 inclusive were set to LAYTYP = 4 such that change to storage (Specific Yield, so as to represent mine void and goafing) could be enabled. In previous versions of the numerical groundwater model, it was identified that attempting to apply change to storage when LAYTYP = 5 led to the model convergence issues in MODFLOW-USG.

Table 4-2: Model Geometry

Layer	Description	Unit	IDNum[a]	Hydrogeologic Categorisation[a]	Average Thick. (m)
1	Sandstone / Regolith	Burralow Formation	12	Sandstone	15.7
2	Shale (YS1)	-	14	Shale	2.1
3	Sandstone / Regolith	-	12	Sandstone	11.6
4	Shale (YS2)	-	14	Shale	1.6
5	Sandstone / Regolith	-	12	Sandstone	9.7
6	Shale (YS3)	-	14	Shale	2.2
7	Sandstone / Regolith	-	12	Sandstone	11.4
8	Shale (YS4)	-	14	Shale	3.2
9	Sandstone / Regolith	-	12	Sandstone	12.0
10	Shale (YS5)	-	14	Shale	2.1
11	Sandstone / Regolith	-	12	Sandstone	9.6
12	Shale (YS6)	-	14	Shale	1.9
13	Quartzose sandstone	Banks Wall Sandstone	12	Sandstone	39.4
14	-	-	12	Sandstone	40.9
15	Claystone	Mt York Claystone	16	Claystone	19.9
16	Quartzose to quartz-lithic sandstone	Burra-Moko Head Sandstone	12	Sandstone	44.6
17	Claystone / Shale / Sandstone	Caley Formation	13	Siltstone	55.5
18	Coal	Katoomba Seam	10	Coal	2.6
19	Claystone / Shale	Farmers Creek Formation	13	Siltstone	20.3
20	Lithic sandstone / Claystone / Quartz-Lithic Sandstone	Gap Sandstone/State Mine Creek Formation/Angus Place Formation (Watts Sandstone)	12	Sandstone	20.5
21	Mudstone / Siltstone / Claystone (Marine Incursion)	Denman Formation	15	Mudstone	23.6
22	Sandstone / Mudstone (Lower delta plain)	Glen Davis / Long Swamp Formation	13	Siltstone	42.9
23	Conglomerate (Fluvial)	Blackmans Flat Conglomerate / Lidsdale Coal Seam	11	Conglomerate	8.2
24	Coal (Fluvial)	Lithgow Seam	10	Coal	2.5
25	Conglomerate (Fluvial)	Marrangaroo Conglomerate	11	Conglomerate	16.1
26	Sandstone (Shoreline complex - delta front)	Nile Subgroup	12	Sandstone	32.1
27	-	-	12	Sandstone	60.9
28	-	-	12	Sandstone	86.8
29	Siltstone / Sandstone (Shoreline)	Shoalhaven Group	13	Siltstone	55.8
30	Crystalline, Extremely Weathered (Fractured)	Carboniferous	60	Igneous	89.5

Notes. a) "IDNum" is the number used with Cosimulation (on a layer-by-layer basis). "Hydrogeologic Categorisation" is the description associated with the "IDNum" category.

4.7.2 Hydraulic Properties

There were two aspects to applying hydraulic properties. The first was heterogeneity in the distribution of hydraulic properties and the second is cosimulation. As noted above, cosimulation was applied to ensure consistency within each hydrogeologic unit and with respect to its hydrogeologic unit type.

The approach to modelling hydraulic properties comprised:

- Horizontal Hydraulic Conductivity, Kh, as Pilot Points, including covariance matrices (via the PEST utility, PPCOV), deployed on a layer-by-layer basis
- Zone-based bearing and anisotropy were applied to the covariance matrix, so as to give regional trends, as relevant
    - Whilst available, bearing and anisotropy was not used in the current version of the model. The lag length, however, was adjusted (trial and error) so that the relatedness ('cross variance') of Pilot Points was sensible. i.e. that the influence of Pilot Points, in a particular layer, that were 'too distant' was suitably small/'geologically reasonable'.
- Cosimulation to derive consistent values of vertical hydraulic conductivity, Kv, specific storage, Ss and specific yield, Sy, as well as parameters for variably saturated flow such as van Genuchten's *alpha* and *beta* and Brooks-Corey exponent, *n*
    - This was achieved by looking at the position (via geomean) of the calibrated value of Kh with respect to the range of Kh, for the particular categorisation
    - That position was then used to inform the values of other parameters. i.e. use the position within the range of Kv, Ss, Sy and other parameters, noting that the ranges of other parameters were fixed, but dependent on the parameter type and 'context'.
    - By way of example, if a Pilot Point existed within a sandstone category, and its value calibrated toward the lower end of the range of sandstone, what is the 'empathetic' value of Kv, Ss and Sy, given that, for sedimentary rocks, the geomorphological circumstance (prior to diagenesis) that would lead to that lower end value of Kh?
- 'Warping Fields', as Pilot Points, including covariance matrices (on a layer-by-layer basis), for Kv, Ss and Sy, so as to allow adjustment of cosimulated values
    - Zone-based bearing and anisotropy were applied to the covariance matrix, so as to give regional trends, as relevant.
        - Again, bearing and anisotropy was not required to be turned on, however, lag length was adjusted so that relatedness between Pilot Points, in a particular layer, that were 'too distant' was suitably small/'geologically reasonable'.
- Layer-based 'warping values' for variably saturated flow parameters, for Layers 1 to 17 and Layers 20 to 22, so as to allow adjustment of cosimulated values.

The components of the soil water characteristic curve, which are all layer-based, were van Genuchten's *alpha* and *beta*, *porosity*, *specific yield* and *capillary head at field capacity*. Those components are used to generate the content required for the Layer Property File (.LPF), which is read in response to the TABRICH keyword (which stands for Tabulated Richards) in USG-Transport.

Table 4-3 presents the number of Pilot Points used in each model layer, as well as the number of Pilot Points used in each layer for the 'warping fields'. As noted, the same Pilot Point locations were used for Kv, Ss and Sy, but each group had their own values at individual Pilot Points.

Table 4-3: Number of Pilot Points used for Horizontal Hydraulic Conductivity and Warping Fields for Cosimulated Values of Vertical Hydraulic Conductivity, Specific Storage and Specific Yield

Layer	Kh (Kx)	Kv (Kz), Ss (S1) and Sy (S2)
1	134	42
2	147	41
3	147	43
4	160	44
5	198	48
6	205	41
7	216	44
8	210	52
9	200	51
10	225	44
11	216	55
12	205	46
13	218	49
14	211	51
15	204	54
16	191	62
17	153	69
18	118	45
19	187	68
20	160	62
21	153	67
22	152	67
23	175	68
24	215	65
25	202	71
26	164	59
27	160	60
28	177	57
29	71	25
30	89	28

The location of Pilot Points of hydraulic properties is presented in Appendix D.

4.7.3 Lineaments

Geological lineaments within the groundwater model domain, in the vicinity of 918 Panel are presented in **Figure 3-9**.

Lineaments were incorporated into the model through modification of the hydraulic properties (bulk) of a cell that was intersected by a lineament using the technique of Freeze and Cherry (1979). That technique considers the proportional contribution of a small (1m to 10m width) feature of higher hydraulic conductivity and storage to the bulk properties of the cell. It is noted that a check is made to the adjusted properties, such that geological lineaments act to only increase values (bulk) of hydraulic properties of a cell, else the influence of the lineament is ignored.

Implementation of lineaments has changed since JBS&G (2025ab). The new approach considers the value of vertical hydraulic conductivity of the feature, with non-linear dependent derived values of horizontal hydraulic conductivity, specific yield and specific storage. Furthermore, the lineaments can now be applied as basement to surface, basement to seam or seam to surface features (refer **Section 3.5.6** for further details).

As presented in **Section 3.5.6**, there are three lineament types with further subcategories at Clarence Colliery These lineament types include Type 1 which is considered the most significant through to Type 3, which is considered the least significant. Each of the lineaments is assumed to act from surface-to-basement, which is a conservative assumption. As noted in **Section 3.5.6**, geological lineaments are considered to increase the values of hydraulic properties, hence are 'open', rather than 'closed' type features.

The approach to implementation was to assign a lineament type to applicable cells, whilst taking into consideration the number of lineaments crossing that cell. In doing so, areas in the model with a higher density of lineaments ended up with a higher relative value of hydraulic properties, as applicable.

To ensure consistency between lineament types, the vertical hydraulic conductivity of Type 1 was specified, and Type 2 was a sequential multiplier of Type 1 and Type 3 was a sequential multiplier of Type 2.

The non-linear dependence of vertical hydraulic conductivity to other hydraulic properties was based on a table, with log interpolation. **Table 4-4** presents the adopted relationship between vertical hydraulic conductivity and other hydraulic properties.

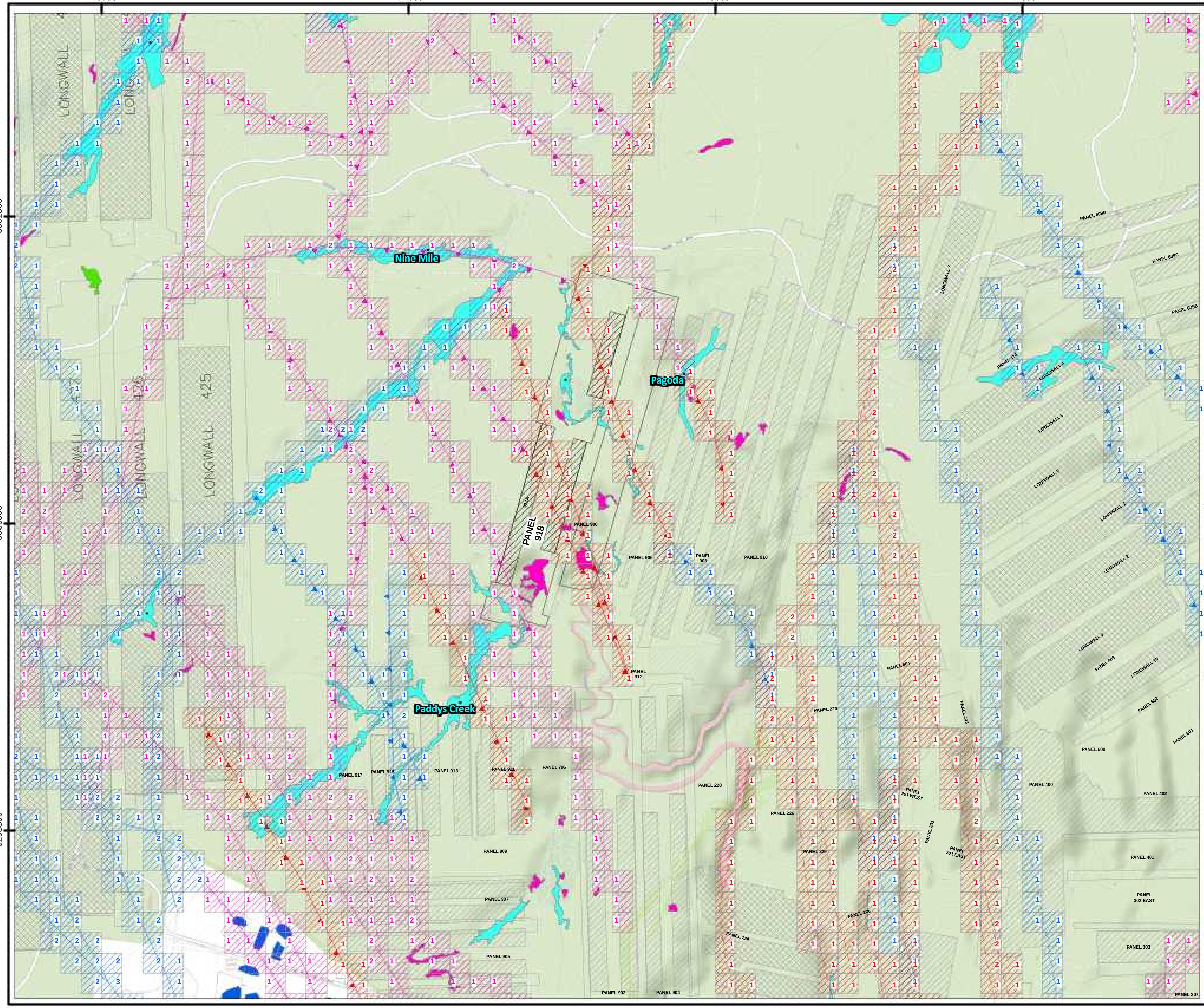
Table 4-4: Non-Linear Relationship between Vertical Hydraulic Conductivity and other Hydraulic Properties in Lineaments

Kv(m/s)	Kh(m/s)	S1(Ss)(1/m)	S2(Sy)(frac.)
1.00E-04	1.50E-04	9.00E-06	0.042
1.00E-05	2.00E-05	7.00E-06	0.039
1.00E-06	3.00E-06	6.00E-06	0.033
1.00E-07	4.00E-07	5.00E-06	0.027
1.00E-08	5.00E-08	4.00E-06	0.021
1.00E-09	6.00E-09	3.00E-06	0.017
1.00E-10	4.00E-10	4.00E-06	0.012

Where there was more than one lineament in a particular cell, this was taken into account when calculating the composite hydraulic property values using the methodology of Freeze and Cherry (1979).

Figure 4-2 presents the implementation of geological lineaments in the groundwater model at Clarence.

In **Figure 4-2**, Type 1 is red, Type 2 is Blue and Type 3 is Pink. In **Figure 4-2**, numbers in corners of model cells are the number of lineaments per model cell. Where there was a confluence of lineaments in a single cell, additional 'number of lineaments per cell' were added to surrounding cells, as relevant.



Legend:

Mining Methods:
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:
- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):
- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Lineament Type:
- Type 1
- Type 1a
- Type 1b
- Type 2
- Type 2a
- Type 2b
- Type 3
- Type 3a
- Type 3b

Modelling:
- Lineament Cells Type 1
- Lineament Cells Type 2
- Lineament Cells Type 3

Job No: 68229

Client: Clarence Colliery Pty Ltd

Version: R01RevA	Date: 04-Nov-2025
Drawn By: DAW	Checked By: JRWB

Scale 1:25,000

0 0.5 1
km

Coor. Sys. GDA 1994 MGA Zone 56

Example of Modelled Geological Lineaments

FIGURE: 4.2

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D040_ModelledGeologicalLineaments.mxd
Reference: © Department of Customer Service 2020

4.7.4 Depth-Dependent Modification

An objective of the groundwater model was to constrain hydraulic property values to within their literature ranges. To meet that objective, where a hydrogeologic unit (layer) was close to outcrop, its values were increased as a function of depth. This modification was intended to represent the effect of near-surface processes, such as weathering, both with respect to current day ground surface as well as 'Top of Group', which is relevant to the time where there was a change to a different geologic/hydrogeologic unit.

Figure 4-3 presents the adopted depth-dependent modification relationship with respect to ground surface. In **Figure 4-3**, Group 1 is Banks Wall Sandstone (Layer 13 and 14); Group 2 is Nile Subgroup (Layers 26 to 28); Group 3 is Burralow Formation (Layers 1 to 12); Group 4 is 'Deep Groundwater System' (Layers 15 to 25); Group 5 is 'Basement' (Shoalhaven Group) (Layer 29) and Group 6 is 'Basement' (Carboniferous) (Layer 30).

Figure 4-4 presents the adopted depth-dependent modification relationship with respect to 'Top of Group'. In **Figure 4-4**, Group 1 is Banks Wall Sandstone (Layer 13 and 14); Group 2 is Nile Subgroup (Layer 26 to Layer 28) and Group 3 is Shoalhaven Group (Layer 29).

The custom-developed script includes consideration of a reduction in value of hydraulic properties with depth (either below ground surface or below 'Top of Group'). This aspect was not needed for a sedimentary rock environment.

The limit of change was 100m below ground surface and ranged between 40 and 60m for change below 'Top of Group'.

4.8 Temporal Discretisation

Temporal discretisation of the model was as follows:

- Transient Calibration (Steady-State through to 30 September 2025) – SP001 to end of SP144
- Prediction Simulation (Steady-State through to 31 December 2049) – SP001 to end of SP241.

It is noted when solving the variably saturated flow equation, it is necessary to start USG-Transport (and MODFLOW-USG) at Stress Period 1 (SP001) for all model simulations. This is because the drawdown file (.DDN) is used to store cell saturation when using variably saturated flow, but MODFLOW does not accommodate use of a .DDN as a 'second' initial condition.

An issue in JBS&G (2025ab) was that USG-Transport, when conducting steady-state simulations, would crash. A workaround was developed by JBS&G and SP001 in the simulations presented in this report are now steady-state, rather than quasi steady-state.

Table 4-5 presents the adopted temporal discretisation of the groundwater model.

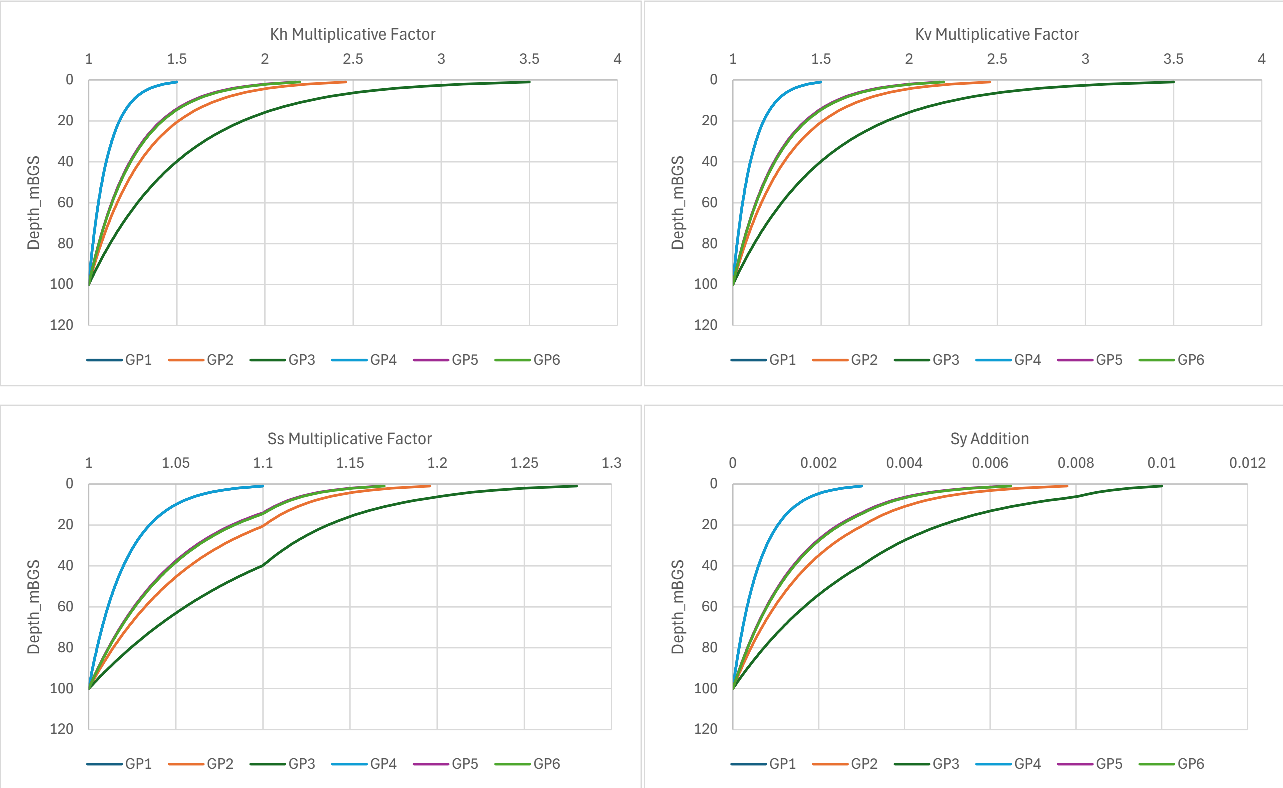


Figure 4-3: Depth-Dependent Modification to Hydraulic Properties (Ground Surface)

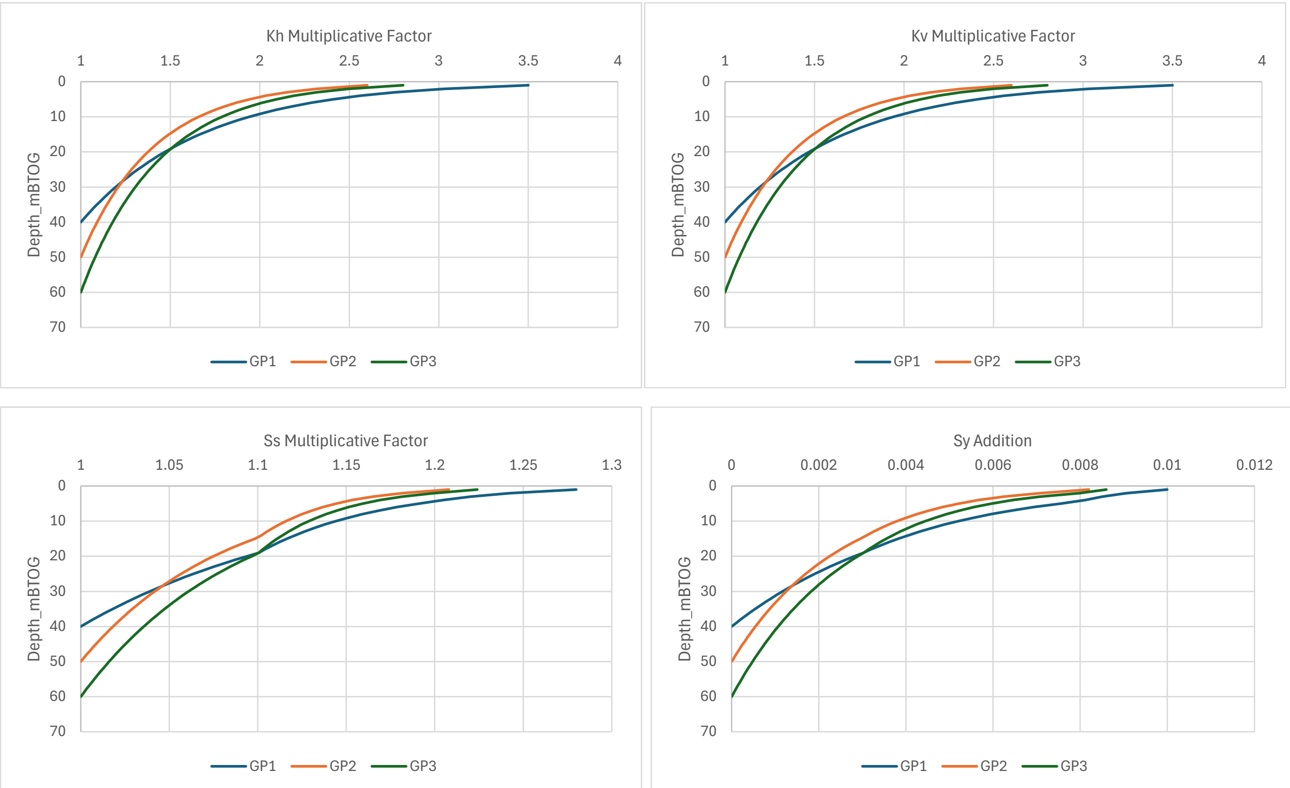


Figure 4-4: Depth-Dependent Modification to Hydraulic Properties (Top of Group)

Table 4-5: Model Temporal Discretisation

Stress Period	Time-Steps	Time-Step Multiplier	Duration	SP Start Date	SP End Date
Transient Calibration (Calibration Period only)					
1	1, with output at TS1	1.00	1 day	31/12/1867	31/12/1867
2	10, with output at TS10	2.00	1827	01/01/1868	31/12/1872
3	10, with output at TS10	2.00	3288	01/01/1873	31/12/1881
4	10, with output at TS10	2.00	3653	01/01/1882	31/12/1891
5	10, with output at TS10	2.00	2923	01/01/1892	31/12/1899
6	10, with output at TS10	2.00	4018	01/01/1900	31/12/1910
7	10, with output at TS10	2.00	4018	01/01/1911	31/12/1921
8	10, with output at TS10	2.00	2191	01/01/1922	31/12/1927
9	10, with output at TS10	2.00	2922	01/01/1928	31/12/1935
10	10, with output at TS10	2.00	2192	01/01/1936	31/12/1941
11	10, with output at TS10	2.00	3287	01/01/1942	31/12/1950
12	10, with output at TS10	2.00	2557	01/01/1951	31/12/1957
13	10, with output at TS10	2.00	2557	01/01/1958	31/12/1964
14	10, with output at TS10	2.00	2922	01/01/1965	31/12/1972
15	10, with output at TS10	2.00	2191	01/01/1973	31/12/1978
16	10, with output at TS10	2.00	2738	01/01/1979	30/06/1986
17	10, with output at TS10	2.00	2741	01/07/1986	31/12/1993
18 to 144	5, with output at TS4 and TS5	2.50	90 to 92 days	01/01/1994	30/09/2025
Prediction Simulation (combined Calibration and Prediction Period)					
1	1, with output at TS1	1.00	1 day	31/12/1867	31/12/1867
2	10, with output at TS10	2.00	1827	01/01/1868	31/12/1872
3	10, with output at TS10	2.00	3288	01/01/1873	31/12/1881
4	10, with output at TS10	2.00	3653	01/01/1882	31/12/1891
5	10, with output at TS10	2.00	2923	1/1/1892	31/12/1899
6	10, with output at TS10	2.00	4018	1/01/1900	31/12/1910
7	10, with output at TS10	2.00	4018	1/01/1911	31/12/1921
8	10, with output at TS10	2.00	2191	1/01/1922	31/12/1927
9	10, with output at TS10	2.00	2922	1/01/1928	31/12/1935
10	10, with output at TS10	2.00	2192	1/01/1936	31/12/1941
11	10, with output at TS10	2.00	3287	1/01/1942	31/12/1950
12	10, with output at TS10	2.00	2557	1/01/1951	31/12/1957
13	10, with output at TS10	2.00	2557	1/01/1958	31/12/1964
14	10, with output at TS10	2.00	2922	1/01/1965	31/12/1972
15	10, with output at TS10	2.00	2191	1/01/1973	31/12/1978
16	10, with output at TS10	2.00	2738	1/01/1979	30/06/1986
17	10, with output at TS10	2.00	2741	1/07/1986	31/12/1993
18 to 241	5, with output at TS4 and TS5	2.50	90 to 92 days	1/01/1994	31/12/2049

For the purposes of the clarity when discussing findings in this report:

- Calibration Period (Pre-Mining through to 30 September 2025; end of SP144)
- Prediction Period (1 October 2025 through to 31 December 2049; SP241).

It is noted that PEST recalibration presented in this report was based on observation data received prior to 31 December 2021 (end of SP129). i.e. due to the nature of the Jacobian matrix, observations (rows) can not be added therefore, that data (prior to 31 December 2021 (end of SP129)), together with recent observations (which is validation) are presented as the Calibration Period, but PEST only saw observation data through to end of 31 December 2021. This limitation did not impede the calibration process.

4.9 Model Solver Settings

MODFLOW-USG uses the Sparse Matrix Solver (.SMS).

HCLOSE was set at 0.05m and HICLOSE was set at 0.001m.

4.10 Model Boundary Conditions

4.10.1 Inputs

4.10.1.1 Recharge

The recharge (RCH) MODFLOW module was used in the groundwater model.

Spatially distributed, grid-based, rainfall input was obtained from the SILO climatic database (QLD DETSI).

A recharge factor was applied to that rainfall to represent the proportion of rainfall that would enter the groundwater system.

Pilot Points (168) ("RCH001" through "RCH168") were used to provide spatial variability to the recharge factor. Pilot Points were manipulated during calibration by the PEST utility, PLPROC (Watermark Numerical Computing, 2024). A covariance matrix (via the PPCOV utility of Watermark Numerical Computing (2024)) on Pilot Points was used to ensure Pilot Points that are in close spatial proximity to each other were not adjusted independently. Lastly, zone-based bearings and anisotropy were applied to the covariance matrix.

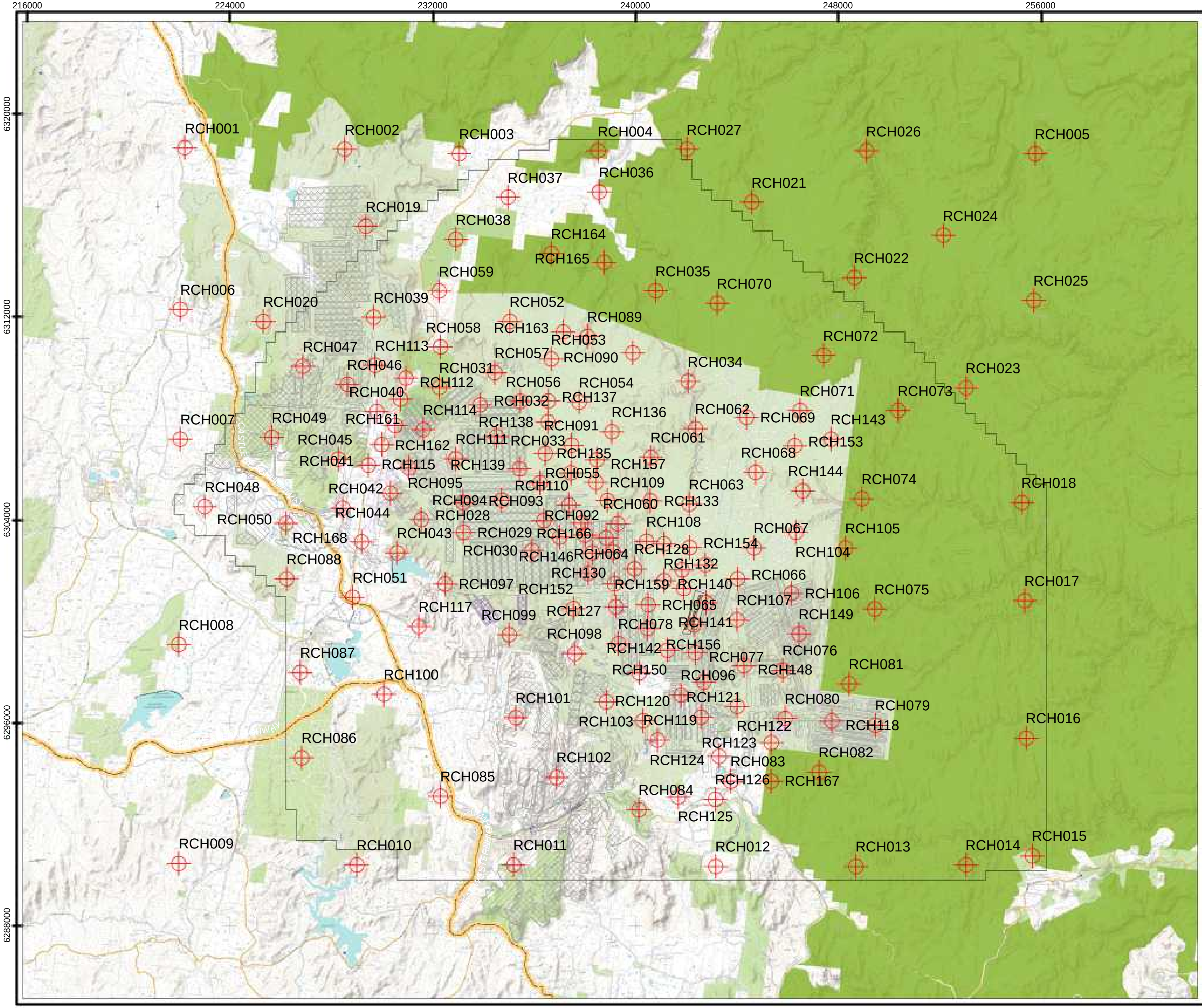
It is noted that recharge is applied to the highest active node.

Due to the extensive representation of surface watercourses in the groundwater model, a higher value for recharge factor was adopted in some parts of the model compared to what is typically used for regional groundwater models. In the recalibration of the model, these values were reduced compared to that presented in JBS&G (2025ab).

Figure 4-5 presents the distribution of recharge factor Pilot Points used in the model.

The custom-developed script for generating the recharge (RCH) MODFLOW module also includes:

- time-varying recharge zonation
  - 'non-rainfall' recharge was applied in the vicinity of Lithgow township. Due to extensive historical mining, leakage from municipal activities (leaking water mains, washing cars, watering gardens) 'non-rainfall' recharge was identified as a process that should be included.
- an option to include 'enhanced recharge'
  - this was applied to a limit of 100% of rainfall, where extraction (Model Mining Method 3, 4 and 5) disturbs ground surface and thereby leads to greater than normal recharge
  - the following calibration parameters were used:
    - open cut ("RCHE_OC")



Legend:

- Highway
- Greater Blue Moutains World Heritage Area

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Modelling:

- Active Model Domain
- Recharge Factor Pilot Point

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 04-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:200,000	

0 4 8
km

Coor. Sys. GDA 1994 MGA Zone 56

Distribution of Recharge Factor Pilot Points

FIGURE: 4.5

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D041a_RechargeFactor_PilotPoints.mxd.mxd
Reference: © Department of Customer Service 2020

- extraction (Model Mining Method 3, 4 and 5): Low (“RCHE_LOW”) for 0.4 < W/H ≤ 0.7, Medium (“RCHE_MED”) for 0.7 < W/H ≤ 0.9 and High (“RCHE_HIG”), for W/H > 0.9.

  - the enhanced recharge values were additive (decimal component only) to the existing recharge factor (derived from Pilot Points).

4.10.1.2 River

The River (RIV) MODFLOW module was used to represent perennial watercourses within model domain.

These included:

- Wolgan River
- Upper Coxs River, immediately upstream of Lake Wallace
- Lake Wallace
- Farmers Creek Dam
- Farmers Creek.

Model geometry was adjusted to allow setting of the bottom elevation of the RIV cells to a level representative of the expected depth of water in the watercourse.

The streambed hydraulic conductivity was calibrated through use a custom-developed script, with four classes of rivers (“RIV11” through “RIV14”), from less significant to more significant and one class for perennial waterbody (“RIV21”). The river classes were loosely based on Strahler Order.

For this model, the location of river boundary conditions is such that that they are far from the area of interest and therefore their definition is not particularly consequential.

4.10.2 Outputs

4.10.2.1 Evapotranspiration

The evapotranspiration (EVT) MODFLOW module was used in the groundwater model.

Spatially distributed, grid-based, evapotranspiration input was obtained from the SILO climatic database (QLD DETSI). The FAO56 dataset was used (UN, 2006).

An evapotranspiration factor was applied to that evapotranspiration value to represent that portion of evapotranspiration that would extract water from the groundwater system. Pilot Points (168) (“EVTF001” through “EVTF168”) were used to provide spatial variability to the evapotranspiration factor. Pilot Points were manipulated during calibration by PLPROC (Watermark Numerical Computing, 2024), incorporating a covariance matrix. Zone-based bearings and anisotropy were also used in the covariance matrix.

The location of the evapotranspiration factor Pilot Points were the same as that used for recharge factor Pilot Points (refer **Figure 4-5**).

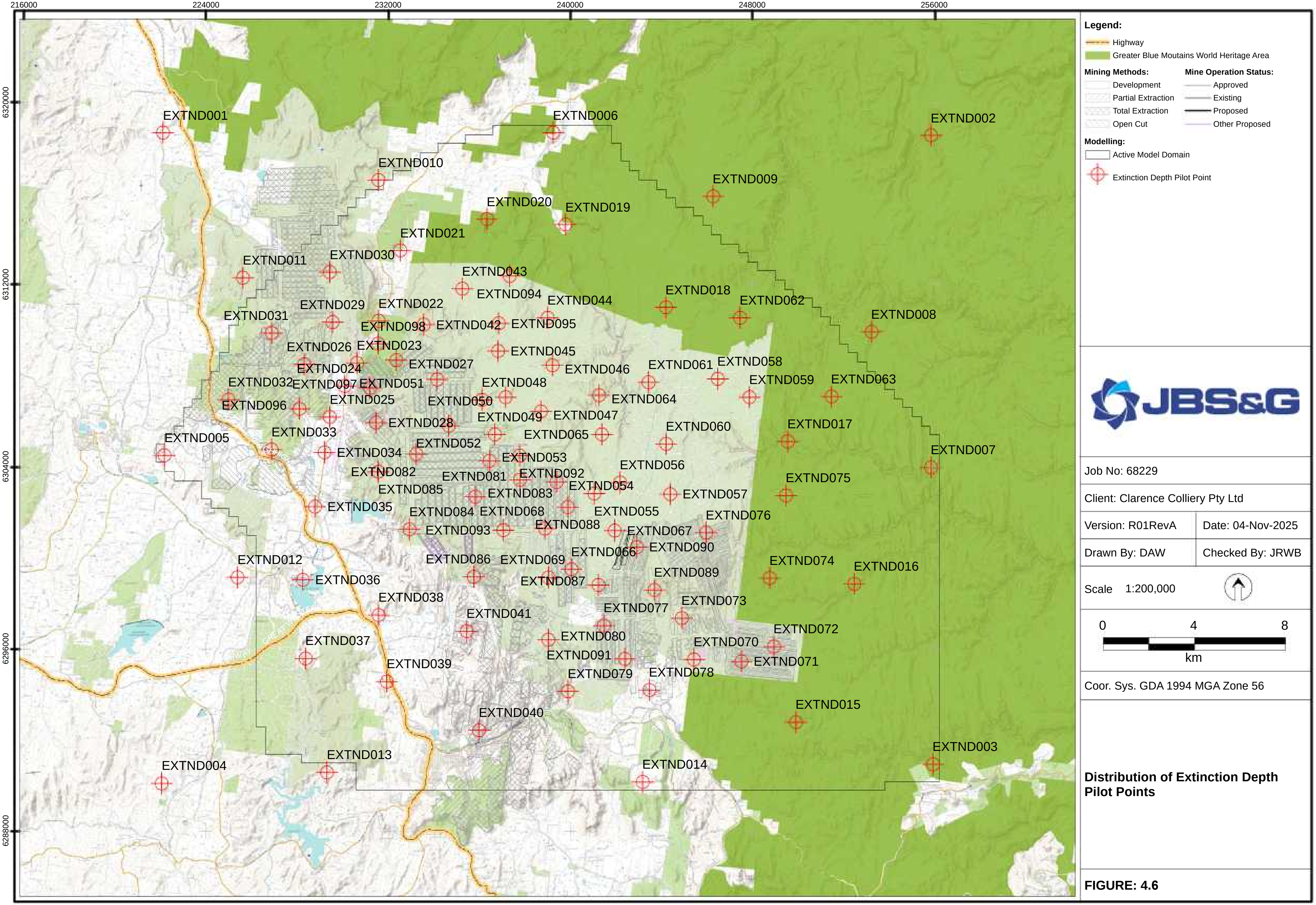
The extinction depth for the evapotranspiration MODFLOW module also used Pilot Points (98) (“ED001” through “ED098”), including a covariance matrix.

Top01 (top of model) was used to set the evaporation surface.

Figure 4-6 presents the distribution of extinction depth Pilot Points.

4.10.2.2 Ephemeral Watercourses and Swamps (DRN)

The NSW Clip and Ship hydrologic dataset (https://maps.six.nsw.gov.au/clipnship.html) was used as the basis of selecting watercourses included in the groundwater model. Regionally, the scale for inclusion of watercourses were those appearing at a scale of 1:25,000. That scale was used to be consistent with the definition of Strahler Order in NSW legislation.



JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 04-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:200,000	
Coor. Sys. GDA 1994 MGA Zone 56	

Distribution of Extinction Depth Pilot Points

FIGURE: 4.6

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D041b_Ext_depth_Factor_PilotPoints.mxd

Reference: © Department of Customer Service 2020

In the area of interest, a finer scale was used, of the order of 1:10,000, leading to more watercourses being included in the model.

All Temperate Highland Peat Swamps on Sandstone (THPSS) were included as drain (DRN) cells. As noted in **Section 3.5.3** all watercourses in the Newnes Plateau and in the Wolgan Valley are considered to be gaining watercourses. Drain (DRN) boundary conditions were used because River (RIV) boundary conditions would introduce a source of water into the model in the area of interest. The area of interest being the modelled change to groundwater elevation in the highest active node (uppermost water table).

The drain (DRN) boundary condition simulates the loss of groundwater to surface through the swamp or creek, with the conductance of the boundary condition simulating the combination of streambed hydraulic conductivity (in this case the peat matrix, where a swamp is represented), width and length of the swamp or watercourse.

The stage of the drain (DRN) cells was set at 0.5m below TopEl of model geometry.

The Strahler order was then determined (using the 1:25,000 dataset) for all drain (DRN) cells that represent ephemeral watercourses and swamps. In the custom-developed script that generates the DRN MODFLOW module, the streambed hydraulic conductivity (m/d) was calibrated for Strahler Order = 1 (“DRN_K_SO1”) and sequential multipliers (also a calibration parameter) were used for higher Strahler Orders (“DRN_K_SO2X” through “DRN_K_SO5X”), with five and above being the maximum.

The conductance of drain (DRN) cells is grid size dependent, and was taken into account in the custom-developed script that generates the Drain MODFLOW module file. It is noted that the relationship between width of the watercourse and the expected streambed thickness of that watercourse is such that the width of individual watercourses is not required to be determined.

The calculated conductance was then modified by a reach-based scaling factor. That scaling factor was also calibrated (“DRN00011” through “DRN00015”).

An exceedance check on conductance is also included in the custom-developed script, so that calibration did not lead to an unrealistically high value.

The distribution of ephemeral watercourses and swamps represented as drain (DRN) cells is illustrated in **Appendix C**.

4.10.2.3 Seepage Faces (DRN)

Seepage faces were assigned adjacent to wherever a model layer ‘pinched out’.

The global conductance of seepage faces was a calibrated parameter (“DRN_C_SEEP”).

The stage of the seepage faces were set at +0.5m to BotEl of the respective layer.

A reach-based scaling factor was applied to the global conductance during calibration. These scaling factors were applied to Layer 02 through Layer 28, for a total of 27 parameters (“DRN00102” through “DRN00128”).

The distribution of ephemeral watercourses and swamps represented as drain (DRN) cells is illustrated in **Appendix C**.

4.10.2.4 Ephemeral Water Bodies (DRN)

Drain (DRN) cells were assigned where there was a non-permanent waterbody. There were not many instances of this circumstance.

The streambed conductivity (m/d) was a calibration parameter (“DRN_K_WB”) and was based on conductance based on cell area, rather than an interpretation of expected watercourse width. The streambed thickness of ephemeral water bodies was assumed to be 1m.

A scaling factor was used to modify the calculated conductance (“DRN00021”). That scaling factor was included as a calibration parameter.

4.10.2.5 Surface Overland Flow (DRN)

For the highest active node, which is ground surface, a surface overland flow drain (DRN) cell was applied where there was not already a watercourse, water body or seepage face.

Surface overland flow was conceptualised as narrow, shallow tribulets that are below the scale of hydrologic mapping.

The streambed conductivity (m/d) assigned to the tribulets was a calibration parameter ("DRN_K_SOF") and the conductance was calculated based on an assumed narrow 'channel' width and commensurate shallow streambed thickness.

The stage of surface overland flow cells was set at Top01.

A scaling factor was used then to modify the calculated conductance ("DRN00051"). That scaling factor was included as a calibration parameter.

4.10.2.6 Mine Dewatering

Stacked Drains

A 'Stacked Drains' approach was used to represent the Height of Fracturing Zone A, informed by the Tammetta (2013) equation. 'Zone A' encompasses both 'Zone A (Caved Zone)' and 'Zone A (Fractured)'. **Section 4.11** presents further detail of the use of Tammetta (2013), as well as schematics of the 'Zone A', 'Zone B', 'Zone C' and 'Zone D' designations.

For development (Model Mining Method 1), the top of 'Zone A' was set at 3 times the mining height (xT) and the top of 'Zone B' was set at 6 times the mining height (xT).

From a geotechnical/subsidence engineering perspective, continuous fracturing is associated with 'Zone A'; however, from a hydrogeological perspective, continuous fracturing is not a requirement to depressurise 'Zone A'. i.e. 'Zone A' does not need to be completely, continuously fractured in an equivalent porous media for depressurisation to occur.

During work on the Springvale/Angus Place Groundwater Model it was found that 'Stacked Drains' is required to be used to represent the initial depressurisation within 'Zone A'. It was found that a drain (DRN) cell in the mined seam, with changes to hydraulic properties in overlying strata, could not calibrate observed inflows and changes to groundwater elevation at both Springvale and at Angus Place. The reason for this is the limitation of equivalent porous media in representing that process.

The 'Stacked Drains' act on a single SP, in this case, quarterly, before turning off.

The conductance of the 'Stacked Drains' was calibrated using a bottom and top value, with linear interpolation in between:

- "DRN_C_B01" and "DRN_C_T01" – 'Stacked Drains' of development (Model Mining Method 1)
- "DRN_C_B11" and "DRN_C_T11" – 'Stacked Drains' of development (Model Mining Method 1)
- "DRN_C_B21" and "DRN_C_T21" – 'Stacked Drains' of extraction (Model Mining Method 2)
- "DRN_C_B31" and "DRN_C_T31" – 'Stacked Drains' of extraction (Model Mine Method 3 & 4)
- "DRN_C_B61" and "DRN_C_T61" – 'Stacked Drains' of extraction (Model Mining Method 5)

The stage (elevation) of each of the 'Stacked Drains' cells were set at +0.1m above bottom elevation of model cells.

Where an extraction (mining) cell (Model Mining Method 3, 4 and 5) intersected a lineament cell, a scaling factor was applied when determining the height of the 'Stacked Drains'. The scaling factor was applied to panel width, in accordance with the methodology presented in **Section 4.11.1**, in the determination of the height of the 'Stacked Drains'.

Table 4-6 presents the scaling factors to panel width adopted for Lineament Type 1 through Type 3.

Table 4-6: Scaling factor applied to panel width of Stacked Drains when intersecting various lineament types

	Number of Lineaments		
Type	1	2	3 or more
1	1.100	1.125	1.150
2	1.050	1.075	1.100
3	1.025	1.050	1.075

In **Table 4-6**, "NumLin" is the number of lineaments. In **Table 4-6**, where two lineaments of the same type intersect an extraction cell, the scale factors listed in column "2" were used. e.g. if there were two Type 2 lineaments intersecting an extraction cell then 1.075 would be used instead of 1.050.

In **Table 4-6**, where two lineaments of different types intersect the same extraction cell, the two scale factors were added, and then subtract 1. e.g. if a Type 2 and a Type 3 lineament intersected an extraction cell, then the scale factor would be 1.050 + 1.025 – 1 = 1.075.

In **Table 4-6**, where two lineaments of the same type and one other different type intersect the same extraction cell, the scale factors were added, and then subtract 1. e.g. if there were 2 x Type 3 lineaments and a Type 1 lineament intersecting an extraction cell, then the scale factor would be 1.050 (from column "2") + 1.100 (from column "1") - 1 = 1.150.

Following that, a scaling factor was used then to modify the calculated conductance for all reaches. Different scaling factors were used for different mining methods. The scaling factors were included as calibration parameters.

Mining methods considered included development (Model Mining Method 1) and extraction (Model Mining Method 2, 3, 4 and 5).

Each mine or colliery was assigned a 'series' number, and a set of scaling factors, depending on the mining method used, were included in PEST.

Mine Water Management

Drain (DRN) cells were used to represent mine water management, after the 'Stacked Drains' step.

Where a particular mine is maintained in a dewatered state, the drain (DRN) cells remain on until recovery commences.

Where a particular mine uses underground storage (see **Figure 3-12**), the elevation of the store was used to inform which cells had their stage adjusted to match the elevation of the store.

The conductance of mine water management cells were calibration parameter, and a different value used for each mining method:

- "DRN_C_MWM01" – conductance of mine water management cell in development (Model Mining Method 1)
- "DRN_C_MWM11" – conductance of mine water management cell in development (Model Mining Method 1)
- "DRN_C_MWM21" – conductance of mine water management cell in extraction (Model Mining Method 2)

- "DRN_C_MWM31" – conductance of mine water management cell in extraction (Model Mining Method 3 and 4)
- "DRN_C_MWM61" – conductance of mine water management cell in extraction (Model Mining Method 5)

A scaling factor was used then to modify the global conductances at each mine. Those scaling factors were calibration parameters.

It is noted that reach numbers of various mining methods were assigned carefully such that the custom-developed script that generates the drain MODFLOW module prioritises extraction over development etc.

4.10.2.7 Lineament Reactivation

Section 3.5.6 presents the implementation of geological lineaments into the numerical groundwater model. As noted in **Section 3.5.6**, the lineaments could be surface-to-seam, seam-to-basement or surface-to-basement.

A 'Stacked Drains' approach was used to represent the depressurisation along the lineament to the top of 'Zone A'. As will be presented in **Section 4.11.4**, a scaling factor was used to reduce the calculated height of the top of 'Zone A' with lineal distance away from the extraction cell (Model Mining Method 4 and 5 only).

Figure 4-7 presents the extraction cells (green) and lineament reactivation cells (yellow cross-hatch) that occur during the lineament reactivation in Springvale Mine (SP116), immediately adjacent to 918 Panel at Clarence. **Figure 4-7** also presents lineament reactivation that has occurred prior to the selected dates (red/brown cross-hatch), but is only just in that figure (southwest corner).

In **Figure 4-7**, extraction cells (green) have a green number. That number is the Stress Period (SP) that extraction occurs. Where an extraction cell intersects a lineament, it is considered that the extraction cell reactivates the lineament (Model Mining Method 4 and 5 only).

Details of the extraction cell are copied to the relevant lineament cells. In **Figure 4-7**, lineament reactivation cells (yellow cross-hatch) have a yellow/black number. The first part of that number is the Stress Period (SP) and the second is the scaling factor on that reactivation.

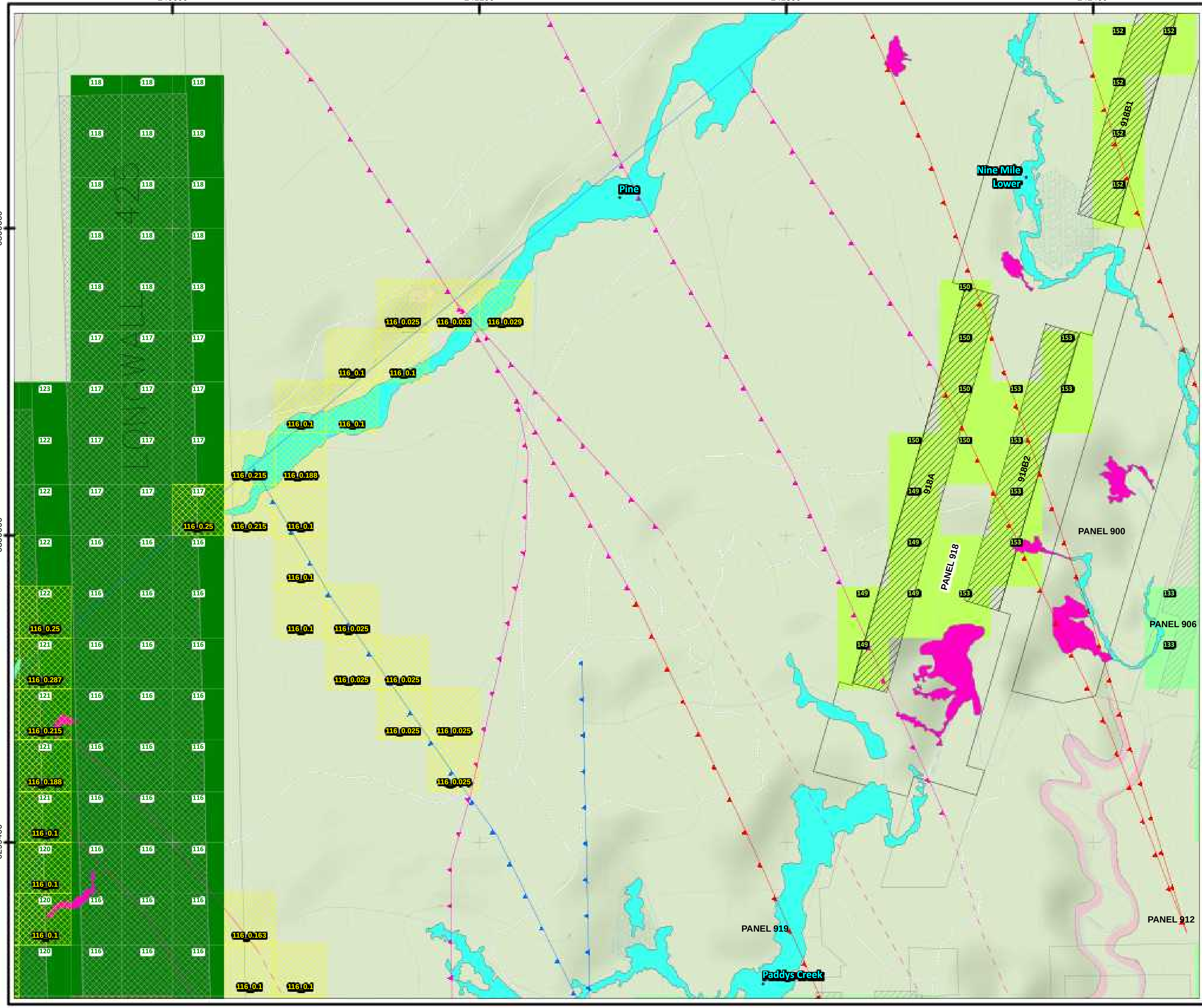
The scaling factor in **Figure 4-7**, with respect to lineament cells is used to scale panel width. The panel width used reflects the details of the extraction cell that reactivates the lineament. If application of the scaling factor to panel width results in a panel width of less than 10.0m, then a minimum width of 10.0m is applied.

In **Table 4-7**, for Type 2 (blue), the distance of reactivation is 900m. Lineal distance along lineament lines was used to identify affected cells. Where a lineament type intersected other lineaments of the same type, it was assumed that the potential for propagation of reactivation would continue.

Table 4-7: Lineal Distance of Lineament Reactivation based on Lineament Type

Type	Maximum Distance of Lineal Change (m)
1	1200
2	900
3	550

Another aspect of lineament reactivation is reduction in scaling factor with lineal distance from the extraction cell (Model Mining Method 4 and 5 only). The magnitude of reactivation is also related to lineament type. **Table 4-8** presents the applied relationship between scaling factor and lineal distance along reactivated lineament and lineament type. **Figure 4-8** presents data from **Table 4-8** as a chart.



Legend:

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Model Mine Method:

- #1 - 1st (development; non-goafing)
- #2 - 2nd (partial extraction, single-sided lift; non-goafing)
- #3 - 2nd (PPPE and double-sided lifting; limited goafing)
- #4 - 2nd (total pillar extraction; limited to full goafing)
- #5 - 2nd (longwall extraction; full goafing)
- #6 - 2nd (backfilling of open cut; n/a)
- #7 - 2nd (grouting; n/a)
- #8 - 2nd (open cut; n/a)

Lineament Reactivation in response to Model Mine Method (Selected SP):

- #4 - 2nd (total pillar extractionl limited to full goafing)
- #5 - 2nd (longwall extraction; full goafing)

Lineament Reactivation in response to Model Mine Method

- #4 - 2nd (total pillar extractionl limited to full goafing)
- #5 - 2nd (longwall extraction; full goafing)

Note: Number at top of extraction cells (green) is the Stress Period (SP) that extraction occurs. Number at bottom of lineament reactivation cells (yellow cross-hatch) contains Stress Period (SP) in the first part and scaling factor on that reactivation in second part. Refer to Figure 3.7 for lineament and mining method symbology.

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 08-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:10,000	

0 200 400
Meters

Coor. Sys. GDA 1994 MGA Zone 56

Lineament Reactivation due to extraction (Model Mining Method 4 and 5 only):
- September 2018 (SP116)

FIGURE: 4.7

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D042_LineamentReactivation.mxd
Reference: © Department of Customer Service 2020

Table 4-8: Reduction of scaling factor applied to Stacked Drains with increasing lineal distance along reactivated lineament for various lineament types

	Distance (from cell edge) (m)				
Type	100	350	550	900	1200
1	0.700	0.550	0.350	0.125	0.075
2	0.500	0.375	0.200	0.050	n/a
3	0.325	0.200	0.075	n/a	n/a

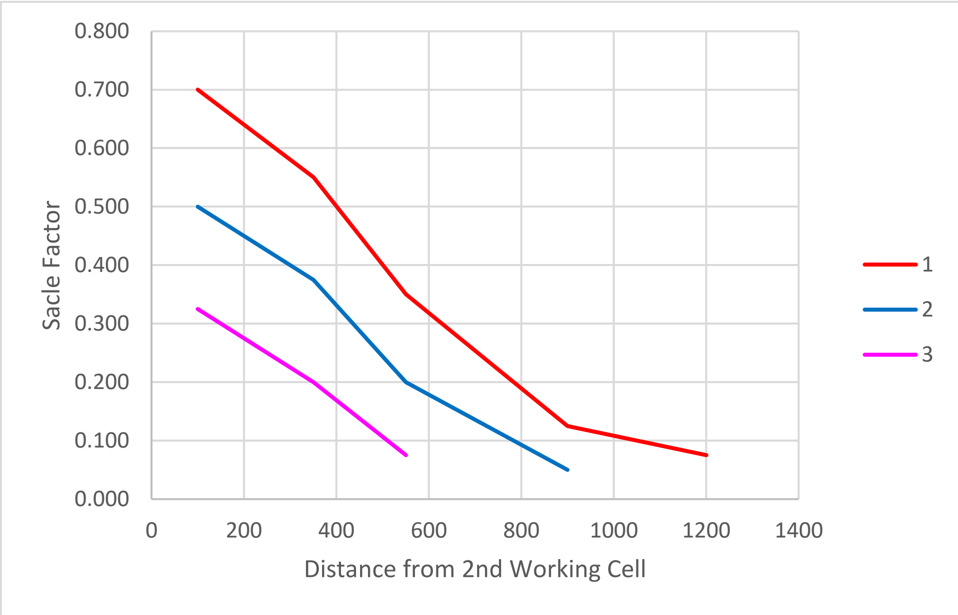


Figure 4-8: Graph of reduction of scaling factor with increasing lineal distance along reactivated lineament

From **Table 4-8**, for Type 3 (pink), cells within 100m of the extraction cell (measured lineally along lineament line) have a 0.325 scaling factor applied. Where cells are more than 100m to a limit of 350m, a scaling factor of 0.05 is applied. From **Figure 4-8**, for Type 2 (blue), cells within 100m of the extraction cell (measurement commences from edge of extraction cell) have a 0.50 scaling factor applied, between 100 and 350m, the applied scaling factor is 0.375, between 350 and 550m, the applied scaling factor is 0.200 and between 550 and 900m, the applied scaling factor is 0.05.

Some further aspects of lineament activation include:

- lineament reactivation does not occur through goaf (Model Mining Method 4 and 5)
- lineament reactivation is assumed to occur in extraction (Model Mining Method 4 and 5 only)
- where multiple lineaments of the same type occur in a lineament cell, the scaling factor is increased by 15% for two and 30% for three lineaments
- where there is crossover of a different lineament type that are not in direct contact (not activated), then apply the following increases to scaling factor:
  - if two types higher, increase scaling factor by 30%
  - if one type higher, increase scaling factor by 20%
  - if one type lower, increase scaling factor by 15%
  - if two types lower, increase scaling factor by 10%.

- where there is crossover of more than one different lineament type that are not in direct contact (not activated) then multiply each of the above increases together
- where more than one lineament type is reactivated by an extraction cell/s at the same SP, add the scaling factors presented in **Figure 4-8** and subtract the lineament count minus one. i.e. if there three lineaments reactivated by an extraction cell at the same SP, add the scaling factors in **Figure 4-8** and subtract two.
- Lastly, an 'incremental profile' type approach to lineament reactivation was developed.
    - Due to the temporal and spatial discretisation of the groundwater model, it may be that a lineament cell is reactivated multiple times
    - The approach adopted was to assess the maximum potential change (maximum with respect to the most significant lineament that is closest to the extraction cell).
        - where a lineament cell has already been reactivated to that maximum, it is not increased further
        - where a lineament cell has already been reactivated, but is not at maximum, then adjust the scaling factor to reflect the difference towards the maximum and/or truncate at the maximum.

The above detail was implemented as a 'Stacked Drain', in the same way as described in **Section 4.10.2.6**, but with significantly reduced Height of Fracturing 'Zone A', HA2, due to the scaled panel width.

A scaling factor was used then to modify the calculated conductance. That scaling factor was included as a calibration parameter.

It is noted that mine water management was not applied to lineament reactivation cells.

4.10.2.8 General Head Boundary (GHB)

General head boundary conditions were used on the northeastern and eastern model domain boundaries to optimise the number of active cells in the model, in Layer 17, Layer 21 and Layer 27.

Those boundary conditions were set up in lineal segments. The global head of the segment was a calibration parameter ("GHBH17", "GHBH21", "GHBH24"), as well as the detail within each segment (so that horizontal gradient could change). As well, the global conductance in each layer was a calibration parameter ("GHBC17", "GHBC21", "GHBC24") as well as detail within each segment.

General head boundary conditions were also used to represent the mine water store in the State Mine Complex, at an elevation of 895mAHD. As presented in the Conceptual Model (see **Section 3.5.3**), the groundwater elevation in State Mine Complex is controlled by an adit located to the far southeast of Lithgow township. Recharge to the State Mine Complex is from lateral groundwater flow (supplemented by additional recharge from the township (urban activity)) as well as vertical percolation of groundwater through the mine roof (into the goafed areas, where applicable). The groundwater elevation in State Mine Complex was obtained by dipping the groundwater level in air ventilation shafts in the State Mine Complex.

The location of general head boundaries is presented in **Appendix C**.

4.10.2.9 Deep Leakage (WEL)

Leakage through the base of the groundwater model was represented using the MODFLOW WEL (Well) module.

The leakage rate was applied on a Length over Time (L/T) basis, consistent with the approach used for the MODFLOW RCH (Recharge) package.

The leakage rate was fixed at 0.5mm/year (equivalent to -1.369E-06m/d).

4.11 Subsidence-Induced Changes to Hydraulic Properties

There were several mining methods (referred to as Model Mining Method for simplicity) represented in the custom-developed script used to generate the Time-Varying Material (TVM) MODFLOW module.

There are three components to the modelled change to hydraulic properties:

- The first is disruption of strata above the top of the mined seam. This is undertaken using a 'ramp function', informed by Tammetta (2013), as well as other assumptions, such as for the height of the top of top of 'Zone A', H_{A2} and top of 'Zone B', H_B (defined in **Section 4.11.1**)
- The second is modification of the magnitude of change to hydraulic properties in those overlying strata. That modification comprises either a maximum or minimum resultant hydraulic conductivity (refer **Section 4.11.2**).
- The third component is 'direct void space' calculation and applies to development (Model Mining Method 1) and extraction (Model Mining Method 2 only) (refer **Section 4.11.3**).

4.11.1 Ramp Function

Top of A (Caved Zone)

'Zone A' comprises two components, the caved zone and the fractured zone.

The approach used for determining the height of the 'A(Caved Zone)', H_{A1}, above the top of the mined height was a simple multiple of mining height, as is convention.

It is noted that if the mined height is less than the thickness of the seam that is mined, the mining height is calculated from the bottom of the seam that is mined.

For development (Model Mining Method 1), H_{A1} is 1x*t*.

For extraction (Model Mining Method 5), H_{A1} is 10x*t*, where *t* is the mining height. For extraction (Model Mining Method 3 and 4), H_{A1} is 6x*t*. For extraction (Model Mining Method 2), H_{A1} is 2x*t*.

These factors were kept constant.

Top of Zone A (Fractured)

The fracture zone is the second component of 'Zone A'. As presented in **Section 4.10.2.6**, 'Stacked Drains' were used to represent the effect of depressurisation of 'Zone A', which encompasses both the caved zone and the fractured zone.

For development (Model Mining Method 1), H_{A2} was set at 3x*t* and kept constant.

For extraction (Model Mining Method 5), the Tammetta (2013) equation was used to derive the Height of Fracturing 'Zone A', H_{A2}. The Tammetta equation is based on an empirical relationship fitted to a multicomponent term that includes panel width, cover depth and mining height.

$$H_{A2} = 1438 \ln(4.315x10^{-5}u + 0.9818) + 26$$

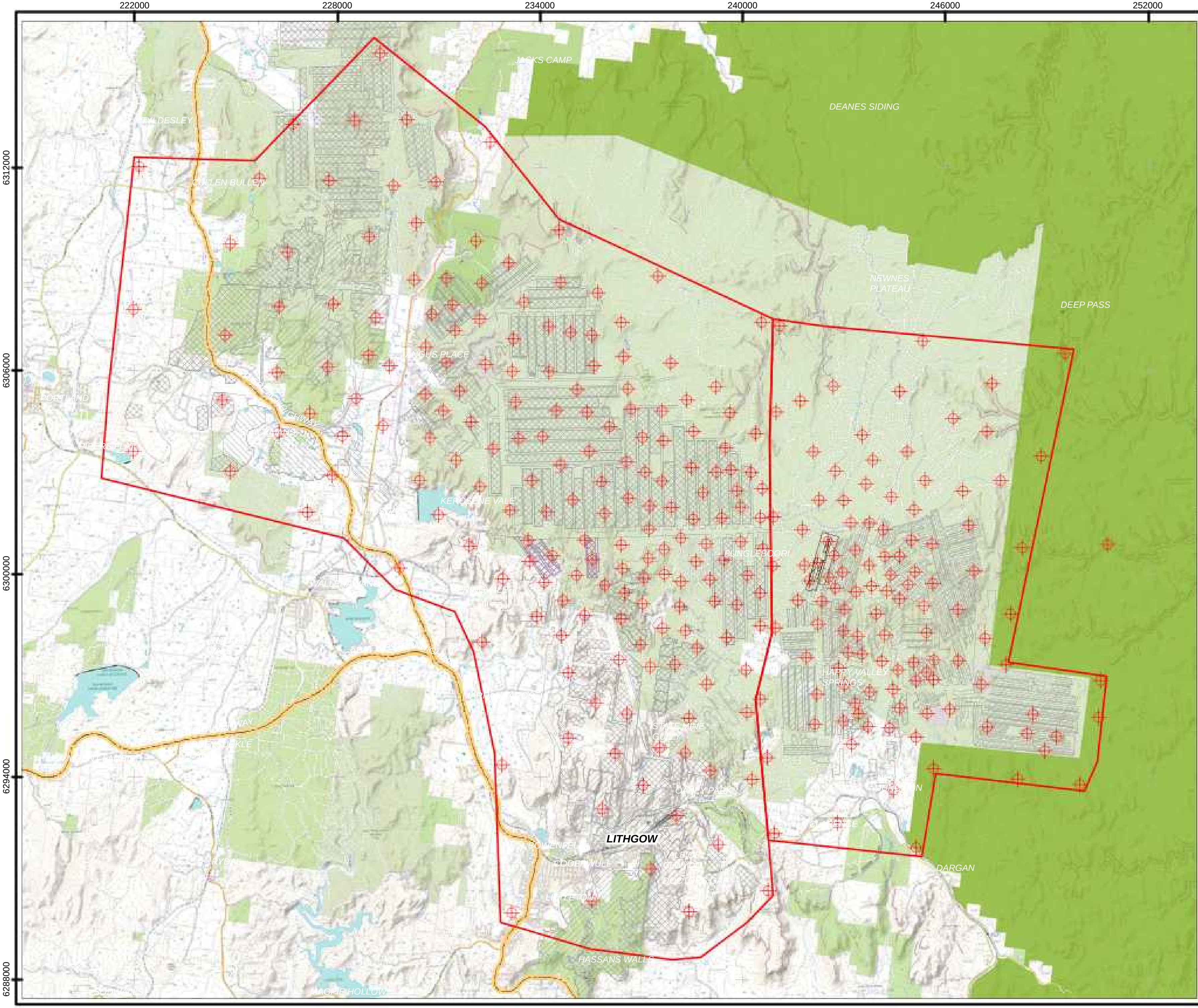
where

$u = wt^{1.4}d^{0.2}$ and H_{A2} is Height of Fracturing 'Zone A' above the top of the mined height, *w* is panel width, *t* is mining height and *d* is covered depth.

The derived value of H_{A2} was then modified by an adjustment factor, being -31m to +37m, with an initial value of 0m.

Figure 4-9 presents the distribution of Pilot Points used to make that adjustment to H_{A2}.

For extraction (Model Mining Method 4), the equation used for H_{A2} (Model Mining Method 5) was modified to account for the difference between Model Mining Method 4 and Model Mining Method 5, reflecting



Legend:

- Highway
- Greater Blue Moutains World Heritage Area

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Modelling:

- Tammetta HA2 Pilot Point
- Tammetta HA2 Zones

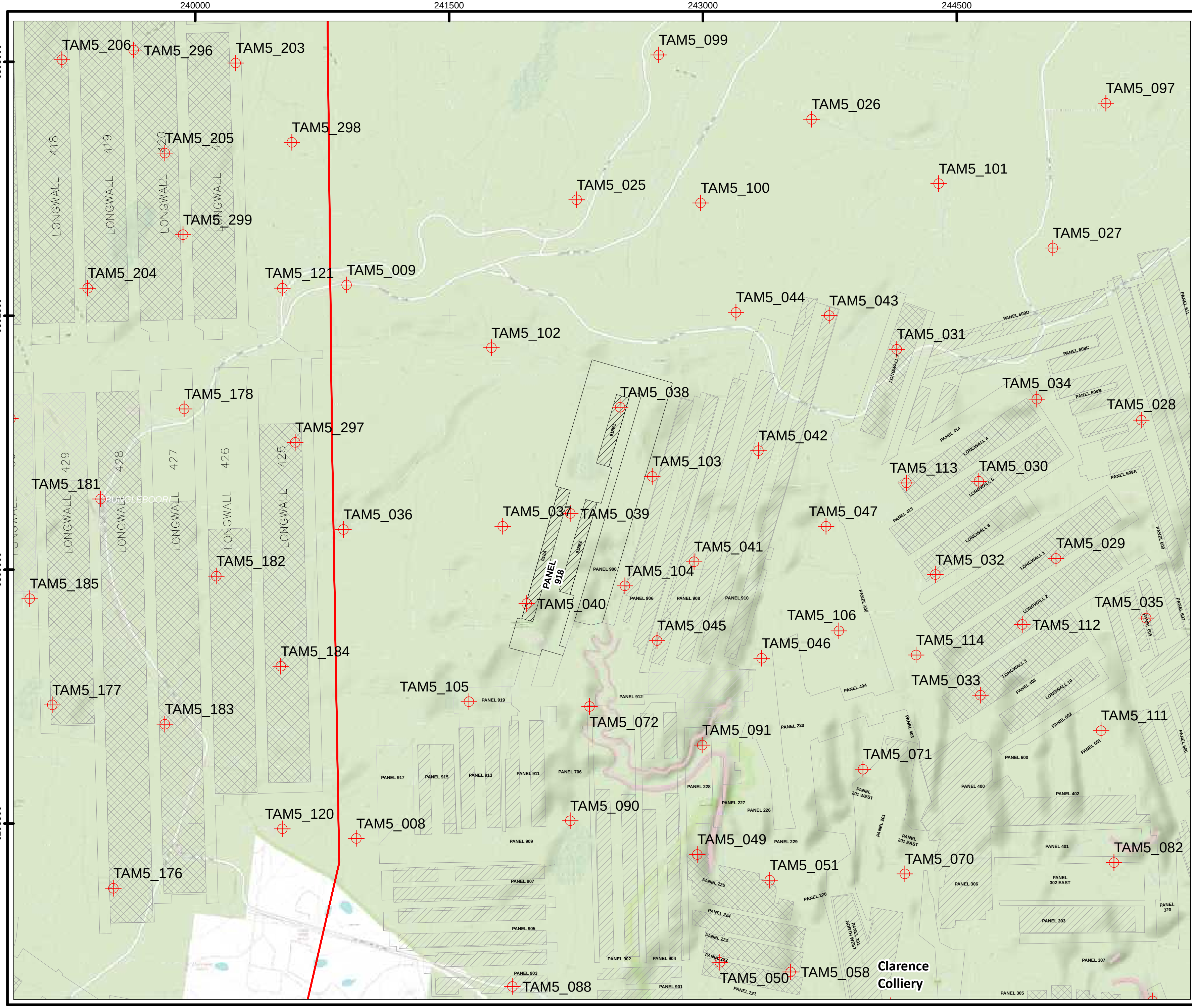
JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 06-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:150,000	
0 2 4 km	
Coor. Sys. GDA 1994 MGA Zone 56	

Pilot Point Distribution for Tammetta HA2 (Model Mining Method 3 to 5)

FIGURE: 4.9a

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D54a_TAM5.mxd
Reference: © Department of Customer Service 2020



Legend:

Mining Methods:
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:
- Approved
- Existing
- Proposed
- Other Proposed

Modelling:
- Tammetta HA2 Pilot Point
- Tammetta HA2 Zones

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 06-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:30,000	

0 0.5 1 km

Coor. Sys. GDA 1994 MGA Zone 56

Pilot Point Distribution for Tammetta HA2 (Model Mining Method 3 to 5) - Vicinity of 918 Panel

FIGURE: 4.9b

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D54a_TAM5_Zoom.mxd
Reference: © Department of Customer Service 2020

reduced extraction ratios and therefore subsidence levels. That modification was a multiplication of H_{A2} by a factor, which was included as a calibration parameter. The range of that factor in PEST was 0.85 and 0.95, with the calibrated value being 0.85.

For extraction (Model Mining Method 3), the same method as Model Mining Method 4 was used. In a previous version of the numerical groundwater model, an adjustment to panel width was applied for PPPE at Clarence Colliery. That adjustment has been removed in this version of the model (conservative).

For extraction (Model Mining Method 2), the relationship between H_{A2} and Tammetta's multicomponent term, 'u' was fitted to Figure 4c of Tammetta (2013) and was H_{A2}=0.135*u^0.84. Figure 4c of Tammetta (2013) is described as "room [bord] and pillar with pillar extraction".

The derived value of H_{A2} was then modified by an adjustment factor, being 0.110 to 0.160.

Figure 4-10 presents the distribution of Pilot Points used to adjust H_{A2} for Model Mining Method 2.

It is noted that collapse at the interface between 'Zone A' and 'Zone B' was also included in the ramp function, as will be illustrated below.

Top of 'Zone B'

'Zone B' is described as the constrained zone.

Tammetta (2013) does not present a method for determining H_B, only H_{A2}.

For development (Model Mining Method 1), whilst H_B was fixed at 2 in the custom-developed script, it is not used. i.e. there is no 'Zone B' applied for development.

For extraction (Model Mining Method 2, 3, 4 and 5), H_B was based on the following relationship developed by JBS&G:

$$H_B = 2.9 * ({H_{A2}}^{0.87})$$

where H_B is the height of top of 'Zone B' above the top of the mined seam and H_{A2} is the height of the top of 'Zone A' above the top of the mined seam.

It is noted that dilation of strata at the interface between the 'Zone B' and 'Zone C' was also included in the ramp function, as will be illustrated below.

Top of 'Zone C'

The top of 'Zone C' was set equal to the bottom of 'Zone D'. The bottom of 'Zone D' was set at 15m below ground surface and kept constant.

Allowance was also made for the dilation of strata at the interface between 'Zone C' and 'Zone D'.

It is also noted that the degree of dilation of strata between 'Zone C' and 'Zone D' is minor compared to that between 'Zone B' and 'Zone C', and, in turn, is smaller again compared to that between 'Zone A' and 'Zone B'.

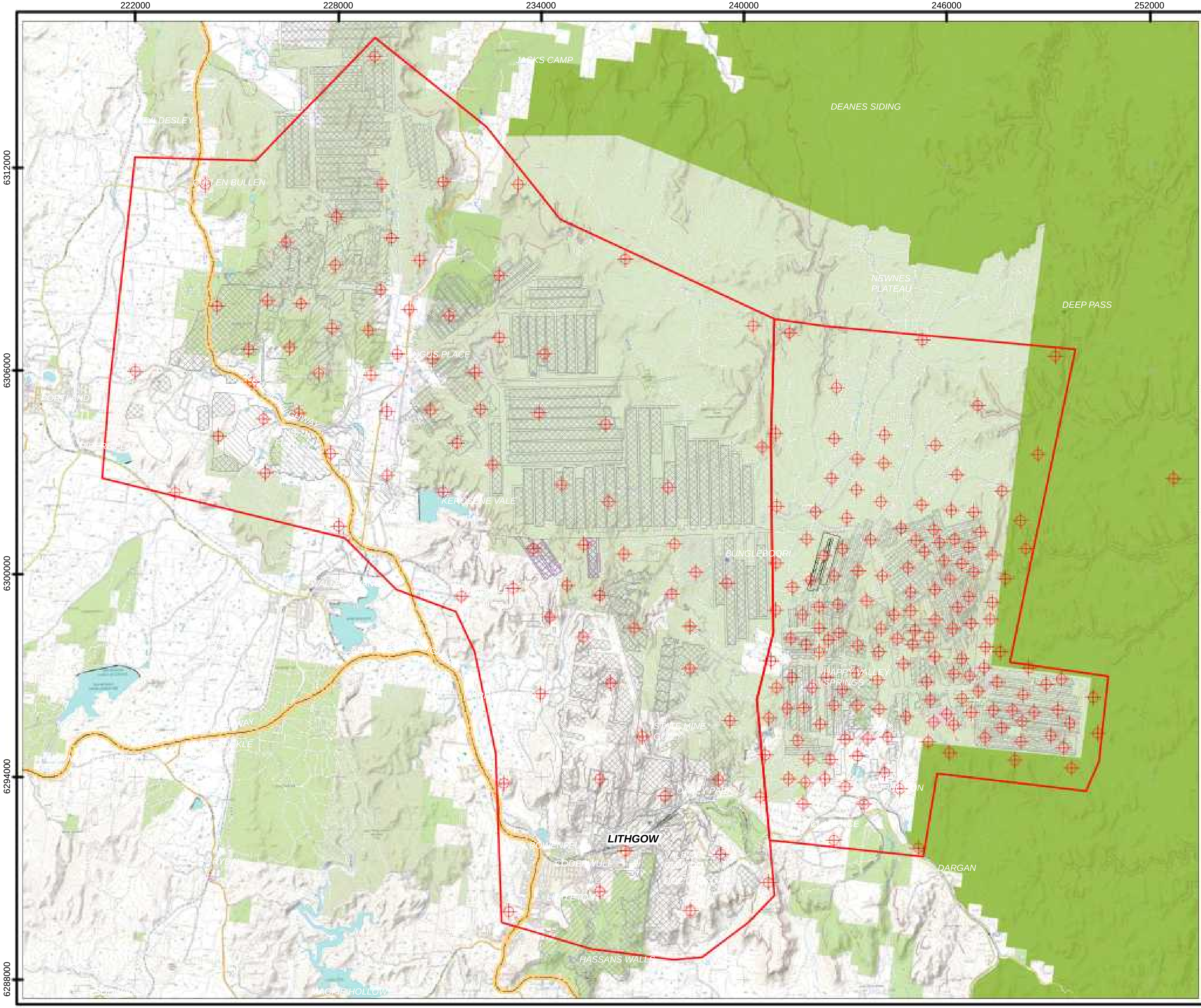
Truncation of Ramp Function

Where the calculated 'ramp function' is truncated by ground surface, for example where the combination of panel width, mining height and cover depth is such that the top of 'Zone A', 'Zone B', or 'Zone C' exceeds ground surface, the approach in the custom-developed script was to assign the maximum value from any of the 'Zones' that were truncated to the highest active 'Zone'.

Ramp Function

The 'ramp function' needs to account for the 'fine detail' of the nature of the strata overlying the mined seam.

As part of several Australian Coal Association Research Projects (ACARP) at Springvale Mine (ACARP, 2007 and ACARP, 2012), as well as the CSIRO (2013) groundwater model for Springvale Mine, 'ramp functions' were



Legend:

- Highway
- Greater Blue Moutains World Heritage Area

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Modelling:

- Tammetta HA2 Pilot Point
- Tammetta HA2 Zones

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 06-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:150,000	

0 2 4
km

Coor. Sys. GDA 1994 MGA Zone 56

Pilot Point Distribution for Tammetta HA2 (Model Mining Method 2)

FIGURE: 4.10a

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D54c_TAM3.mxd
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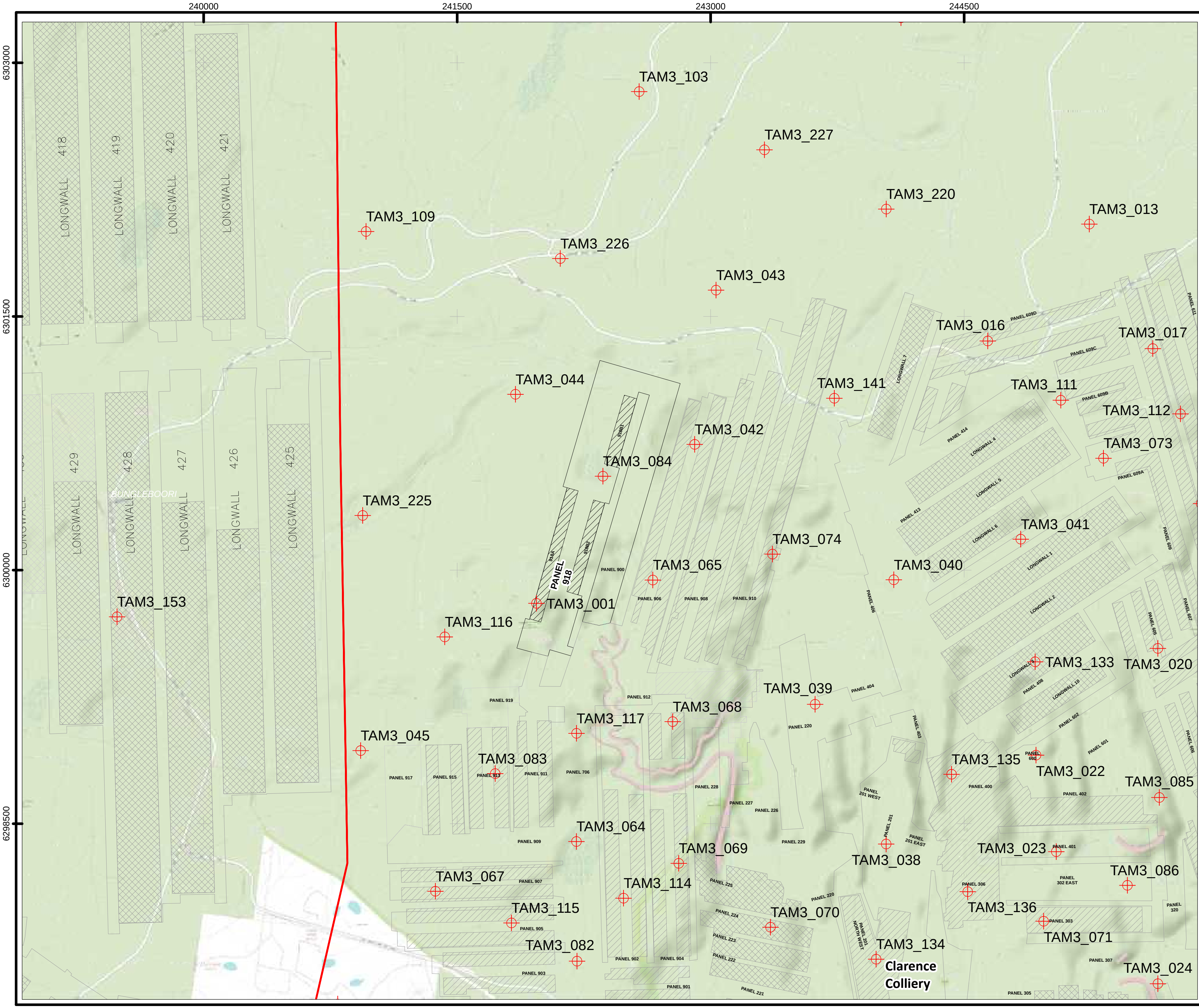


Legend:

Mining Methods:
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:
- Approved
- Existing
- Proposed
- Other Proposed

Modelling:
- Tammetta HA2 Pilot Point
- Tammetta HA2 Zones

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 06-Nov-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:30,000	

0 0.5 1
km

Coor. Sys. GDA 1994 MGA Zone 56

Pilot Point Distribution for Tammetta HA2 (Model Mining Method 2) - Vicinity of 918 Panel

FIGURE: 4.10b

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D54d_TAM3_Zoom.mxd
Reference: © Department of Customer Service 2020

developed. Figure 27 and 28 of CSIRO (2013) were extracted and are presented as **Figure 4-11**. **Figure 4-12** is the 'ramp function' used during actual calibration of the CSIRO model for Springvale Mine (CSIRO, 2013).

JBS&G has developed its own 'ramp function' and this is presented in **Figure 4-13** and **Figure 4-14**. It is based on **Figure 4-11** and **Figure 4-12** and includes each of the subsidence zones. **Figure 4-13** and **Figure 4-14** also includes transition between subsidence zones, although they do not make a significant difference to the applied change to hydraulic properties, because they are thin compared to model layer thickness.

The magnitude of change in the various zones in JBS&G's ramp function is determined using a sequential multiplier. A sequential approach ensures that, during calibration, the shape of the ramp function does not become inconsistent. The sequential multiplication commences from the top down (C-D Interface).

The height of JBS&G's ramp function is varied on a cell-by-cell basis, since mining height, cover depth and panel width can vary on a cell-by-cell basis. In JBS&G's function, if a particular zone exceeds ground surface, then it is truncated. During truncation, the resultant multiplier values of various truncated zones are checked and the maximum value applied.

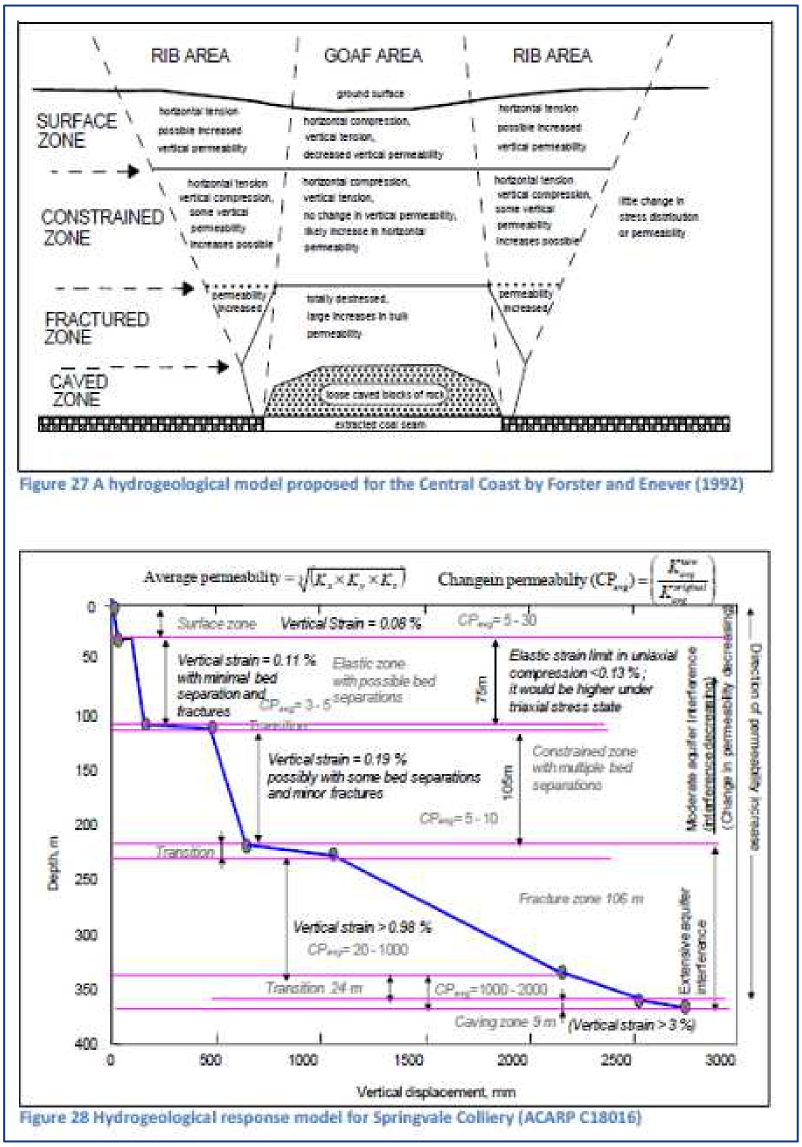


Figure 4-11: Ramp function developed by CSIRO for Springvale Mine (after Figure 27 and 28 of CSIRO (2013))

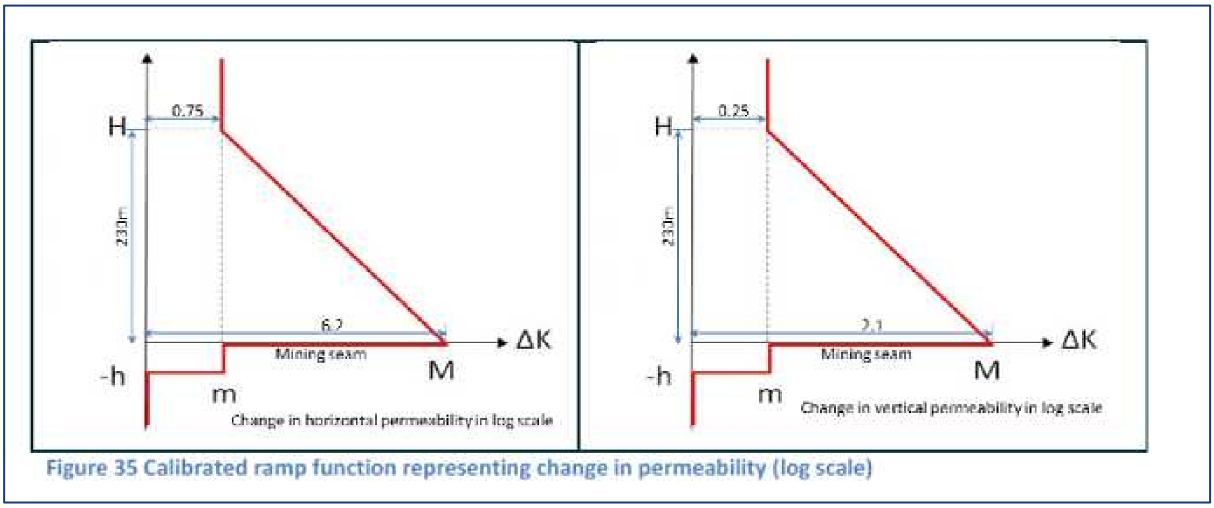


Figure 4-12: Ramp function applied by the CSIRO for Springvale Mine (after Figure 35 of CSIRO (2013))

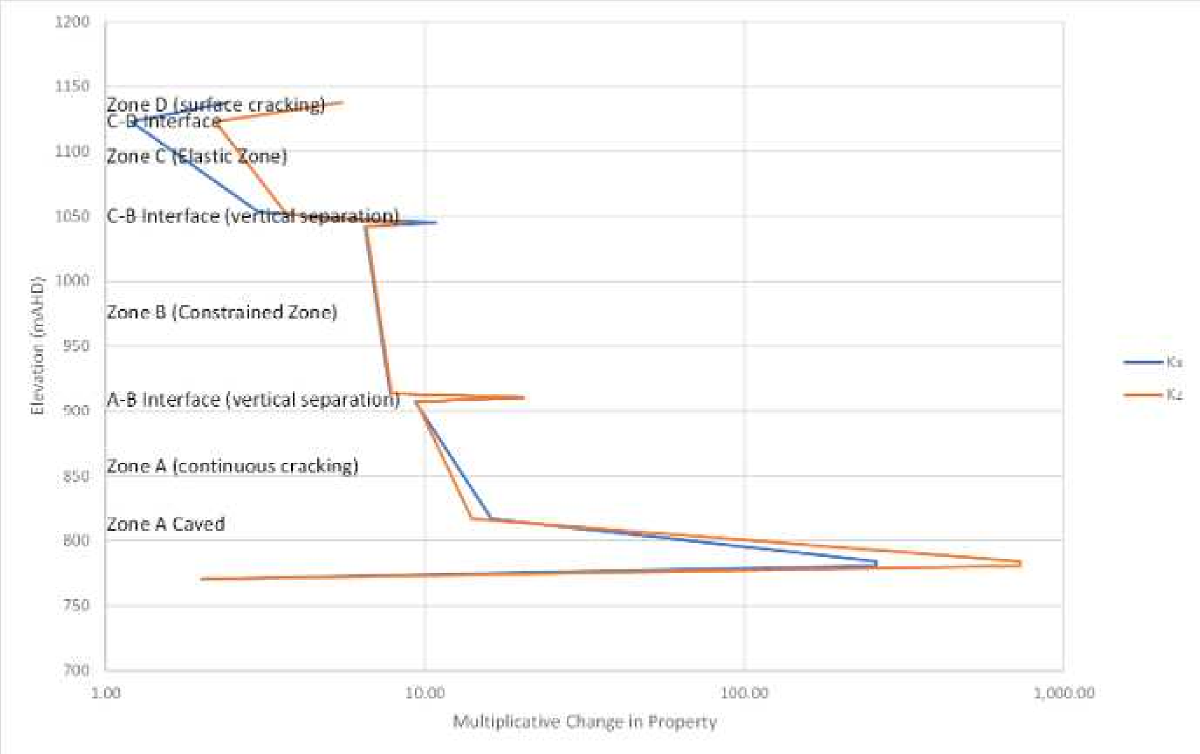


Figure 4-13: Multiplicative Change in Property (Kh (Kx) and Kv (Kz)) Ramp Function developed by JBS&G

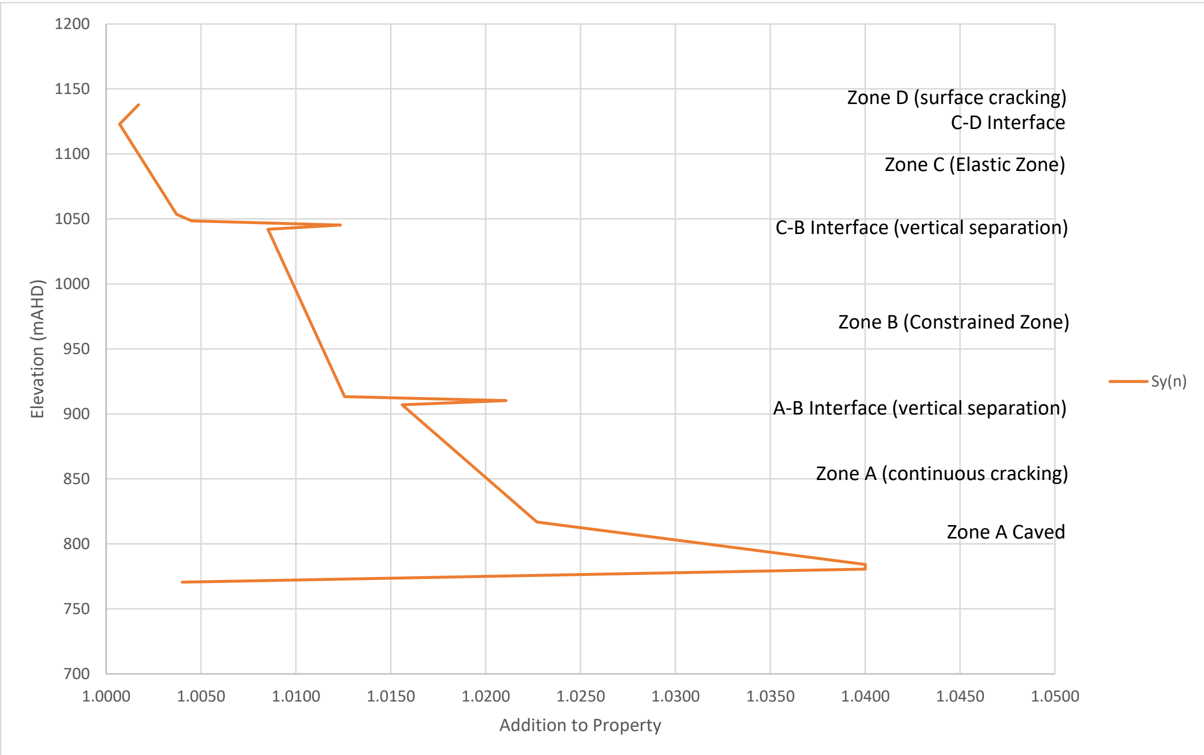


Figure 4-14: Addition to Property (Sy) Ramp Function developed by JBS&G

4.11.2 Maximum or Minimum Resultant Hydraulic Conductivity

Maximum Resultant Hydraulic Conductivity

The custom-developed script used to generate the time-varying-material (TVM) MODFLOW module included an exceedance check for horizontal and vertical hydraulic conductivity.

Those exceedance checks were included as calibration parameters and were applied as follows:

- Above 'Zone A': 6.8E-06m/s for Kh and Kv
- 'Zone A': 4.6E-05m/s for Kh and Kv
- 'Caved Zone': 4.8E-04m/s for Kh and Kv.

It is noted that the above values, where using 'Stacked Drains' to represent depressurisation of 'Zone A' at time of mining, represent partially reconsolidated hydraulic conductivities, rather than the hydraulic conductivities that would be implied by a rock mechanics-based fracture aperture flow model analysis.

An exceedance check was also applied to specific yield, Sy. That exceedance check of 0.3163 (fixed value) was ignored for development (Model Mining Method 1) and extraction (Model Mining Method 2), due to use of 'Direct Void Space' calculation, which is described below.

Minimum Resultant Hydraulic Conductivity

The "minimum resultant hydraulic conductivity" hypothesis is that any vertical cracking of a very low hydraulic conductivity unit, such as the Mt York Claystone (or the Caley Formation, as calibrated), will be, relatively, more significant, in terms of contribution to bulk hydraulic conductivity, in a claystone than a sandstone.

Due to the need to account for differences in mine design (panel width, extraction ratio and mining height) as well as local setting (such as cover depth), a "minimum change base value" was calibrated (1.00E-09m/s) and that 'base value' was then multiplied by the 'ramp' function, as applied to the model grid, to create a local "minimum resultant hydraulic conductivity".

If the resultant hydraulic conductivity was less than the "minimum resultant hydraulic conductivity", then the calculated hydraulic conductivity was increased to the "minimum resultant hydraulic conductivity". This was undertaken on each layer. If the calculated hydraulic conductivity was greater than the "minimum resultant hydraulic conductivity", then there was no change to the calculated hydraulic conductivity.

4.11.3 Direct Void Space Calculation

For development (Model Mining Method 1) and extraction (Model Mining Method 2 only), a 'direct void space' calculation was undertaken within the mined seam. The number of bords were entered in the Geographic Information System (GIS) for each development cell and the custom-developed script, internally, accounts for grid cell size. The grid cell size in the area of interest was 100m; however, some historical mines, at distance from the area of interest, had a grid cell size of 200m (some) and 400m (few). For extraction (Model Mining Method 2 only), the equivalent 'width' of partial extraction was entered into the GIS.

The custom-developed script calculates the relative contribution of void (represented by a hydraulic conductivity of 1.0E-02m/s (864m/d) and a specific yield of 0.9) compared to the unmined pillars. As the number of bords or partial extraction increases, the closer the bulk properties approach the void values.

Due to the significant difference in hydraulic conductivity and specific yield of the void space compared to unmined coal, the void values are approached relatively rapidly.

It is noted that the hydraulic property values determined from the direct void space calculation are used to overwrite previous changes, such as the ramp function in **Section 4.11.1** with respect to lineament reactivation away from the particular cell, so to avoid nonsensical cumulative change to hydraulic properties. It is further noted that multi-seam mining does not occur in the Western Coalfields.

4.11.4 Parameterisation

This section presents a summary of the calibration parameters in the custom-developed script that generates the TVM MODFLOW module introduced and explained above.

<u>Subsidence Model</u>

There are subsidence models for development (Model Mining Method 1) – Bord and Pillar (6m width assumed), development (Model Mining Method 1) – Individual additional bords (6m width assumed) and extraction (Model Mining Method 5 – Longwall).

As described above, these subsidence models were calibrated and applied to model geometry.

Also as presented above, the subsidence model for extraction (Model Mining Method 4 – Total Extraction) was derived from extraction (Model Mining Method 5 – Longwall) through use of a multiplier ("TVM_MOD3161") (range in PEST as 0.60 to 0.80, with the calibrated value being 0.600).

The subsidence model for extraction (Model Mining Method 2 – Partial Extraction) was derived from extraction (Model Mining Method 4 – Total Extraction) through use of a multiplier ("TVM_MOD2131") (range in PEST was 0.10 to 0.30, with calibrated value being 0.117).

For extraction (Model Mining Method 3, which is PPPE and double-sided lifting at Clarence Colliery), the subsidence model used was extraction (Model Mining Method 4 – Total Extraction). In a previous version of the numerical groundwater model, an adjustment to panel width was applied to PPPE cells. That adjustment was not applied in this version of the model (conservative).

Table 4-9 presents the subsidence model for development (Model Mining Method 1 – Bord and Pillar (6m width)). The values are multiplicative factors (or addition, for Sy).

Table 4-9: Subsidence Model – Development (Model Mining Method 1 – Bord and Pillar (6m width))

Subsidence Zone Num	Subsidence Zone	Top[1]	Bottom[1]	Kh Multi.[2]	Kv Multi.[2]	Ss Mulit.[2]	Sy Addn.
1	D (Surface)	1121.63	1106.63	1	1	1	1
2	C (Elastic)	1106.63	855.83	1	1	1	1
3		855.83	850.83	1	1	1	1
4		850.83	849.14	1	1	1	1
5	B (Constrained)	849.14	847.44	1	1	1	1
6		847.44	844.20	1	1	1	1
7		844.20	842.51	1	1	1	1
8	A (Fractured)	842.51	840.82	1	1	1	1
9		840.82	837.58	1	1	1	1
10	A (Caved)	837.58	835.88	"TVM01_KH10"	"TVM01_KV10"	1	"TVM01_SY10"
11	Mined Seam	835.88	834.19	"TVM01_KH11"	"TVM01_KV11"	1	"TVM01_SY11"
12[3]		n/a	n/a	"TVM01_KH11"	"TVM01_KV11"	1	"TVM01_SY11"
13	Basement	834.19	824.18	1	1	1	1

Notes. 1) The elevation profile is determined for each TVM cell, including where the subsidence model is truncated at ground surface.; 2) Kh, Kv and Ss are multiplicative factors. Sy is an addition, only the decimal component is considered; 3) Subsidence Zone Num 12 is a repeat of 11 to ensure the mined seam receives the target value.

Change in storage parameters (specific yield, Sy) has been implemented in this version of the numerical groundwater model. This is a change from the previous version (JBS&G, 2025ab). The assumption required to resolve the previous issue, which was a numerical engine issue within MODFLOW-USG itself, was to use LAYTYP = 4 for layers (one layer either side of the mined seam and the mined seam itself) where void space or increase in Sy due to goafing was intended to be included.

The limitation of use of LAYTYP = 4 (saturated flow equation) instead of LAYTYP = 5 (variably saturated flow) for these layers is not significant, since, where depressurisation does occur, it is in the mined seam (and one layer above or below), hence it is not the case that there will be a perched water table immediately above or below the mined seam.

From **Table 4-9**, there is no change 'above A (Caved)' in the subsidence model. This is to ensure that the transition from the value assigned to the 'A (Caved)' and the lower portion of the 'A (Fractured)', which is assigned a multiplier of 1.0, does not lead to small changes through 'Zone B' to 'Zone D'.

Table 4-10 presents the subsidence model for development (Model Mining Method 1 - Individual additional bords (6m width assumed)). It is noted that this subsidence model is applied as a multiplier to a development cell already subject to the development (Model Mining Method 1 - Bord and Pillar (6m width)) subsidence model. There were not many cells in the groundwater model that used this development (Model Mining Method 1 - Individual additional bords (6m width assumed)) subsidence model.

Table 4-10: Subsidence Model – Development (Model Mining Method 1 – Individual additional bords (6m width assumed))

Subsidence Zone Num	Subsidence Zone	Top[1]	Bottom[1]	Kh Multi.[2]	Kv Multi.[2]	Ss Multi.[2]	Sy Addn.
1	D (Surface)	1121.63	1106.63	1	1	1	1
2	C (Elastic)	1106.63	855.83	1	1	1	1
3		855.83	850.83	1	1	1	1
4		850.83	849.14	1	1	1	1
5	B (Constrained)	849.14	847.44	1	1	1	1
6		847.44	844.20	1	1	1	1
7		844.20	842.51	1	1	1	1
8	A (Fractured)	842.51	840.82	1	1	1	1
9		840.82	837.58	1	1	1	1
10	A (Caved)	837.58	835.88	"TVM11_KH10"	"TVM11_KV10"	1	"TVM11_SY10"
11	Mined Seam	835.88	834.19	"TVM11_KH11"	"TVM11_KV11"	1	"TVM11_SY11"
12		n/a	n/a	"TVM11_KH11"	"TVM11_KV11"	1	"TVM11_SY11"
13	Basement	834.19	824.18	1	1	1	1

Notes. 1) The elevation profile is determined for each TVM cell, including where the subsidence model is truncated at ground surface.; 2) Kh, Kv and Ss are multiplicative factors to that already applied in **Table 4-9**. Sy is an addition, only the decimal component is considered, and is added to that already applied in **Table 4-9**.; 3) Subsidence Zone Num 12 is a repeat of 11 to ensure the mined seam receives the target value.

Table 4-11 presents subsidence model used for extraction (Model Mining Method 5) with respect to multiplicative factors for horizontal hydraulic conductivity, Kh and vertical hydraulic conductivity, Kv.

In **Table 4-11**, the calibrated parameters are sequential multipliers used to adjust the shape and magnitude of the ramp function, from the top down.

From **Table 4-11**, by way of example, the multiplier to Kh in the mined seam is 259x and the multiplier to Kv in the mined seam is 730x. The shape of the 'ramp function' in **Table 4-11** is presented graphically in **Figure 4-13**, albeit using different elevations and values.

Table 4-11: Subsidence Model - Extraction (Model Mining Method 5) - Multiplicative Factors (Kh and Kv)

Subsidence Zone Num	Subsidence Zone	Top	Bottom	Sequential Multi. Kh	Resultant Multi. Kh	Sequential Multi. Kv	Resultant Multi. Kv
1	D (Surface)	1091.93	1076.93	"TVM61_KH01"	2.41	"TVM61_KV01"	5.50
2	C (Elastic)	1076.93	877.55	"TVM61_KH02"	1.20	"TVM61_KV02"	2.20
3		877.55	872.55	"TVM61_KH03"	3.00	"TVM61_KV03"	3.63
4		872.55	869.68	"TVM61_KH04"	5.40	"TVM61_KV04"	4.36

5	B (Constrained)	869.68	866.82	"TVM61_KH05"	10.8	"TVM61_KV05"	8.71
6		866.82	863.79	"TVM61_KH06"	6.48	"TVM61_KV06"	6.53
7		863.79	860.93	"TVM61_KH07"	7.78	"TVM61_KV07"	7.84
8	A (Fractured)	860.93	858.06	"TVM61_KH08"	20.2	"TVM61_KV08"	20.4
9		858.06	852.13	"TVM61_KH09"	9.33	"TVM61_KV09"	9.41
10	A (Caved)	852.13	846.41	"TVM61_KH10"	16.1	"TVM61_KV10"	14.0
11	Mined Seam	846.41	843.54	"TVM61_KH11"	259	"TVM61_KV11"	730
12		n/a	n/a	"TVM61_KH11"	259	"TVM61_KV11"	730
13	Basement	843.54	833.54	"TVM61_KH13"	2.00	"TVM61_KV13"	2.00

Notes. a) Refer to notes presented in **Table 4-9**.

Table 4-12 presents the subsidence model for extraction (Model Mining Method 5) with respect to multiplicative factors for specific storage, Ss and specific yield, Sy.

In **Table 4-12**, specific yield is a simple addition, with the decimal component being added to the previous value of hydraulic properties. There is no change to specific storage, Ss in **Table 4-12**. This is not relevant anyway, since the model layer either side of the mined seam (when depressurisation) will be acting in an unconfined manner, rather than unconfined manner.

Table 4-12: Subsidence Model – Extraction (Model Mining Method 5) – Addition (Sy)

Subsidence Zone Num	Subsidence Zone	Top[1]	Bottom[1]	Sequential Multi. Ss	Resultant Multi. Ss	Addn. Sy
1	D (Surface)	1091.93	1076.93	1	1	1
2	C (Elastic)	1076.93	877.55	1	1	1
3		877.55	872.55	1	1	1
4		872.55	869.68	1	1	1
5	B (Constrained)	869.68	866.82	1	1	1
6		866.82	863.79	1	1	1
7		863.79	860.93	1	1	1
8	A (Fractured)	860.93	858.06	1	1	1
9		858.06	852.13	1	1	1
10	A (Caved)	852.13	846.41	1	1	"TVM61_SY10"
11	Mined Seam	846.41	843.54	1	1	"TVM61_SY11"
12		n/a	n/a	1	1	"TVM61_SY11"
13	Basement	843.54	833.54	1	1	"TVM61_SY13"

Notes. 1) The elevation profile is determined for each TVM cell, including where the subsidence model is truncated at ground surface.; 2) Ss is a multiplicative factor, but is not used. Sy is an addition, where only the decimal component is considered; 3) Subsidence Zone Num 12 is a repeat of 11 to ensure the mined seam receives the target value.

Other Parameters

Other parameters used in the custom-developed script were as follows:

- TVM_MTH4 – adjustment to height of continuous fracturing (from Tammetta (2013)), H_{A2} to account for Model Mining Method 4, rather than Model Mining Method 5
- TVM_KMAX01 through TVM_KMAX03 – upper limit (partially reconsolidated) for hydraulic conductivity for Goaf (Caved Zone and Mined Seam), Zone A and Above Zone A respectively

- TVM_BASEK – minimum change base value (hydraulic conductivity) due to extraction (Model Mining Method 4 and 5)
- TVM_FILLKH and TVM_FILLKV – assumed values of hydraulic conductivity (horizontal and vertical, respectively) for backfilled open cut mines (Model Mining Method 6)
- TVM_MODS_01 and TVM_MODS_21 – scaling factor of 'ramp function' for development (Model Mining Method 1) and extraction (Model Mining Method 2) respectively
- TVM_MOD3161 and TVM_MOD2131 – scaling factor of 'ramp function' from extraction (Model Mining Method 5) to extraction (Model Mining Method 4), and scaling factor of 'ramp function' from extraction (Model Mining Method 4) to extraction (Model Mining Method 2)
- TVM_REF21, TVM_REF31 and TVM_REF61 – reference width-to-height ratios for extraction (Model Mining Method 2), extraction (Model Mining Method 3 and 4) and extraction (Model Mining Method 5)
    - The values are used for adjustment of Scale Factor (read from GIS). The initial values for reference W/H were 0.1, 0.4 and 0.7, with calibrated values being 0.05, 0.65 and 0.60 respectively.
- TVM_SC_LIN, TVM_SC_EXT – adjustment factors for ScaleFactor (nominated in GIS file) of lineaments and lineament reactivation (extraction (Model Mining Method 4 and 5 only))
- TVM_SC_LINMX – adjustment factor for influence of lineaments (all Model Mining Methods).

4.12 Model Calibration

4.12.1 Approach to Cumulative Change

All surrounding mining operations since the mid-1800s have been included in the groundwater model.

4.12.2 Calibration Targets

A combination of targets was used in the calibration model.

The targets included:

- Head Targets (divided into those that were appropriate for steady-state calibration and those where heads were available, however, after potentially being impacted by mining)
    - Head data comprised of standpipe piezometer data (ridgeline, swamp and shallow aquifer piezometers) as well as vibrating wire piezometer data:
        - Data was filtered from daily data to monthly
        - Vibrating wire piezometers with anomalous trends omitted.
- Change in Head Targets
    - These were derived by a custom-developed script which acts similarly to the TARGPESTU.exe utility provided by Groundwater Vistas. The utility takes a time-series hydrograph, separates the first value as a Head target and sets the remainder as a 'change in head' target. In this way, PEST focuses separately on 'Head' and 'Drawdown' targets:
        - It is noted that 'Drawdown' is the grouping used by PEST but, technically, when solving the Richards Equation, there is no drawdown (.DDN) file.
- Hydraulic Conductivity Targets
    - Pre-mining and post-mining targets were available.
- Flux Targets.

- Operational dewatering rates to Springvale Mine, Angus Place Colliery and Clarence Colliery were included calibration datasets:
  - It is highlighted that whilst dewatering rates are similar to inflow rates, the former is complicated by underground water management including operational recirculation; however, dewatering rates is the data that is available and most reliable
- To provide PEST with two separate foci with respect to inflow, relative cumulative inflow and inflow rate were generated and considered.
  - Relative cumulative inflow was calculated using a custom-developed script.

Weighting of observations was guided by the inverse of measurement error, with the magnitude of error being observation type specific and dependent on interpreted measurement quality.

Observations obtained from piezometers were assigned a measurement error, depending on the quality of the observation (Good, Fair and Poor). It is noted that the values of measurement error reflect 'structural uncertainty', as well as the actual precision of reading of the respective instrument.

- Swamp standpipe piezometers (0.15, 0.30 and 0.45m for Good, Fair and Poor)
- Regional standpipe piezometers (0.30, 0.60 and 1.2m for Good, Fair and Poor)
- Vibrating wire piezometers (3.0, 4.5 and 7m for Good, Fair and Poor).

Table 4-13 presents the applied weights for the first observed head at a particular monitoring site.

Table 4-13: Applied Weights for Observed Head

Measurement Type / Measurement Quality	Good (1)	Fair (2)	Poor (3)
Swamp piezometers (Group 1)	1.000	0.952	0.889
Regional standpipe piezometers (Group 2)	0.976	0.909	0.833
Vibrating wire piezometers (Group 3)	0.930	0.833	0.714

Table 4-14 presents the applied weights used for change in heads. Change in heads were calculated based on the difference between the first observed head and subsequent observed heads.

Table 4-14: Applied Weights for Change in Observed Head

Measurement Type / Measurement Quality	Good (1)	Fair (2)	Poor (3)
Swamp piezometers (Group 1)	1.000	0.952	0.889
Regional standpipe piezometers (Group 2)	0.976	0.909	0.833
Vibrating wire piezometers (Group 3)	0.952	0.870	0.741

The weighting of observation groups were then adjusted using a custom-developed script such that the objective function was balanced. As explained in Watermark Numerical Computing (2024), balancing of the objective function is required such that PEST gives appropriate attention to each observation group, with the degree of attention to each group guided by the modeller.

The resultant objective function is presented in **Section 4.12.4**.

4.12.3 Calibration Approach

The model was calibrated using PEST_HP_MKL, Version 18.46 (Watermark Numerical Computing, 2025). The calibration model comprised 11,354 parameters, of which 4 were fixed.

When compared to recent previous use of the numerical groundwater model (JBS&G, 2025ab), some parameters have been removed and some have been added. Where parameters were removed, these were excised from the previous, large Jacobian. Where parameters were added, the sensitivity of these parameters was obtained (small Jacobian) and combined with the revised large Jacobian.

A generalised description of model parameters is presented below, in order of the command file, with detail presented in **Section 4.10** and **Section 4.11**.

- Hydraulic Properties:
  - Horizontal Hydraulic Conductivity, Kh, as Pilot Points, including covariance matrices, deployed on a layer-by-layer basis
  - Cosimulation to derive consistent values of vertical hydraulic conductivity, Kv, specific storage, Ss and specific yield, Sy, as well as parameters for variably saturated flow such as van Genuchten's *alpha* and *beta* and Brooks-Corey exponent, *n*
    - the value of Kh in a particular cell was compared to the range of Kh of the assigned cosimulation category.
  - 'Warping Fields', as Pilot Points, including covariance matrices (on a layer-by-layer basis), for Kv, Ss and Sy, so as to allow adjustment of cosimulated values
  - Layer-based 'warping values' for position within range of Kh of the respective layer for variably saturated flow parameters, for Layer 01 to Layer 15, inclusive and Layer 20 to Layer 22, inclusive.
    - for these layer-based 'warping values', the position within the range of Kh was determined by the geometric mean of all Kh in a layer.
  - Calibrated value of Kv of Type 1 lineaments, with non-linear dependent relationship to derive values of other hydraulic properties (Kh, Ss and Sy)
    - sequential multiplier to Kv of Type 1 to derive Kv of Type 2, followed by sequential multiplier of Kv of Type 2 to derive Kv of Type 3
    - use 'composite' hydraulic property approach of Freeze and Cherry (1979), with a check that updated hydraulic properties are an increase, and not a decrease.
  - Depth dependent modification to hydraulic properties (Kh, Kv, Ss and Sy), with increased values closer to ground surface and top of group.
- Recharge:
  - Recharge Factors using Pilot Points, including a covariance matrix incorporating zone-based bearings and anisotropy
  - Enhanced recharge factors (low, medium and high)
- Evapotranspiration:
  - Evapotranspiration Factors using Pilot Points, including a covariance matrix incorporating zone-based bearings and anisotropy

  - the location of Pilot Points for Evapotranspiration Factor are the same as for Recharge Factor.
- Extinction Depths using Pilot Points, including a covariance matrix incorporating zone-based bearings and anisotropy

- Rivers:
  - Streambed hydraulic conductivity in River (RIV) cells
- General Head Boundary:
  - Global head and conductance of General Head Boundary (GHB), on a layer-by-layer basis, as well as 'reach-based' modification to head and conductance
  - The head and conductance of the GHB used to represent the State Mine Complex was not subject to calibration, as the head was known from observation (there is hydraulic control by the adit in the Vale of Clywdd located to the far southeast of Springvale Mine). The conductance was fixed at a reasonable, but high value, to represent a mine water store.
- Subsidence-Induced Change to Hydraulic Properties:
  - Derivation of top of Zone A, H_{A2}, for Model Mining Method 5 (Longwall Extraction) using the Tammetta (2013) regression equation, whilst incorporating Pilot Point heterogeneity (inclusive of covariance matrices)
  - Modification factor of H_{A2} of Model Mining Method 5 for use in Model Mining Method 3 (PPPE) and Model Mining Method 4 (Total Extraction)
  - Derivation of top of Zone A, H_{A2}, for Model Mining Method 2 (Partial Extraction) using a fit to Tammetta (2013) 'Special H' (for partial extraction), whilst incorporating Pilot Point heterogeneity (inclusive of covariance matrices)
  - Subsidence models for Model Mining Method 1 (Development) and Model Mining Method 5 (Longwall Extraction)
    - Scaling factor (reduction) on subsidence model ('ramp function') for Model Mining Method 4 (Total Extraction) from Model Mining Method 5 (Longwall Extraction)
    - Scaling factor (reduction) on subsidence model ('ramp function') for Model Mining Method 2 (Partial Extraction) from Model Mining Method 4 (Total Extraction).
  - Maximum resultant hydraulic conductivity values for 'Caved and Mined Seam', 'Zone A' and 'above Zone A'
  - Minimum change base value of hydraulic conductivity for extraction (Model Mining Method 4 and 5 only)
  - Horizontal and vertical hydraulic conductivities applied to backfilled open cuts (Model Mining Method 6)
    - there are only a few areas of historical backfilled open cut mines and are not, near current area of interest.
  - Reference width-to-height ratios for extraction (Model Mining Method 2), extraction (Model Mining Method 4) and extraction (Model Mining Method 5)
    - The values are used for adjustment of Scale Factor (read from GIS). The initial values for reference W/H were 0.1, 0.4 and 0.7, with calibrated values being 0.05, 0.65 and 0.60.
  - Global scaling factor of influence of lineaments on extraction (Model Mining Method 4 and 5 only)

- Global scaling factor of lineament reactivation on extraction (Model Mining Method 4 and 5 only)

- Drains:
  - Streambed hydraulic conductivity for ephemeral watercourses (1st order)
    - Sequential multipliers of streambed hydraulic conductivity for ephemeral watercourses (2nd order through 5th order and above)
  - Streambed hydraulic conductivity of ephemeral water bodies
  - Streambed hydraulic conductivity for surface overland flow
  - Global conductance (DRN) of seepage faces
  - Global conductance (DRN) of open cut dewatering
  - Global conductance (DRN) of bottom and top of 'Stacked Drains' of various mining types
  - Global conductance (DRN) of mine water management cells of various mining types
  - Scaling factor of calculated conductance (DRN) of ephemeral watercourses, waterbodies and surface overland flow
  - Scaling factor of global conductance (DRN) of seepage faces, on a layer-by-layer basis
  - Scaling factors of global 'Stacked Drain' conductances at each mine/colliery, with different factors for each mining type
  - Scaling factors of global mine water management conductances at each mine/colliery, with different factors for each mining type.

Figure 4-15 presents the command line (pestgv.bat) of the model.

Lister - [c:\Users\jbell\Jobs\68229_R01RevA_APR_03c\pestgv.bat]

File Edit Options Plugins Encoding Help

```
@echo off
TITLE pestgv
REM Pre-Processing:
del 68229_R01RevA_APR_01a.hds
del 68229_R01RevA_APR_01a.cbb
del 68229_R01RevA_APR_01a.lst
plproc plproc_kx_krige.dat
SWCC_Generator_PEST_R.exe < SWCC_Generator_PEST.in
LPF_TABRICH_USG_R.exe < LPF_TABRICH_USG.in
ExtArrayPropertyWriter_R.exe < ExtArrayPropertyWriter.in
plproc plproc_KzF_krige.dat
plproc plproc_SsF_krige.dat
plproc plproc_SyF_krige.dat
ExtArrayMultiplier_R.exe < ExtArrayMultiplier_Kv.in
ExtArrayMultiplier_R.exe < ExtArrayMultiplier_Ss.in
ExtArrayMultiplier_R.exe < ExtArrayMultiplier_Sy.in
ExtArrayLineaments_R.exe < ExtArrayLineaments.in
ExtArrayDepthDependModifier_R.exe < ExtArrayDepthDependModifier.in
plproc plproc_rchf_krige.dat
RCHPEST_USG_Active_R.exe < RCHPEST_USG_Active.in
plproc plproc_evtf_krige.dat
plproc plproc_ed_krige.dat
EVTPEST_USG_Active_R.exe < EVTPEST_USG_Active.in
RIVPEST_USG_Active_R.exe < RIVPEST_USG_Active.in
GHBPEST_USG_Active_R.exe < GHBPEST_USG_Active.in
WELPEST_USG_R.exe < WELPEST_USG.in
plproc plproc_TAM3_krige.dat
plproc plproc_TAM5_krige.dat
TVMPEST_USG_StackedDrains_ExtArr_R.exe < TVMPEST_USG_StackedDrains_ExtArr.in
DRNPEST_USG_StackedDrains_R.exe < DRNPEST_USG_StackedDrains.in
REM Running:
usgs_2_5_0_2.exe 68229_R01RevA_APR_01a.nam
REM Post-Processing:
TARGPEST3D_R.exe < TARGPEST3D.in
ExtArrayTarget_R.exe < ExtArrayTarget.in
TVMPEST_USG_Target_R.exe < TVMPEST_USG_Target.in
ZonBudUSG.exe < ZonBudUSG.in
CumulativeInflowProcessor_R.exe < CumulativeInflowProcessor.in
LST_Summariser_R.exe < LST_Summariser.in
```

Figure 4-15: Groundwater Model Command Line

PEST utility SUPCALC (Watermark Numerical Computing, 2024) was used to deduce the number of singular value that will divide the calibration solution space from the null space. SUPCALC suggested the number of superparameters to consider ranged between 840 and 1418, with 940 being selected.

4.12.4 Calibration Results

The calibration model incorporated Tikhonov regularisation (preferred value) via the PEST utility ADDREG2. The PEST utility SVDAPREP was then applied, using 940 as the number of superparameters to consider.

The model control file associated with the main part of calibration was:

- 68229_R01RevA_APR_01a_calib05br_svda_04PostSVD

The initial and final objective function is presented below:

```
INITIAL CONDITIONS:
   Current regularisation weight factor                        =   1.0000
   Current value of measurement objective function             =  3.89408E+07
   Current value of regularisation objective function          =  1.10613E-08

   Sum of squared weighted residuals (ie phi)                  =  3.89408E+07
   Contribution to phi from observation group "head1"          =   48731.
   Contribution to phi from observation group "head2"          =  1.79869E+06
   Contribution to phi from observation group "head3"          =  5.81476E+05
   Contribution to phi from observation group "ddn1"           =   44209.
   Contribution to phi from observation group "ddn2"           =  4.20284E+05
   Contribution to phi from observation group "ddn3"           =  1.05749E+07
   Contribution to phi from observation group "packerk"        =  1.36057E+05
   Contribution to phi from observation group "infl_2"         =   57847.
   Contribution to phi from observation group "infl_2cuml"     =  1.60623E+07
   Contribution to phi from observation group "infl_3"         =  4.82221E+05
   Contribution to phi from observation group "infl_3cuml"     =  7.95249E+06
   Contribution to phi from observation group "infl_4"         =  1.28216E+05
   Contribution to phi from observation group "infl_4cuml"     =  6.53276E+05
```

```
OPTIMISATION ITERATION NO.        : 4
   Model calls so far             : 2180
   Current regularisation weight factor                        :  7.54697E-05
   Current value of measurement objective function             :  8.26067E+06
   Current value of regularisation objective function          :  4.32997E+11
   Note: regularisation objective function is not comparable between
   iterations because of IREGADJ regularisation weights adjustment.

   Starting phi for this iteration                             :  8.26314E+06
   Contribution to phi from observation group "head1"          :   53651.
   Contribution to phi from observation group "head2"          :  6.43515E+05
   Contribution to phi from observation group "head3"          :  6.62170E+05
   Contribution to phi from observation group "ddn1"           :   14877.
   Contribution to phi from observation group "ddn2"           :  9.86496E+05
   Contribution to phi from observation group "ddn3"           :  5.23646E+06
   Contribution to phi from observation group "packerk"        :   95505.
   Contribution to phi from observation group "infl_2"         :   38882.
   Contribution to phi from observation group "infl_2cuml"     :  1.81584E+05
   Contribution to phi from observation group "infl_3"         :   38173.
   Contribution to phi from observation group "infl_3cuml"     :  2.06930E+05
   Contribution to phi from observation group "infl_4"         :   36439.
   Contribution to phi from observation group "infl_4cuml"     :   65989.
```

Following this, there was manual calibration (without use of SVDAPREP) to overcome the misfit to mine dewatering rate at Springvale Mine at late time.

The model control file associated with the concluding part of calibration was:

- 68229_R01RevA_APR_03c_05Soln_ManAdjust_calib05b

The objective function of the final serial PEST run (NOPTMAX = 0) is presented below:

```
Objective function ----->

  Sum of squared weighted residuals (ie phi)                = 1.33023E+07
  Contribution to phi from observation group "head1"        =  50853.
  Contribution to phi from observation group "head2"        = 5.00668E+05
  Contribution to phi from observation group "head3"        = 6.56290E+05
  Contribution to phi from observation group "ddn1"         =  20331.
  Contribution to phi from observation group "ddn2"         = 3.99436E+05
  Contribution to phi from observation group "ddn3"         = 5.54214E+06
  Contribution to phi from observation group "packerk"      =  95505.
  Contribution to phi from observation group "infl_2"       =  17439.
  Contribution to phi from observation group "infl_2cuml"   = 1.21031E+06
  Contribution to phi from observation group "infl_3"       =  30815.
  Contribution to phi from observation group "infl_3cuml"   =  55467.
  Contribution to phi from observation group "infl_4"       = 1.21092E+05
  Contribution to phi from observation group "infl_4cuml"   = 4.60198E+06
```

4.12.4.1 Model Mass Balance

Figure 4-16 presents the model mass balance error of the Approved Case (defined below) for the Calibration Period. It is noted that in **Figure 4-16**, "STORED TIME" is MODFLOW "TOTIM" and is elapsed time (in days).

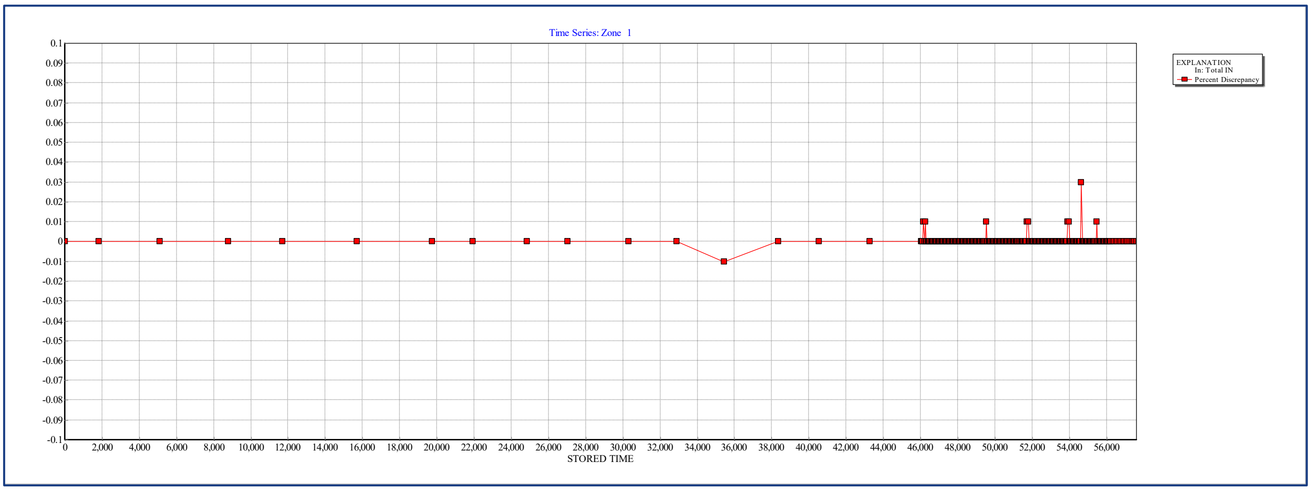


Figure 4-16: Whole Model Mass Balance Error (Percent Discrepancy) – Calibration Period (Approved Case)

From **Figure 4-16**, the model mass balance error is less than 0.1% and therefore meets the guidance value in the Australian Groundwater Modelling Guidelines (Barnett et. al., 2012).

Figure 4-17 presents the listing file output from MODFLOW in the steady-state period (SP001), 31 December 1957 (end of SP012), 31 December 2013 (end of SP097) and 30 September 2025 (end of SP144).

From **Figure 4-17**, for the steady-state period (SP001), inflow into the groundwater model domain is dominated by recharge, with river leakage being negligible in comparison, as is regional throughflow. From **Figure 4-17**, the largest component of outflow is evapotranspiration (large), followed by ephemeral watercourses and seepage faces (small). There is no dewatering associated with mining activity in the steady-state period. From **Figure 4-17**, outflow via regional throughflow is negligible, as is river leakage and deep leakage.

From **Figure 4-17**, at 31 December 1957 (end of SP012), inflow remains dominated by recharge, with river leakage continuing to be small. From **Figure 4-17**, the largest component of outflow is still evapotranspiration with drains (which will include dewatering due to mining) being larger than SP001. Outflow due to deep leakage is the same (the rate is fixed, so this is expected). Regional throughflow and river leakage at this Stress Period is the same as that in SP001.

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 1

	CUMULATIVE VOLUMES L**3	RATES FOR THIS TIME STEP L**3/T
IN:		
STORAGE =	0.0000	0.0000
CONSTANT HEAD =	[illegible]	[illegible]
WELLS =	0.0000	0.0000
DRAINS =	[illegible]	[illegible]
RIVER LEAKAGE =	2052.3560	2052.3560
ET =	[illegible]	[illegible]
HEAD DEP BOUNDS =	5.2305	5.2305
RECHARGE =	[illegible]	[illegible]
TOTAL IN =	[illegible]	[illegible]
OUT:		
STORAGE =	[illegible]	[illegible]
CONSTANT HEAD =	0.0000	0.0000
WELLS =	[illegible]	[illegible]
DRAINS =	116154.9041	116154.9041
RIVER LEAKAGE =	[illegible]	[illegible]
ET =	266800.7188	266800.7188
HEAD DEP BOUNDS =	[illegible]	[illegible]
RECHARGE =	0.0000	0.0000
TOTAL OUT =	392980.9650	392980.9650
IN - OUT =	4.0902	4.0902
PERCENT DISCREPANCY =	0.00	0.00

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 10 IN STRESS PERIOD 12

	CUMULATIVE VOLUMES L**3	RATES FOR THIS TIME STEP L**3/T
IN:		
STORAGE =	215931291.7104	5767.1849
CONSTANT HEAD =	0.0000	0.0000
WELLS =	0.0000	0.0000
DRAINS =	0.0000	0.0000
RIVER LEAKAGE =	83717019.0067	2861.7712
ET =	0.0000	0.0000
HEAD DEP BOUNDS =	172433.9355	5.3066
RECHARGE =	12891306747.2500	393522.3750
TOTAL IN =	13191127491.9027	402156.6378
OUT:		
STORAGE =	55798473.6868	2785.1089
CONSTANT HEAD =	0.0000	0.0000
WELLS =	33417525.3984	1016.5645
DRAINS =	4427614823.6598	143018.6913
RIVER LEAKAGE =	13255505.2584	394.9507
ET =	8380062930.3049	246410.6875
HEAD DEP BOUNDS =	280863611.7491	8527.1641
RECHARGE =	0.0000	0.0000
TOTAL OUT =	13191012870.0575	402153.1669
IN - OUT =	114621.8438	3.4708
PERCENT DISCREPANCY =	0.00	0.00

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 5 IN STRESS PERIOD 97

	CUMULATIVE VOLUMES L**3	RATES FOR THIS TIME STEP L**3/T
IN:		
STORAGE =	904633919.8773	74429.6182
CONSTANT HEAD =	0.0000	0.0000
WELLS =	0.0000	0.0000
DRAINS =	0.0000	0.0000
RIVER LEAKAGE =	142037783.0037	5662.1226
ET =	0.0000	0.0000
HEAD DEP BOUNDS =	15852085.5796	3862.1196
RECHARGE =	20722875117.9531	281200.3438
TOTAL IN =	21785398906.4137	365154.2041
OUT:		
STORAGE =	530963241.7338	31786.7495
CONSTANT HEAD =	0.0000	0.0000
WELLS =	54210336.0485	1016.5645
DRAINS =	7541070284.6394	145550.9159
RIVER LEAKAGE =	21915345.5392	173.6733
ET =	13082956546.1951	168500.4219
HEAD DEP BOUNDS =	554272068.2855	18126.8535
RECHARGE =	0.0000	0.0000
TOTAL OUT =	21785387822.4415	365155.1786
IN - OUT =	11083.9727	-0.9745
PERCENT DISCREPANCY =	0.00	-0.00

VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 5 IN STRESS PERIOD 144

	CUMULATIVE VOLUMES L**3	RATES FOR THIS TIME STEP L**3/T
IN:		
STORAGE =	1199621626.0419	102251.2500
CONSTANT HEAD =	0.0000	0.0000
WELLS =	0.0000	0.0000
DRAINS =	0.0000	0.0000
RIVER LEAKAGE =	153960068.0622	2591.1580
ET =	0.0000	0.0000
HEAD DEP BOUNDS =	39006957.0463	7756.6597
RECHARGE =	22387523889.0547	174302.2344
TOTAL IN =	23780112540.2051	286901.3020
OUT:		
STORAGE =	753720319.4590	13521.1836
CONSTANT HEAD =	0.0000	0.0000
WELLS =	58572414.3950	1016.5645
DRAINS =	8312637858.8068	162015.8054
RIVER LEAKAGE =	24253667.9020	385.2749
ET =	13999378191.6074	92167.7031
HEAD DEP BOUNDS =	631530807.4764	17794.2148
RECHARGE =	0.0000	0.0000
TOTAL OUT =	23780093259.6466	286900.7464
IN - OUT =	19280.5586	0.5555
PERCENT DISCREPANCY =	0.00	0.00

Figure 4-17: Excerpts of Model Mass Balance – Calibration Period (Approved Case)

From **Figure 4-17**, at 31 December 2013 (end of SP097), inflow remains dominated by recharge (large), with inflow from river leakage being higher than previous Stress Period output times, but is still a negligible component of the water balance (being less than 5%). Regional throughflow (inflow) has increased, and will be due to the representation of the observed mine water storage in the State Mine Complex by a General Head Boundary. Regional throughflow (inflow) is still a negligible component of the water balance. From **Figure 4-17**, outflow from the groundwater model domain is via evapotranspiration (large, 46%); however, is now similar in magnitude to outflow via drains (medium, 40%). Outflow via regional throughflow has increased, but is small (5.0%). As per previous model output, deep leakage via well is the same.

From **Figure 4-17**, at 30 September 2025 (end of SP144), inflow comprises recharge (large), with other components the same as that for 31 December 2013 (end of SP097). From **Figure 4-17**, outflow via drains (which includes dewatering due to mining) is now the largest component (large; 56%), followed by evapotranspiration (medium; 32%). Regional throughflow (outflow) is, essentially the same as at for 31 December 2013 (end of SP097).

Figure 4-18 presents the time-series inflows of the model mass balance. **Figure 4-19** presents the time-series outflows of the model mass balance. It is noted that the x-axis of **Figure 4-18** and **Figure 4-19** commences on 1 January 1994 (start of SP018).

From **Figure 4-19**, the contribution of drains (which includes mine dewatering) increases gradually over time.

Figure 4-18 and **Figure 4-19** does not indicate that there is significant drift, which would imply the model is not in relative dynamic equilibrium. By dynamic equilibrium, that the stresses being experienced in the model are changing significantly over the simulated period.

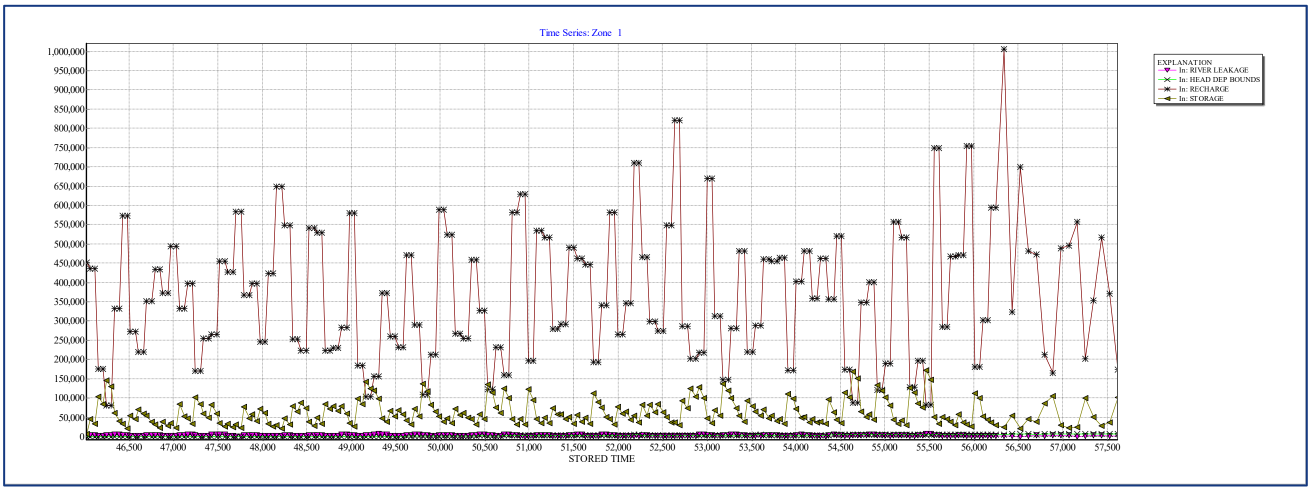


Figure 4-18: Model Mass Balance - Time-Series Inputs (m³/d) – Calibration Period (Approved Case)

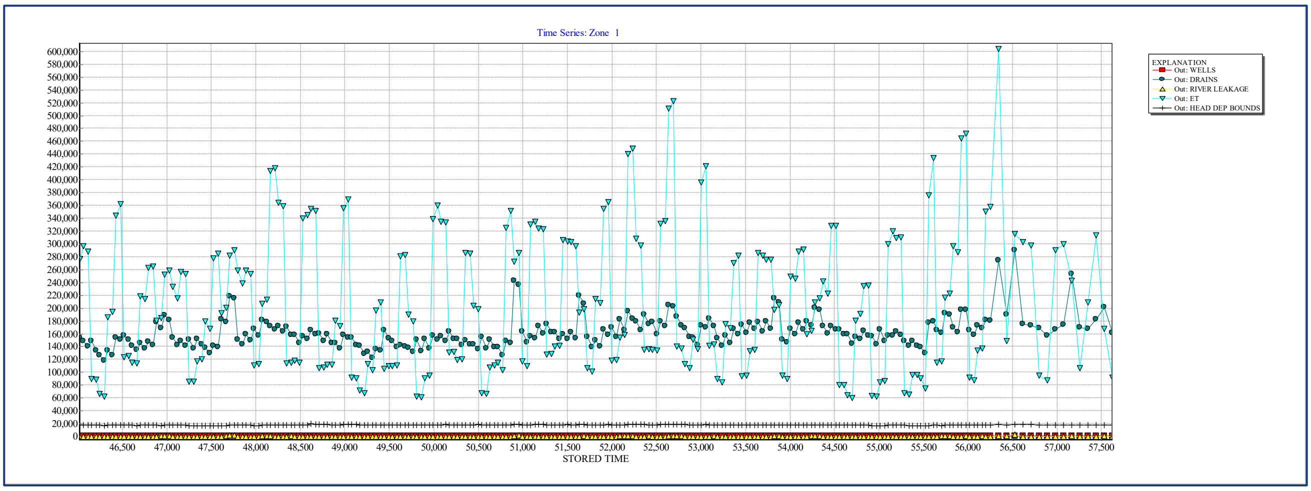


Figure 4-19: Model Mass Balance - Time-Series Outputs (m³/d) – Calibration Period (Approved Case)

4.12.4.2 Model Parameters

The calibrated values of all model parameters are presented in **Appendix K**.

Hydraulic Properties (Kh, Kv, Ss and Sy)

The calibrated values of horizontal hydraulic conductivity, Kh, vertical hydraulic conductivity, Kv, specific storage, Ss and specific yield, Sy for each model layer is presented in **Appendix E**.

Spatially distributed values of hydraulic properties is provided at the following model output times:

- Steady-State (SP001)
  - Pre-Mining
- 30 September 2025 (SP144)
  - during development of 918 Panel
- 30 September 2026 (SP148)

  - immediately prior to extraction of 918 Panel
- 31 December 2049 (SP241)
  - end of simulation.

Table 4-15 presents the geometric mean of the horizontal hydraulic conductivity, Kh (m/s), vertical hydraulic conductivity, Kv (m/s), specific storage, Ss (1/m) and specific yield, Sy (frac.).

The values presented in **Table 4-15**, also reflect the influence of geological lineaments (which are not conceptualised as being 'very vertical hydraulic conductivity conduits', since THPSS would not otherwise be able to maintain their standing water level above them) as well as depth-dependent modification.

Model calibration has indicated that the value of vertical hydraulic conductivity of Type 1 lineaments is low, and therefore Type 2 and Type 3 are also low. Whilst calibration has indicated the vertical hydraulic conductivity of lineaments is low, they are subject to reactivation.

Variably Saturated Flow

Table 4-15 presents the calibrated values of van Genuchten's ALPHA and BETA parameters (van Genuchten, 1980) and Brooks-Corey's N (Brooks and Corey, 1966). The lower and upper bounds are those parameters are presented in **Appendix K**.

Figure 4-20 presents the calibrated relationship between saturation, S (frac.) and capillary head (m) (also known as matrix suction (m)).

From **Figure 4-20**, for shales, as expected, the residual saturation (the asymptote), Sr, is high, whereas for sandstone, the residual saturation is lower. The highest residual saturation occurs in the Mount York Claystone (Layer 15).

As noted above, to enable change in storage (specific yield, Sy) via the TVM MODFLOW module, LAYTYP was required to be set to 4 (saturated flow) for Layer 17 to 19 and Layers 23 to 25. This means that soil water characteristic curves (SWCC) are not relevant for Layers 17 to 19 and Layers 23 to 25.

At depth in the model (Layer 26 through to Layer 30), saturated flow conditions will occur, hence these layers were allocated LAYTYP = 4, as per previous versions of the numerical groundwater model.

Figure 4-21 presents the calibrated relationship between relative hydraulic conductivity, Krw (frac.) and capillary head (m).

From **Figure 4-21**, as expected, there is a sharp decline in relative hydraulic conductivity for sandstone units, and is less sharp for siltstone. The slowest decline in relative hydraulic conductivity is associated with claystone.

The relative hydraulic conductivity of all consolidated rock decline with only medium capillary head. This is expected and is consistent with the findings of Brooks and Corey (1966) at the time.

Table 4-15: Calibrated Values of Hydraulic Properties

Layer	Class	Unit	Hydrogeologic Categorisation[a]	Kh (m/s) *Geomean	Kv (m/s) *Geomean	Ss (1/m) *Geomean	Sy (frac.) *Geomean	V-G ALPHA	V-G BETA	n[1] (fract.)	Sr[2] (frac.)	Brooks n
1	Sandstone / Regolith	Burralow Formation	Sandstone	2.51E-07	3.58E-08	2.33E-06	0.0872	1.920	7.974	0.217	0.315	3.287
2	Shale (YS1)	-	Shale	1.61E-08	7.44E-10	1.99E-06	0.0217	2.489	2.599	0.149	0.834	4.251
3	Sandstone / Regolith	-	Sandstone	2.16E-07	3.02E-08	2.26E-06	0.0850	1.945	8.021	0.220	0.342	3.285
4	Shale (YS2)	-	Shale	1.37E-08	6.33E-10	1.93E-06	0.0202	2.458	2.582	0.147	0.838	4.265
5	Sandstone / Regolith	-	Sandstone	1.96E-07	2.72E-08	2.22E-06	0.0845	1.942	8.014	0.220	0.338	3.285
6	Shale (YS3)	-	Shale	1.25E-08	5.19E-10	1.90E-06	0.0200	2.481	2.594	0.149	0.834	4.254
7	Sandstone / Regolith	-	Sandstone	1.83E-07	2.53E-08	2.20E-06	0.0819	1.944	8.018	0.220	0.340	3.285
8	Shale (YS4)	-	Shale	1.19E-08	5.76E-10	1.88E-06	0.0190	2.488	2.598	0.149	0.834	4.252
9	Sandstone / Regolith	-	Sandstone	1.58E-07	2.24E-08	2.13E-06	0.0823	1.944	8.017	0.220	0.340	3.285
10	Shale (YS5)	-	Shale	1.05E-08	5.19E-10	1.84E-06	0.0179	2.488	2.598	0.149	0.834	4.251
11	Sandstone / Regolith	-	Sandstone	1.41E-07	1.96E-08	2.08E-06	0.0808	1.940	8.010	0.220	0.336	3.285
12	Shale (YS6)	-	Shale	1.03E-08	5.34E-10	1.83E-06	0.0175	2.495	2.602	0.150	0.834	4.248
13	Quartzose sandstone	Banks Wall Sandstone	Sandstone	1.74E-07	2.51E-08	2.20E-06	0.0855	1.949	8.026	0.221	0.345	3.285
14	-	-	Sandstone	1.12E-07	1.57E-08	2.01E-06	0.0803	1.922	7.978	0.217	0.317	3.287
15	Claystone	Mt York Claystone	Claystone	2.69E-09	2.17E-10	7.66E-06	0.0093	1.164	2.362	0.281	0.910	4.469
16	Quartzose to quartz-lithic sandstone	Burra-Moko Head Sandstone	Sandstone	9.68E-08	1.36E-08	1.91E-06	0.0791	1.948	8.025	0.221	0.344	3.285

Layer	Class	Unit	Hydrogeologic Categorisation[a]	Kh (m/s) *Geomean	Kv (m/s) *Geomean	Ss (1/m) *Geomean	Sy (frac.) *Geomean	V-G ALPHA	V-G BETA	n[1] (fract.)	Sr[2] (frac.)	Brooks n
17	Claystone / Shale / Sandstone	Caley Formation	Siltstone	3.10E-08	2.07E-09	3.51E-06	0.0335	n/a	n/a	n/a	n/a	n/a
18	Coal	Katoomba Seam	Coal	8.81E-07	3.87E-07	3.97E-06	0.0597	n/a	n/a	n/a	n/a	n/a
19	Claystone / Shale	Farmers Creek Formation	Siltstone	3.48E-08	2.57E-09	3.66E-06	0.0339	n/a	n/a	n/a	n/a	n/a
20	Lithic sandstone / Claystone / Quartz-Lithic Sandstone	Gap Sandstone/State Mine Creek Formation/Angus Place Formation (Watts Sandstone)	Sandstone	9.29E-08	1.30E-08	1.86E-06	0.0781	1.921	7.975	0.217	0.316	3.287
21	Mudstone / Siltstone / Claystone (Marine Incursion)	Denman Formation	Mudstone	9.05E-09	6.68E-10	6.58E-06	0.0187	1.386	3.090	0.247	0.824	3.957
22	Sandstone / Mudstone (Lower delta plain)	Glen Davis / Long Swamp Formation	Siltstone	3.47E-08	2.34E-09	3.65E-06	0.0346	1.596	4.202	0.179	0.310	3.625
23	Conglomerate (Fluvial)	Blackmans Flat Conglomerate / Lidsdale Coal Seam	Conglomerate	3.75E-07	1.09E-07	1.58E-06	0.0643	n/a	n/a	n/a	n/a	n/a
24	Coal (Fluvial)	Lithgow Seam	Coal	8.85E-07	3.80E-07	3.93E-06	0.0609	n/a	n/a	n/a	n/a	n/a
25	Conglomerate (Fluvial)	Marrangaroo Conglomerate	Conglomerate	4.13E-07	1.21E-07	1.61E-06	0.0659	n/a	n/a	n/a	n/a	n/a
26	Sandstone (Shoreline complex - delta front)	Nile Subgroup	Sandstone	1.63E-07	2.48E-08	2.09E-06	0.0829	n/a	n/a	n/a	n/a	n/a

Layer	Class	Unit	Hydrogeologic Categorisation[a]	Kh (m/s) *Geomean	Kv (m/s) *Geomean	Ss (1/m) *Geomean	Sy (frac.) *Geomean	V-G ALPHA	V-G BETA	n[1] (fract.)	Sr[2] (frac.)	Brooks n
27	-	-	Sandstone	1.16E-07	1.75E-08	1.95E-06	0.0811	n/a	n/a	n/a	n/a	n/a
28	-	-	Sandstone	1.13E-07	1.69E-08	1.94E-06	0.0814	n/a	n/a	n/a	n/a	n/a
29	Siltstone / Sandstone (Shoreline)	Shoalhaven Group	Siltstone	5.28E-08	4.10E-09	3.79E-06	0.0370	n/a	n/a	n/a	n/a	n/a
30	Crystalline, Extremely Weathered (Fractured)	Carboniferous	Igneous / Metamorphic	1.01E-08	1.50E-08	4.71E-06	0.0314	n/a	n/a	n/a	n/a	n/a

Notes. *Geomean is geometric mean of cells within a layer.; a) Categorisation with respect to cosimulation.; 1) "n (fract.)" is the total porosity (layer-based) used to derive tabular input of moisture retention and relatively permeability curves for Richards' equation.; 2) Sr is Residual Saturation, not Specific Retention, although is a similar concept.

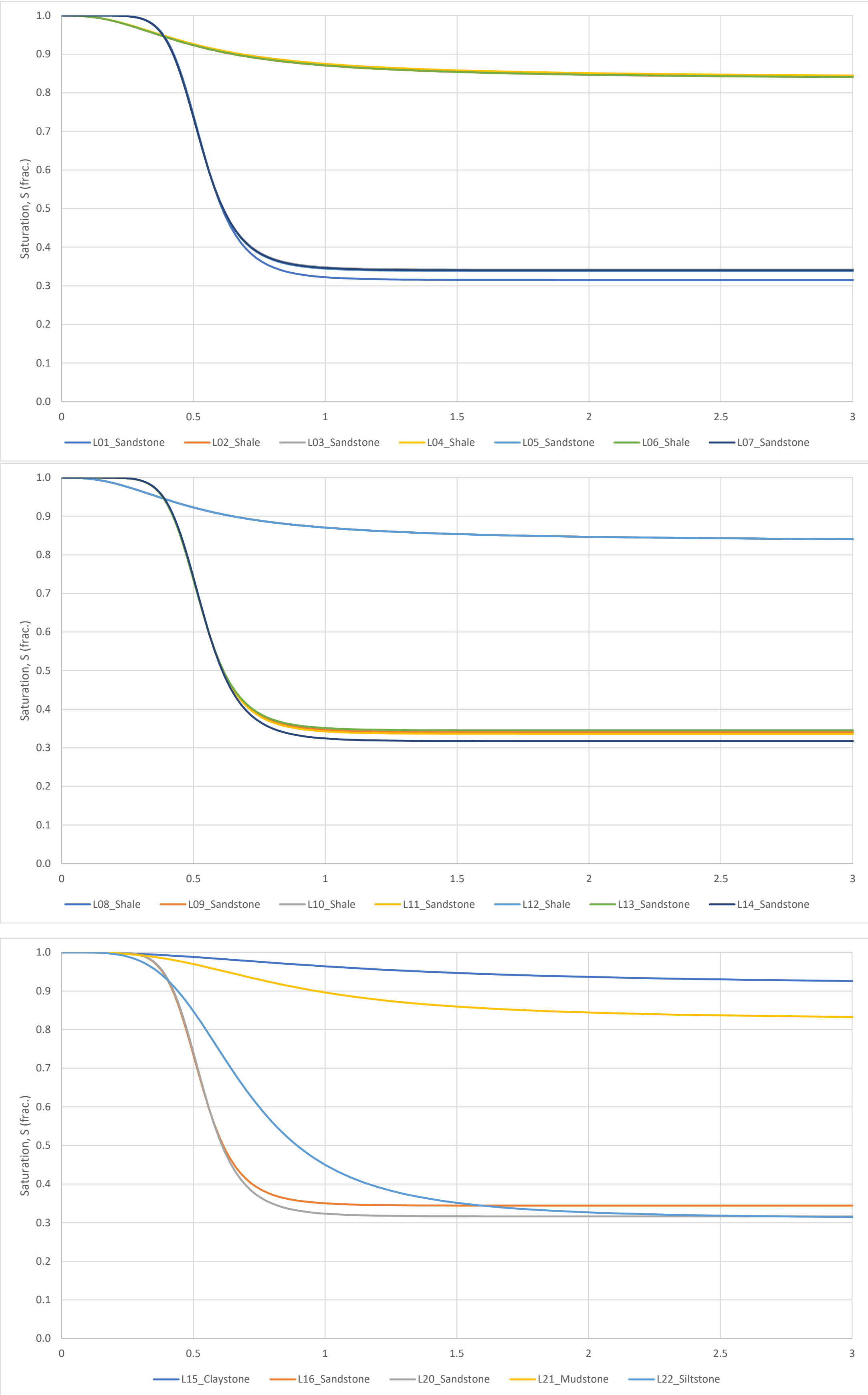


Figure 4-20: Calibrated Saturation (frac.) versus Capillary Head (m)

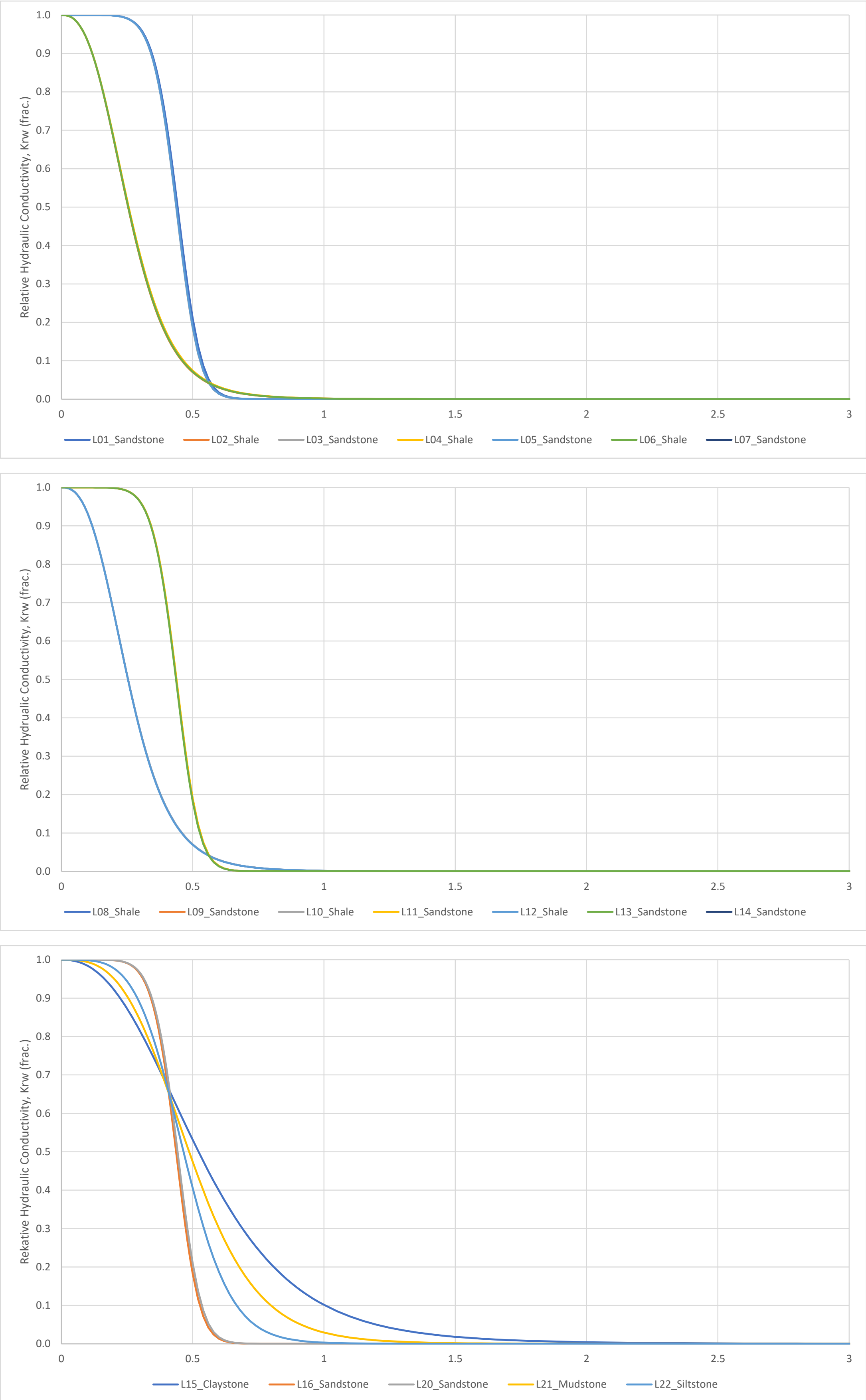


Figure 4-21: Calibrated Relative Hydraulic Conductivity (frac.) versus Capillary Head (m)

Recharge

Figure 4-22 presents the calibrated distribution of recharge factor. Each model cell receives a SILO gridded rainfall (0.05° (degree of latitude and longitude) grid), before being multiplied by a recharge factor. The resultant recharge rate is written into the Recharge MODFLOW module format by a custom-developed script.

The location of recharge factor Pilot Points is presented in **Figure 4-5**, with the calibrated value of each Pilot Point presented in **Appendix K**.

From **Figure 4-22**, the recharge factor appears to be lower on the southwest side of the topographic divide (the divide runs from southeast to northwest through Springvale Mine/Angus Place Colliery), than the northeast side. There is also a generally higher value of recharge factor above Clarence Colliery than above Springvale or Angus Place Colliery.

Evapotranspiration

Figure 4-22 presents the calibrated distribution of evapotranspiration factor and the extinction depth.

The calibrated values of individual Pilot Points for both attributes are presented in **Appendix K**.

From **Figure 4-22**, there is a general trend with respect to southwest and northeast side of the topographic divide that runs from southeast to northwest. The trend being slightly lower to the northeast of the divide and slightly higher to the southwest of the divide.

There is no particularly regional trend with respect to extinction depth, except for several deeper pockets around Springvale Mine, which correspond to THPSS.

River

The calibrated values of streambed hydraulic conductivity for river (RIV) cells are presented in **Table 4-16**, and were obtained from **Appendix K**.

The conductivities presented in **Table 4-16** are similar to their initial values, with a sequential multiplier used between each of the reach numbers, namely Reach 11 through to Reach 14. Reach 21 is a static water body (Lake Wallace) in the model.

Table 4-16: Calibrated values of River (RIV) boundary condition parameters

Parameter	Reach 11	Reach 12	Reach 13	Reach 14	Reach 21
Streambed Hydraulic Conductivity (m/s)	9.99E-08	3.00E-07	6.01E-07	9.03E-07	1.99E-07
Conductance (m^2/d)[2]	4.32	12.97	25.94	38.96	31.94

Notes. 1) Reach 21 is a perennial water body, namely Lake Wallace.; 2) Normalised with respect to cell size.

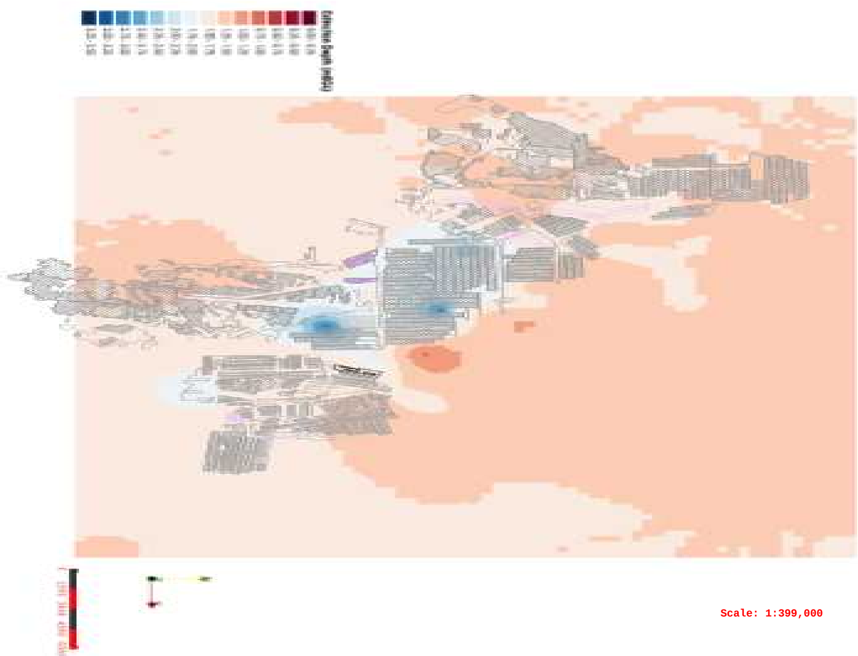
General Head Boundary (GHB)

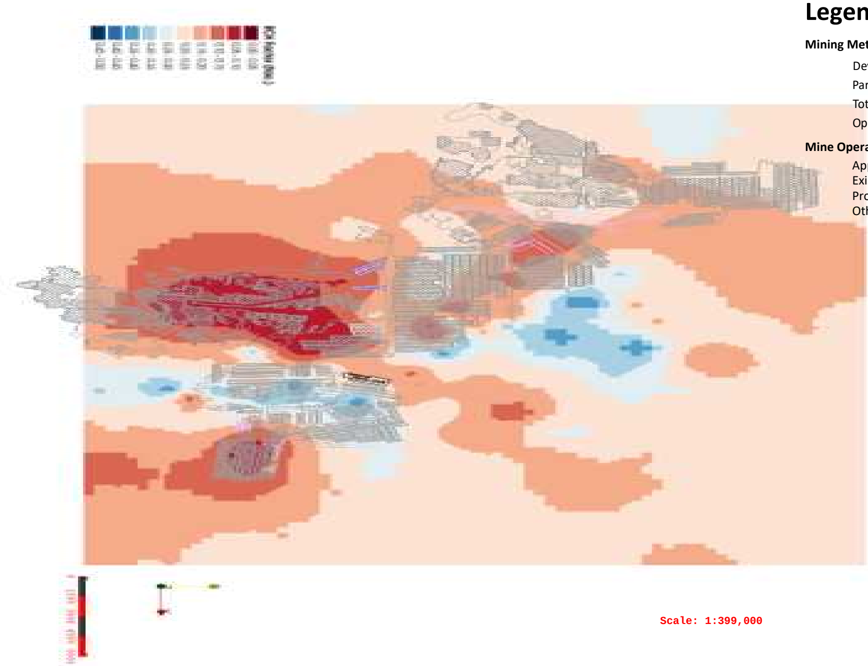
Table 4-17 presents the calibrated values of conductance for general head boundary (GHB) cells. As noted in **Section 4.10.2.8**, the calibrated values comprised a global conductance, as well as segment-based adjustments to that conductance. Other calibration parameters include the head of the general head boundary (GHB).

Appendix K presents the values of each of the parameters, including their lower and upper bounds.

The location of general head boundary (GHB) cells is presented in **Appendix C**.

From **Table 4-17**, the normalised conductance ranges between ~1m^2/d and 40m^2/d, which is considered to be reasonable.





Legend

Mining Methods:

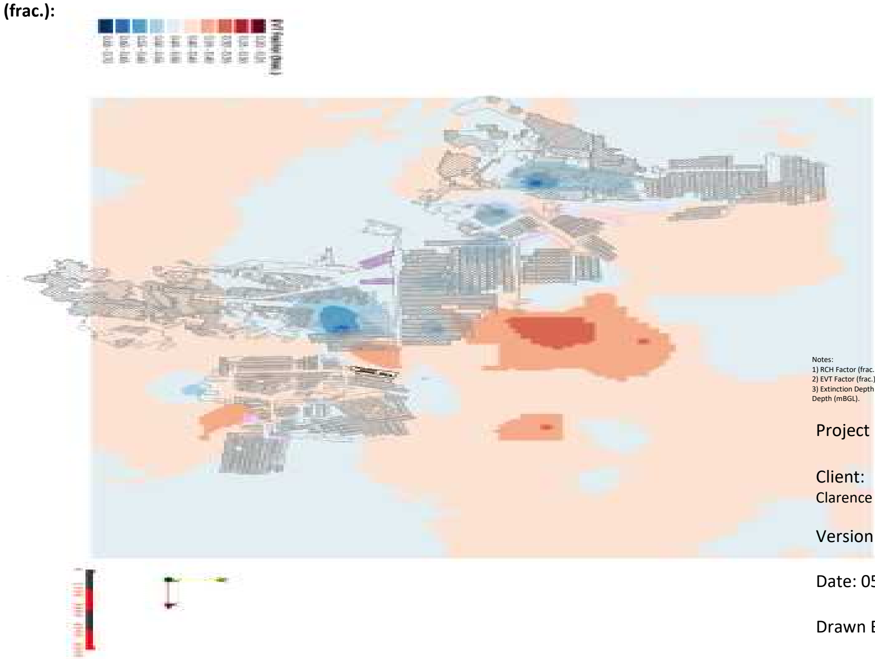
- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Recharge Factor (frac.):

Evaporation Factor (frac.):



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Notes:
1) RCH Factor (frac.): Recharge Factor (fraction).
2) EVT Factor (frac.): Evapotranspiration Factor (fraction).
3) Extinction Depth (mBGL): Evapotranspiration Extinction Depth (mBGL).

Project No: 68229

Client:
Clarence Colliery Pty Ltd

Version: R01RevA

Date: 05/11/2025

Drawn By: DAW

Checked By: JRWB

Evapotranspiration Extinction Depth (m):

n/a:

Figure 4.22: Distribution of Recharge Factor, Evapotranspiration Factor and Evapotranspiration Extinction Depth

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Reference: 68229_R01RevA_61645_R01RevA_CON-Single_03a_TMP

Table 4-17: Calibrated values of General Head Boundary (GHB) parameters

	Conductance at Various Reaches				
Layer 17					
Reaches	*1701*	*1702*	*1703*		
Conductance (m^2/d)[1]	6.19	5.36	5.83		
Layer 21					
Reaches	*2101*	*2102*	*2103*	*2105*	
Conductance (m^2/d)[1]	1.73	1.94	2.01	1.42	
Layer 27					
Reaches	*2701*	*2702*	*2703*	*2704*	*2705*
Conductance (m^2/d)[1]	32.90	31.93	35.96	38.06	27.38

Notes. 1) Normalised with respect to cell size.

Deep Leakage (WEL)

The value of deep leakage was fixed at 0.5mm/year, and the rate is not a calibration parameter.

Subsidence-Induced Changes to Hydraulic Properties

Table 4-18 presents the calibrated values of the subsidence model for Model Mining Method 1 (development; non-goafing). **Appendix K** presents the lower and upper bounds of these parameters.

Table 4-18: Calibrated Subsidence Model – Model Mining Method 1 (development; non-goafing) – Multiplicative Factors

Subsidence Zone Num	Subsidence Zone	Top	Bottom	Kh Multi.	Kv Multi.	Ss Multi.	Sy Addn.[1]
1	D (Surface)	1121.63	1106.63	1	1	1	1
2	C (Elastic)	1106.63	855.83	1	1	1	1
3		855.83	850.83	1	1	1	1
4		850.83	849.14	1	1	1	1
5	B (Constrained)	849.14	847.44	1	1	1	1
6		847.44	844.20	1	1	1	1
7		844.20	842.51	1	1	1	1
8	A (Fractured)	842.51	840.82	1	1	1	1
9		840.82	837.58	1	1	1	1
10	A (Caved)	837.58	835.88	4.33	1.1	1	1.001
11	Mined Seam	835.88	834.19	41.26	43.26	1	1.150
12		n/a	n/a	41.26	43.26	1	1.150
13	Basement	834.19	824.18	1	1	1	1

Notes. 1) Decimal component only.

Table 4-19 presents the calibrated values of the subsidence model for Model Mining Method 1 (development, individual additional bords; non-goafing).

It is noted that the values presented in **Table 4-19** are sequential multipliers to the already applied values due to Model Mining Method 1 (development; non-goafing) (refer **Table 4-18**).

Table 4-19: Calibrated Subsidence Model – Model Mining Method 1 (development, individual additional bords; non-goafing) – Multiplicative Factors

Subsidence Zone Num	Subsidence Zone	Top	Bottom	Kh Multi.	Kv Multi.	Ss Multi.	Sy Addn.[1]
1	D (Surface)	1121.63	1106.63	1	1	1	1
2	C (Elastic)	1106.63	855.83	1	1	1	1
3		855.83	850.83	1	1	1	1
4		850.83	849.14	1	1	1	1
5	B (Constrained)	849.14	847.44	1	1	1	1
6		847.44	844.20	1	1	1	1
7		844.20	842.51	1	1	1	1
8	A (Fractured)	842.51	840.82	1	1	1	1
9		840.82	837.58	1	1	1	1
10	A (Caved)	837.58	835.88	1.90	1.73	1	1.0002
11	Mined Seam	835.88	834.19	1.47	3.97	1	1.0010
12		n/a	n/a	1.47	3.97	1	1.0010
13	Basement	834.19	824.18	1	1	1	1

Notes. 1) Decimal component only.

Table 4-20 presents the calibrated subsidence model for Model Mining Method 5 (extraction; longwall method, with extraction ratios greater than 85%; full goafing) for Kh and Kv. As noted above, PEST calibrates sequential multiplier terms to generate the profile of multiplicative factors.

Table 4-20: Calibrated Subsidence Model – Model Mining Method 5 (extraction; longwall method; full goafing) – Multiplicative Factors (Kh and Kv)

Subsidence Zone Num.	Subsidence Zone	Top	Bottom	Sequential Multi. Kh	Resultant Multi. Kh	Sequential Multi. Kv	Resultant Multi. Kv
1	D (Surface)	1091.93	1076.93	1.60	3.04	2.17	2.82
2	C (Elastic)	1076.93	877.55	1.90	1.90	1.30	1.30
3		877.55	872.55	2.50	4.75	1.20	1.56
4		872.55	869.68	1.80	8.55	1.20	1.87
5[1]	B (Constrained)	869.68	866.82	2.00	17.1	2.00	3.74
6		866.82	863.79	1.20	10.3	1.20	2.25
7		863.79	860.93	1.41	14.5	1.31	2.94
8[1]	A (Fractured)	860.93	858.06	1.30	37.7	1.30	7.64
9		858.06	852.13	1.70	24.6	1.20	3.52
10	A (Caved)	852.13	846.41	2.30	56.6	2.50	8.81
11	Mined Seam	846.41	843.54	90.0	90.0	1000	1000
12		n/a	n/a	90.0	90.0	1000	1000
13	Basement	843.54	833.54	2.00	2.00	2.00	2.00

Notes. 1) Parameters TVM61_KH05 and TVM61_KV05, which were sequential multipliers, were fixed at 2.00. Parameters TVM61_KH08 and TVM61_KV08, which were sequential multipliers, were fixed at 1.30.

Table 4-21 presents the calibrated subsidence model for Model Mining Method 5 (extraction; longwall method, with extraction ratios greater than 85%; full goafing) for Ss and Sy.

Table 4-21: Calibrated Subsidence Model – Model Mining Method 5 (extraction; longwall method; full goafing) – Multiplicative Factors (Ss and Sy)

Subsidence Zone Num	Subsidence Zone	Top	Bottom	Sequential Multi. Ss	Resultant Multi. Ss	Addn. Sy[1]
1	D (Surface)	1091.93	1076.93	1	1	1
2	C (Elastic)	1076.93	877.55	1	1	1
3		877.55	872.55	1	1	1
4		872.55	869.68	1	1	1
5	B (Constrained)	869.68	866.82	1	1	1
6		866.82	863.79	1	1	1
7		863.79	860.93	1	1	1
8	A (Fractured)	860.93	858.06	1	1	1
9		858.06	852.13	1	1	1
`10	A (Caved)	852.13	846.41	1	1	1.003
11	Mined Seam	846.41	843.54	1	1	1.02
12		n/a	n/a	1	1	1.02
13	Basement	843.54	833.54	1	1	1.0002

Notes. 1) decimal component used.

Appendix K presents the lower and upper bound for parameter values presented in **Table 4-21**.

Other subsidence-related parameters are presented in **Table 4-22**, with the lower and upper bounds of these parameters presented in **Appendix K**.

Table 4-22: Other Calibrated Subsidence-Related Parameters

Parameter	Description	Value
TVM_MTH4	adjustment to H_{A2} between extraction (Model Mining Method 5) and extraction (Model Mining Method 4)	0.85
TVM_FILLKH	horizontal hydraulic conductivity of backfilled open cut (Model Mining Method 6)	5.68E-05m/s
TVM_FILLKV	vertical hydraulic conductivity of backfilled open cut (Model Mining Method 6)	1.93E-05m/s
TVM_KMAX03	upper limit (partially reconsolidated) of hydraulic conductivity 'Above Zone A'	6.84E-06m/s
TVM_KMAX02	upper limit (partially reconsolidated) of hydraulic conductivity in 'Zone A'	4.59E-05m/s
TVM_KMAX01	upper limit (partially reconsolidated) of hydraulic conductivity in Caved Zone and Mined Seam	4.76E-04m/s
TVM_MODS_01	scaling factor of 'ramp function' for development (Model Mining Method 1)	1.0025
TVM_MODS_21	scaling factor of 'ramp function' for extraction (Model Mining Method 2)	1.25
TVM_MOD3161	scaling factor of 'ramp function' from extraction (Model Mining Method 5) to extraction (Model Mining Method 4)	0.600

Parameter	Description	Value
TVM_MOD2131	scaling factor of 'ramp function' from extraction (Model Mining Method 4) to extraction (Model Mining Method 2)	0.117
TVM_BASEK	minimum change base value (hydraulic conductivity) due to extraction (Model Mining Method 4 and 5)	1.00E-09m/s
TVM_REF21	reference width-to-height ratios for extraction (Model Mining Method 2)	0.109
TVM_REF31	reference width-to-height ratios for extraction (Model Mining Method 4)	0.65
TVM_REF61	reference width-to-height ratios for extraction (Model Mining Method 5)	0.90
TVM_SC_LIN	scaling parameter for ScaleFactor (nominated in GIS file) of lineaments (extraction (Model Mining Method 3, 4 and 5))	0.50
TVM_SC_EXT	scaling parameter for ScaleFactor (nominated in GIS file) of lineament reactivation (extraction (Model Mining Method 4 and 5) only)	1.19
TVM_SC_LINMX	adjustment factor for influence of lineaments (all Model Mining Methods)	0.50

Figure 4-23a presents a cross-section, A-A', through the groundwater model and **Figure 4-23b** presents a cross-section, B-B'. The time-varying change to vertical hydraulic conductivity, Kv, is presented **Figure 4-23a** and **Figure 4-23b**, as well as the modelled groundwater elevation (groundwater elevation in the highest active cell, Banks Wall Sandstone (Layer 14), Mount York Claystone (Layer 15), Katoomba Seam (Layer 18), as well as where groundwater pressure is less than 1mH_2O.

The location of the cross-section is illustrated in **Figure 4-1**.

Model input and output is presented at the following times:

- Steady-state (SP001)
- 31 December 1993 (SP017)
- 31 December 2018 (SP117)
- 30 September 2024 (SP144).

From **Figure 4-23a**, there is a change to groundwater elevation occurring from the steady-state (SP001) to 31 December 1993 (SP017) reflecting development in the vicinity of the longwalls at Clarence (which were extracted between SP018 and SP031). In **Figure 4-23a**, the effect on vertical hydraulic conductivity, Kv, of subsidence-induced change to hydraulic properties is evident in 31 December 2018 (SP117) and 30 September 2024 (SP144), both at Clarence and the adjacent operation, at Springvale Mine.

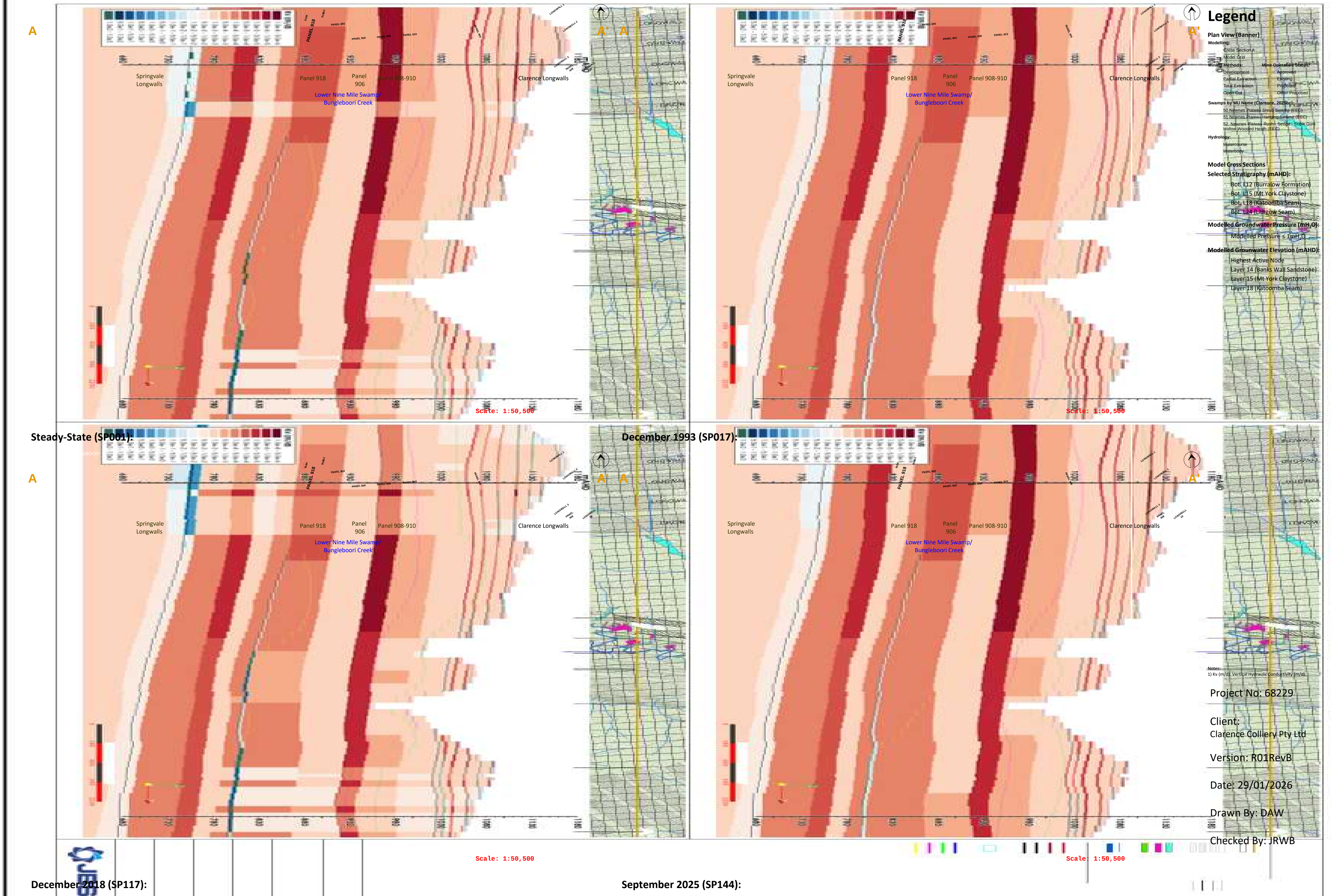
From **Figure 4-23b**, development and extraction of the 900 Panel Area at Clarence leads to depressurisation of the Katoomba Seam (Layer 18) and changes to hydraulic properties overlying strata.

In **Figure 4-23a** and **Figure 4-23b**, depressurisation in the Katoomba Seam (Layer 18) and the Lithgow Seam (Layer 24) is indicated where groundwater pressure (mH_2O) is less than 1m.

Drain – Ephemeral Watercourses and Swamps, Water Bodies and Surface Overland Flow

Table 4-23 presents the calibrated average values of conductance of drain (DRN) cells (normalised with respect to cell size) used to represent ephemeral watercourses and swamps. It is noted that conductances presented in **Table 4-23** take into account the global scaling factors.

The lower and upper bound of each of these parameters is presented in **Appendix K**.



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Reference: 68229_R01RevA_APR_03c_21_SIM0

Figure 4.23a: Vertical Hydraulic Conductivity (m/d) Time-Series (Calibration Period) - Cross-Section A-A'

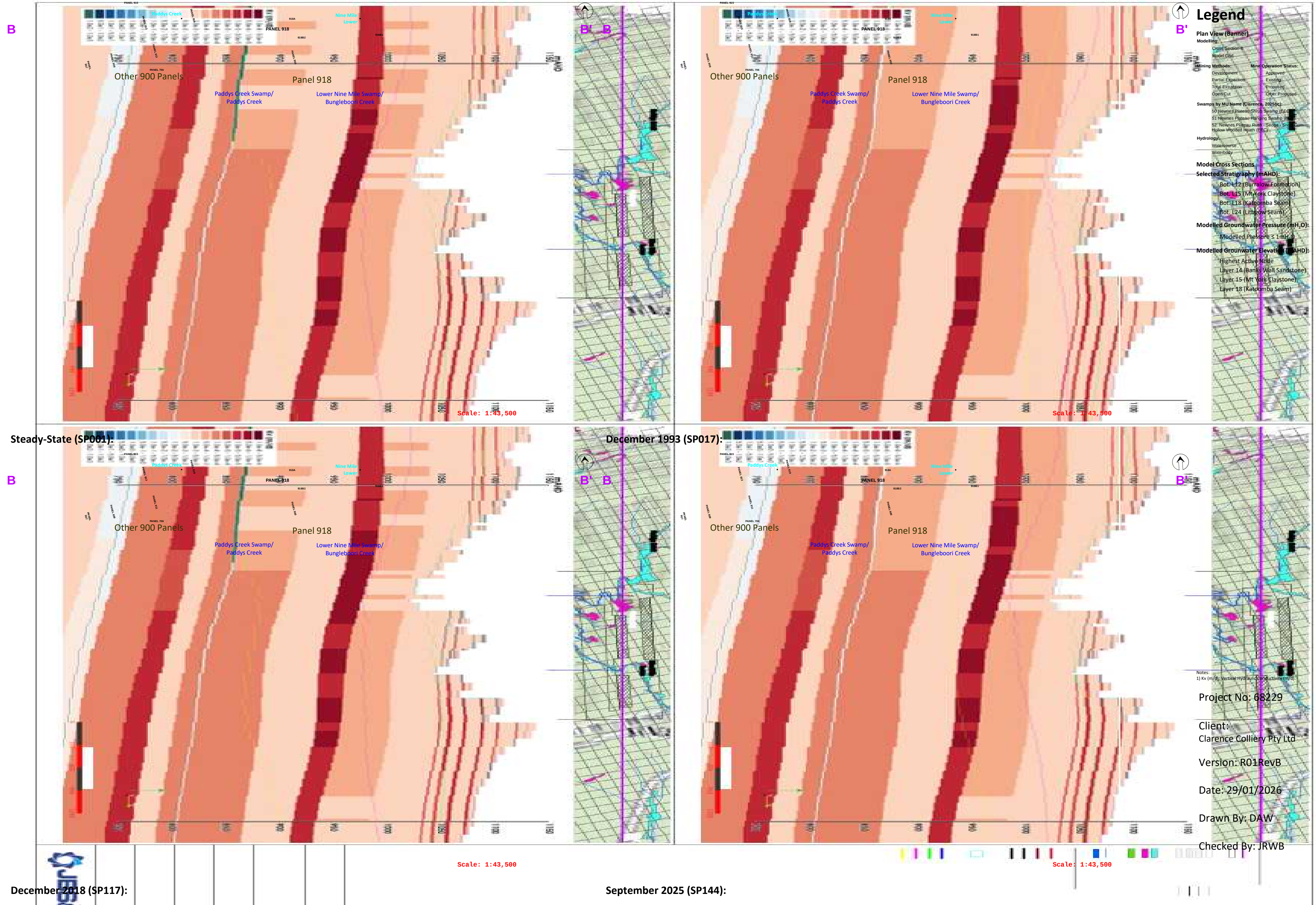


Figure 4.23b: Vertical Hydraulic Conductivity (m/d) Time-Series (Calibration Period) - Cross-Section B-B'

Table 4-23: Calibrated Values of Drain Conductance (m^2/d) (average of normalised) – Ephemeral Watercourses (including Swamps), Ephemeral Water Bodies and Surface Overland Flow

Parameter	Reach 11[1]	Reach 12	Reach 13	Reach 14	Reach 15	Reach 21[1]	Reach 51[1]
Conductance (m^2/d)[2]	3.98	6.41	9.09	14.50	45.5	800	10.0
Parameter	DRN00011	DRN00012	DRN00013	DRN00014	DRN00015	DRN00021	DRN00051

Notes. 1) Reach 11 to 15 are watercourses, in order of increasing Strahler Order. Reach 21 is water bodies (applied to whole cell area). Reach 51 is surface overland flow.; 2) Normalised with respect to minimum cell size (so as to allow comparison between reaches).

Drain – Seepage Faces

Table 4-24 presents the calibrated average conductance values for seepage faces in Layer 2 through to Layer 27. It is noted that the average conductance values presented in **Table 4-24** take into account the global scaling factors.

The calibrated global conductance (minimum cell size) of seepage faces was 9.81m^2/d.

Appendix K presents the lower and upper bound of the parameters associated with this boundary condition.

Table 4-24: Calibrated Values of Drain Conductance (m^2/d) (average) and Global Scaling Factors – Seepage Faces

Layer	Description	Unit	Hydrogeologic Categorisation[a]	Conductance (m^2/d)[1]	Parameter
2	Shale (YS1)	Burralow Formation	Shale	2.60	"DRN00102"
3	Sandstone / Regolith	-	Sandstone	2.31	"DRN00103"
4	Shale (YS2)	-	Shale	3.44	"DRN00104"
5	Sandstone / Regolith	-	Sandstone	1.89	"DRN00105"
6	Shale (YS3)	-	Shale	2.29	"DRN00106"
7	Sandstone / Regolith	-	Sandstone	1.65	"DRN00107"
8	Shale (YS4)	-	Shale	2.00	"DRN00108"
9	Sandstone / Regolith	-	Sandstone	1.83	"DRN00109"
10	Shale (YS5)	-	Shale	1.09	"DRN00110"
11	Sandstone / Regolith	-	Sandstone	2.05	"DRN00111"
12	Shale (YS6)	-	Shale	0.40	"DRN00112"
13	Quartzose sandstone	Banks Wall Sandstone	Sandstone	1.85	"DRN00113"
14	-	-	Sandstone	1.86	"DRN00114"
15	Claystone	Mt York Claystone	Claystone	2.66	"DRN00115"
16	Quartzose to quartz-lithic sandstone	Burra-Moko Head Sandstone	Sandstone	2.42	"DRN00116"
17	Claystone / Shale / Sandstone	Caley Formation	Siltstone	1.57	"DRN00117"
18	Coal	Katoomba Seam	Coal	1.73	"DRN00118"
19	Claystone / Shale	Farmers Creek Formation	Siltstone	2.67	"DRN00119"
20	Lithic sandstone / Claystone / Quartz-Lithic Sandstone	Gap Sandstone/State Mine Creek Formation/Angus Place Formation (Watts Sandstone)	Sandstone	2.33	"DRN00120"

Layer	Description	Unit	Hydrogeologic Categorisation[a]	Conductance (m^2/d)[1]	Parameter
21	Mudstone / Siltstone / Claystone (Marine Incursion)	Denman Formation	Mudstone	2.22	"DRN00121"
22	Sandstone / Mudstone (Lower delta plain)	Glen Davis / Long Swamp Formation	Siltstone	1.86	"DRN00122"
23	Conglomerate (Fluvial)	Blackmans Flat Conglomerate / Lidsdale Coal Seam	Conglomerate	2.62	"DRN00123"
24	Coal (Fluvial)	Lithgow Seam	Coal	1.84	"DRN00124"
25	Conglomerate (Fluvial)	Marrangaroo Conglomerate	Conglomerate	1.87	"DRN00125"
26	Sandstone (Shoreline complex - delta front)	Nile Subgroup	Sandstone	1.99	"DRN00126"
27	-	-	Sandstone	1.68	"DRN00127"
28	-	-	Sandstone	2.22	"DRN00128"

Notes. a) "Hydrogeologic Categorisation" is the description associated with the "IDNum" category used with Cosimulation (on a layer-by-layer basis).; 1) Normalised with respect to minimum cell size (so as to allow comparison between reaches).

Drain – Mine Dewatering

Table 4-25 presents the calibrated global drain conductance of the bottom and the top of 'Stacked Drains' of different mining methods in the groundwater model. Those conductance values were linearly interpolated (using distance) between the mined seam and H_{A2}.

Appendix K presents the lower and upper bounds of the parameters.

From **Table 4-25**, the conductance of the bottom of the 'Stacked Drain' is greater than the conductance of the top of the 'Stacked Drain', as is intended. From **Table 4-25**, in general, lower subsidence mining methods, such as development (Model Mining Method 1), have lower bottom conductance than extraction (such as Model Mining Method 4 and 5), as is intended, to reflect the greater degree of disruption of overlying strata with higher extraction ratios.

As presented in **Section 4.10.2.6**, the global values presented in **Table 4-25** were then adjusted using a scaling factor, on a per mine/colliery basis, including subdivision for various districts within a particular mine/colliery, as required, including where mine water management (storage of groundwater underground, managed by changing stage) was undertaken.

Mine water management refers to maintaining the workings in a dewatered state after mining. Where recovery is allowed, usually in the form of an underground water storage, mine water management cells were set with a target stage (higher than the base of the mined seam), so that groundwater elevation could recover to that target stage. Where recovery is not allowed, the target stage is set at 0.1m above the base of the mined seam. It is noted that mine water management is not applied to lineament reactivation cells.

As noted in **Section 4.2.1**, 'return flow' was developed during this study, however, was not turned on in this use of the numerical groundwater model, since it led to mounding at point of 'return'.

Section 4.10.2.6 explains that the values presented in **Table 4-25** were then scaled with respect to each mine as well as within each mine (e.g. for different districts). The values of these scaling factors is presented in **Appendix K**.

For open cut (historical) mines (Model Mining Method 6), the calibrated global conductance (normalised with respect to cell size) was 62.4m^2/d.

Table 4-25: Calibrated Values of 'Stacked Drains' and Mine Water Management Drain Conductance (m^2/d)

Mining Method	'Stacked Drain' Bottom Conductance $(m^2/d)^2$	'Stacked Drain' Top Conductance $(m^2/d)^2$	Mine Water Management Conductance $(m^2/d)^2$
Development (Model Mining Method 1; non-goafing)	61.7	0.043	17.0
Development (Model Mining Method 1 - individual additional bords; non-goafing)	34.0	4.22	7.54
Extraction (Model Mining Method 2 – non-goafing)	110	5.05	49.3
Extraction (Model Mining Method 3)	175[1]	4.69[1]	85.6[1]
Extraction (Model Mining Method 4)	175	4.69	85.6
Extraction (Model Mining Method 5)	2000	1.00	193

Notes. 1) Model Mining Method 3 uses the same values as Model Mining Method 4.; 2) Normalised with respect to minimum cell size.

4.12.4.3 Observed versus Modelled Head

Figure 4-24 presents the weighted observed versus modelled steady-state heads (groundwater elevation). The steady-state calibration represents pre-mining conditions. Steady-state targets were selected where it could be reasonably expected that there has been no anthropogenic change to the groundwater regime, including due to mining (dewatering and/or subsidence). This ended up being the swamp piezometers, since it could not be guaranteed that the far field vibrating wire piezometers (such as in the Angus Place Mine Extension Project area) were not impacted by previous dewatering at Angus Place Colliery. This was an update to the previous version of the calibration of the model, namely that those locations were changed to transient only.

The groups presented in **Figure 4-24**, and subsequent figures, are:

- Swamp Standpipe Piezometers (Group 1)
- Shallow or Regional Standpipe Piezometers (Group 2)
- Vibrating Wire Piezometers (Group 3).

The sRMS (Scaled Root Mean Square) error of the fit presented in **Figure 4-24** is 1.00%, with a RMS (Root Mean Square) error of 2.75m. Barnett et. al. (2012) advise that an sRMS of less than 10% can indicate that a model is appropriately calibrated.

It is noted that weighted observations are used in **Figure 4-24**. The values of these weights are presented in **Section 3.5.8**. i.e. prior to changes associated with rebalancing of the objective function.

It is further noted that modelled heads (groundwater elevation) presented in **Figure 4-24**, and in other calibration results presented in this section, were interpolated in three dimensions.

The fit presented in **Figure 4-24** is considered to be good.

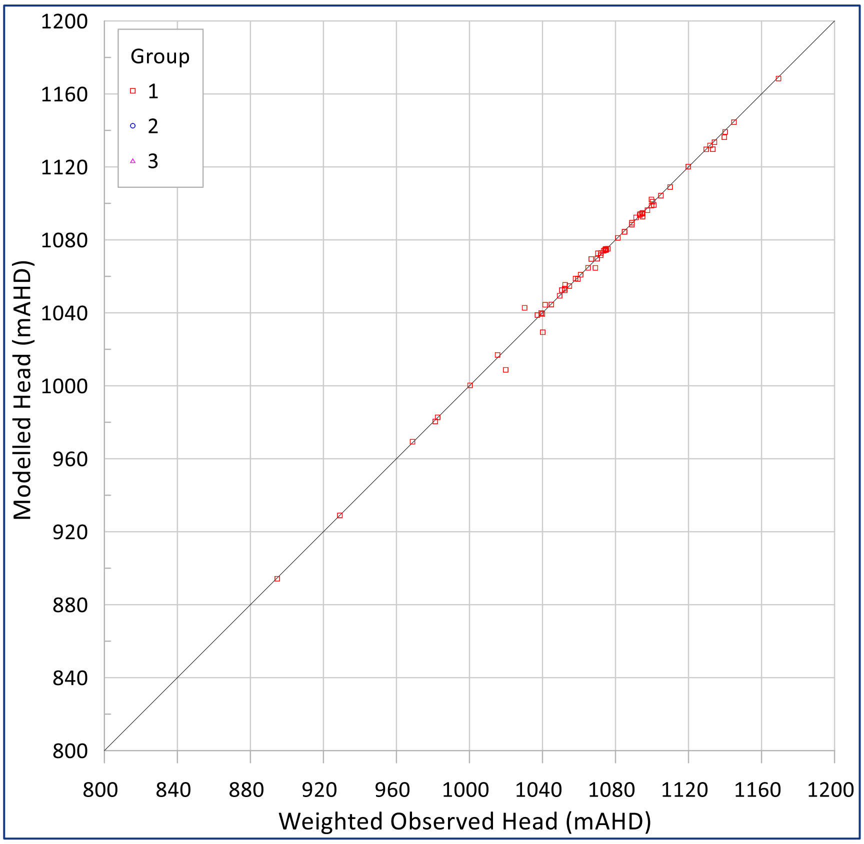


Figure 4-24: Steady-State Observed (Weighted) versus Modelled Heads (mAHD)

Figure 4-25 presents weighted observed versus modelled heads (groundwater elevation).

From **Figure 4-25**, the sRMS error is 6.23%, with a RMS error of 27.2m.

The fit presented in **Figure 4-25** is also considered to be good.

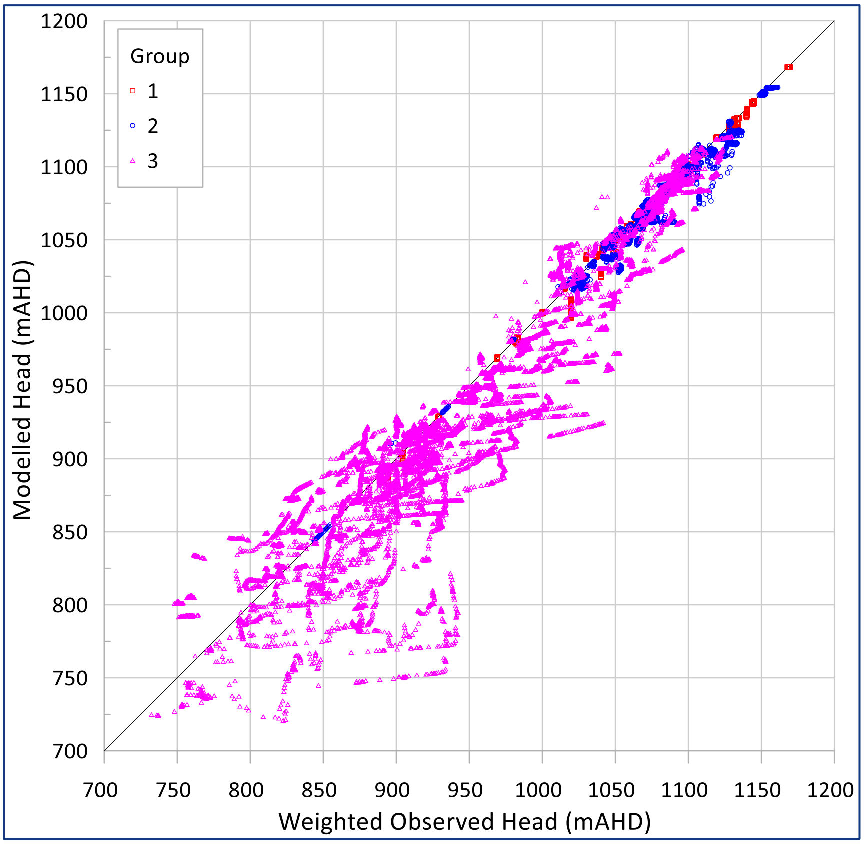


Figure 4-25: Observed (Weighted) versus Modelled Heads (mAHD)

The spatial distribution (assigned to relevant layers, but calculated based on three dimensional interpolation) of calibration residuals (weighted) were calculated and presented in **Appendix F**, at the following times:

- 31 December 2009 (SP081; TOTIM = 51866)
- 30 June 2012 (SP091; TOTIM = 52778)
- 31 March 2015 (SP102; TOTIM = 53782)
- 30 June 2017 (SP111; TOTIM = 54604)
- 31 December 2018 (SP117; TOTIM = 55153)
- 31 December 2020 (SP125; TOTIM = 55884).

Output presented in **Appendix F** indicates that where large residuals exist (differences between observed and modelled groundwater elevation), they are: a) spatially distributed and not locally clustered or b) occur near active mining, and hence differences in the rate of development of the 'cone of depression' can lead to large differences between observed and modelled head, despite the trend (hydrogeologic response to depressurisation) being reasonably matched.

Figure 4-26 presents observed groundwater elevation (hydraulic head) versus weighted residual. The group numbers used in **Figure 4-26** are the same as that used in **Figure 4-24** and **Figure 4-25**.

From **Figure 4-26**, there is an even distribution of weighted residual above and below zero for Group 1 (Swamp piezometers). From **Figure 4-26**, the distribution of weighted residual for Group 2 (Regional standpipe piezometers) is centred around zero with a negative skew. From **Figure 4-26**, the distribution of weighted residual for Group 3 (Vibrating Wire Piezometers) is more negative than positive. As discussed in JBS&G

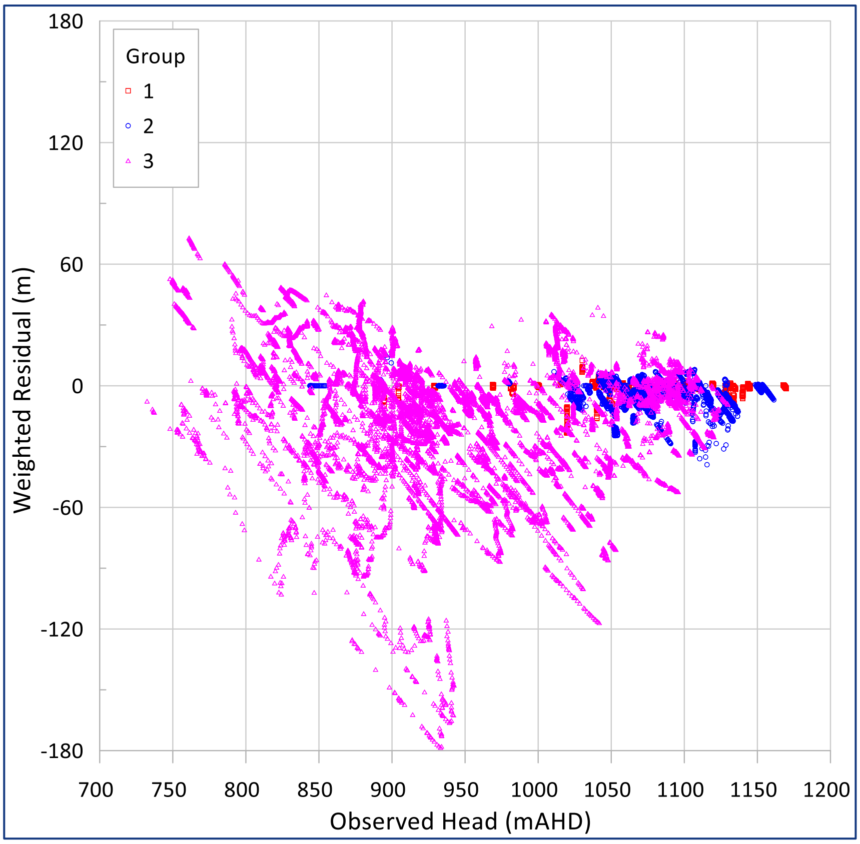


Figure 4-26: Observed Head (mAHD) versus Weighted Residual (m)

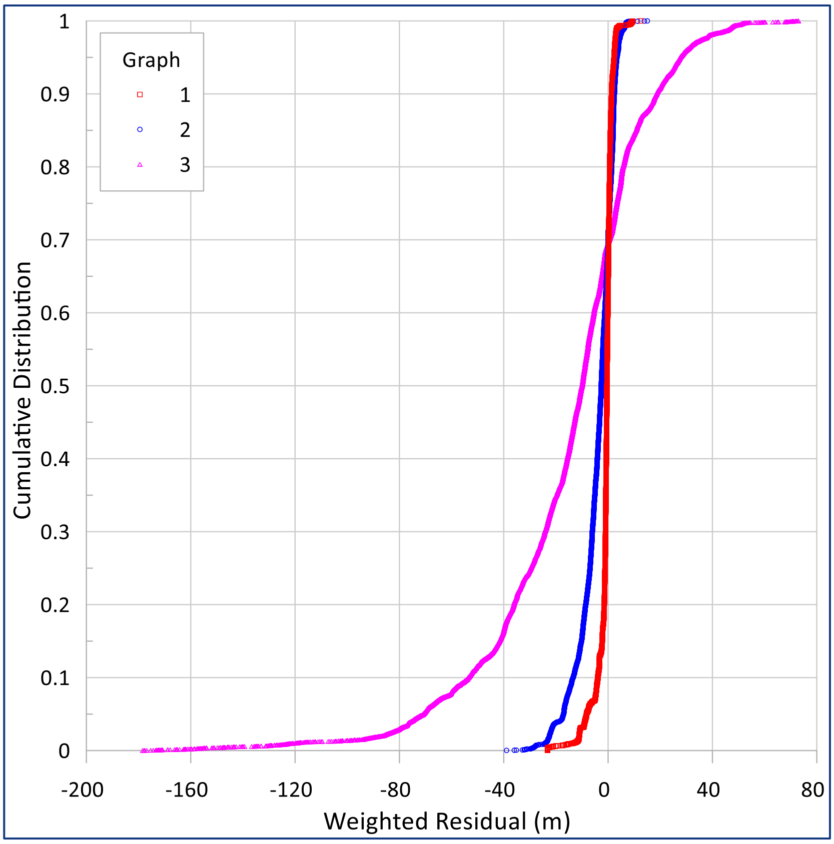


Figure 4-27: Cumulative Distribution of Weighted Residual (m)

(2025ab), and presented further below, this is due to initiation of decline in groundwater elevation at depth (in response to mine dewatering) earlier than observed. This issue is not significant, however.

4.12.4.4 Groundwater Hydrographs and Depth Versus Pressure

Modelled and observed groundwater elevation (interpolated and multilevel) hydrographs and depth versus groundwater elevation pressure diagrams plots were extracted in the vicinity of 918 Panel.

Output is presented at the following locations:

- CLRP40, CLRP27_V, CLRP42R and CLRP41A (**Figure 4-28**)
- CLRP29_V, CLRP28, CLRP18_V and CLRP22_V (**Figure 4-29**)
- CLRP14_V, CC115_V, CLRP17_V and CLRP13_V (**Figure 4-30**)
- CLRP33_V, CLRP2_V, CLRP3_V and CLR19_V (**Figure 4-31**)
- SPR48_V, SPR36_V, SPR67_V and SPR66_V (**Figure 4-32**)
- GW099052, GW099053, GW099054, CSP9, CLRP31 and CSP8 (**Figure 4-33**)
- CSP1, PG1, CSP2 and PG2 (**Figure 4-34**)
- CSP6, CSP34, PSE1 and PSE2 (**Figure 4-35**)
- Paddys Creek Shrub Swamp (**Figure 4-36**)
- Paddys Creek Hanging Swamp (**Figure 4-37**)
- Lower Nine Mile Hanging Swamp (**Figure 4-38**).

A three-dimensional interpolation of model output was used, prior to comparison to observed groundwater elevation.

Groundwater hydrographs were also extracted from the calibration simulation for each of the locations, for each model layer, as times-series, on a vertical elevation scale. This provides the means to review modelled vertical gradient, if of interest.

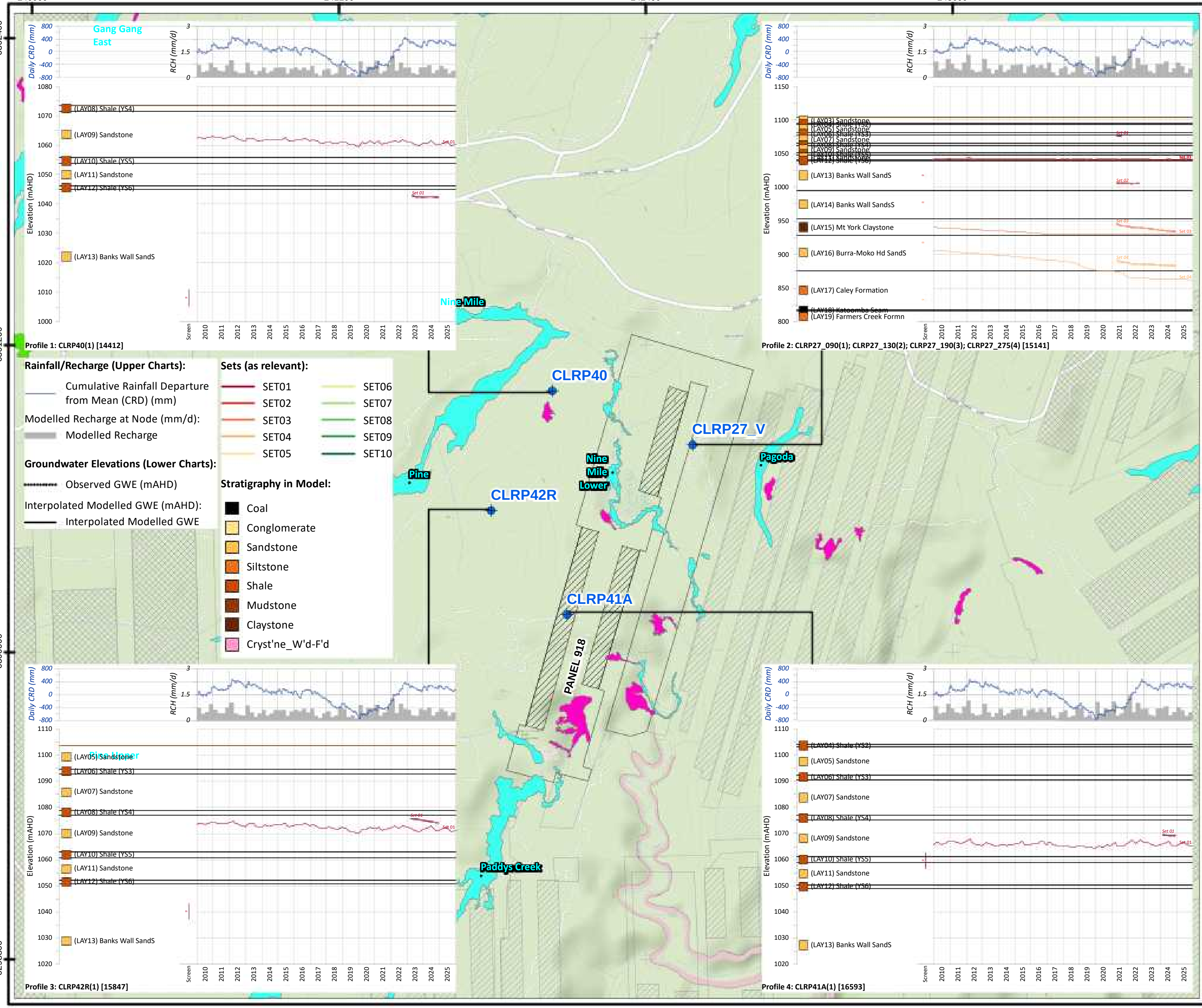
To supplement determination of location of multiple groundwater system, depth versus pressure plots were also created.

CLRP40, CLRP27_V, CLRP42R and CLRP41A

From **Figure 4-28a**, the groundwater model is high with respect to CLRP40, and is reasonably close for CLRP42R and CLRP41A. From **Figure 4-28a**, the fit to CLRP27_V is reasonable for the lowermost sensors and is low for Sensor#2 and is high for Sensor #1. Those sensors are both installed into the Banks Wall Sandstone, which is a friable sandstone.

From **Figure 4-28b**, model behaviour indicates a large vertical hydraulic gradient across the Mount York Claystone (Layer 15), which is consistent with the conceptual model presented in **Section 3.5.3**. From **Figure 4-28b**, modelled groundwater elevation in the Burralow Formation is relatively steady at each monitoring location, whereas at depth, in the Illawarra Coal Measures, there is decline over time reflecting depressurisation due to mining in the vicinity.

From **Figure 4-28c**, whilst there is limited observation data, depth versus pressure profiles for CLRP40 and CLRP27 indicate reasonable agreement with modelled behaviour. From **Figure 4-28c**, the depth-versus-pressure profile implies formation of water table above the Mount York Claystone (Layer 15) in the Banks Wall Sandstone (Layer 13/14) and/or multiple perched water tables in the Burralow Formation (Layer 01 to 12).



Legend:

- Model Output Locations

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Notes:
1) GWE: Groundwater Elevation.
2) CRD Trace dates from 01/01/2010 - 31/12/2049.

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 22-Oct-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:20,000	

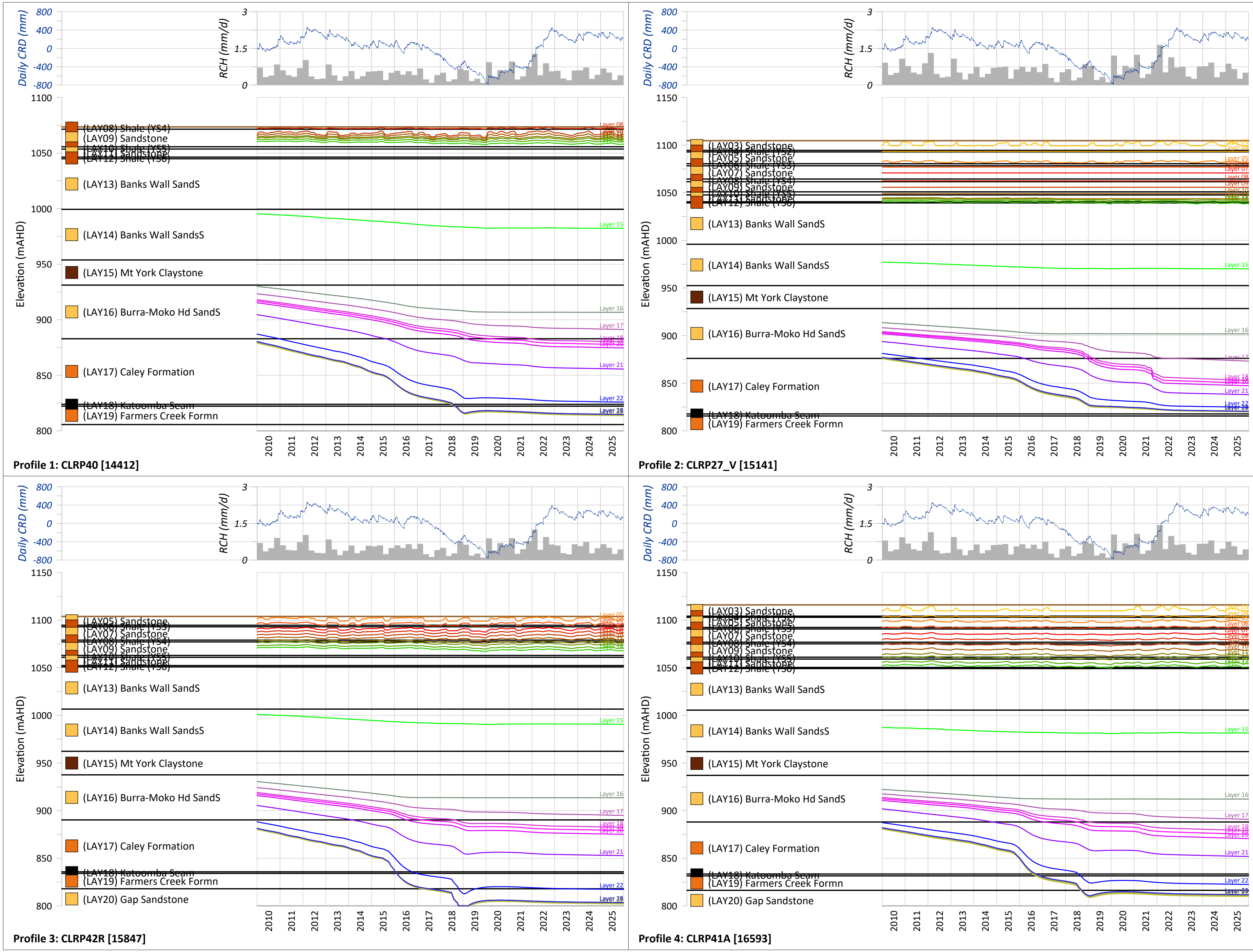
0 400 800
Meters

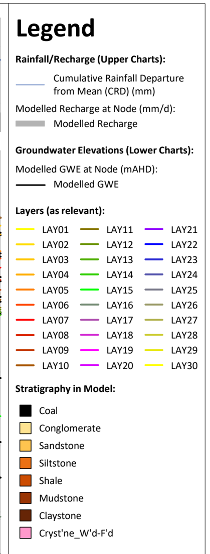
Coor. Sys. GDA 1994 MGA Zone 56

Groundwater Hydrographs (Calibration Period):
- CLRP40
- CLRP27_V
- CLRP42R
- CLRP41A

FIGURE: 4.28a

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D002a_CAL_Hydrographs_CLRP40_CLRP27_CLRP42R_CLRP41A.mxd
Reference: © Department of Customer Service 2020





Notes:
1) GWE: Groundwater Elevation.
2) CRD Trace dates from 01/01/2010 - 30/06/2043.

Project No: 68229

Client: Clarence Colliery Pty Ltd

Version: R01RevA

Date: 21/10/2025

Drawn By: DAW

Checked By: JRWB

JBS&G

Figure 4.28b: Multilevel Groundwater Hydrographs (Calibration Period) - CLRP40, CLRP27_V, CLRP42R, CLRP41A

File Path: N: Projects CentennialCoal ClarenceColliery 68229_UpdateTo918EP Figures Grapher 68229_R01RevA_D003_BinaryHDSMultiLevelHydrographGenerator 68229_R01RevA_D003a 68229_R01RevA_BinaryHDSMultiLevelHydrographGenerator_01_CLRP40_CLRP27_CLRP42R_CLRP41A.grf

Reference: 68229_R01RevA_APR_03c

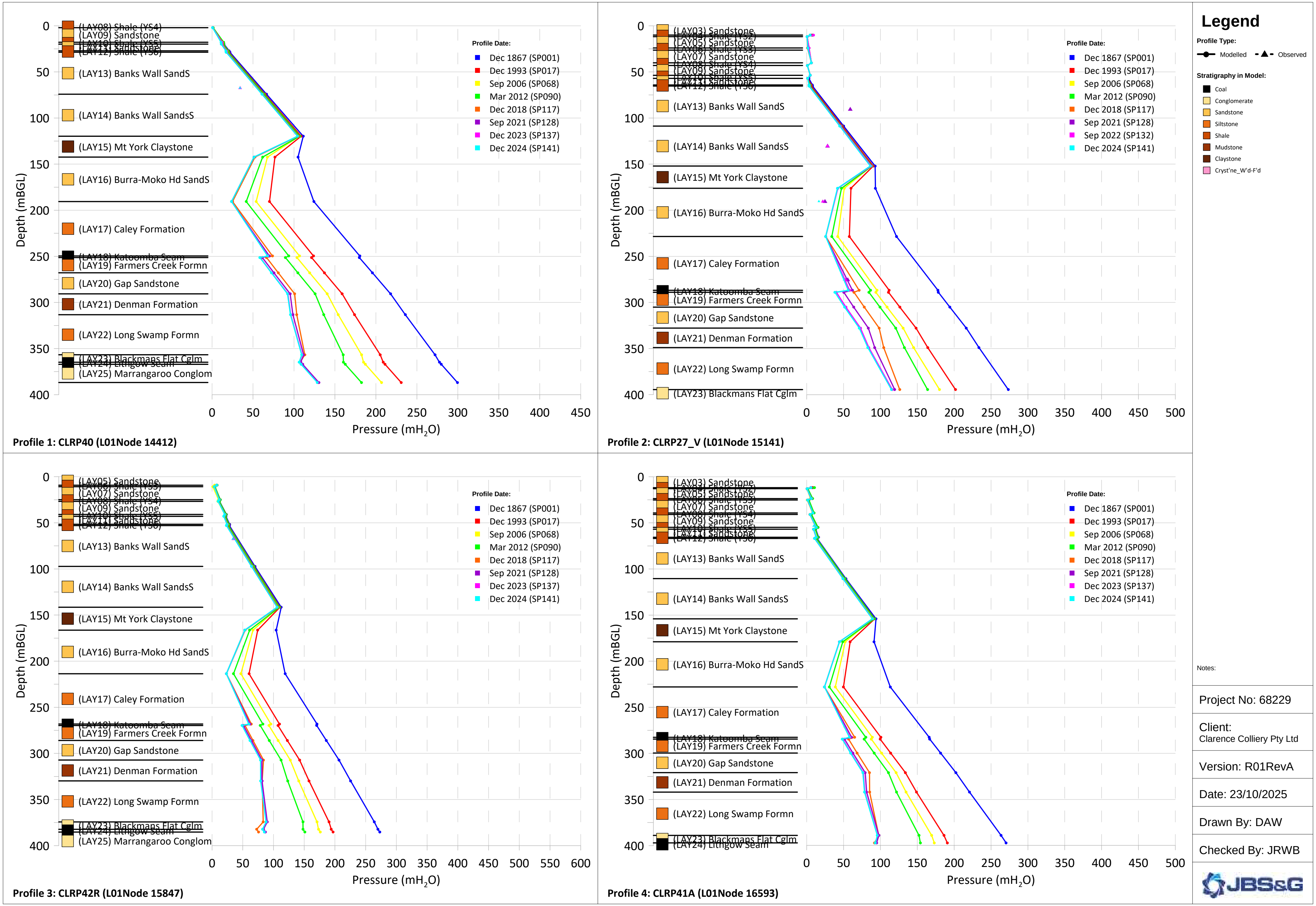


Figure 4.28c: Depth versus Groundwater Pressure Diagrams (Calibration Period) - CLRP40, CLRP27_V, CLRP42R, CLRP41A

Reference: 68229_R01RevA_APR_03c.

File Path: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\Grapher\68229_R01RevA_D004_BinaryHDSVerticalProfileExtraction_Pressure\68229_R01RevA_D004a\68229_R01RevA_D004a_VerticalProfileExtraction_Pressure_01_CLRP40_CLRP27_CLRP42R_CLRP41A.grf

CLRP29_V, CLRP28, CLRP18_V and CLRP22_V

From **Figure 4-29a**, modelled fit at CLRP29_V is consistent for Sensor#1 and underpredicted for Sensor#2. Sensor#1 is installed into the Banks Wall Sandstone (Layer 13) and Sensor#2 is installed in the Burra-Moko Head Sandstone (Layer 16). From **Figure 4-29a**, the modelled groundwater elevation in Sensor#2 reflects depressurisation from Springvale Mine to the southwest and Clarence to the southeast. From **Figure 4-29a**, the fit to Sensor#3 and #4 at CLRP_V is reasonable (noting that they are installed in lower formations).

From **Figure 4-29a**, the fit to standpipe piezometer CLRP28 is only fair, with the modelled groundwater elevation being lower than the observed groundwater elevation. From **Figure 4-29a**, the modelled fit to the single sensor at site CLRP18 is also considered only fair, with the model being low compared to observed groundwater elevation. From **Figure 4-29a**, the two sensors at CLRP22_V are both reasonably matched.

From **Figure 4-29b**, model behaviour reflects separation of depressurisation of the deep groundwater system from the shallow groundwater system (and perched groundwater system, within the Burralow Formation).

From **Figure 4-29c**, there limited data (there would have to be tens of sensors in each vibrating wire piezometer installation, to be otherwise), but model behaviour is consistent with observation. From **Figure 4-29c**, model behaviour is a water table at the top of the Banks Wall Sandstone (Layer 13), above the Mount York Claystone, and within the Burralow Formation aquitard plies. At CLRP18_V and CLRP22_V, which are adjacent existing mine workings at Clarence, output presented in **Figure 4-29c** indicates formation of water table in the Katoomba Seam (Layer 18), which is expected.

CLRP14_V, CC115_V, CLRP17_V and CLRP13_V

From **Figure 4-30a**, the modelled fit to observation is only fair at CLRP14_V. Sensor#1 and #2 are reasonably matched, but the model is lower than observed in Sensor#3 and #4. The behaviour (steady trend) is matched by the model. From **Figure 4-30a**, observed groundwater elevation is reasonably matched for each sensor at CC115_V. Sensor #2 and #3 are initially close, but as depressurisation in the 800 Panel Area proceeds, the model ends up being lower than observation. That difference is not significant, however. From **Figure 4-30a**, the fit to CLRP17_V is considered reasonable, as is the fit to CLRP13_V.

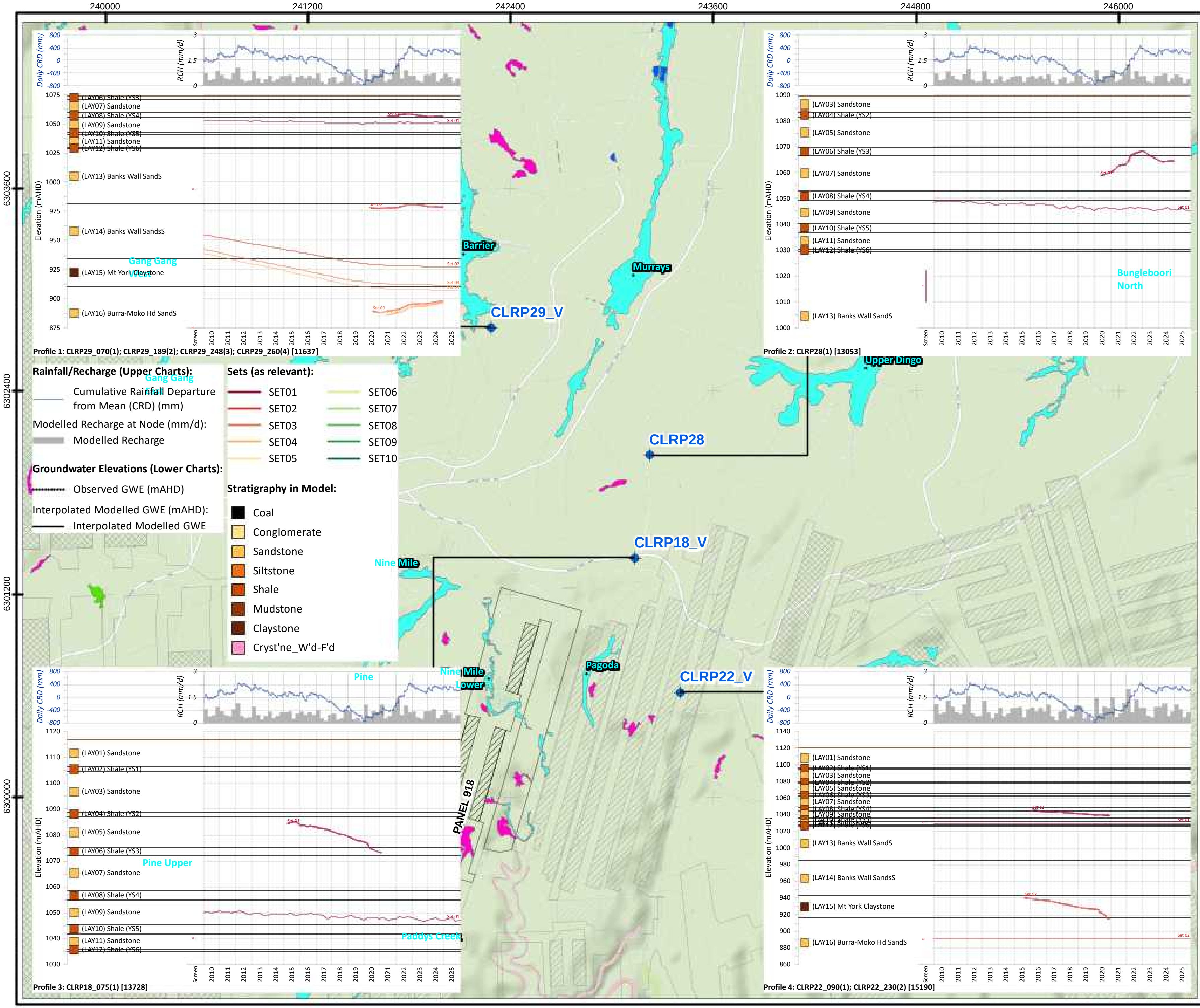
From **Figure 4-30b**, at CLRP14_V and CC115_V, there is a sharp decline in groundwater elevation below the Mount York Claystone (Layer 15). Modelled groundwater elevation in layers above the Mount York Claystone are steady. From **Figure 4-30b**, model behaviour is similar at CLRP17_V and CLRP13_V. From **Figure 4-30b**, the modelled groundwater elevation in Banks Wall Sandstone (Layer 13) is steady at the centre of the layer. That behaviour in the model tends to point to a water table, namely that there is steady throughflow that cell.

From **Figure 4-30c**, the depth-versus-pressure profiles indicate a water table may be occurring in the model in the Banks Wall Sandstone (Layer 13). Given that these monitoring locations overlie mining activity, model output indicates a water table is formed, in the Katoomba Seam (Layer 18), at each location. From **Figure 4-30c**, the fit to observed groundwater pressure is considered to be good.

CLRP33_V, CLRP2_V, CLRP3_V and CLR19_V

From **Figure 4-31a**, the modelled fit to CLRP33_V is considered to be fair, with observed behaviour (trend) being well matched. The model underestimates Sensor#1 and #2. From **Figure 4-31a**, the fit is also considered to be fair. The fit to Sensor#1 and #2 is considered to be good, but the model underestimates the groundwater elevation of Sensor#3, which is installed in the Burra-Moko Head Sandstone (Layer 16). From **Figure 4-31a**, the fit to Sensor#1 and Sensor#3 is good. It is noted that data from Sensor#2 was not considered to be representative, so was omitted. From **Figure 4-31a**, the fit to observed groundwater elevation at CLR19_V is considered to be good.

From **Figure 4-31b**, layer-by-layer model output at CLRP33_V is steady, which is expected, since it is located to the north of the 300 Panel Area, in an area that has not been subject to depressurisation due to mining. From **Figure 4-31b**, recovery and then commencement of a small decline in groundwater elevation in recent



Legend:

- Model Output Locations

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Notes:
1) GWE: Groundwater Elevation.
2) CRD Trace dates from 01/01/2010 - 31/12/2049.

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 22-Oct-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:30,000	

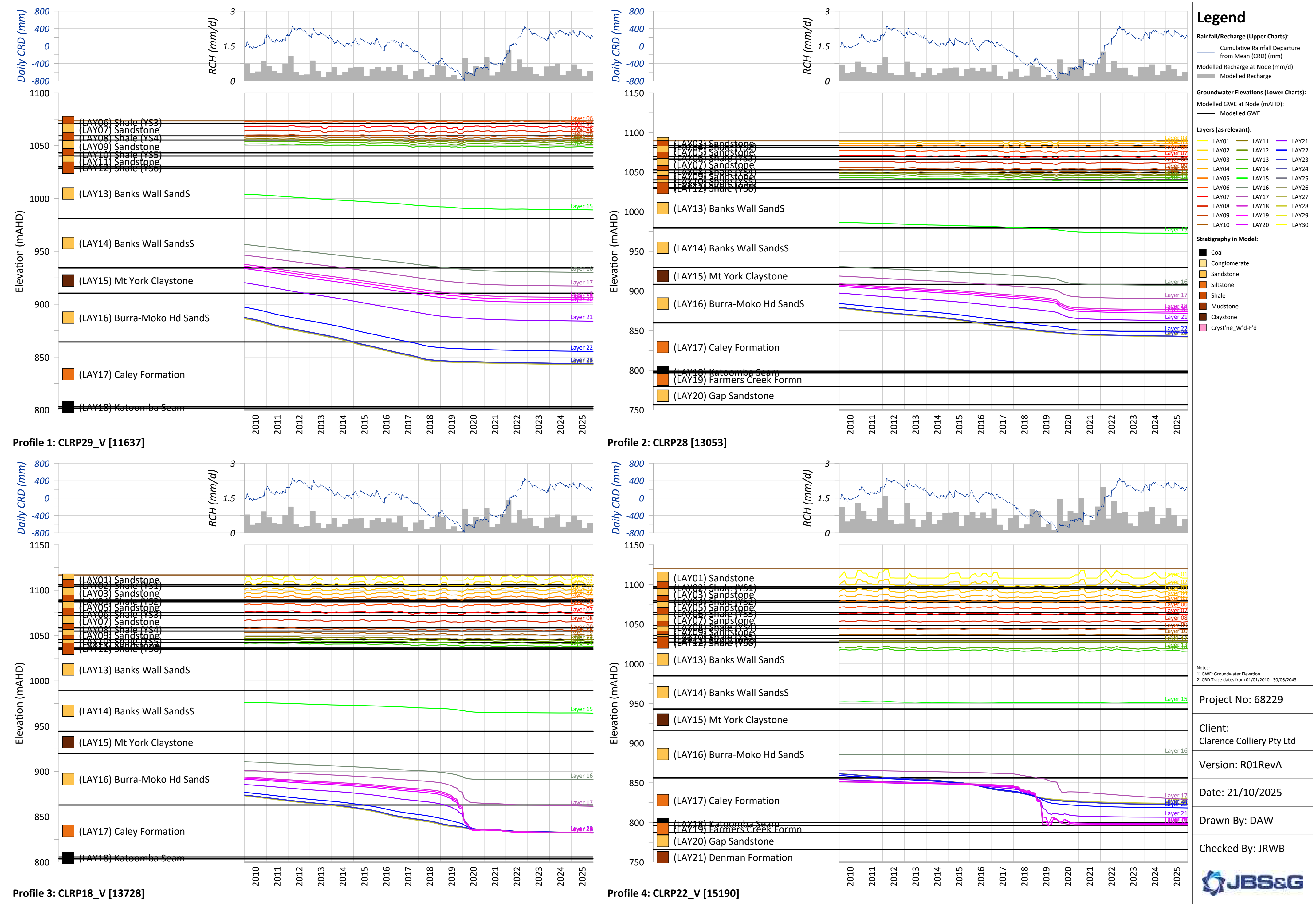
0 500 1,000
Meters

Coor. Sys. GDA 1994 MGA Zone 56

Groundwater Hydrographs (Calibration Period):
- **CLRP29_V**
- **CLRP28**
- **CLRP18_V**
- **CLRP22_V**

FIGURE: 4.29a

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D002b_CAL_Hydrographs_CLRP29_CLRP28_CLRP18_CLRP22.mxd
Reference: © Department of Customer Service 2020



Project No: 68229

Client:
Clarence Colliery Pty Ltd

Version: R01RevA

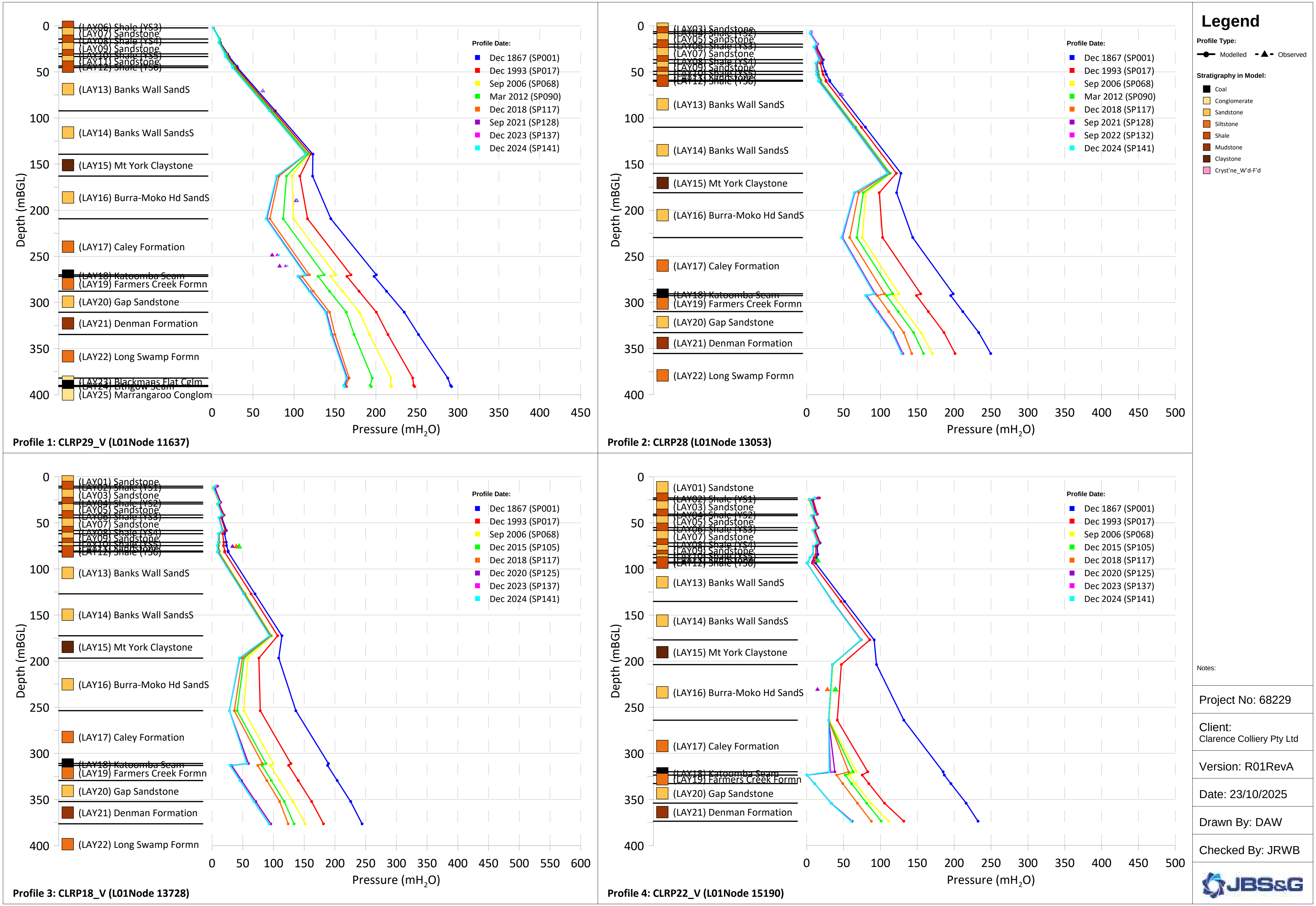
Date: 21/10/2025

Drawn By: DAW

Checked By: JRWB

JBS&G

Figure 4.29b: Multilevel Groundwater Hydrographs (Calibration Period) - CLRP29_V, CLRP28, CLRP18_V, CLRP22_V



Project No: 68229

Client: Clarence Colliery Pty Ltd

Version: R01RevA

Date: 23/10/2025

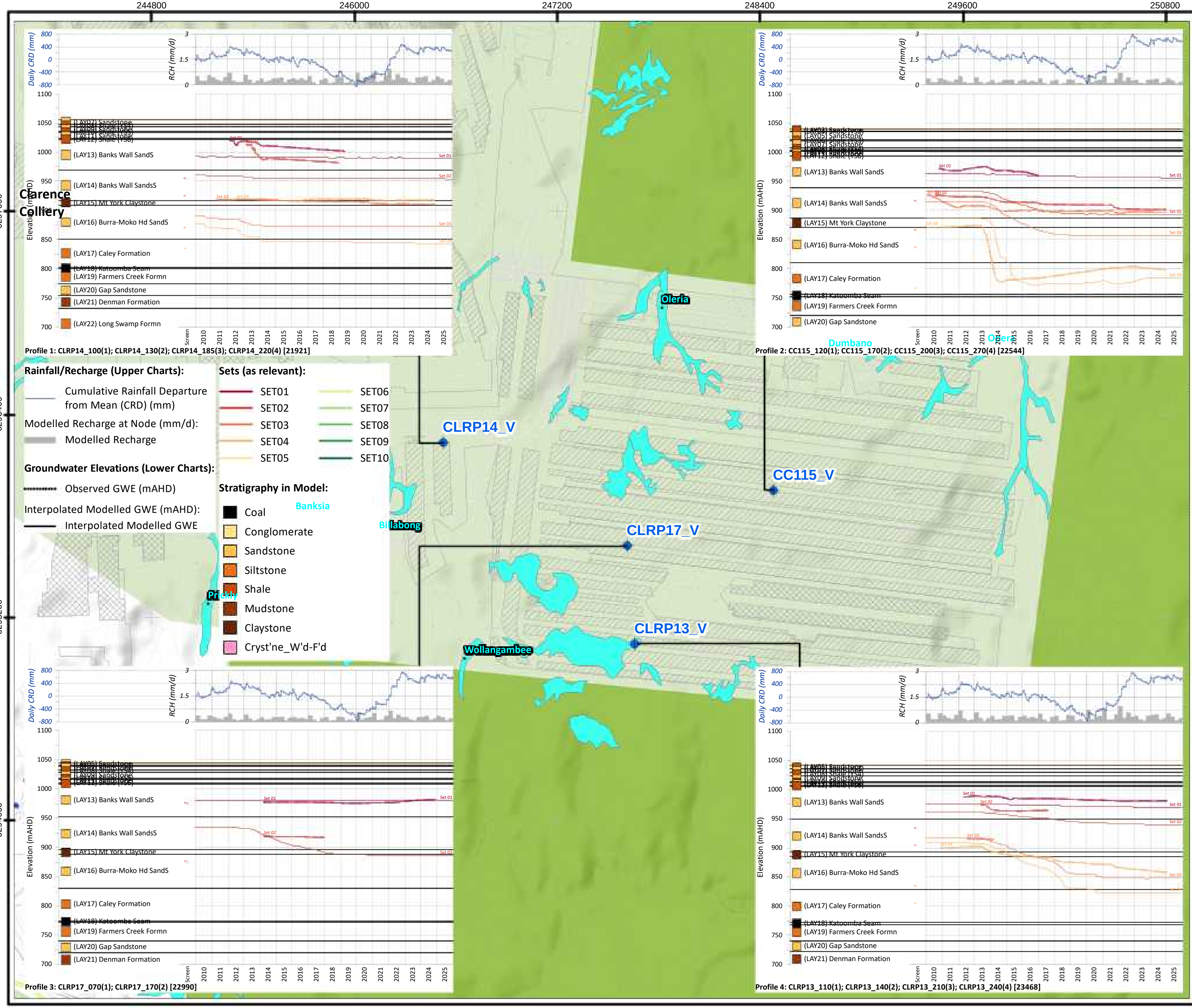
Drawn By: DAW

Checked By: JRWB

JBS&G

Figure 4.29c: Depth versus Groundwater Pressure Diagrams (Calibration Period) - CLRP29_V, CLRP28, CLRP18_V, CLRP22_V

Reference: 68229_R01RevA_APR_03c.



Legend:

- Greater Blue Moutains World Heritage Area
- Model Output Locations

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Notes:
1) GWE: Groundwater Elevation.
2) CRD Trace dates from 01/01/2010 - 31/12/2049.

Job No: 68229

Client: Clarence Colliery Pty Ltd

Version: R01RevB	Date: 29-Jan-2026
Drawn By: DAW	Checked By: JRWB

Scale 1:30,000

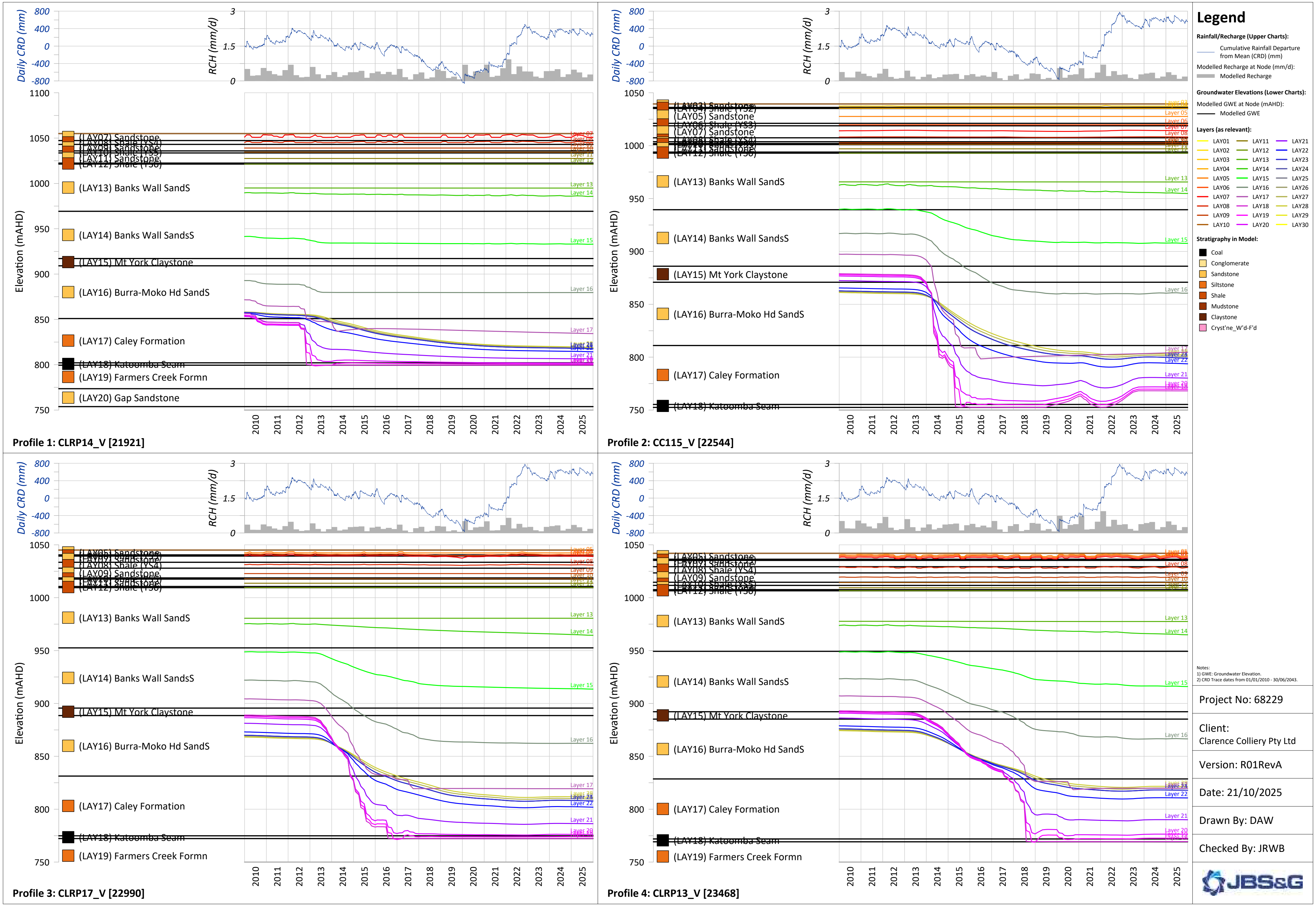
0 500 1,000
Meters

Coor. Sys. GDA 1994 MGA Zone 56

Groundwater Hydrographs (Calibration Period):
- CLRP14_V
- CC115_V
- CLRP17_V
- CLRP13_V

FIGURE: 4.30a

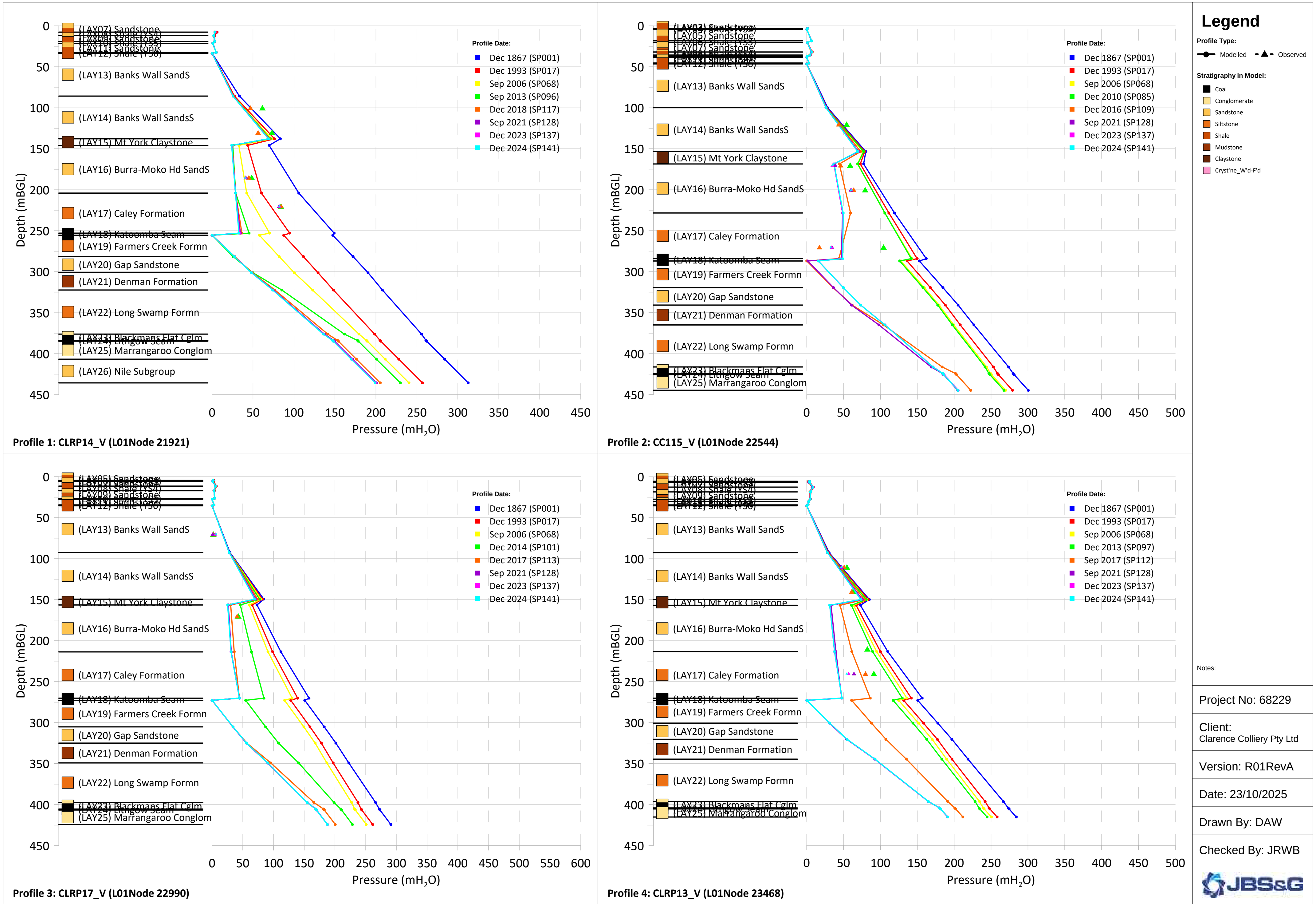
File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D002c_CAL_Hydrographs_CLRP14_CC115_CLRP17_CLRP13.mxd



File Path: N: Projects CentennialCoal ClarenceColliery 68229_UpdateTo918EP Figures Grapher 68229_R01RevA_D003_BinaryHDSMultiLevelHydrographGenerator 68229_R01RevA_D003c 68229_R01RevA_BinaryHDSMultiLevelHydrographGenerator_03_CLRP14_CC115_CLRP17_CLRP13.grf

Reference: 68229_R01RevA_APR_03c

Figure 4.30b: Multilevel Groundwater Hydrographs (Calibration Period) - CLRP40, CLRP27_V, CLRP42R, CLRP41A



Project No: 68229

Client:
Clarence Colliery Pty Ltd

Version: R01RevA

Date: 23/10/2025

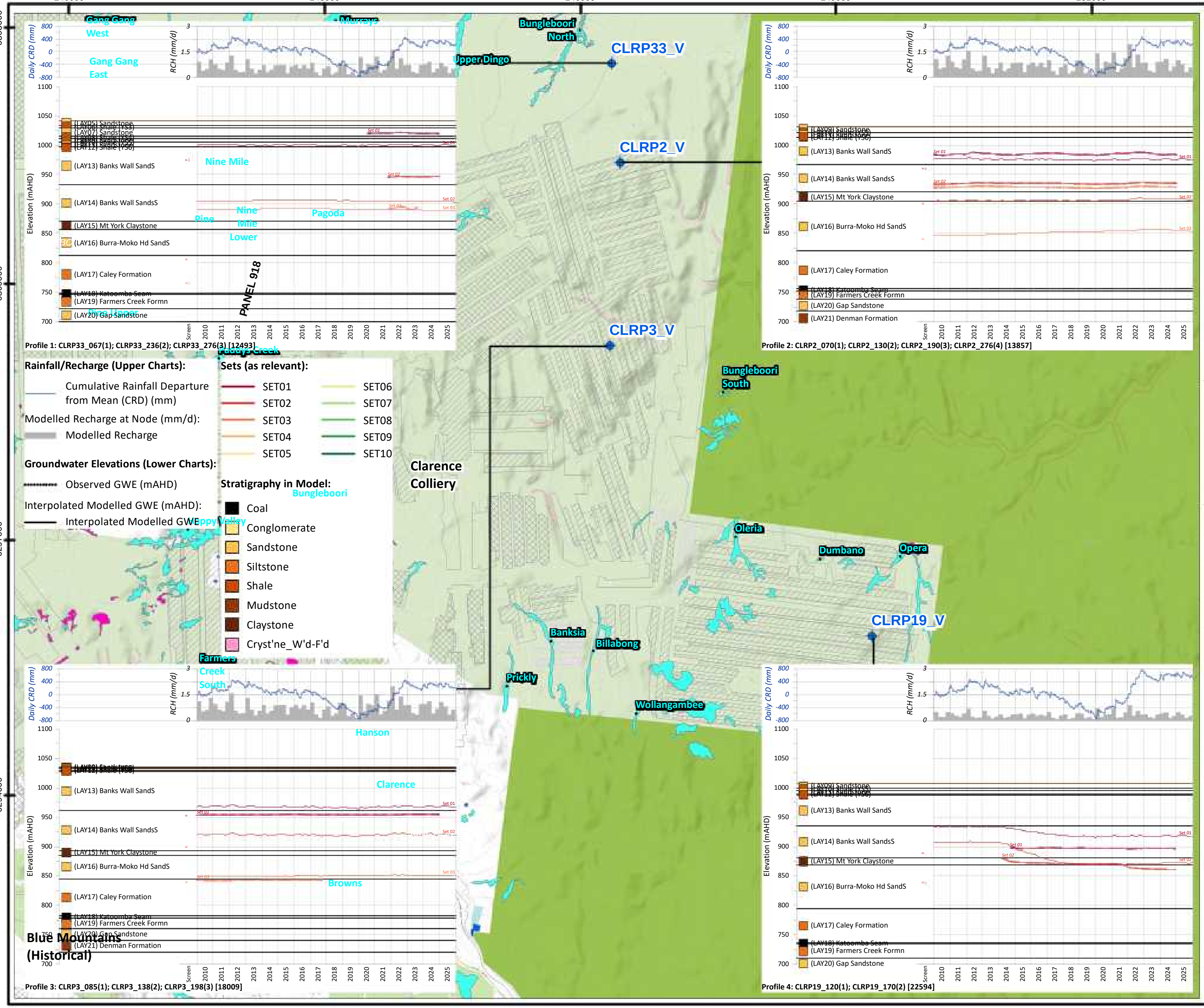
Drawn By: DAW

Checked By: JRWB

Figure 4.30c: Depth versus Groundwater Pressure Diagrams (Calibration Period) - CLRP14_V, CC115_V, CLRP17_V, CLRP13_V

Reference: 68229_R01RevA_APR_03c.

File Path: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\Grapher\68229_R01RevA_D004_BinaryHDSVerticalProfileExtraction_Pressure\68229_R01RevA_D004c\68229_R01RevA_D004c_VerticalProfileExtraction_Pressure_03_CLRP14_CC115_CLRP17_CLRP13.grf



Legend:

- Greater Blue Moutains World Heritage Area
- Model Output Locations

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Notes:
1) GWE: Groundwater Elevation.
2) CRD Trace dates from 01/01/2010 - 31/12/2049.

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 22-Oct-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:60,000	

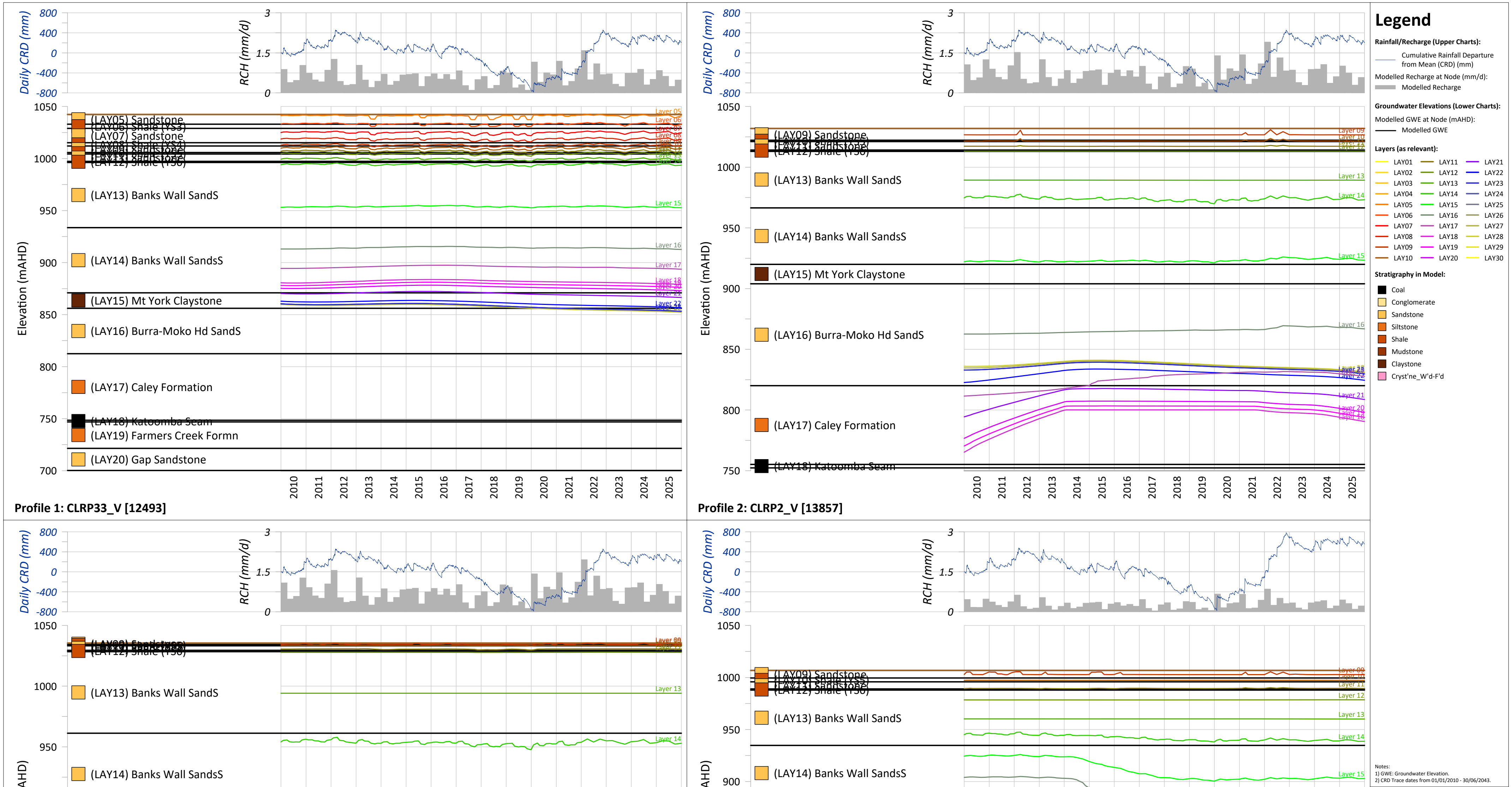
0 1 2
Kilometers

Coor. Sys. GDA 1994 MGA Zone 56

Groundwater Hydrographs (Calibration Period):
- CLRP33_V
- CLRP2_V
- CLRP3_V
- CLRP19_V

FIGURE: 4.31a

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D002d_CAL_Hydrographs_CLRP33_CLRP02_CLRP03_CLRP19.mxd



Project No: 68229

Client: Clarence Colliery Pty Ltd

Version: R01RevA

Date: 21/10/2025

Drawn By: DAW

Checked By: JRWB

JBS&G

Figure 4.31b: Multilevel Groundwater Hydrographs (Calibration Period) - CLRP33_V, CLRP2_V, CLRP3_V, CLRP19_V

File Path: N: Projects CentennialCoal ClarenceColliery 68229_UpdateTo918EP Figures Grapher 68229_R01RevA_D003_BinaryHDSMultiLevelHydrographGenerator 68229_R01RevA_D003d 68229_R01RevA_BinaryHDSMultiLevelHydrographGenerator_04_CLRP33_CLRP02_CLRP03_CLRP19.grf
Reference: 68229_R01RevA_APR_03c

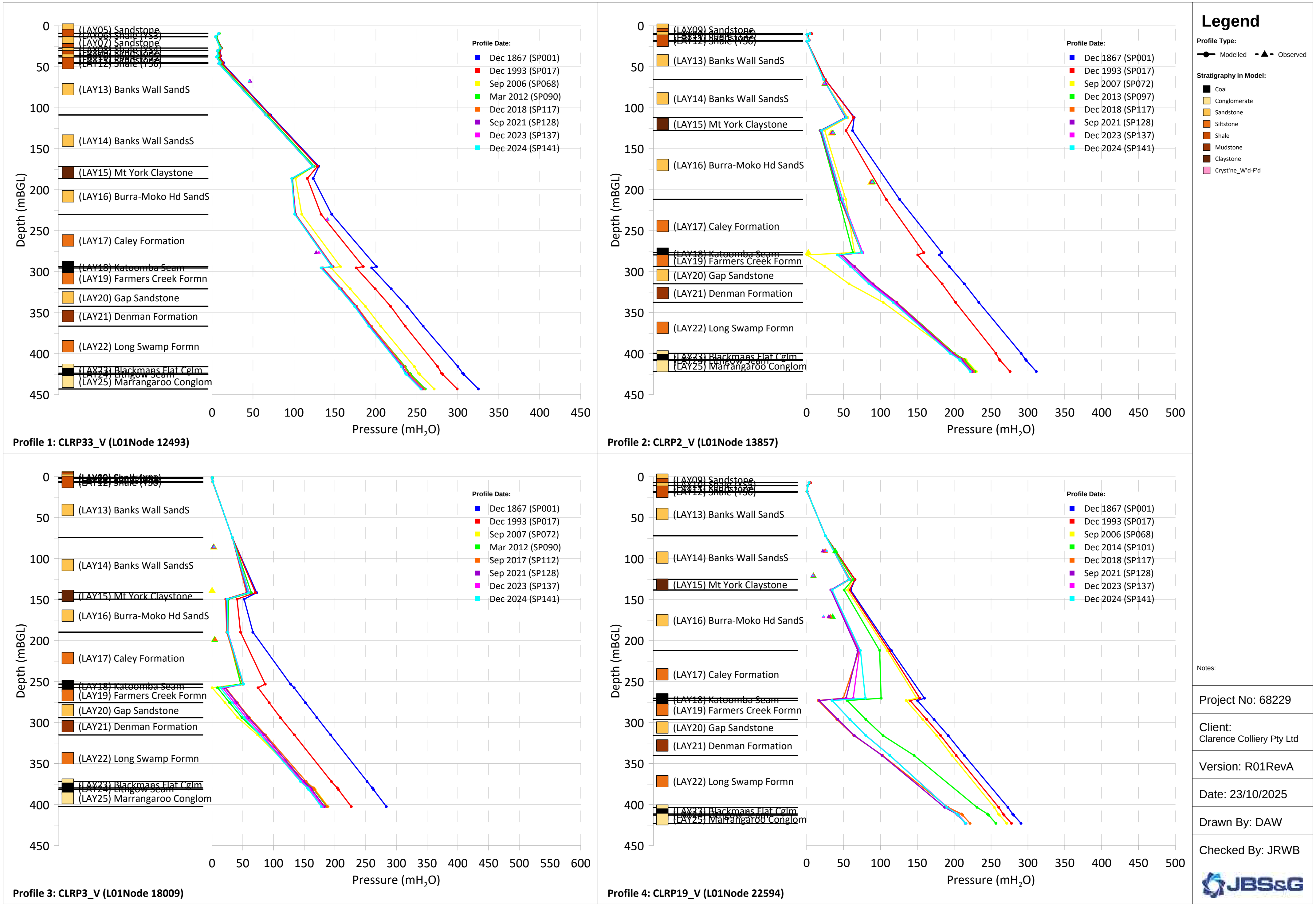


Figure 4.31c: Depth versus Groundwater Pressure Diagrams (Calibration Period) - CLRP33_V, CLRP2_V, CLRP3_V, CLRP19_V

Reference: 68229_R01RevA_APR_03c.

File Path: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\Grapher\68229_R01RevA_D004_BinaryHDSVerticalProfileExtraction_Pressure\68229_R01RevA_D004d\68229_R01RevA_D004d_VerticalProfileExtraction_Pressure_04_CLRP33_CLRP2_CLRP3_CLRP19.grf time in the model at CLRP2_V and CLRP3_V and is considered to reflect proximity to development of Panel 834.

From **Figure 4-31c**, at CLRP33_V, given its location, model output suggests a water table above the top of the Banks Wall Sandstone (Layer 13) (aside from perched water tables within the Burralow Formation). The depth-versus-pressure profile suggests the deep groundwater system at this location is confined, with the water table being just above the Mount York Claystone (Layer 15). The fit to observed pressure is considered to be good. From **Figure 4-31c**, at CLRP2_V, model behaviour suggests recovery from previous depressurisation of the Katoomba Seam (Layer 18), but observed pressure in the Burra-Moko Head Sandstone is higher than modelled. From **Figure 4-31c**, the observed pressure profile at CLRP3_V implies all strata above the Katoomba Seam (Layer 18) are depressurised. The model suggests the Mount York Claystone (Layer 15) is still having an influence on groundwater behaviour, but the angle of change (hydrostatic line) is not met. From **Figure 4-31c**, the fit to observed pressure at CLRP19_V is considered to be fair.

SPR48_V, SPR36_V, SPR67_V and SPR66_V

From **Figure 4-32a**, these monitoring locations are located at the adjacent operation at Springvale Mine. These are each vibrating wire piezometers. From **Figure 4-32a**, the modelled fit to SPR48_V is considered reasonable. That vibrating wire piezometer is installed into a chain pillar between LW412 and LW413A. From **Figure 4-32a**, modelled fit to SPR36_V is also considered reasonable. Modelled groundwater elevation at Sensor#6 and #7 is underestimated, but the behaviour (trend) is well matched. From **Figure 4-32a**, SPR67_V is also well matched. An exception is Sensor#5, where the model response is steady, which suggests a water table may be being formed in that layer (Burra-Moko Head Sandstone (Layer 16)) in the model. From **Figure 4-32a**, the fit to observed groundwater elevation at SPR66_V is considered fair. Whilst the lower Sensors#5 and #6 are no well matched, with the model indicating earlier-than-observed depressurisation in the deep groundwater system, the sharp drop, upon extraction, at the end of 2016/beginning of 2017 is captured.

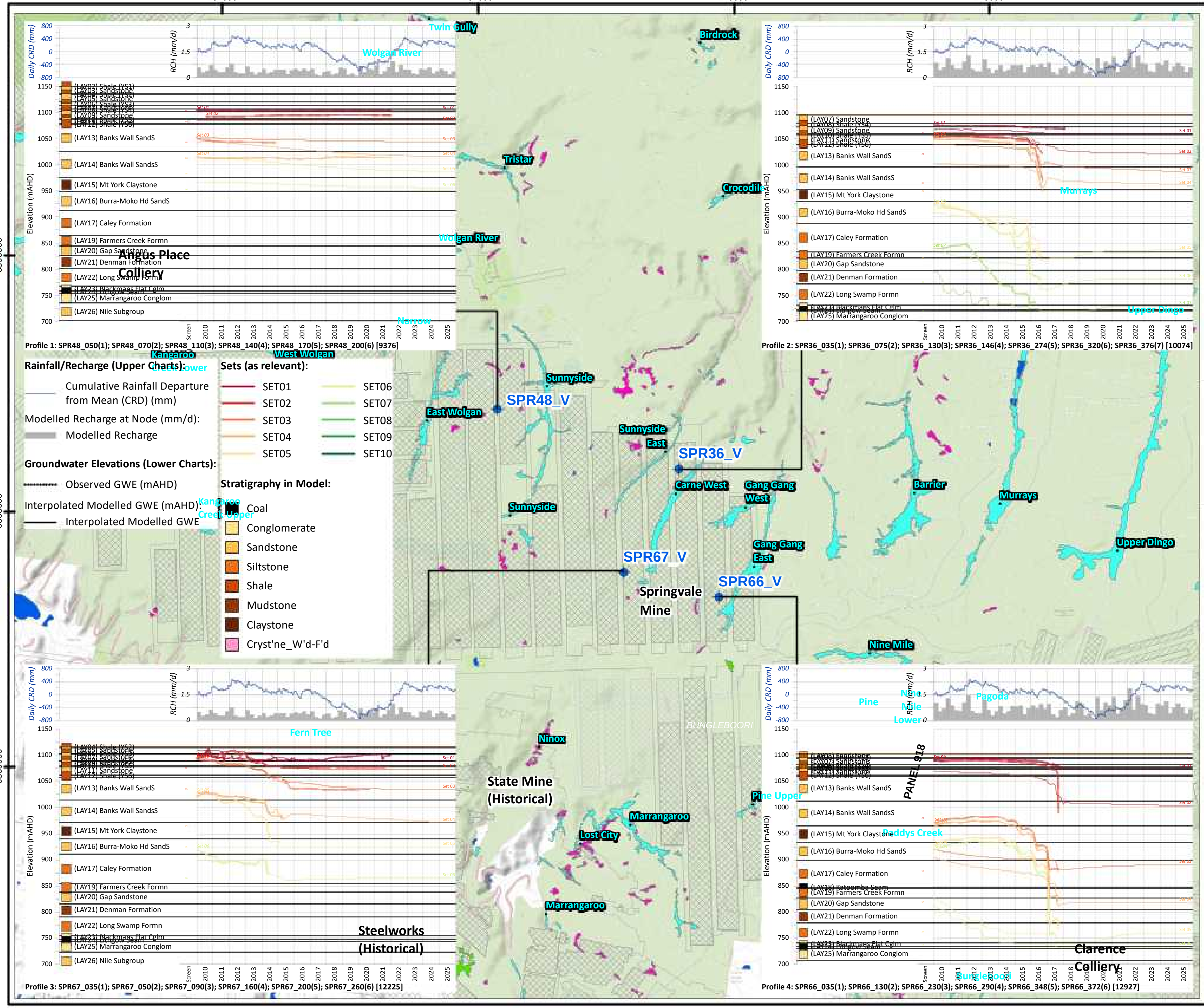
From **Figure 4-32b**, at SPR48_V, modelled groundwater elevation in the Burralow Formation is steady and in other hydrogeologic units. From **Figure 4-32b**, there is a pronounced responses to extraction at SPR36_V, including change to the highest active layer. This is consistent with decline in the uppermost water table in the vicinity of SPR36_V. As explained in JBS&G (2025ab), this was largely due to the highest active layer being 'lower in the profile' for this part of the northern longwalls at Springvale Mine. From **Figure 4-32b**, at SPR67_V, there is a significant decline in the shallow groundwater system in response to extraction at this location. From **Figure 4-32b**, depressurisation is initiated many years before extraction occurs. The sharp decline at SPR66_V upon extraction is well captured by the model, however.

From **Figure 4-32c**, the observed pressure profile obtained from the vibrating wire piezometers is reasonably matched to the modelled pressure profile. Particularly good fits are obtained at SPR36_V and SPR67_V.

GW099052, GW099053, GW099054, CSP9, CLRP31 and CSP8

From **Figure 4-33a**, the modelled fit to the new NSW DCCEEW monitoring cluster, GW099052, GW099053 and GW099054 is considered only fair. The vertical hydraulic gradient is reasonable, but the model is underpredicting groundwater elevation at this location. From **Figure 4-33a**, the modelled fit to CSP9 is reasonable, all the modelled groundwater elevation does not quite intersect with ground surface. From **Figure 4-33a**, the modelled fit to standpipe piezometer CLPR31 is considered to be fair. The model trend matches the observed trend, but the modelled groundwater elevation is lower than the observed elevation. From **Figure 4-33a**, the modelled fit to CSP8 is considered reasonable.

From **Figure 4-33b**, the modelled groundwater elevation in the deep groundwater system has declined at location of GW099052 to GW099054. GW099052 to GW099054 is located about 2.5km north of current mining at Clarence Colliery and about 2.5km east of the eastmost longwall at Springvale Mine. From **Figure 4-33b**, groundwater elevation is relatively steady at CSP9, CLRP31 and at CSP8. That behaviour is expected, given that these monitoring locations are between 1.5 and 3km from current workings at Clarence.



Legend:

- Model Output Locations

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Notes:
1) GWE: Groundwater Elevation.
2) CRD Trace dates from 01/01/2010 - 31/12/2049.

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 22-Oct-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:60,000	

0 1 2
Kilometers

Coor. Sys. GDA 1994 MGA Zone 56

Groundwater Hydrographs (Calibration Period):
- SPR48_V
- SPR36_V
- SPR67_V
- SPR66_V

FIGURE: 4.32a

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D002e_CAL_Hydrographs_SPR48_SPR36_SPR67_SPR66.mxd
Reference: © Department of Customer Service 2020

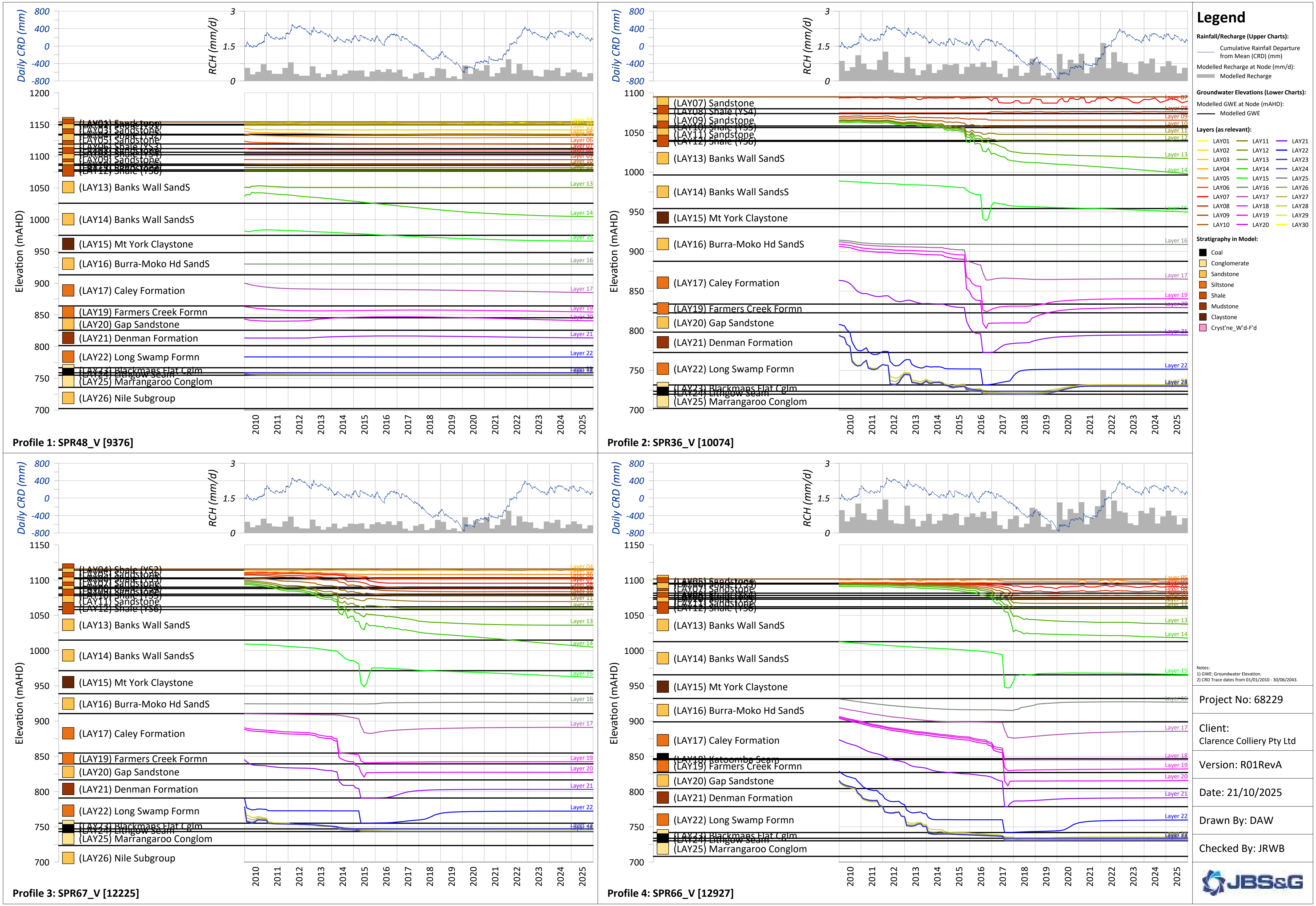
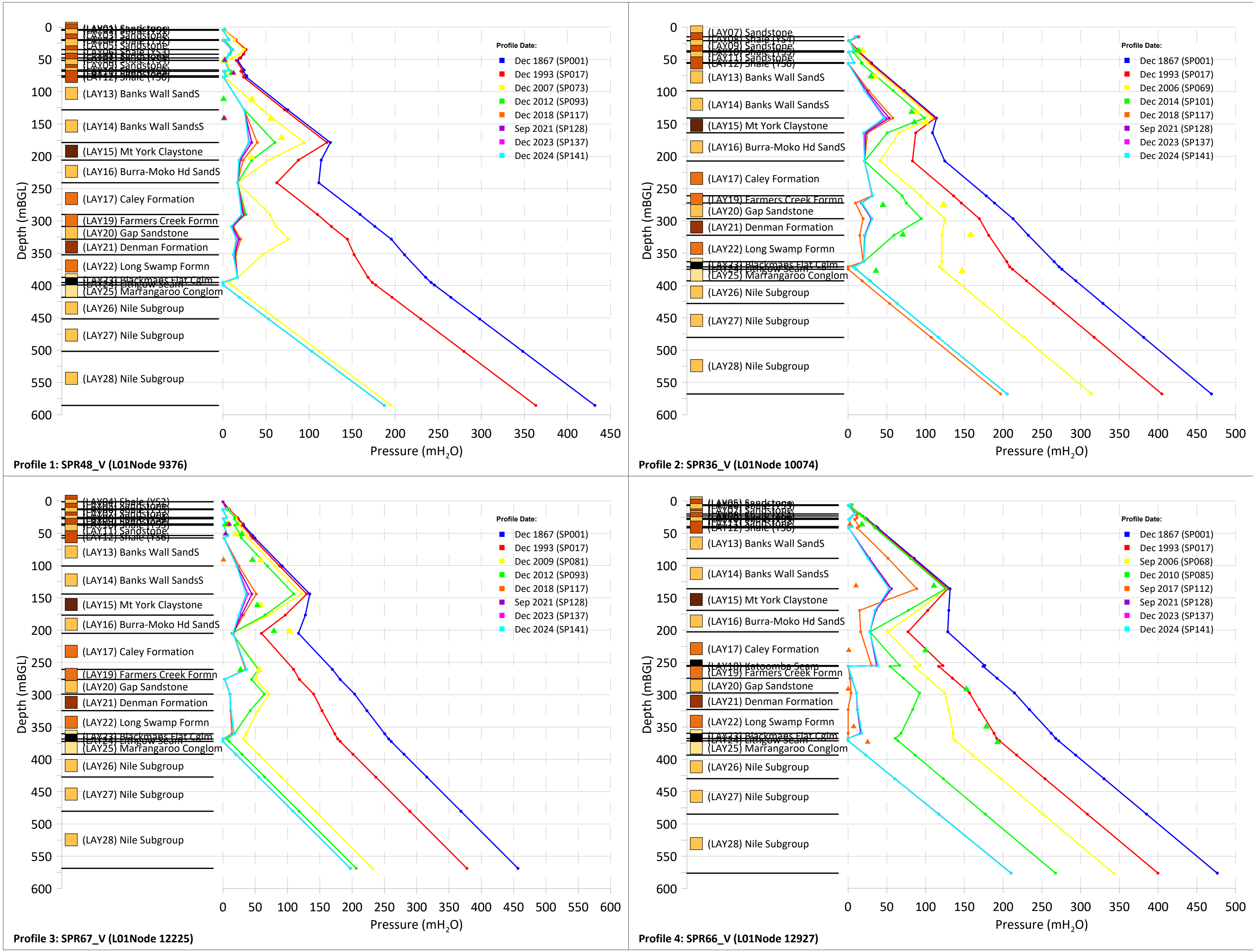


Figure 4.32b: Multilevel Groundwater Hydrographs (Calibration Period) - SPR48_V, SPR36_V, SPR67_V, SPR66_V



Legend

Profile Type: Modelled; Observed

Stratigraphy in Model:
- Coal
- Conglomerate
- Sandstone
- Siltstone
- Shale
- Mudstone
- Claystone
- Cryst'ne_W'd-F'd

Notes:

Project No: 68229

Client:
Clarence Colliery Pty Ltd

Version: R01RevA

Date: 23/10/2025

Drawn By: DAW

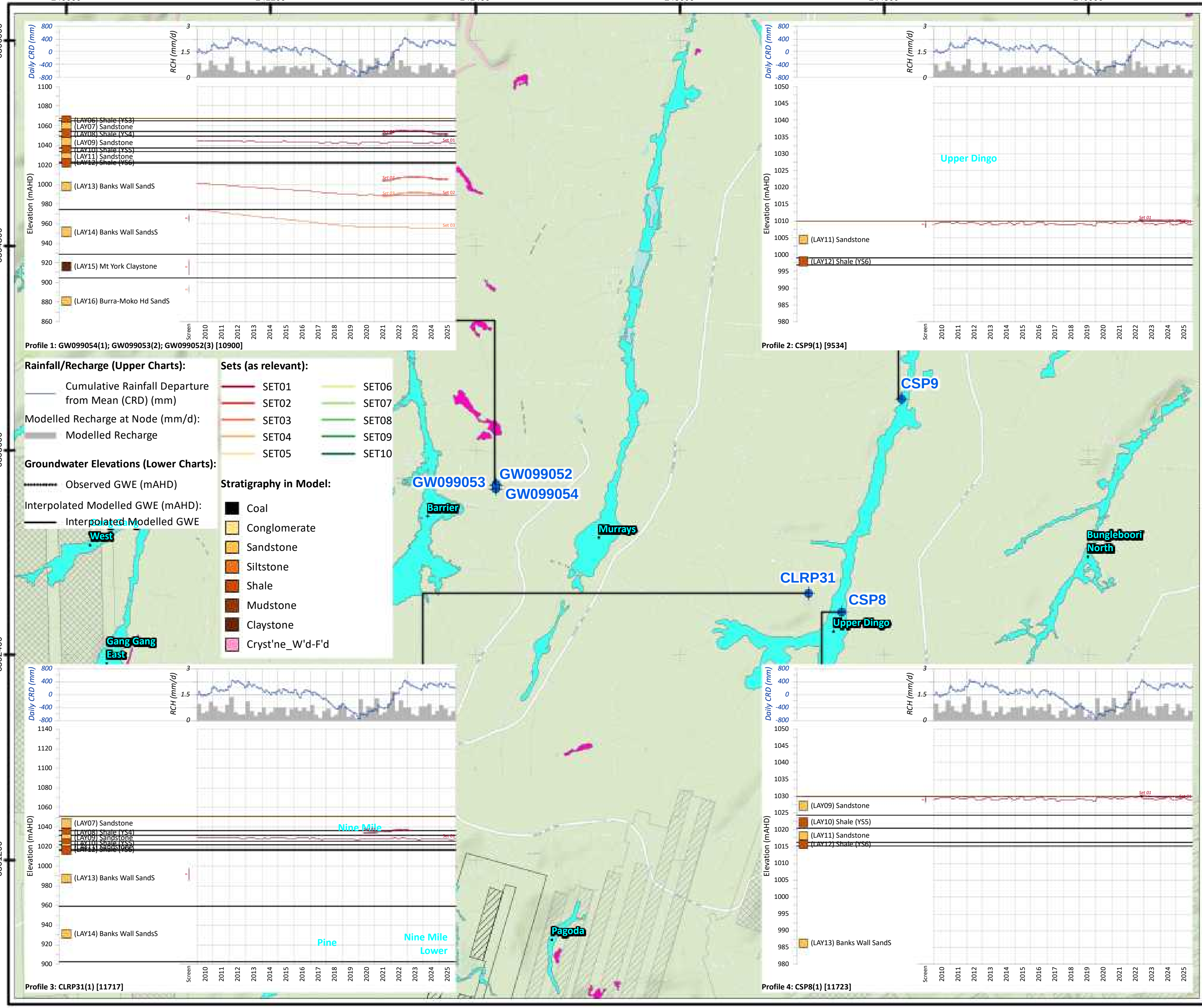
Checked By: JRWB

JBS&G

Figure 4.32c: Depth versus Groundwater Pressure Diagrams (Calibration Period) - SPR48_V, SPR36_V, SPR67_V, SPR66_V

Reference: 68229_R01RevA_APR_03c.

File Path: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\Grapher\68229_R01RevA_D004_BinaryHDSVerticalProfileExtraction_Pressure\68229_R01RevA_D004e\68229_R01RevA_D004e_VerticalProfileExtraction_Pressure_05_SPR48_SPR36_SPR67_SPR66.grf



Legend:

- Model Output Locations

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
- 51 Newnes Plateau Hanging Swamp (EEC)
- 52 Newnes Plateau Rush - Sedge - Snow Gum Hollow Wooded Heath (EEC)

Notes:
1) GWE: Groundwater Elevation.
2) CRD Trace dates from 01/01/2010 - 31/12/2049.

JBS&G

Job No: 68229	
Client: Clarence Colliery Pty Ltd	
Version: R01RevA	Date: 22-Oct-2025
Drawn By: DAW	Checked By: JRWB
Scale 1:30,000	

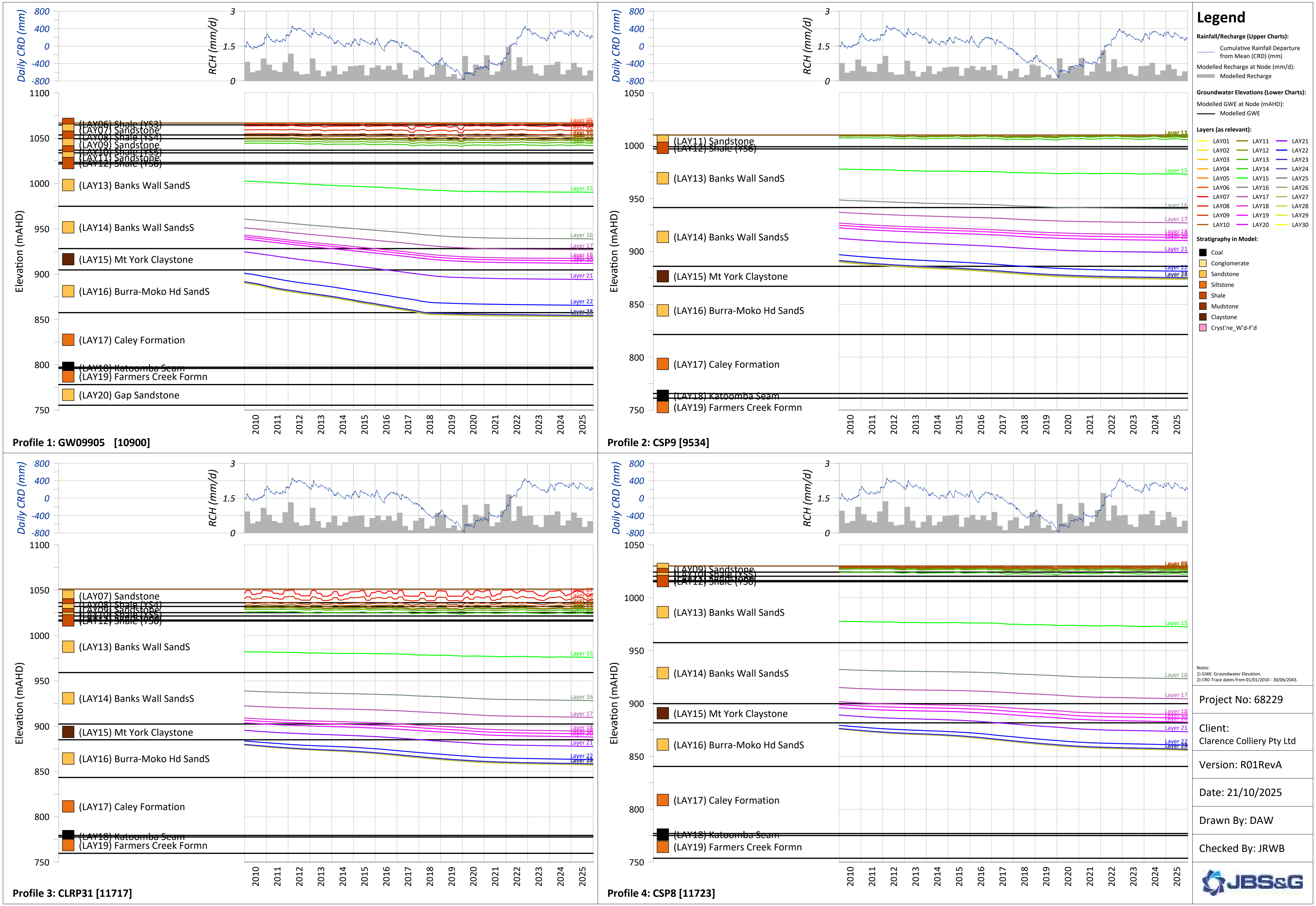
0 500 1,000
Meters

Coor. Sys. GDA 1994 MGA Zone 56

Groundwater Hydrographs (Calibration Period):
- GW09905X
- CSP9
- CLRP31
- CSP8

FIGURE: 4.33a

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevA_D002f_CAL_Hydrographs_GW_CSP9_CLRP31_CSP8.mxd



Project No: 68229

Client:
Clarence Colliery Pty Ltd

Version: R01RevA

Date: 21/10/2025

Drawn By: DAW

Checked By: JRWB

JBS&G

File Path: N: Projects CentennialCoal ClarenceColliery 68229_UpdateTo918EP Figures Grapher 68229_R01RevA_D003_BinaryHDSMultiLevelHydrographGenerator 68229_R01RevA_D003f 68229_R01RevA_BinaryHDSMultiLevelHydrographGenerator_06_GW_CSP9_CLRP31_CSP8.grf
Reference: 68229_R01RevA_APR_03c

Figure 4.33b: Multilevel Groundwater Hydrographs (Calibration Period) - GW09905 , CSP9, CLRP31, CSP8

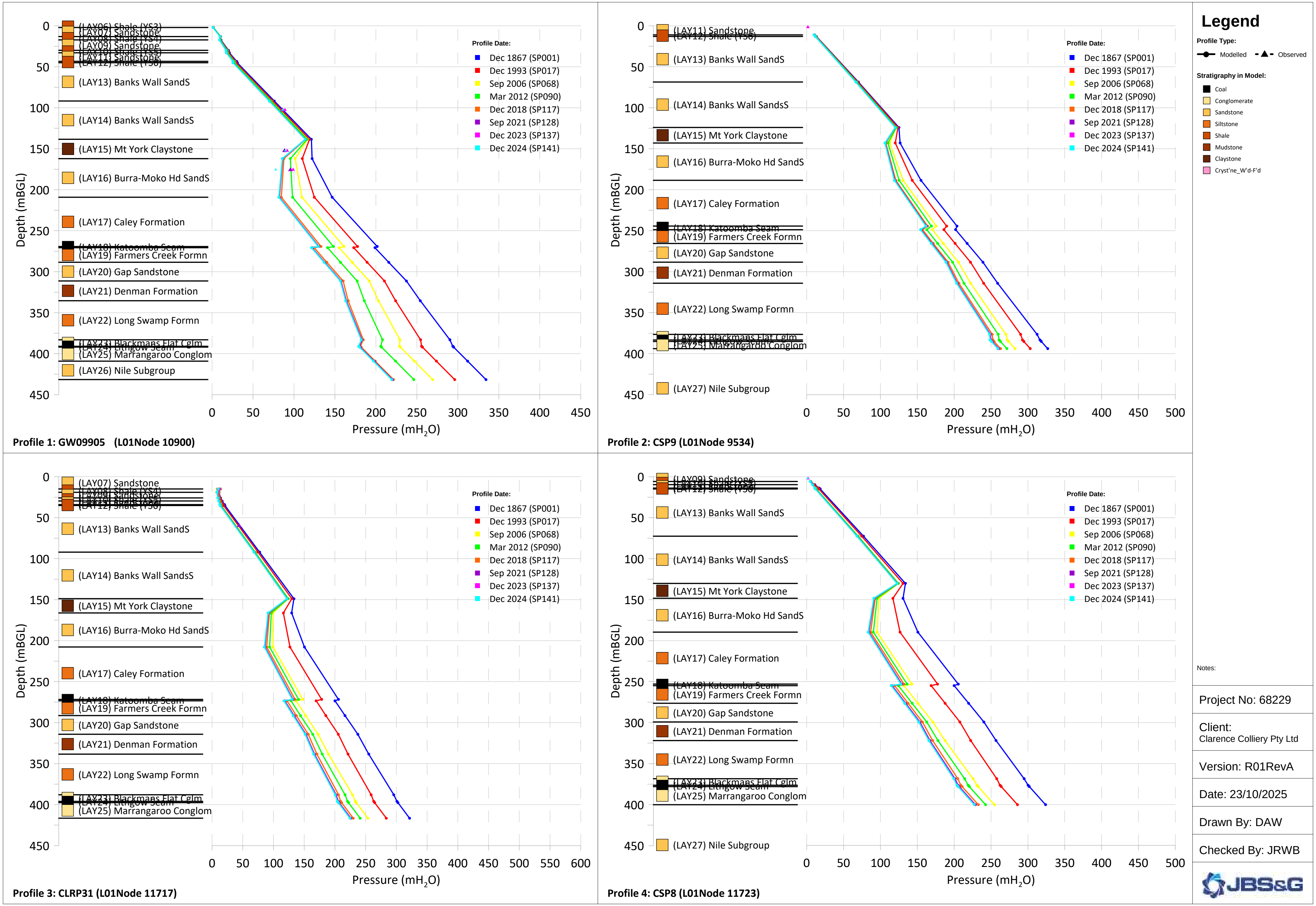


Figure 4.33c: Depth versus Groundwater Pressure Diagrams (Calibration Period) - GW09905X, CSP9, CLRP31, CSP8

Reference: 68229_R01RevA_APR_03c.

From **Figure 4-33c**, the Mount York Claystone (Layer 15) as acting as a regionally significant aquitard, with the deep groundwater system being confined, with an inferred water table above the top of the Burra-Moko Head Sandstone (Layer 16). From **Figure 4-33c**, for GW099052 through GW099054, the fit to modelled pressure plot is considered reasonable.

CSP1, PG1, CSP2 and PG2

From **Figure 4-34a**, the model representation of CSP1 is fair and CSP2 is good. For CSP1, the modelled groundwater elevation is not quite at ground surface. From **Figure 4-34a**, modelled groundwater elevation at PG1 and PG2 is only considered fair, again due to the modelled elevation not being at ground surface.

From **Figure 4-34b**, layer-by-layer output indicates that model behaviour is consistent with conceptual model, namely that depressurisation in the deep groundwater system occurs without leading to decline in the shallow and perched groundwater system.

From **Figure 4-34c**, given the monitoring locations are each swamp piezometers, pressure observation are at ground surface and are close to zero. From **Figure 4-34c**, model behaviour is well matched, namely that the Mount York Claystone (Layer 15) as a regionally significant aquitard. Of particular note in **Figure 4-34c**, by 31 December 2024 (end of SP141), the Katoomba Seam (Layer 18) is depressurised, thereby is a water table, with the water in the shallow groundwater system being unaffected, except for the model representation of changes to hydraulic properties.

CSP6, CSP34, PSE1 and PSE2

From **Figure 4-35a**, the modelled fit to CSP6 is considered reasonable, being close to ground surface, as is CSP34. From **Figure 4-35a**, the modelled fit to PSE1 is considered reasonable, but the fit to PSE2 is only fair. For PSE2, modelled groundwater elevation is not at ground surface, hence is not, in the model, acting like a swamp (modelled elevation at or above ground surface).

From **Figure 4-35b**, for CSP6, it is situated in the Burralow Formation, and regional depressurisation (in the deep groundwater system) is evident in model output. From **Figure 4-35b**, for CSP34, depressurisation in the deep groundwater system is already occurring. This will be being caused by 906 Panel and Panel 908-910 Area. From **Figure 4-35b**, layer-by-layer model output below PSE1 also reflects subdivision between the deep groundwater system and the shallow groundwater system by the Mount York Claystone (Layer 15). From **Figure 4-35b**, model behaviour below PSE2 is equivalent to that below PSE1.

From **Figure 4-35c**, given the observation locations are swamp monitoring piezometers, observation data is limited to near ground surface. From **Figure 4-35c**, model behaviour is consistent, namely the separating of the groundwater systems.

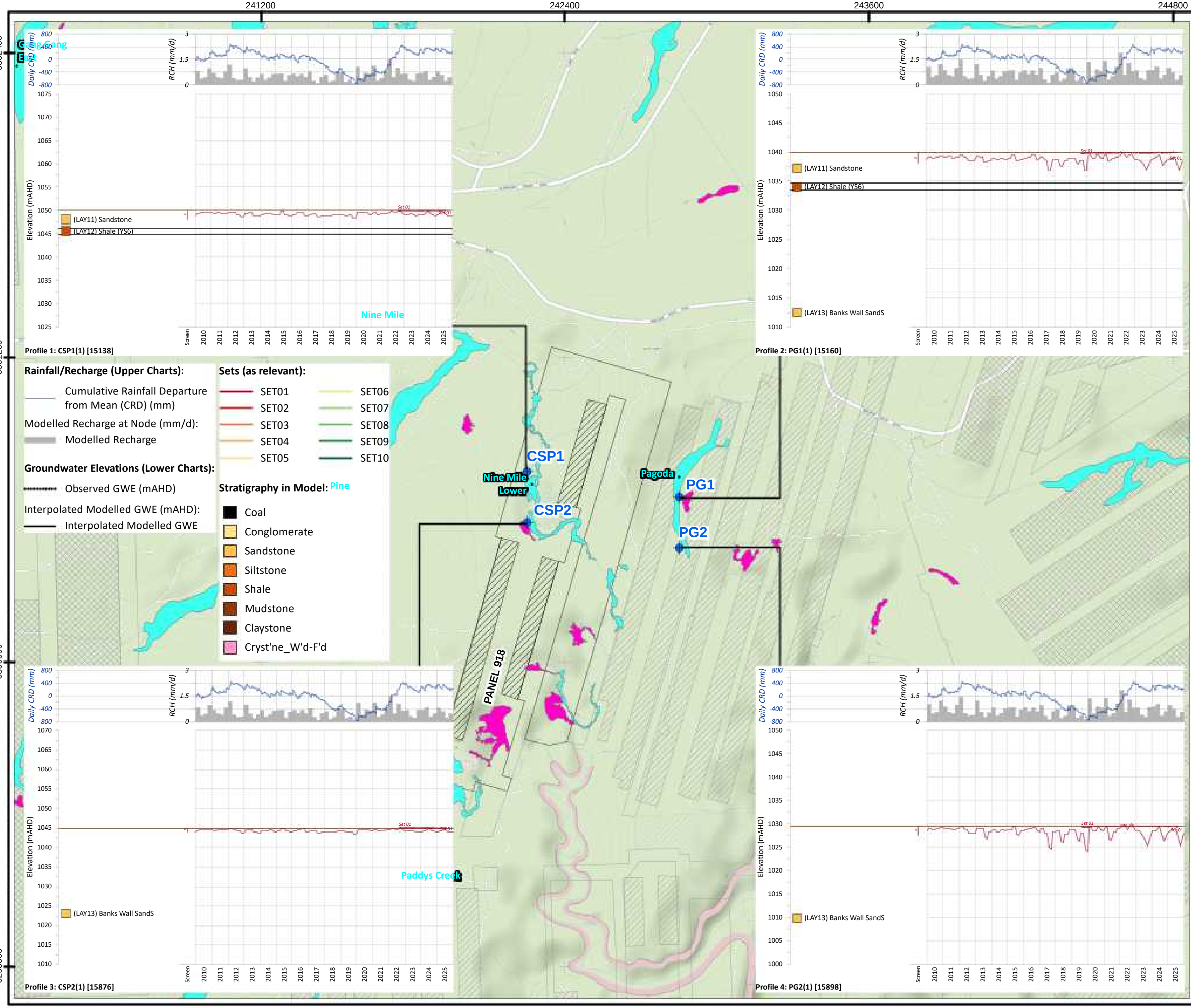
Paddys Creek Shrub Swamp

Figure 4-36 presents output along Paddys Creek Shrub Swamp.

There are four locations output from the model for Paddys Creek Shrub Swamp. From **Figure 4-36a**, [17233] and [17234] have a modelled groundwater elevation that is quite below ground surface. This is due to the limitation of model grid size in that area, in regard to steepness of topography. Most shrub swamps are in a broader valley, so this is not an issue for Nine Mile Lower Swamp. From **Figure 4-36a**, [17238] and [17242] have a modelled groundwater elevation at ground surface, and as [17238] is closest to extraction, that location was selected for detailed reporting.

From **Figure 4-36b**, groundwater model behaviour beneath each of the listed model nodes is the same, therefore is not an influence on the selection of the node to use for detailed reporting.

From **Figure 4-36c**, the pressure-versus-depth profiles are the same for each of the listed model nodes.



Legend:

Model Output Locations

Mining Methods:

- Development
- Partial Extraction
- Total Extraction
- Open Cut

Mine Operation Status:

- Approved
- Existing
- Proposed
- Other Proposed

Swamps by MU Name (Clarence, 2025bc):

- 50 Newnes Plateau Shrub Swamp (EEC)
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Notes:
1) GWE: Groundwater Elevation.
2) CRD Trace dates from 01/01/2010 - 31/12/2049.

Job No: 68229

Client: Clarence Colliery Pty Ltd

Version: R01RevB	Date: 29-Jan-2026
Drawn By: DAW	Checked By: JRWB

Scale 1:20,000

0 250 500
Meters

Coor. Sys. GDA 1994 MGA Zone 56

Groundwater Hydrographs (Calibration Period):
- CSP1
- PG1
- CSP2
- PG2

FIGURE: 4.34a

File Name: N:\Projects\CentennialCoal\ClarenceColliery\68229_UpdateTo918EP\Figures\GIS\Maps\68229_R01RevB_D002g_CAL_Hydrographs_CSP1_PG1_CSP2_PG2.mxd
Reference: © Department of Customer Service 2020