JELLINBAH GROUP PTY LTD

GROUNDWATER REPORT

for

ASSOCIATED WATER LICENCE (AWL) APPLICATION

JELLINBAH CENTRAL NORTH EXTENSION (CNE) AREA

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JBT Consulting Pty Ltd

John Bradley
PRINCIPAL HYDROGEOLOGIST

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1.0 INTRODUCTION

1.1 Background

Jellinbah Resources Ltd (Jellinbah) operates the Jellinbah Coal Mine in central Queensland. The Mine currently encompasses four operating mine areas – Jellinbah Central, Mackenzie North, Jellinbah Plains and Plains South. Mining activities at Plains South are planned to extend into the Central North (CN) and Central North Extension (CNE) areas. Jellinbah South is currently inactive.

The CNE will extend the CN mining area downdip (to the east) by approximately 400 m relative to the CN operation. The location of the CNE relative to the Jellinbah Central, Jellinbah Plains and CN mining areas is shown below in Figure 1-1. The CNE includes three mining lease (ML) areas, including ML700011, ML700012 and ML700013. Mining of coal is to occur only within ML700011, with the other ML areas to be utilised for infrastructure and disposal of mined spoil. The Central North Extension is already authorised under the Project's Environmental Authority (EA) and federal legislation under the *Environment Protection and Biodiversity Conservation Act* (EPBC Act 1999).

This report has been prepared to support the Project's application for an Associated Water Licence (AWL). With respect to the minimum groundwater-related requirements to support an AWL application, the required information (with reference to Part E of the AWL checklist[1]) is outlined below in Table 1-1, which includes reference to the report section where the information resides.

1.2 Report Structure

This report is structured as follows:

- Section 1 presents the Project background and AWL requirements;
- Section 2 presents a summary of the geology and hydrogeology of the Project site, including a summary of groundwater level data, hydraulic conductivity data, and the drilling/construction of groundwater monitoring bores for the CNE Project';
- Section 3 presents the setup and results of groundwater modelling that was undertaken to support the Project's State and Federal approval applications;
- Section 4 presents discussion of the groundwater impacts from mining, including impacts on existing groundwater users, cumulative impacts, impacts on groundwater quality and potential impacts to groundwater dependent ecosystems; and,
- Section 5 presents a summary and conclusions of the report.

[1] Application for an associated water licence, Part E Minimum Requirements Checklist. Form W2F154-v4, Department of Natural Mines and Resources, Queensland Government, 2019.

Table 1-1: Requirements of AWL and Report Section

Checklist Section	Requirement	Report Section
Existing water entitlements and authorities to take or interfere with water	Identify all other water users through a recent bore census	4.1.2
	Submission of a hydrological report, which includes a detailed underground water model and details predicted impacts of the take of underground water on other underground water and surface water users, including cumulative impacts	3.0 (Groundwater Modelling) 4.0 (Groundwater Impacts)
Information about the effects of taking, or interfering with, water on natural ecosystems	Detailed information on any interactions between groundwater and surface water systems, and any ecosystems linked to those systems.	4.4
	Information related to any groundwater dependent ecosystems (GDE's)	4.4
	Detailed information on predicted impacts and risks to those ecosystems from the take of underground water	4.4
Information about the effects of taking, or interfering with, water on the physical integrity of watercourses, lakes, springs and aquifers	Details on the predicted impacts on the function of an aquifer, such as impacts on recharge and groundwater flow.	3.8
Strategies for the management of impacts on underground water, including the impacts of dewatering	A copy of the groundwater monitoring program reviewed and approved by a suitably qualified person, which meets, but is not limited to, the following objectives: • to provide for the monitoring of impacts on any springs and watercourses dependent on underground water flow • to provide for the monitoring of impacts on other underground water users • to provide for underground water level monitoring in all identified geological units across and adjacent to the mine site • to estimate underground water inflow to, and take from, mine workings • to provide for the refinement and validation of the numerical underground water model used to assess impacts.	Attachment B
	Details of all make good and/ or other mitigation measures, including the dates of any agreements and details of water bores subject to agreements	4.3

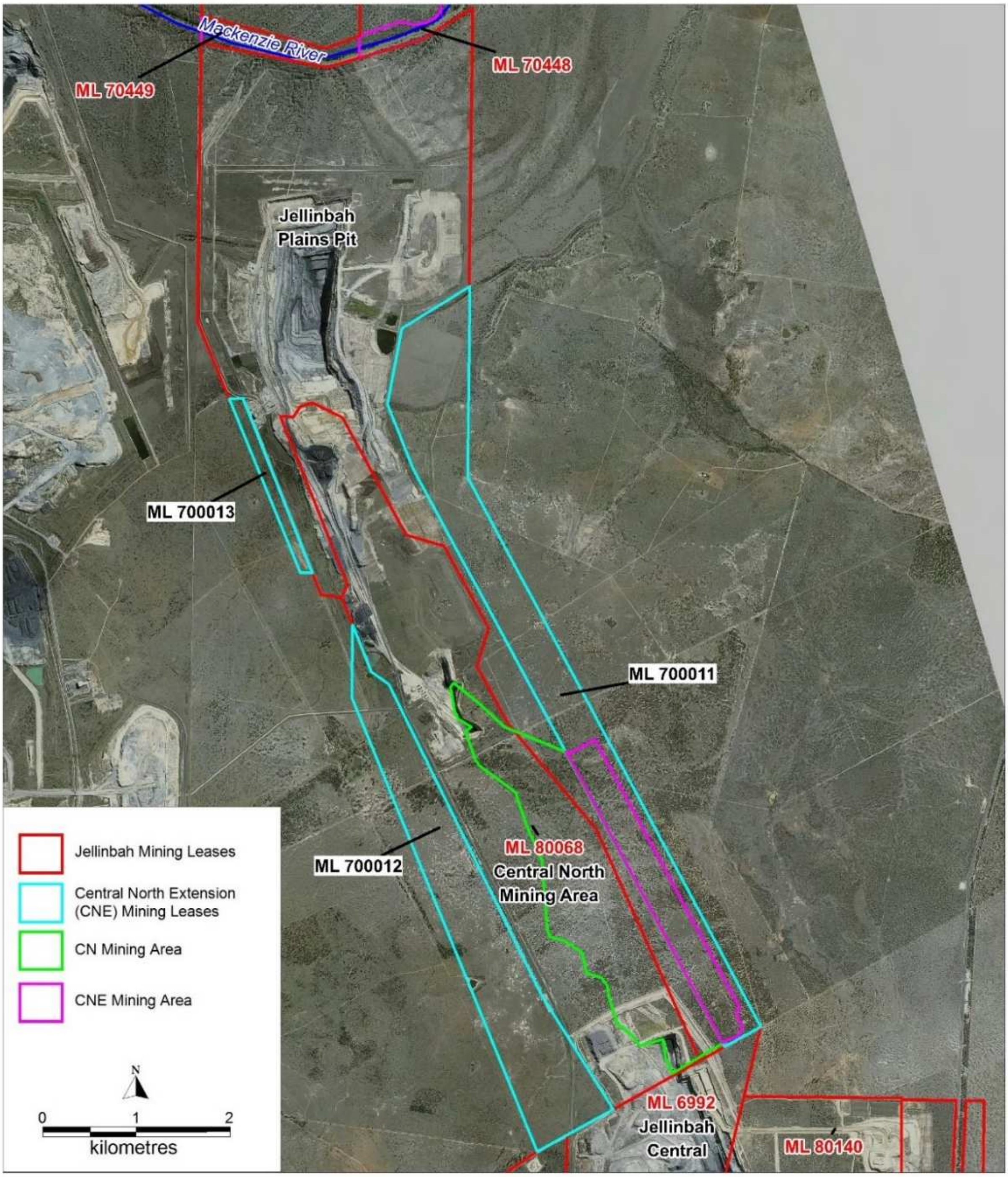

Figure 1-1: Project Layout

2.0 GEOLOGY AND HYDROGEOLOGY

2.1 Regional and Site Geology

Regional and site geology is described below and is summarised in Table 2-1. Figure 2-1 shows the project location in relation to 1:100,000-scale surface geology. Figure 2-2 shows the project location in relation to the underlying Bowen Basin solid geology (i.e. the surficial unconsolidated Quaternary and Tertiary units have been removed, revealing the relationship between the underlying Triassic and Permian sediments as well as the prevalence of regional-scale faults). With reference to Figures 2-1 and 2-2 it is observed that:

- The open cut mines are developed in areas where the Rangal Coal Measures subcrop beneath the Tertiary cover, i.e. mining is undertaken in areas where the coal measures are shallowest. The dip of the coal seams is to the east or southeast, so that the CNE extends mining down-dip from the CN mining area;
- The Jellinbah mines are situated within the Jellinbah Thrust Belt, which lies between the Jellinbah fault to the west and the Yarrabee Fault to the east; the faults act to compartmentalise the various groundwater units in the project area.

Site and regional stratigraphy includes:

- Quaternary-age alluvium associated with current surface drainage features such as Blackwater Creek, Twelve Mile Creek and the Mackenzie River;
- Tertiary deposits comprising mudstone, sandstone, siltstone and conglomerate of the Duaringa Formation, as well as sediments that are derived from Tertiary weathering and remobilisation of older units;
- Triassic sediments of the Rewan Group, which comprise lithic sandstone and green to reddish brown mudstone and which occur in the eastern area of the CNE; and,
- Coal-bearing sediments of the Late Permian Blackwater Group, including the Rangal Coal Measures, which contains the target coal seam for mining within the CNE (Pollux Seam).

Table 2-1: Summary of Regional Geology

Age	Unit	Description	Thickness (m)
Quaternary	-	Unconsolidated soil, silt clay, sand and gravel associated with current surface drainage systems, e.g. Blackwater Creek and Mackenzie River	0 to 50 m
Tertiary	Duaringa Formation and residual units	Mudstone, sandstone, conglomerate, siltstone	0 to 30 m
Triassic	Rewan Group	Lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanilithic pebble conglomerate at base	0 to 100 m+
Late Permian Blackwater Group	Rangal Coal Measures	Feldspathic and lithic sandstone, carbonaceous mudstone, siltstone, tuff and coal seams. Includes the Pollux Coal Seam, which is the target coal seam for mining within the CNE	0 to 100 m+ Aries Seam – 0 to 1 m Castor Seam – 0 to 1 m Pollux Seam - ~10 m
	Burngrove Formation	Mudstone, siltstone, sandstone, coal, tuff	0 to 90 m
	Gyranda Formation	Siltstone and shale with minor tuff and volcanilithic sandstone and rare coal (lower part - Banana Formation); calcareous sandstone, mudstone and siltstone (upper part - Wiseman Formation)	0 to 500 m+

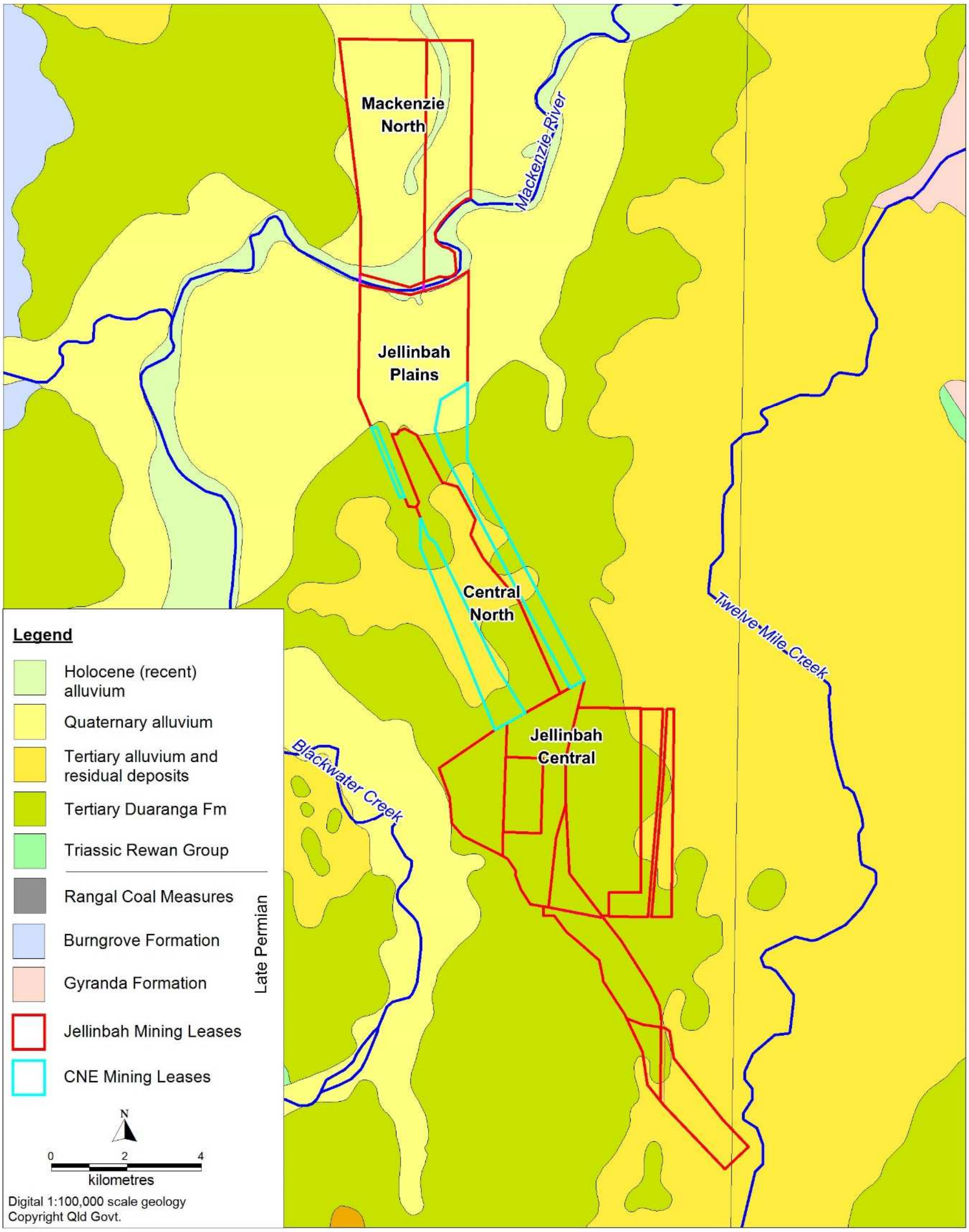

Figure 2-1: Project Location and Surface Geology (1:100,000 Scale Digital Geology)

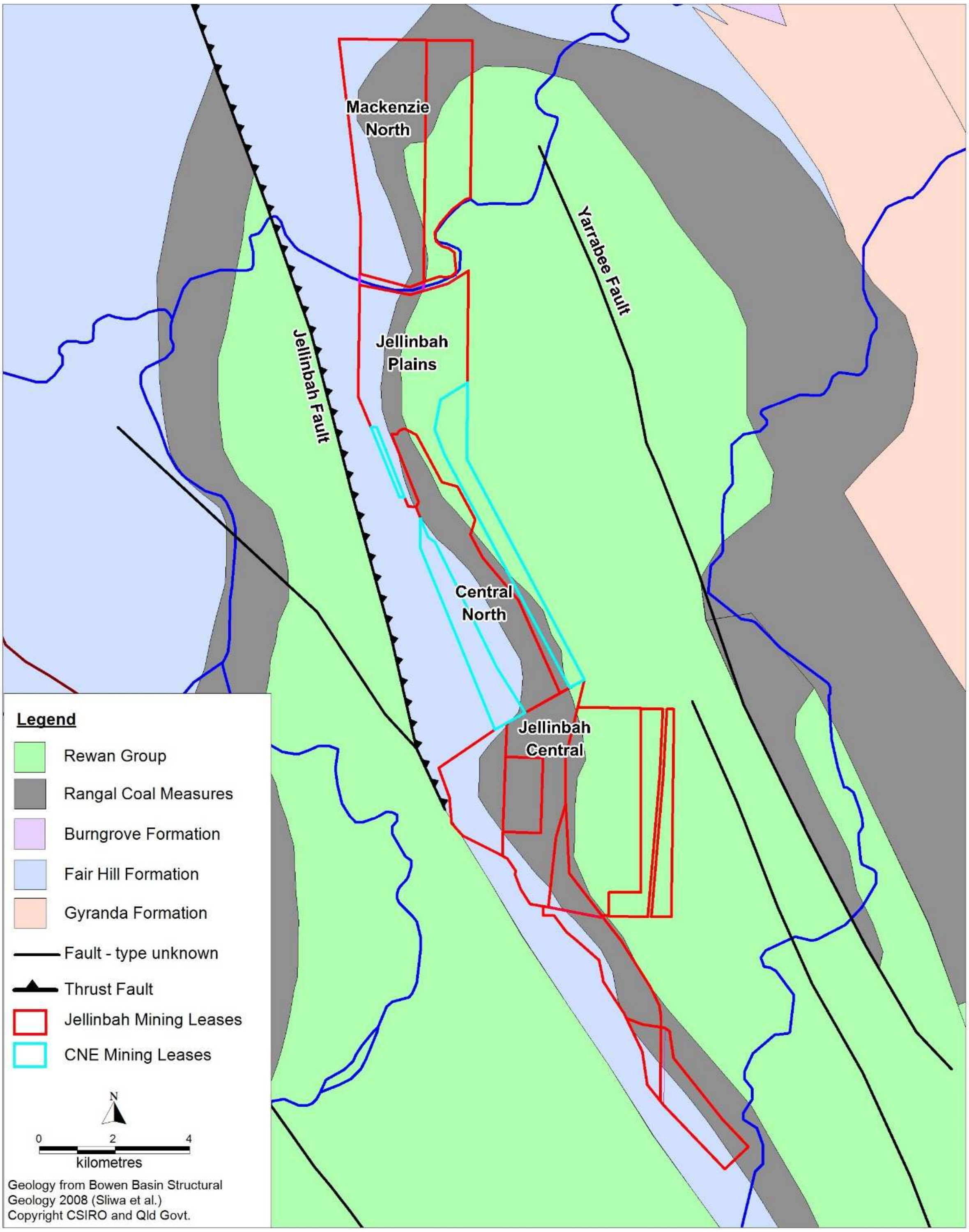

Figure 2-2: Project Location and Bowen Basin Solid Geology

2.2 Hydrogeology

2.2.1 Groundwater Occurrence

Two main groundwater-bearing units have been identified in the Jellinbah mining area, including:

- Quaternary alluvium, which is associated with prior channels and flood deposits of the Mackenzie River (to the north). In part due to the presence of water supply structures (e.g. Bingegang Weir upstream of the Jellinbah mining area and Tartrus weir downstream) the Mackenzie River tends to be a perennial stream adjacent to the Jellinbah mining area. Quaternary alluvium is encountered in the northern section of the Jellinbah Plains operation (Figure 2-1), but there are no Quaternary alluvial deposits within the Central North or Central North Extension mining areas.

  Quaternary alluvium is also associated with ephemeral streams such as Blackwater Creek (to the west of the Jellinbah mining area).

  It is noted that Twelve Mile Creek (to the east of the Jellinbah mining area) is mapped as occurring within Tertiary alluvium and residual deposits (Figure 2-1) and has no mapped Quaternary alluvium at 1:100,000 scale. From discussions with environmental personnel (AARC pers. comm.) it is understood that Twelve-Mile Creek is a minor drainage feature and has no associated riparian vegetation.

- Permian Coal Measures, which comprise interbedded siltstone, sandstone, shale (interburden) and coal. The Permian interburden is hydrogeologically “tight” and hence very low yielding, with the majority of groundwater storage and movement occurring within the coal seams (AGE 2016). Faults at site are generally identified as dry (AGE 2016 in discussion of Boyd 2015). It has been observed from face mapping within the Jellinbah Central Pit that faults and joints can act as conduits for water flow; however, this is interpreted to be related to the relaxation of the strata and associated structures adjacent to the pit, with the source of the water being predominantly surface water infiltration in the zone adjacent to the pit crest.

2.2.2 Groundwater Levels

Groundwater level data for the Jellinbah mining area south of the Mackenzie River is available from two sources, including:

1. Long-term monitoring of bores adjacent to the Mackenzie River, which is undertaken as part of the environmental authority (EA) conditions of the operation. Bores that are monitored are shown on Figure 2-3 and include:
   - MSP0209 (Mackenzie River alluvium), with the bore screened from 31-34 metres below ground level (mbgl)
   - MSP0213 (Mackenzie River alluvium), with the bore screened from 35-38 mbgl;
   - JMR026WA (Mackenzie River alluvium), with the bore screened from 18.2-21.2 mbgl
   - JP0911T and JP0912T (Tertiary sediments), with the bores screened from 22-28 mbgl and 36-42 mbgl respectively; and,
   - MS0203 (Pollux Seam), with the bore screened from 42-48 mbgl. This bore is located adjacent to MSP0213 and therefore monitors the Pollux Seam at a location where the seam subcrops beneath the alluvium.

Bore hydrographs are shown in Figure 2-4. From review of the bore hydrographs it is interpreted that:

- The alluvium is directly recharged by rainfall, as evident from the water level increase in 2010/2011 that shows a direct correlation with the rainfall residual mass curve (RRMC);
- The Pollux Seam is directly recharged by the alluvium at this location (i.e. this is a recharge location for the Permian coal measures) as the water level and water level response is almost

identical for bore MS0203 (Pollux Seam) and bore MSP0213 (overlying alluvium at the same location); and,

- The waters level in the alluvium and Pollux Seam tend to follow the trend of the RRMC, which indicates a direct response to rainfall recharge. However, a downward trend in water levels is evident in data post 2016, at a time when a sharp increase in the RRMC is recorded due to above-average rainfall; this is interpreted to indicate that groundwater seepage is occurring towards the advancing Jellinbah Plains Pit.
- In September 2017 the monitoring of bores JMR26WA (alluvium) and JP0911T and JP0912T (Tertiary sediments) commenced. JMR26WA is dry, while the water levels in JP0911T and JP0912T are showing a downward water level trend that is interpreted to be related to a combination of climatic conditions (below-average rainfall) and mining at the nearby Plains Pit.

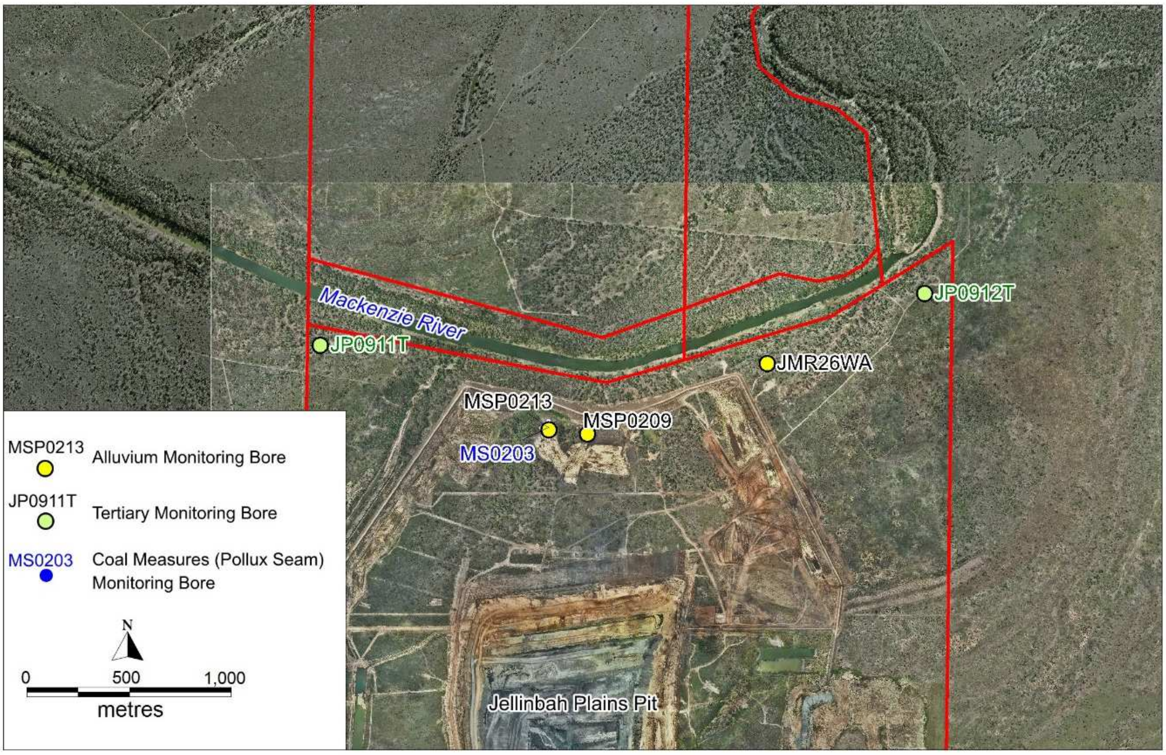

Figure 2-3: Location of Groundwater Monitoring Bores at Plains Pit

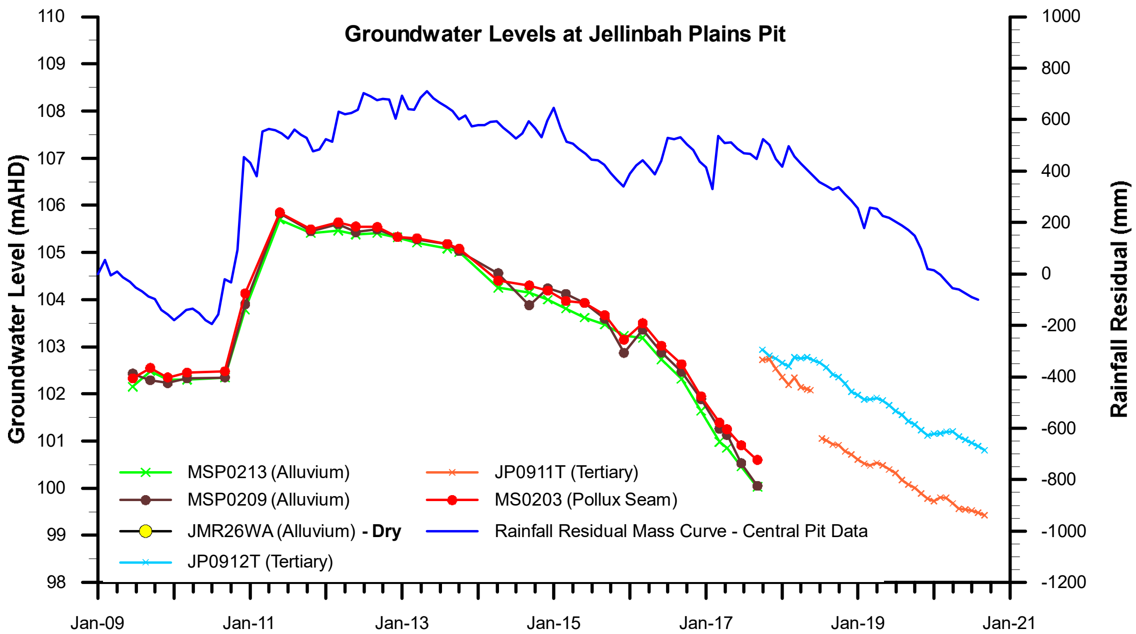

Figure 2-4: Hydrographs for Plains Pit Monitoring Bores

2. Water levels from exploration bores within the Central North (CN) and Central North Extension (CNE) lease areas, collected from a site visit undertaken by JBT in December 2015, are shown below in Figure 2-5. It is noted that the water levels are “bulk” water levels from the entire open sequence that has been intersected by the bores. However, the water levels are instructive in that they indicate a water level at this location of approximately 40 – 50 metres below ground level (mbgl) in this area. From review of bore logs for bores within the CNE lease area it is observed that:

   - The base of Tertiary occurs at depths between 8 mbgl (bore JPS0001) and 25 mbgl (bore JPS0005) in the CN area;
   - The recorded water level is within the Permian coal measures in overburden just below the base of weathering, or in the case of bore JPS0003, the water level is at 49.98 mbgl, which is below the bases of the Aries Seam (43.6 mbgl). The Tertiary sediments are therefore interpreted to be dry in the CN and CNE areas.

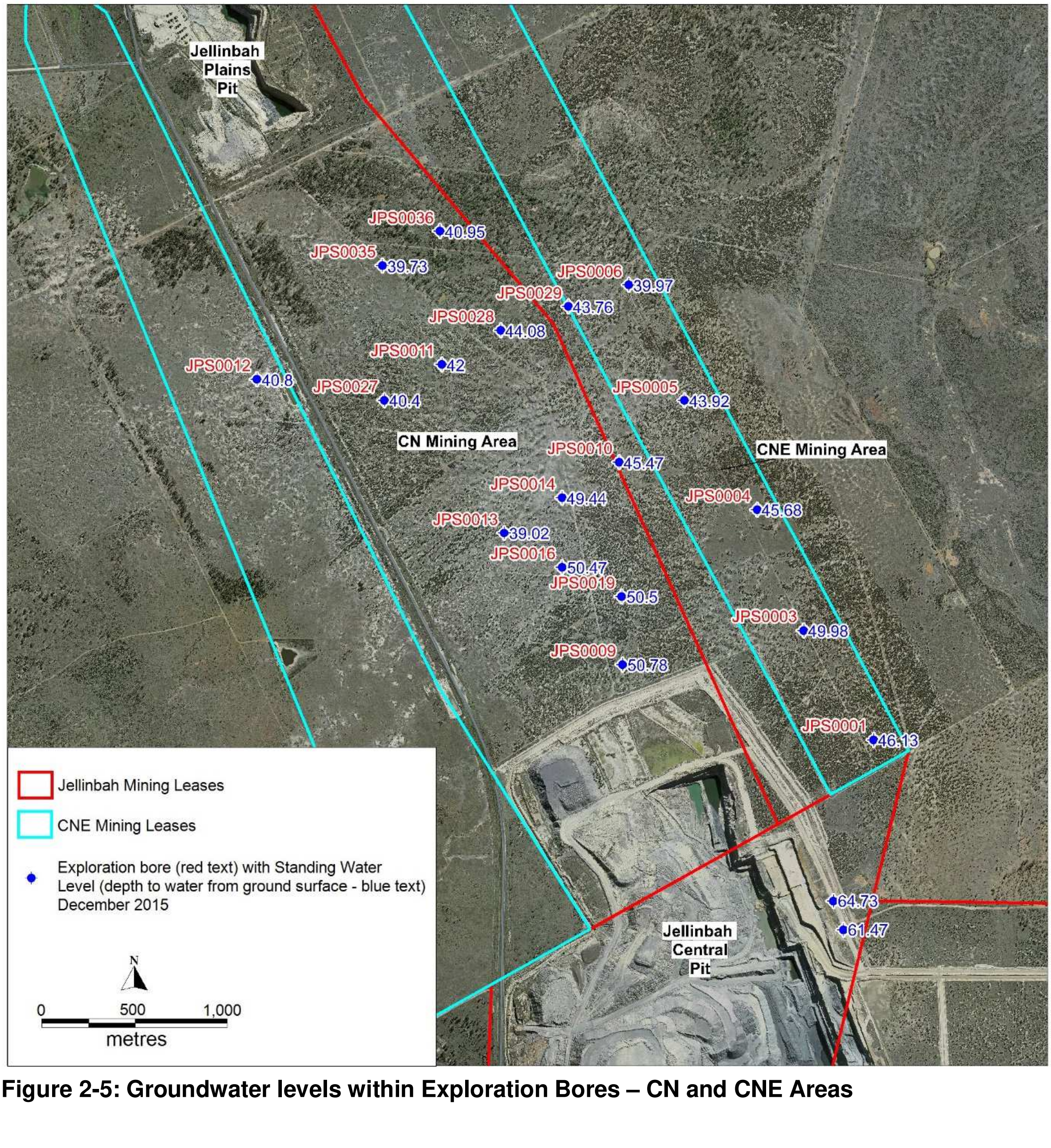

Figure 2-5: Groundwater levels within Exploration Bores – CN and CNE Areas

2.2.3 Groundwater Monitoring Bores at CNE

Following liaison with DNRME, groundwater monitoring bores were drilled and constructed at three locations adjacent to the CNE project area. The bores have been constructed as vibrating wire piezometer (VWP) bores, which allow the recording of groundwater level data at a number of vertical locations within the same bore. All bores include five VWP sensors and the same intervals are targeted in each bore, i.e.:

- The Aries coal seam
- The interburden between the Aries Seam and the Pollux Upper Seam
- The Pollux Upper seam
- The Pollux Lower Seam; and,
- The sandstone/siltstone immediately below the floor of the Pollux Lower Seam

All bores have been fitted with a datalogger to allow logging of VWP water level data at daily intervals.

Bore construction details are shown below in Table 2-2, with bore locations shown in Figure 2-6. Bore construction logs are included in Attachment A.

Table 2-2: Groundwater Monitoring Bore Construction Details

Bore Number	Easting (GDA94	Northing (GDA94)	Collar Elevation (mAHD)	Sensor Depth (mbgl)	Target Unit
JC0894P	700352	7415159	148.58	75.5	Aries Seam
				90	Interburden between Aries Seam and Pollux Upper Seam
				102	Pollux Upper Seam
				141.5	Pollux Lower Seam
				145	Siltstone below Pollux Lower Seam floor
JPS0197P	699602	7416893	146.95	90.5	Aries Seam
				104	Interburden between Aries Seam and Pollux Upper Seam
				137	Pollux Upper Seam
				163	Pollux Lower Seam
				165.5	Siltstone below Pollux Lower Seam floor
JP0963P	697508	7420035	138.94	123	Aries Seam
				135	Interburden between Aries Seam and Pollux Upper Seam
				167	Pollux Upper Seam
				196	Pollux Lower Seam
				200.5	Siltstone below Pollux Lower Seam floor

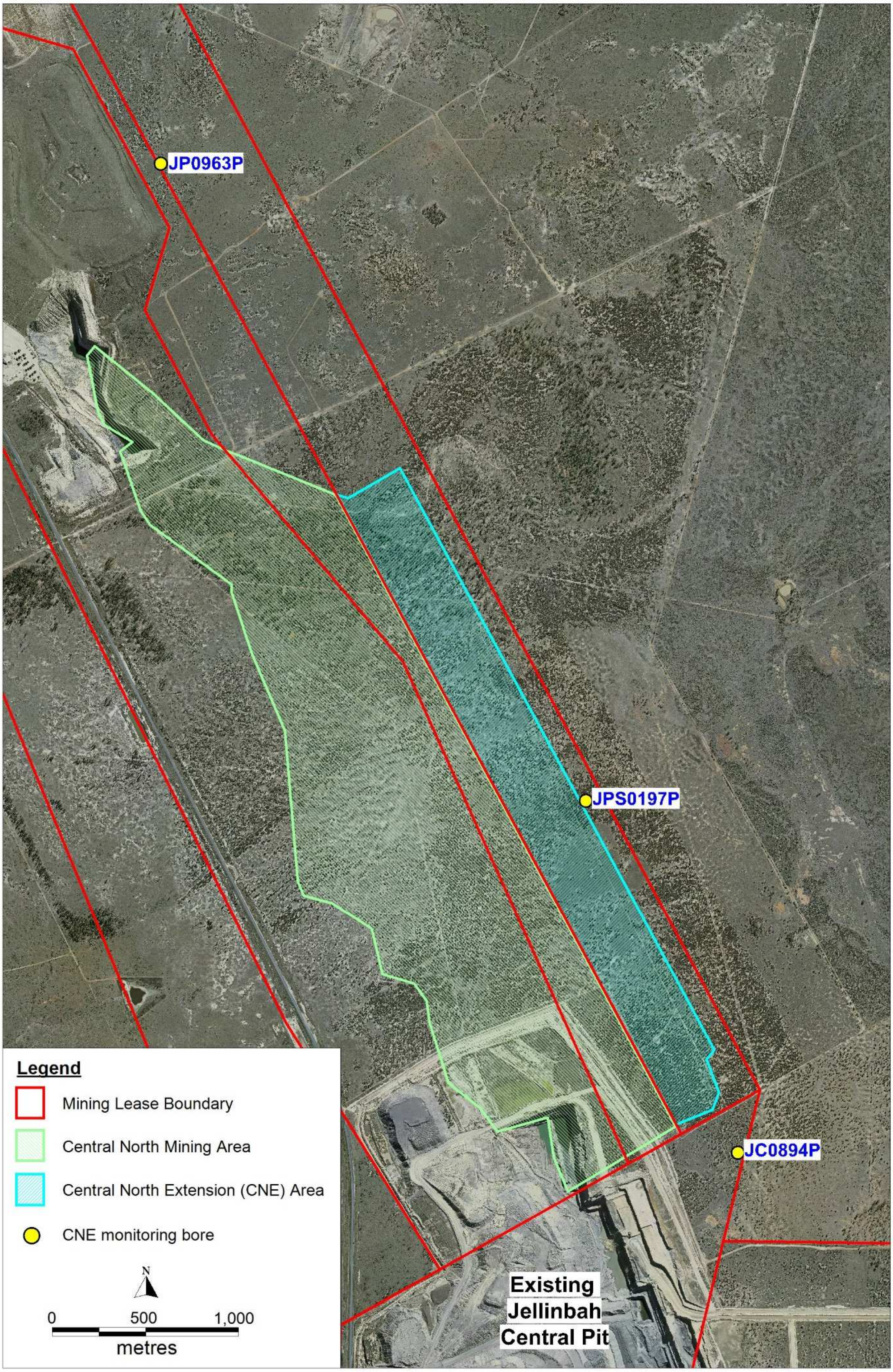

Figure 2-6: Locations of CNE Groundwater Monitoring Bores

2.2.4 Hydraulic Conductivity Data

A total of 11 falling head tests were undertaken on monitoring bores for the Mackenzie North groundwater project (AGE 2013). Of the 11 bores, five were screened within the alluvium, three in the Pollux Seam and three into sandstone interburden. Summary hydraulic conductivity (K) data is shown below in Table 2-3, which indicate that the K of:

- alluvium ranges from 0.7 m/day to 3.7 m/day, with a geometric mean of 1.2 m/day;
- interburden sequences range from 0.06 m/day to 0.8 m/day, with a geometric mean of 0.1 m/day; and,
- coal seams (Pollux Upper) ranges from 0.005 m/day to 0.1 m/day, with a geometric mean of 0.014 m/day. AGE (2013) note that the lowest K occurs in the deepest bore and infer that the K of the groundwater units decreases with increasing depth.

Table 2-3: Summary of Hydraulic Conductivity Data – Mackenzie North (After AGE 2013)

Bore	Groundwater Unit	Hydraulic Conductivity (K)	
		m/day	m/second
JMR4WA	Alluvium	0.7	8.1E-06
JMR21WA	Alluvium	0.7	8.1E-06
JMR25WA	Alluvium	3.7	4.3E-05
JMR26WA	Alluvium	1.3	1.5E-05
JMR23WA	Alluvium	0.9	1.0E-05
Geometric Mean		1.2	1.3E-05
JMR4WP	Pollux Upper	0.1	1.2E-06
JMR15WP	Pollux Upper	0.006	6.9E-08
JMR22WP	Pollux Upper	0.005	5.8E-08
Geometric Mean		0.014	1.7E-07
JMR16WP	Pollux Upper & Siltstone	0.02	2.3E-07
JMR17WP	Interburden	0.8	9.3E-06
JMR24WP	Interburden	0.06	6.9E-07
Geometric Mean		0.10	1.1E-06

Figure 2-7 presents the range of hydraulic conductivity values for each aquifer type north of the Mackenzie River (Mackenzie North investigation, AGE 2013) as well as south of the Mackenzie River (ERM 2012). The major observations from review of Figure 2-7, as well as subsequent monitoring data, include:

- The Mackenzie River alluvium is more permeable on the southern side of the Mackenzie River than the northern side; and,
- The hydraulic conductivity (K) of the Pollux Seam is at the upper end of the K range on the southern side of the river (data from ERM 2012); however, it is noted that the coal seams were shallow at the locations tested by ERM and that the K is likely to be higher in shallow subcrop locations.

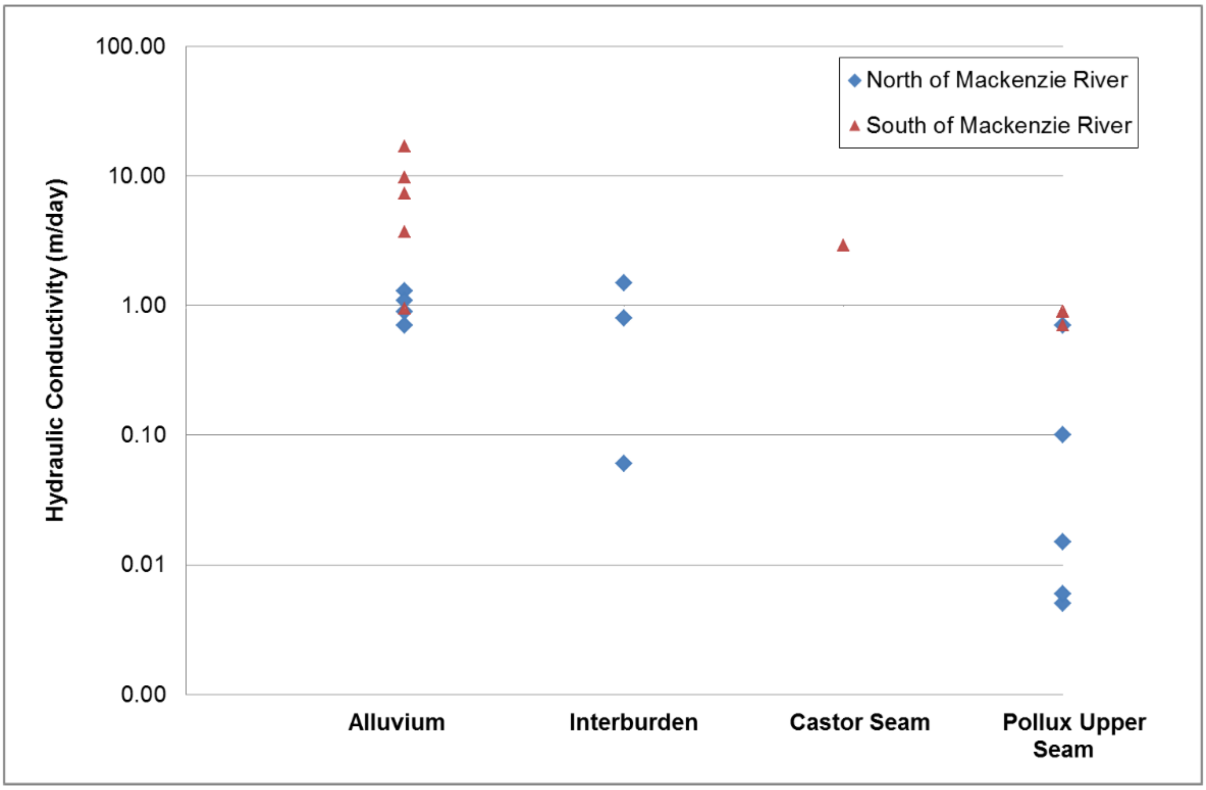

Figure 2-7: Comparison of Hydraulic Conductivity for Data North and South of Mackenzie River (Source: AGE 2013)

2.3 Conceptual groundwater model

Essential elements of the conceptual model that have informed numerical modelling include:

- The Tertiary deposits within the project area comprise mainly sediments of the Duaringa Formation and high-level Tertiary alluvial deposits. The thickness of the Tertiary sediments within the Project ranges from approximately 8 – 25 m. Exploration drilling and monitoring data indicates that the Tertiary sediments in the area of the CNE are dry and that the water level is generally below the base of weathering but generally above the upper coal seam. Therefore, conceptually, the base of weathering is regarded as the depth below which all units at site are saturated (i.e. the phreatic surface occurs at approximately the depth of the base of weathering);
- Recharge to Tertiary sediments is via direct rainfall recharge. The porosity/ permeability of the Tertiary sediments is variable, therefore rates of recharge through the sediments are also variable;
- Quaternary alluvium is associated with drainage features such as the Mackenzie River (to the north), Blackwater Creek (to the west). The Quaternary alluvium is directly recharged by rainfall. The degree of connectivity between the Quaternary alluvium and the Mackenzie River is uncertain. There is no quaternary alluvium within the area of Central North or the CNE;
- The coal seams are recharged primarily in subcrop areas, where the coal seams directly underlay Tertiary and/or Quaternary sediments (for example, where the Pollux Seam underlays alluvium in the Jellinbah Plains mining area);
- The interburden (sediments between the coal seams) are less permeable that the coal seams, therefore the coal seams are the primary conduit for groundwater flow within the coal measures;

- Faults will tend to allow groundwater flow across the fault if more permeable units are connected (such as coal seam to coal seam), and will tend to act as barriers to flow if a conductive unit such as a coal seam is terminated against lower permeability interburden material.

3.0 GROUNDWATER MODELLING

3.1 Choice of Numerical Model

To estimate the extent of water level impact from the proposed project, 2-dimensional seepage modelling has been undertaken using the program Seep/W. The choice of model code has been based on an assessment of the model platform that would be appropriate to the study requirements.

A number of factors are assessed when choosing the appropriate modelling platform for a particular groundwater modelling study. Factors that are relevant to the CNE study include:

- The ability of the model to represent the essential elements of the conceptual groundwater model. At CNE this includes the ability of the model to accurately represent the complexity of the geology including faulting of strata, which acts to compartmentalise the geological and hydrogeological units, as faulting has the potential to significantly impact groundwater occurrence and flow; and,
- The ability of the model to adequately address the requirements of the scope of work. At CNE this includes assessment of the extent of groundwater level impact from mining, as well as assessment of the potential impact of groundwater level changes on any connected surface water and groundwater dependant ecosystems.

Based on assessment of the model requirements, including representation of the essential elements of the conceptual groundwater model, it was concluded that 2-dimensional cross-section modelling would be appropriate for the CNE project and on that basis the model Seep/W was selected. The use of a 2-dimensional Seep/W cross-section model was assessed to be appropriate to this investigation for the following reasons:

- The geology of the mining area is complex, and includes a number of regional-scale faults which significantly disrupt the strata (refer Figure 2-2 for solid geology). It is possible within a 2-dimensional model to reproduce complex cross-sectional geology, whereas such detail could not be included practically within a 3-dimensional model;
- Seep/W is designed to simulate flow in both the saturated zone and the unsaturated zone. When mining occurs below the phreatic surface[2] an unsaturated zone is induced in the pit walls as seepage to the excavation occurs. Seep/W is well suited to investigation of groundwater level impacts resulting from seepage to open pits, particularly for projects such as CNE where mine dewatering via bores does not occur, and seepage to the excavation is the only means via which the mine removes water from the groundwater system;
- In open cut mines groundwater storage conditions transition from confined to unconfined in the zone adjacent to the pit walls. Seep/W models the rate of drainage to an excavation via a property called the volumetric water content (refer Section 3.4.2), which is able to accurately account for the rate of groundwater flow and the rate of change of the phreatic surface as groundwater conditions transition from confined to unconfined and gravity drainage of groundwater occurs to the excavation. Seep/W is able to model this important element of the groundwater system much more accurately than other groundwater flow models (such as Modflow);

[2] The phreatic surface is a line of zero pore water pressure below which all pore spaces are saturated with water, and is analogous to the water table. The term phreatic surface is used throughout this report for consistency with Seep/W modelling terminology.

- One of the main purposes of the model is to investigate the rate and extent of groundwater level drawdown in response to mining, especially in areas of potentially connected surface water and groundwater systems. This can be readily (and potentially more accurately) achieved through the use of a 2-dimensional cross-section models;
- The use of 2-dimensional models is valid in cases where the section can be oriented along a groundwater flow line so that all groundwater flow is along the section rather than across it. In open-cut mines where mining occurs below the water table, groundwater flow towards the excavation tends to dominate over the previous regional flow patterns, making it possible to orient a section along a groundwater flow line. Therefore the use of 2-dimensional cross-section models is assessed to be valid for the purposes of this investigation.

It should be noted that it is not argued that a 2D (SEEP/W) model is inherently better than a 3D (e.g. MODFLOW) model for predicting drawdown, rather that the 2D model is appropriate to the assessment of impacts due to the CNE, for the following reasons (in addition to those listed above):

- The CNE represents a minor expansion of an existing mine (Central Pit) and already approved operation at Central North (CN);
- The CNE occurs to the east of the CN mining area, therefore the main area for drawdown assessment is a distinct area to the east of the CNE and it is judged that a 2D model is an appropriate tool for assessment of groundwater drawdown impacts along a west-east flow line (i.e. in the direction where assessment of potential impacts is most critical)

The selected modelling platform (Seep/W) is an industry-standard finite-element model capable of modelling groundwater movement and pressure distribution within the saturated/unsaturated zone of porous materials such as soil and rock. Seep/W has been used in this study to predict the rate and extent of change to the phreatic surface in response to the ongoing mining of the already approved Central North Mine, as well as the proposed extension of the operation into the extension area.

Two models were prepared for this study including a west-east cross-sectional model and a north-south cross-sectional model. The models are described below in Section 3.3. Other details of the models (e.g. hydraulic parameters, boundary conditions, representation of faulting etc. are discussed in subsequent sections).

3.2 Extent of Proposed mining at CNE

3.2.1 Data from Mine Block Model

Figure 3-1 shows the approved extent of mining at Jellinbah Central Pit and Central North mines, with further detail of the CN and CNE pits shown in Figure 3-2. Also shown on Figure 3-1 is the existing and/or proposed depth of mining. At Jellinbah Central Pit the current depth of mining is approximately 125 metres below ground level (mbgl), extending at full depth to approximately 225 mbgl. At Central North mine, the mine is projected to be in the order of 125 m deep. As mining progresses to the east into the CNE, the depth of mining will be approximately 145-150 mbgl.

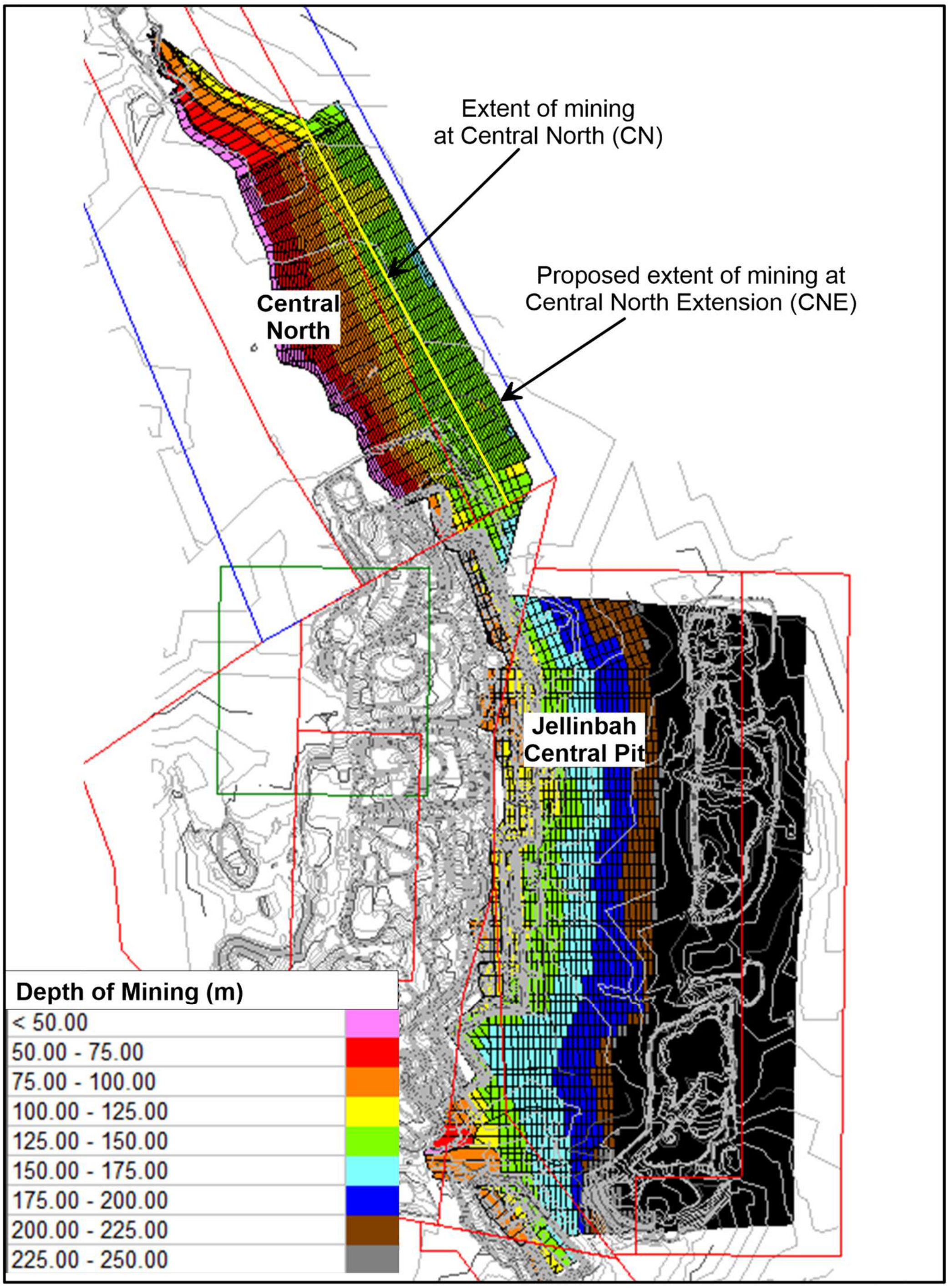

Figure 3-1: Extent of Mining at Jellinbah Central, CN and CNE Pits

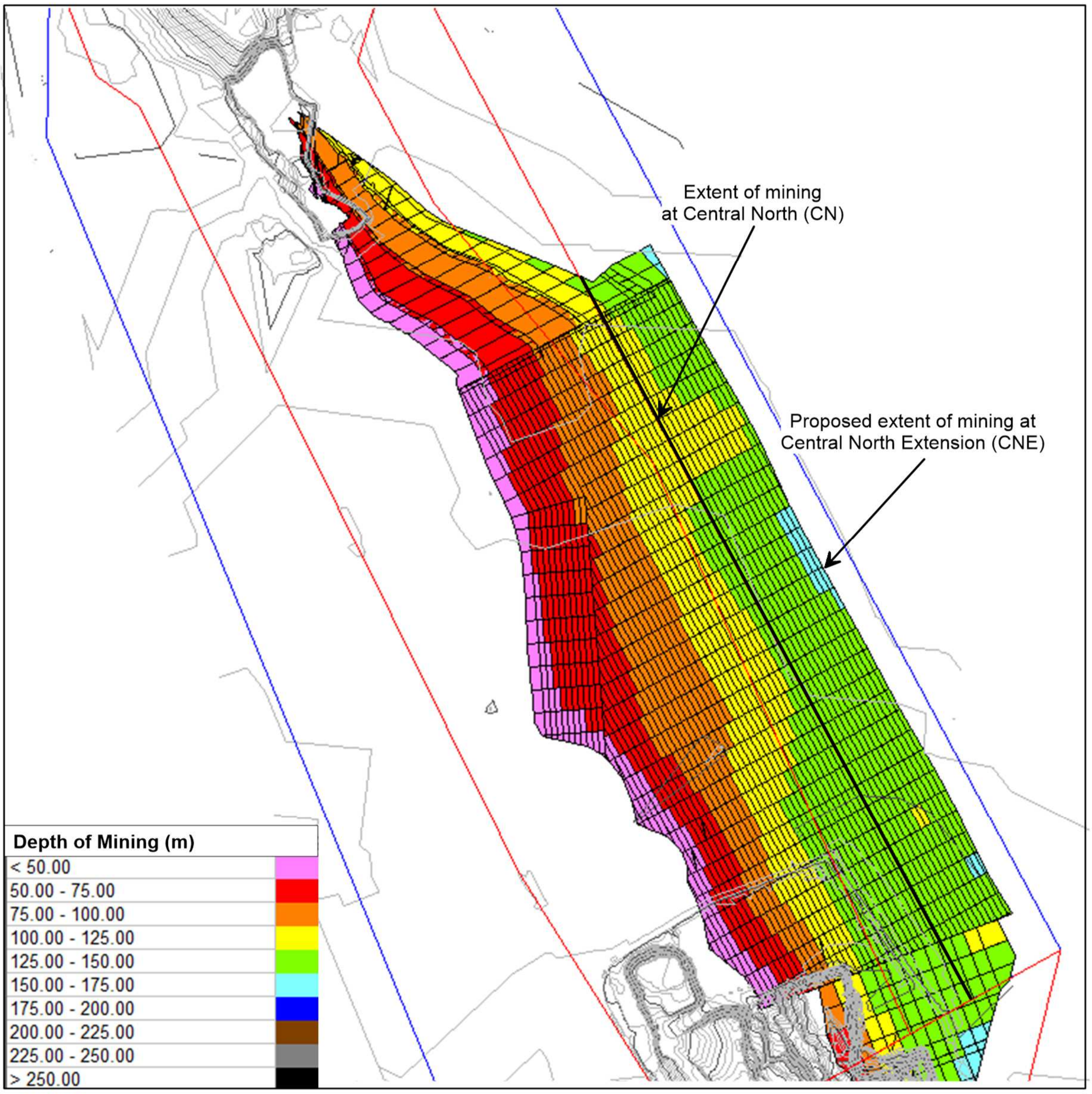

Figure 3-2: Extent of Proposed Mining at CNE vs Extent of Mining at CN

3.2.2 Geological Sections from Site Geological Model

Three west-east cross-sections were generated from the site geological model, with the sections including delineation of the extent of mining for both the CN and CNE operations. The geological cross-sections and cross-section locations are shown below in Figure 3-3. Of the cross-sections, section 2 was selected as being a representative section for inclusion in the cross-sectional groundwater model (discussed in Section 3.3). For the purpose of groundwater modelling the geology of areas to the west and east of the site geological model was interpreted from existing 1:00,000 scale surface geology (Figure 2-1) and Bowen Basin solid geology (Figure 2-2)

A long section through the CN mining area was also generated from the site geological model, with the section and section location shown below in Figure 3-4. For the purpose of groundwater modelling, the coal seams that occur to the north of the section were continued to the north to the Mackenzie River. The thickness of alluvium and coal seam depth in the area of the Mackenzie River/ northern area of Plains Pit was based on information obtained from drilling in that area, e.g. information from the groundwater monitoring bores that are discussed in Section 2.2.2.

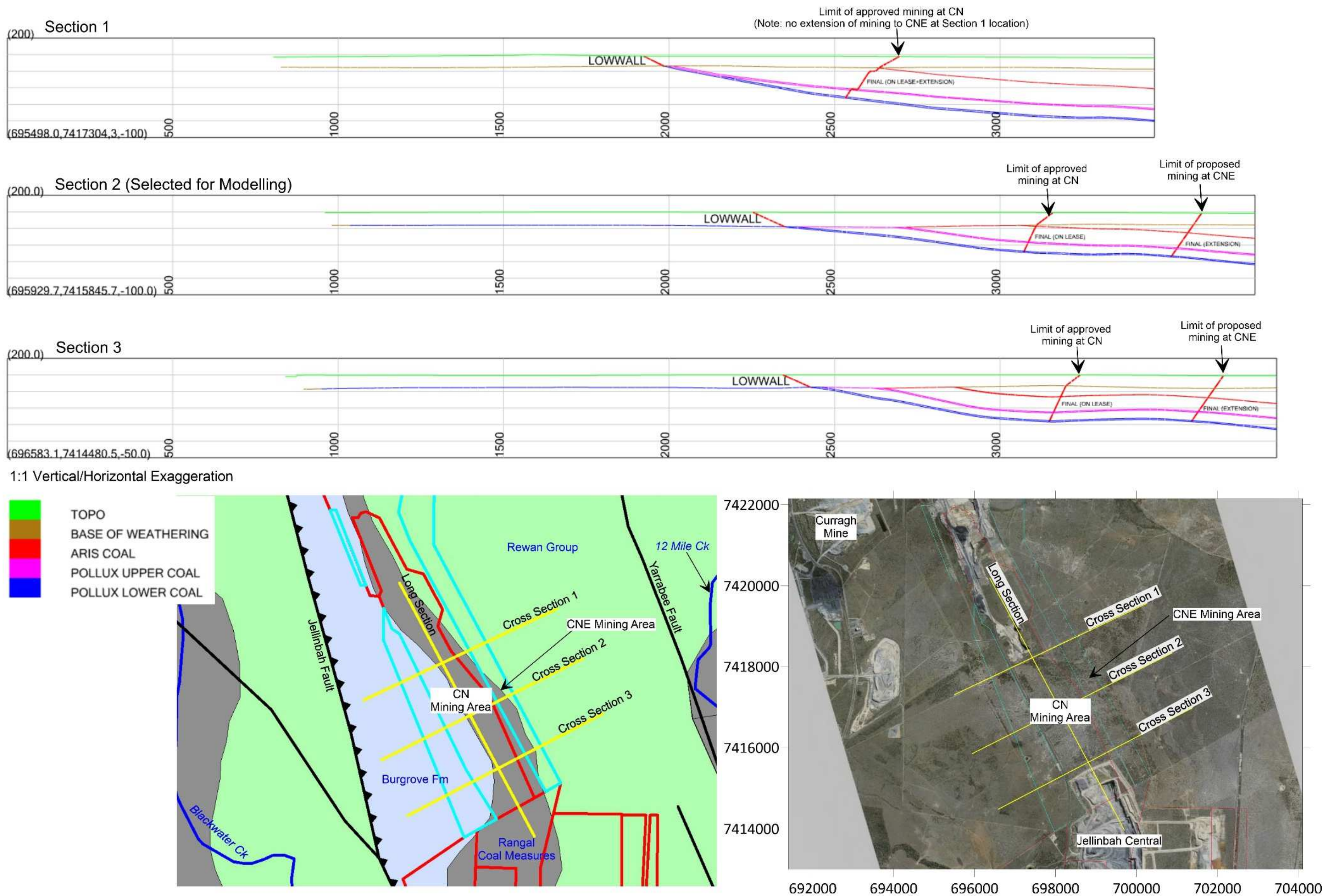

Figure 3-3: Cross-Sections from Site Geological Model

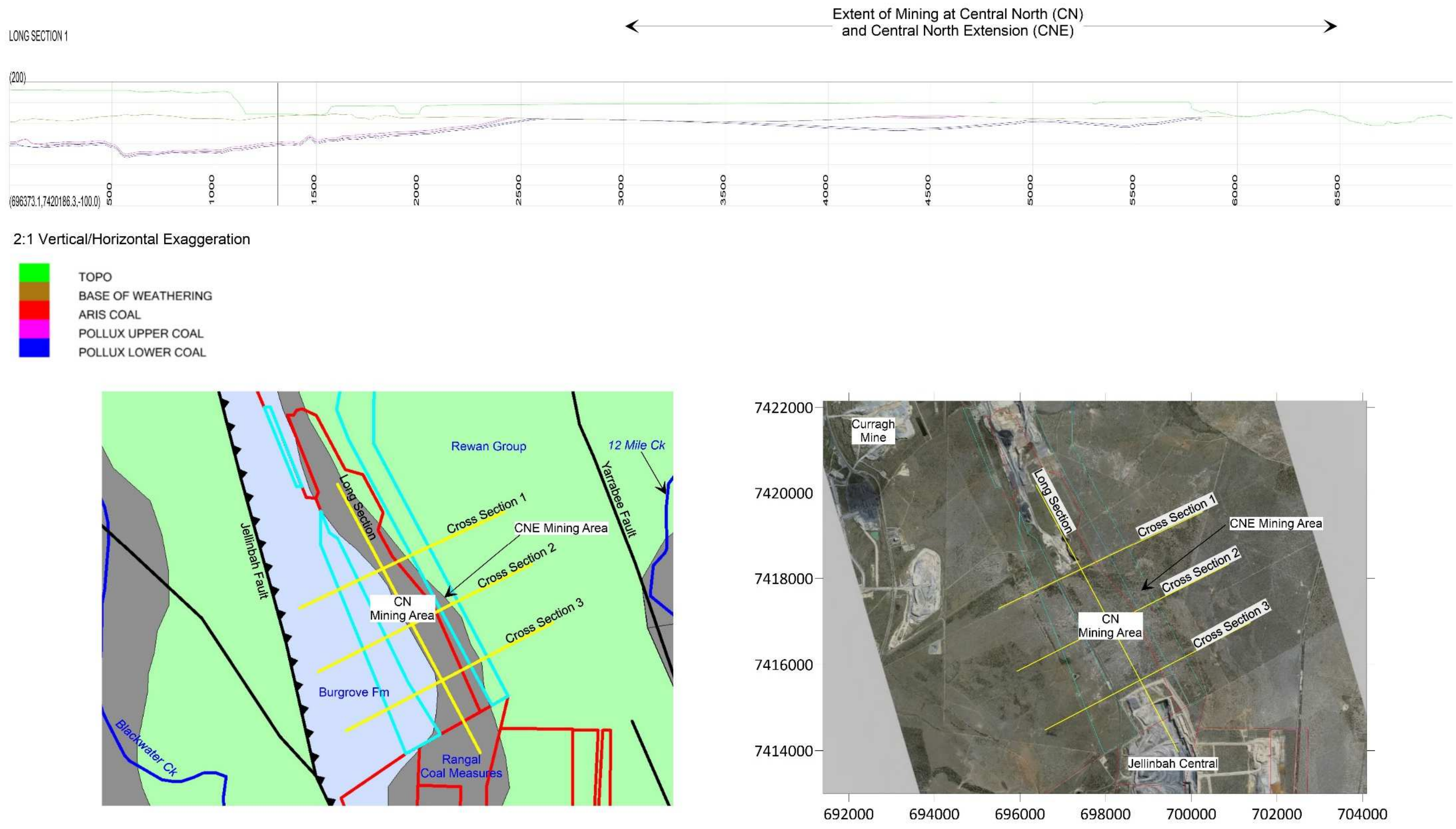

Figure 3-4: Long Section from Site Geological Model

3.3 Model Locations and Scenarios

Two models were generated for the study, including:

- Model 1 - a west-east cross-section model in the location of cross-section 2 (Figure 3-5). Details of the model construction and setup are as follows:
  - The model detail in the mining area was taken from a cross-section that was generated from the site geological model (Figure 3-3);
  - The model was extended to the east and west of the mining area by approximately 14 km in each direction to take the model boundaries beyond the location where the constant head boundary conditions would influence the model results;
  - In areas beyond the limits of the site geological model, the geology that was applied was based on interpretation of the 1:100,000-scale geology (Figure 2-1) and the Bowen Basin solid geology (Figure 2-2) and included representation of the major faults that were encountered along the section (refer Section 3.5 for discussion of faults).
  - Two scenarios were run for the cross-section model, as follows:
    - For scenario 1 the area of mining for the already-approved CN mining area was removed. The model was run for 1000 years, but it was found following model review that the drawdown had achieved steady-state by 150 years post-mining. All model results are therefore presented as drawdown at 150 years post-mining, which is taken to be post-mining equilibrium.
    - The extent of 2 m and 5 m drawdown was established for the Scenario 1 model (CN mining only) to enable comparison with the additional drawdown that would be generated from mining within the CNE;
    - For Scenario 2 the area of mining for the CNE was removed from the model, so that mining of both the CN and CNE mining areas was simulated (Figure 3-5);
  - The extent of 2 m and 5 m drawdown was established for the Scenario 2 model (CN and CNE mining included) and the results were compared with the results of Scenario 1 model, to account for the additional drawdown that is attributable to mining of the CNE.

2. Model 2 – a long section model oriented approximately north-south (Figure 3-6) that extends from the existing Jellinbah Central pit (in the south) to a location that is north of the Mackenzie River. Details of the model construction and setup are as follows:
   - The model detail in the mining area was taken from a cross-section that was generated from the site geological model (Figure 3-4);
   - The model terminates in the south at the Jellinbah Central mined void. The groundwater elevation is held constant at the southern boundary of the model at the floor elevation of the Jellinbah void;
   - The model was extended to the north by approximately 14 km to take the model boundary beyond the location where the constant head boundary conditions would influence the model results. The northern boundary of the model is also approximately 8.5 km north of the location of the Mackenzie River;
   - In areas beyond the limits of the site geological model, the geology that was applied was based on interpretation of the 1:100,000-scale geology (Figure 2-1) and the Bowen Basin solid geology (Figure 2-2);

- No mining was assumed for the area to the north of the CN/CNE mining areas. The intent of the model was to establish any additional drawdown that may be due to mining in the CNE area. However it is judged that, in reality, any significant drawdown to the north is unlikely due to the existing impacts of mining in the Jellinbah Plains area.
- Two scenarios were run for the cross-section model, as follows:
  - For scenario 1 the area of mining for the already-authorised CN mining area was removed. The model was run for 1000 years. As per the cross-sectional model (discussed above) it was found that the drawdown had achieved steady-state by 150 years post-mining; therefore, all model results are therefore presented as drawdown at 150 years post-mining, which is taken to be post-mining equilibrium. The detail of the geological section was adjusted so that the maximum depth to base of coal was 125 mbgl, to simulate the drawdown associated with the deepest area of mining in the CN mining area;
  - The extent of 2 m and 5 m drawdown was established for the Scenario 1 model (CN mining only) to enable comparison with the additional drawdown that would be generated from mining within the CNE;
  - For Scenario 2 the area of mining for the CNE was removed from the model, so that mining of both the CN and CNE mining areas was simulated (Figure 3-6). Detail from the geological section was adjusted so that the maximum depth to base of coal was 145 m, to simulate the drawdown associated with the deepest areas of mining in the CNE mining area;
- The extent of 2 m and 5 m drawdown was established for the Scenario 2 model (CN and CNE mining included) and the results were compared with the results of Scenario 1 model, to account for the additional drawdown that is attributable to mining of the CNE.

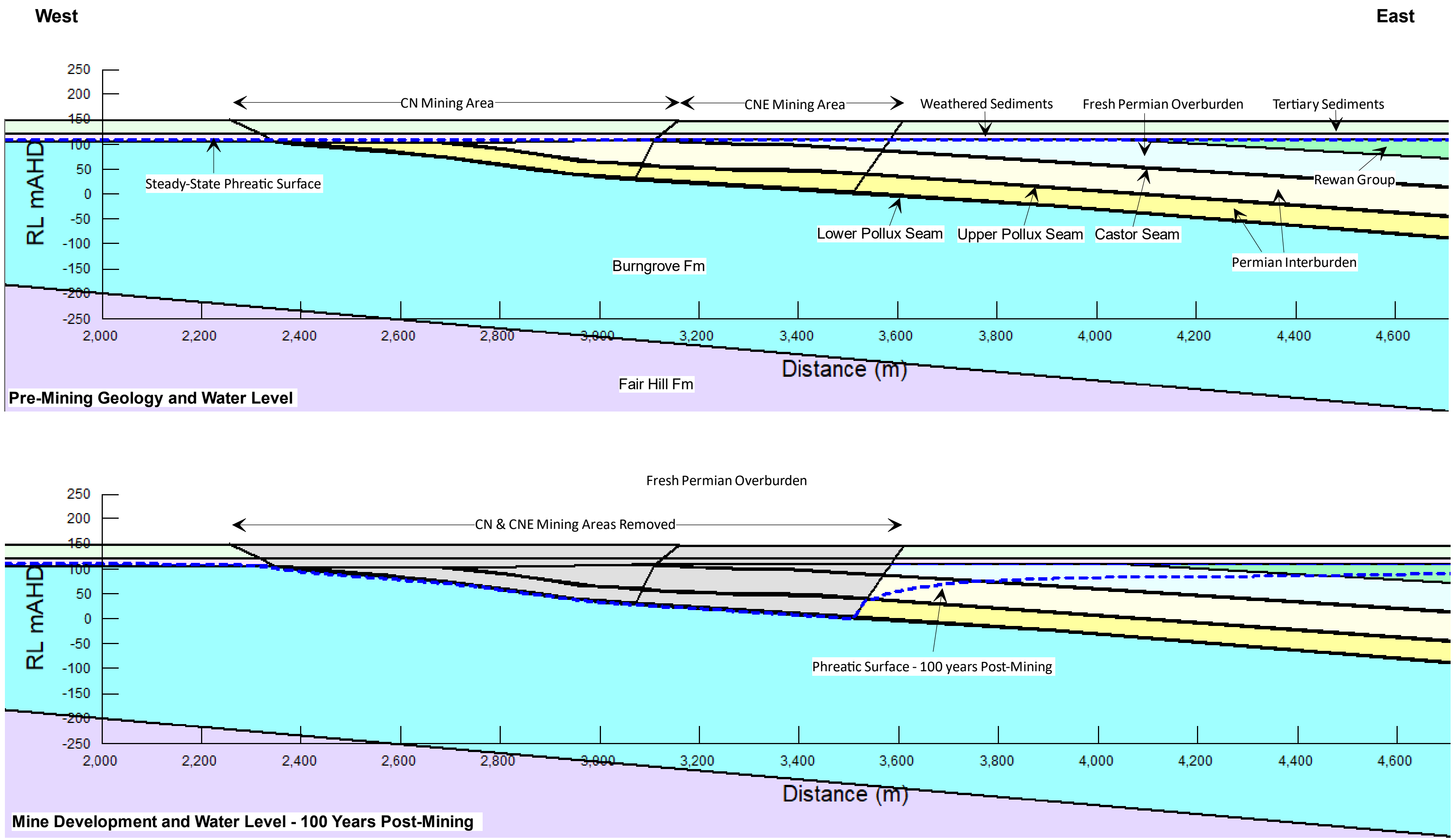

Figure 3-5: Model Detail in Mining Area – West-East Section

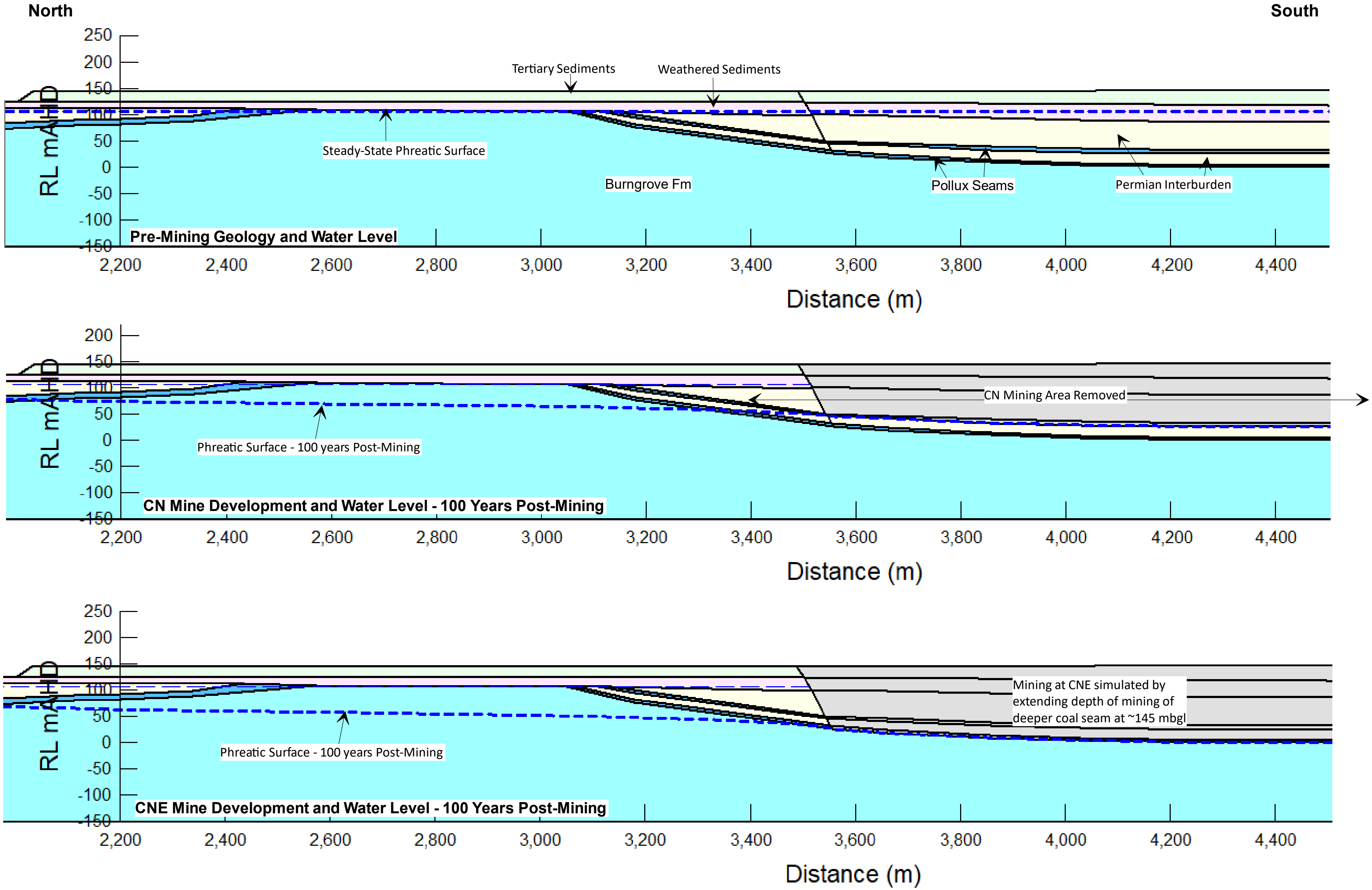

Figure 3-6: Model Detail in Mining Area – North-South Section

3.4 Hydraulic Properties

3.4.1 Hydraulic Conductivity

Hydraulic conductivity (K) data for the Seep/W model is based on calibrated model parameters for the Mackenzie North groundwater model, which is a Modflow model that was developed to support the Environmental Management Plan for the Mackenzie North Project, and which includes the area covered by the CNE project. (AGE 2013). The development of the Mackenzie North model took into consideration the site-specific parameters that were obtained during the field studies for that model and which are summarised in Section 3.7.2. The model values are provided below in Table 3-1 and the distribution of model parameters compared to field values are shown in Figure 3-7.

Table 3-1: Hydraulic Conductivity Values used in Seepage Modelling

Lithology	Hydraulic Conductivity (m/day)		Kz/Kh Ratio
	Horizontal (Kh)	Vertical (Kz)	
Mackenzie River Alluvium	7.0×10^{-1}	9.9×10^{-3}	0.014
Tertiary alluvium and residual deposits	1.0×10^{-2}	5.0×10^{-3}	0.455
Duaringa Formation	9.0×10^{-1}	1.0×10^{-2}	0.011
Rewan Group	9.4×10^{-4}	6.9×10^{-5}	0.073
Permian Overburden (weathered)	5.0×10^{-3}	5.0×10^{-4}	0.100
Permian Overburden (unweathered)	1.1×10^{-4}	5.0×10^{-5}	0.454
Castor/Aries Seams	8.0×10^{-1}	1.0×10^{-1}	0.125
Interburden 1	9.4×10^{-4}	6.9×10^{-5}	0.073
Pollux Upper Seam	8.0×10^{-1}	1.0×10^{-1}	0.125
Interburden 2	3.4×10^{-4}	1.0×10^{-4}	0.294
Pollux Lower Seam	8.0×10^{-1}	9.8×10^{-3}	0.012
Burngrove/ Fair Hill Formations	4.0×10^{-5}	1.1×10^{-6}	0.028

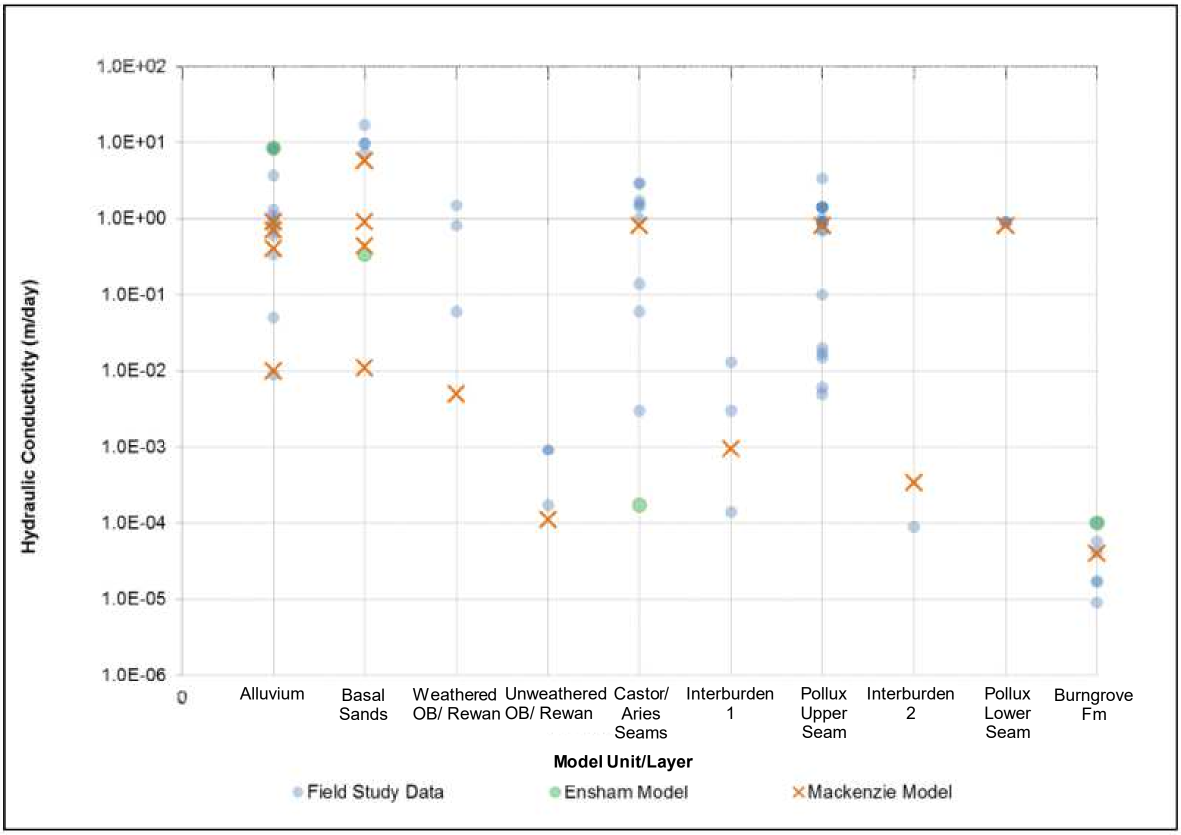

Figure 3-7: Distribution of Kh – Measured vs Modelled Values (adapted from AGE 2013)

3.4.2 Volumetric Water Content

3.4.2.1 Specific Yield

Seep/W represents the water content and drainage properties of different geological materials via a property called volumetric water content. In order to illustrate the concept, volumetric water content curves from two different material types used in the model are shown in Figure 3-8. With respect to concepts utilised in hydrogeology, and with reference to the example material types shown in Figure 3-8, the relationship is as follows:

- The maximum value for total water content is the same as the total porosity of the unit. For both material types shown the porosity is 0.2 m^3/m^3 (20%);
- Total porosity is comprised of specific yield (the volume of water that will drain from the unit under gravity drainage conditions) and specific retention (the volume of water that remains trapped in the unit (e.g. in small pore spaces) even when the unit is fully drained);
- The lowest value on the volumetric water content curve represents specific retention. For the material types shown in Figure 3-8, alluvium has a specific retention of 0.12 m^3/m^3 (12%), while interburden has a specific retention of 0.19 m^3/m^3 (19%);
- The difference between the maximum and minimum volumetric water content is the specific yield (drainable yield) of the unit. For the material types shown in Figure 3-8, alluvium has a specific yield of 0.08 m^3/m^3 (8%), while Permian interburden has a specific yield of 0.01 m^3/m^3 (1%) ; and,

It should be noted that Seep/W only considers the total drainable yield (specific yield), and the rate at which drainage is allowed to occur. In other words, the starting porosity (maximum volumetric water content) is not important for seepage calculations – it is only the total drainable yield and the rate of drainage (in response to suction forces) that is considered by the model.

The specific yield values that were used in modelling are shown below in Table 3-2

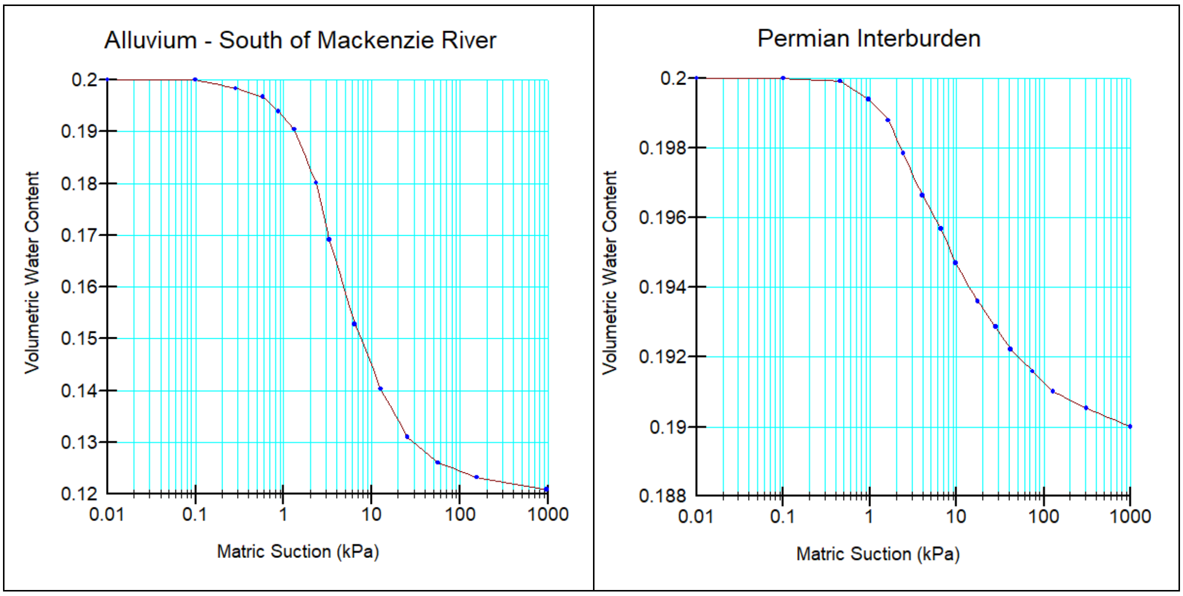

Figure 3-8: Example Volumetric Water Content applied to different material types

Table 3-2: Specific Yield used in Model

Lithology	Specific Yield (Sy)
Mackenzie River Alluvium	0.08 (8%)
Tertiary alluvium and residual deposits	0.05 (5%)
Duaringa Formation	0.01 (1%)
Rewan Group	0.01 (1%)
Permian Overburden (weathered)	0.01 (1%)
Permian Overburden (unweathered)	0.01 (1%)
Castor/Aries/Pollux Seams	0.02 (2%)
Permian Interburden	0.01 (1%)
Burngrove/ Fair Hill Formations	0.01 (1%)

3.4.2.2 Specific Storage

In Seep/W the specific storage (*Ss*) of the aquifer is accounted for via a related property called the coefficient of volume compressibility (*mv*). In areas where groundwater is draining to the pit void, the model utilises the specific yield (*Sy*) portion of the volumetric water content curve (as discussed above). With increasing distance from the pit wall the groundwater storage conditions become increasingly confined, Seep/W automatically transitions from unconfined to confined conditions (i.e. from the portion of the volumetric water content curve where pore pressures are at or below atmospheric pressure (and draining to the pit void) to the portion of the curve where pore pressures are positive) using the properties of the Coefficient of Volumetric Compressibility (*mv*). The relationship between the coefficient of volume compressibility (*mv*) and specific storage (*Ss*), can be established from the following equation (Geoslope 2012):

$$S_S = \rho_w g(\alpha + n\beta) = \rho_w g(mv)$$

Where:

Ss	=	Specific Storage
mv	=	Coefficient of volume compressibility
ρw	=	The density of water
g	=	Acceleration due to gravity
α	=	Compressibility of the aquifer skeleton
n	=	The porosity of the aquifer
β	=	Compressibility of water

The value for *mv* generally ranges from 1 x 10^{-6}/ kPa to 1 x 10^{-3}/kPa and for confined aquifers a value of 1 x 10^{-5}/kPa is generally appropriate (Geoslope 2012). An *mv* of 1 x 10^{-5}/kPa has therefore been applied to all groundwater units in the model.

3.5 Representation of Faulting

Faults are represented in the models as follows:

- The site geological model conforms to the solid geology as shown in Figure 2-2. For areas of the model that are beyond the boundaries of the site geological model the solid geology, including fault locations, is consistent with the geology shown on the solid geology map (Figure 2-2).
- Where faults are shown on the sections produced from the site geological model or regional geological data, the location of the faults has been accurately reproduced in the model. ;
- Figure 3-9 (below) shows the locations of the Jellinbah Fault (west of the CNE) and the Yarrabee Fault (east of the CNE). Note that the section is a continuous west-east section, but has been split

at the approximate location of the western edge of the CN pit to allow more detail to be shown on the section. It is noted that the actual throw on the faults is unknown; however, the geology as depicted conforms to the solid geology that is presented in Figure 2-2. The faults act to vertically disrupt the strata and will impact on groundwater flow where units of differing hydraulic conductivity abut each other. This will be more pronounced in the case of the Yarrabee Fault, where the Permian coal measures and coal seams are truncated against lower hydraulic conductivity sediments of the Burngrove Formation. At the location of the Jellinbah Fault the low hydraulic conductivity sediments of the Burngrove and Fair Hill Formations, which occur to the west of the Jellinbah mining area abut low hydraulic conductivity sediments of the Burngrove Formation and Rewan Group. Sediments of the Permian coal measures occur to the west of the Jellinbah Fault, but there is no continuity with the coal measures that occur in the Jellinbah mining area ;

- The faults have not been assigned any hydraulic properties, as no quantitative data exists to indicate whether individual faults act as groundwater conduits or as barriers to groundwater flow. Rather, the faults will act as described above, i.e. to allow transmission of groundwater across the fault if more permeable units are connected (such as coal seam to coal seam), and will tend to act as barriers to flow if a conductive unit such as a coal seam is terminated against lower permeability interburden material.

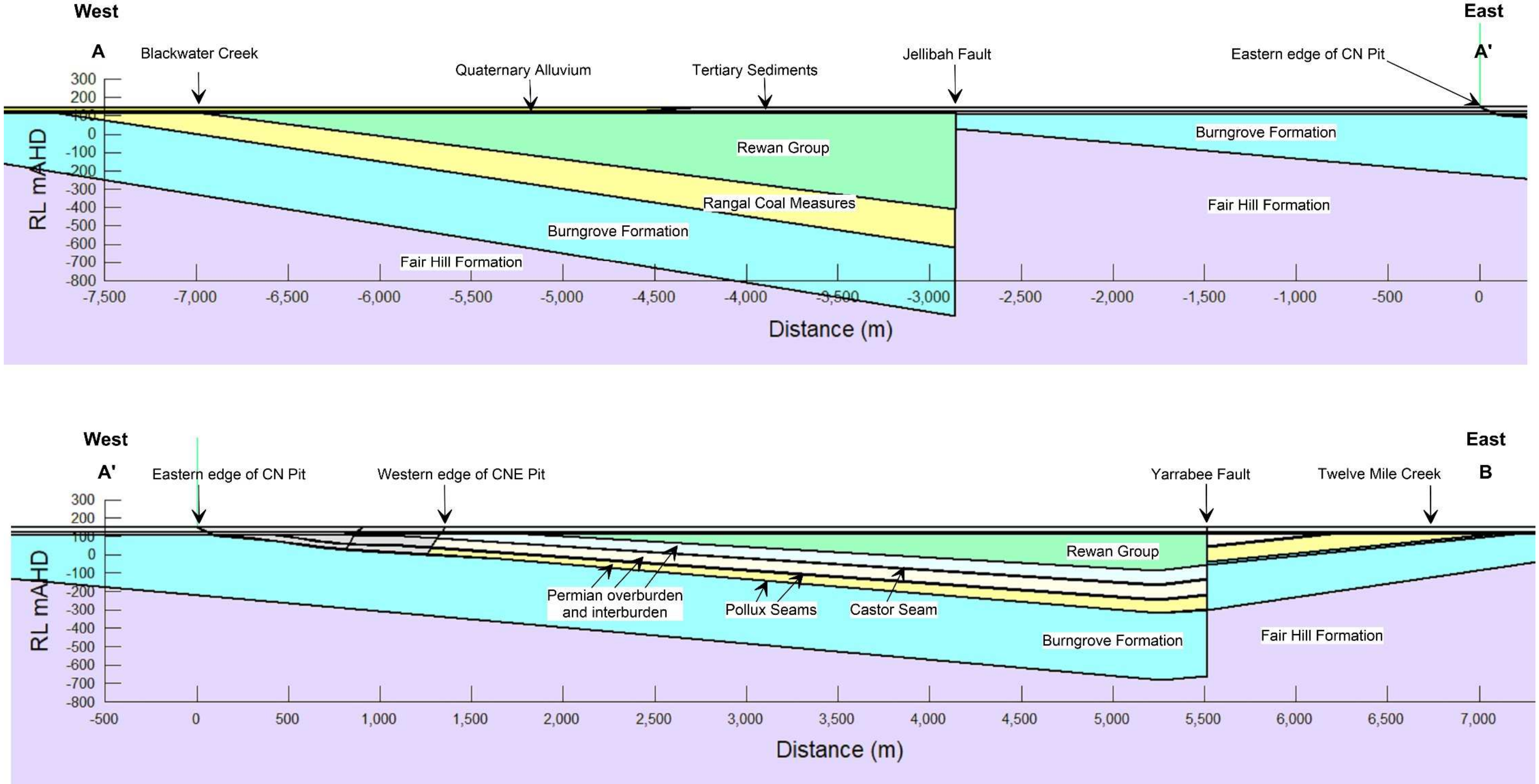

Figure 3-9: Representation of Faulting in West-East Groundwater Model

3.6 Boundary Conditions

3.6.1 Recharge

Groundwater data from site has been utilised to provide an estimate of groundwater recharge based on the chloride mass balance (CMB) method, which utilises the concentration of chloride in rainfall and the concentration of chloride in groundwater to provide an estimate of the net recharge rate to groundwater. The CMB equation is given as:

$$R = \frac{PCp}{Cg}$$

Where:

R = Recharge (mm/year).

P = Rainfall (mm/year).

Cp = Chloride concentration in rainfall (mg/L).

Cg = Chloride concentration in groundwater (mg/L).

Utilising the above formula, the recharge rates for each groundwater unit were calculated using the following input data:

- Mean annual rainfall for the CNE site of 559.4 mm (from SILO data).
- Mean chloride concentration in rainfall for the CNE site of 6.2 mg/L (CSIRO 2014[1]).
- Chloride concentration for groundwater of:
  - Alluvium – 20th percentile 64 mg/L; mean 485 mg/L; 80th percentile 1,490 mg/L;
  - Tertiary sediments – no data – Tertiary sediments unsaturated at site; and,
  - Permian coal seams - 20th percentile 582 mg/L; mean 2,417 mg/L; 80th percentile 5,190 mg/L.

The calculated recharge rates to groundwater are shown below in Table 3-3 and are summarised as follows:

- Recharge rates to the Mackenzie River alluvium are calculated to be between 0.42% of rainfall and 9.63% of rainfall (based on the 20th and 80th percentiles of rainfall) with a mean of 1.28%. It is noted that the Mackenzie River alluvium is not homogenous, but rather contains prior channels that are vertically separated and laterally discontinuous, interspersed with clayey flood-plain deposits; this lithological variation is reflected in the variability of recharge rate as well as the variability in groundwater retention times for this unit;
- Recharge rates to the coal seams are calculated to be between 0.12% and 1.06% of average annual rainfall (based on the 20th and 80th percentiles of the data) with a mean of 0.26%

Table 3-3: Calculated Groundwater Recharge Rates via CMB Method

Parameter	Description	Alluvium			Coal Seams		
		20th %	Mean	80th %	20th %	Mean	80th %
Cg	Chloride concentration in groundwater (mg/L)	64	485	1490	582	2417	5190
Cp	mg/L chloride in rainfall	6.2	6.2	6.2	6.2	6.2	6.2
P	Annual average rainfall (mm)	559.4	559.4	559.4	559.4	559.4	559.4
R	Annual average recharge (mm)	53.89	7.14	2.32	5.94	1.43	0.67
	Recharge as % of average annual rainfall	9.63	1.28	0.42	1.06	0.26	0.12

[1] CSIRO 2014 - Australian Chloride Deposition Rate https://doi.org/10.4225/08/545BEE54CD4FC

Based on the recharge rates calculated from the CMB method, recharge was applied to the model as follows:

- Recharge to areas of Mackenzie River alluvium (i.e. the northern area of the North-South Model) was applied at a rate of 1% of average annual rainfall.
- Recharge to the Tertiary sediments was applied at a rate of 0.5% of average annual rainfall, which is justified as follows:
  - The Tertiary sediments have been observed to be unsaturated in the CN and CNE mining areas; however, recharge to the Tertiary sediments will eventually report as recharge to the underlying coal measures, where recharge will preferentially occur in areas where the coal seams subcrop beneath Tertiary sediments;
  - The highest calculated recharge rates (via the CMB method) will occur in areas where the lowest salinity groundwater occurs, which is observed to be the areas where the coal seams subcrop directly beneath Tertiary sediments. In down-dip areas (e.g. to the east of the CNE and towards 12 Mile Creek) less recharge to the coal seams will occur due to the low permeability of the overlying overburden.
  - It is noted that in the area to the east of the CNE, Tertiary alluvium is mapped at surface. This unit is expected to be relatively thin and a recharge rate of 0.5% of average annual rainfall was also applied to this unit.

Recharge was applied to transient models as a flux boundary condition applied to the upper layer of the model (representing the ground surface). Rainfall was not applied to the steady-state model as the starting phreatic surface was generated based on fixed head boundary conditions at the edges of the model.

3.6.2 Starting Phreatic Surface

The initial phreatic surface was generated in the steady state model by applying fixed heads at the boundaries of the model. The boundaries were set at a distance of approximately 14 km from the edge of mining in order that the boundary conditions did not interfere with the groundwater response to mining.

The level of the fixed head boundary conditions was adjusted so that the initial phreatic surface within the mining area was just below the base of Tertiary and within the weathered Permian sediments, in accordance with observations from drilling and groundwater level monitoring[2]. For the north-south section the boundary conditions at the north of the model were adjusted so that the water level just south of the Mackenzie River was at approximately RL102 mAHD, which placed the water level within the alluvium. This was done to be consistent with available water level monitoring data (refer Section 2.2.2).

3.6.3 Groundwater Seepage to Voids

Seep/W requires the setting of seepage face review boundary conditions to allow water to leave the model and flow to the mine void. The seepage face boundary a flux boundary with total flux (Q) set at 0 m/day. The area of the mine void is set as a material type with no hydraulic properties; in practice the void is modelled as a zone with void into which groundwater flow can occur unimpeded.

2 Note that the groundwater monitoring bores described in Section 2.2.3 had not been constructed at the time of modelling, therefore initial groundwater levels were based on the data described in Section 2.2.2 of this report

3.7 Model Calibration

SEEP/W is not calibrated in the same ways as a model such as MODFLOW (e.g. via the matching of model water level predictions against observed values). Rather, the approach taken is generally to utilise realistic model parameters and to test for variability in results via uncertainty analysis. However, it is possible to undertake a check on the validity of model results for areas where an existing mine is present, such as for the CNE project, where observations are available from the existing and adjacent Central Pit. These observations are discussed further below

3.7.1 Comparison of Modelled Seepage with Observed Seepage

For Bowen Basin coal mines, it is generally observed (based on observations by JBT personnel over the course of approximately 20 years) that:

- For mine depths of less than 100-120 m, there are generally no observable groundwater inflows as the rate of groundwater inflow from the Permian coal measures tends to be so low that evaporation removes all seepage and the pit walls have the appearance of being dry;
- Beyond mine depths of 100-120 m there can be evidence of groundwater seepage that manifests as:
    - Initially, seepage is evident from higher permeability units such as coal seams, where patches of dampness become evident at the base of the coal seams;
    - With increasing depth (towards 150 m), damp interburden may become apparent and soft patches on the pit floor may also become more apparent;
    - As mines develop towards 180-200 m depth, visible seepage becomes apparent and groundwater will make up an increasing percentage of the water (that will include surface water runoff) that is collected in sumps and needs to be removed via pumping
    - Some seepage may be observed at shallower depths from faults and fractures, but it is our experience that this inflow tends to become evident after high rainfall periods and represents enhanced surface water recharge to the dilated zone around the pit, with faults and fractures acting as preferred pathways for flow. This inflow tends to be of relatively short duration and is not interpreted to represent true groundwater that is derived from the formation.
- The increase in seepage with depth is interpreted to be due:
    - In large part to the greater depth of mining below the phreatic surface and the higher hydraulic gradient that drives groundwater flow towards the mined void; and,
    - In smaller part to a reduction in the rate of evaporation with depth (due to shading, less wind etc.). A general rule of thumb is that evaporation is applied to seepage from the pit walls at a rate of 80% of pan evaporation near the ground surface, increasing linearly to 50% of pan evaporation at the base of the mine.

For mining at the adjacent Central Pit, it is observed that the pit is dry (in terms of groundwater inflow) at current mining depths of approximately 100 m below ground level. Therefore, the general observations above are judged to be applicable to the CNE operation. Observations from groundwater modelling are summarised as follows:

- From the SEEP/W model for the CN operation only:
    - the maximum depth of mining is approximately 120 m;
    - the calculated rate of seepage for a 1 m width of pit face at equilibrium is approximately 0.0015 L/s/m. The majority of this seepage occurs from the lower 30 m of the pit wall where a steady-state seepage face is developed;

  - For an average annual evaporation rate of 2,047 mm/year (SILO data), the calculated rate of evaporation (assuming 50% of pan evaporation for the base of the pit) is calculated as approximately 0.0019 L/s/m for the lower 30 m of the pit wall (where the seepage face is developed);
  - The rate of evaporation (0.0019 L/s/m of seepage face) is therefore in excess of the rate of seepage (0.0015 L/s/m of seepage face), which will result in the appearance of a dry pit wall;
  - The model results are therefore consistent with the observation of a dry pit at a similar depth to mining in the Central Pit.
- From the SEEP/W model for the CNE operation:
  - the maximum depth of mining is approximately 150 m;
  - the calculated rate of seepage for a 1 m width of pit face at equilibrium is approximately 0.002 L/s/m. As per the CN-only case, the majority of this seepage occurs from the lower ~30 m of the pit wall where a steady-state seepage face is developed;
  - For an average annual evaporation rate of 2,047 mm/year (SILO data), the calculated rate of evaporation (assuming 50% of pan evaporation for the base of the pit) is calculated as approximately 0.0019 L/s/m, for the lower 30 m of the pit wall (where the seepage face is developed)
  - The rate of seepage (0.002 L/s/m of seepage face) is therefore slightly in excess of the rate of evaporation (0.0019 L/s/m of seepage face) and is therefore consistent with the general observation of seepage in excess of evaporation at a depth of approximately 150 mbgl.

3.7.2 Use of Calibrated Model Parameters

As discussed in Section 3.4.1, the Seep/W model has been amended to include hydraulic parameters from the calibrated Mackenzie North groundwater model, which was developed for the Mackenzie North EMP and which covers the area of the CNE project.

3.8 Modelled Groundwater Level Impacts

3.8.1 Assessment Criteria

The modelled drawdown at 100 years post mining for the two modelled scenarios (CN only and CN plus CNE mining) is shown in Figure 3-10. The following observations are made with respect to modelled impacts on groundwater levels:

The Queensland *Water Act 2000* defines a “bore trigger threshold” (section 362) as:

> *a decline in the water level in the aquifer that is-*
>
> *(a) If a regulation prescribes the bore trigger threshold for an area in which the aquifer is situated – the prescribed threshold for the area; or*
>
> *(b) Otherwise-*
>
> *i. For a consolidated aquifer – 5 m; or*
>
> *ii. For an unconsolidated aquifer – 2 m.*

For the consolidated Permian coal measures it is judged to be appropriate to represent the extent of drawdown for up to 5 m from the original water level. The modelled drawdown beneath surface water features of interest (Mackenzie River to the north and Twelve Mile Creek to the east) is discussed in Section 4.4).

The drawdown beneath Blackwater Creek (to the west) is not discussed as significant groundwater drawdown to the west does not occur (discussed further is Section 3.8.2 below).

Drawdown to the south is also not discussed as drawdown from both the CN and CNE operations could only extend as far as the Jellinbah Central void, which occurs immediately to the south of both operations.

3.8.2 Model Results

Modelled drawdown is discussed below for each direction (north/south/east/west) from the mining area. The model results have been utilised to provide an indication of the extent of the 2 m and 5 m drawdown contours around the mining area (i.e. results from the cross-section models have been used to generate extent of drawdown contours in plan view, with contours manually digitized). Results from modelling are shown in Figure 3-10 and predict:

- On the eastern (high wall) side of the mining area the 5 m extent of drawdown is approximately 3,500 m from the pit crest at post-mining equilibrium (drawdown results at 150 years post-mining were utilised as post-mining equilibrium for all model results), for the CN operation only. With the CNE operation included, the extent of 5 m drawdown extends to approximately 3,750 m from the pit crest at post-mining equilibrium (an increase of 250 m relative to the CN mining only case). The CNE operation extends mining by approximately 360 m to the east and extends the depth of mining from approximately 125 mbgl to 150 mbgl.

  The 2 m drawdown contour extends approximately 5,250 m from the pit crest for the post-mining equilibrium, CN-only case and approximately 5,500 m from the pit crest for the post-mining equilibrium CNE case (an increase of approximately 250 m relative to the CN-only case). The 2 m drawdown contour therefore extends beneath 12 Mile Creek in some areas, as shown in Figure 3-10.
- On the western (low wall) side of the mining area the 5 m and 2 m extent of drawdown contours do not extend appreciably (by less than 100m) due to mining. This is interpreted to be related to the lack of coal measures to the west of the mining area (due to the dip of the strata) and the relatively low permeability of the Burngrove Formation, which is the dominant unit to the west of the mining area.
- On the northern side of the mining area the 5 m extent of drawdown is approximately 2,300 m from the pit crest at post-mining equilibrium for the CN-only case and approximately 2,400 m from the pit crest for the CNE case. The difference in drawdown to the north, relative to the modelled drawdown to the east, is interpreted to be related to the variability of the geology to the north, relative to the east.

  The 2 m drawdown contour extends approximately 2,400 m from the pit crest at post-mining equilibrium for the CN-only case and approximately 2,800 m from the pit crest for the CNE case.

  It is noted that no mining was assumed for the area to the north of the CN/CNE mining areas. The intent of the model was to establish any additional drawdown that may be due to mining in the CNE area. However it is judged that, in reality, any significant additional drawdown to the north is unlikely due to the existing impacts of mining in the Jellinbah Plains area.
- No drawdown was considered to the south as the model terminates in the south at the Jellinbah Central mined void. The groundwater elevation is held constant at the southern boundary of the model at the floor elevation of the Jellinbah void.

Potential impacts from mining are discussed in Section 4.0.

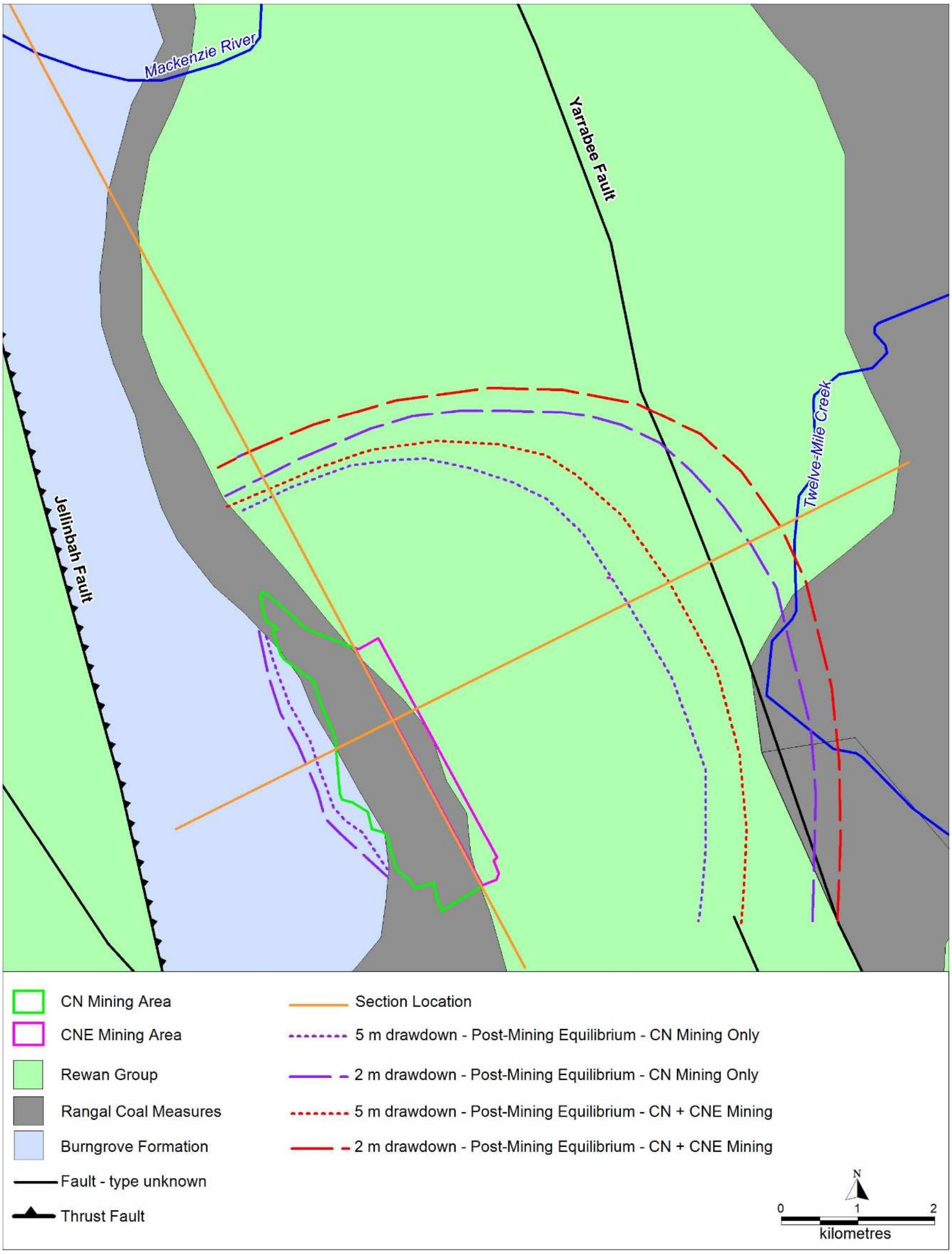

Figure 3-10: Water Level Drawdown for CN and CNE Mining Cases - Post-Mining Equilibrium

3.9 Uncertainty Analysis

3.9.1 Introduction

A sensitivity analysis of the groundwater model developed for the Jellinbah Central North Extension (CNE) has been undertaken with reference to the following documents:

- Barnett et al. (2012) *Australian Groundwater Modelling Guidelines*. Sinclair Knight Merz and National Centre for Groundwater Research and Training, Waterline Report Series No. 82, June 2012; and,
- Middlemis, H. & Peeters, L.J.M. (2018) *Explanatory Note, Uncertainty Analysis in Groundwater Modelling*. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy (Draft).
- Reilly, T.E. & Harbaugh, A.W. (2004) *Guidelines for Evaluation of Groundwater Flow Models.* United States Geological Survey, Scientific Investigations Report 2004-5038.

A groundwater model sensitivity analysis involves the evaluation of model input parameters to see how much they affect model outputs, which are heads and flows (Reilly & Harbaugh 2004). The process of sensitivity analysis can be conducted manually or automatically; in the manual approach, multiple model simulations are made in which ideally a single parameter is adjusted by an arbitrary amount (Reilly & Harbaugh 2004). The emphasis of sensitivity modelling is on determining how sensitive the model is to each parameter tested, using a non-technical interpretation of "sensitive" (Barnett et al. 2012).

The explanatory notes for uncertainty analysis that were prepared for the IESC (Middlemis & Peeters 2018) outline three general approaches to uncertainty analysis; these are, in order of increasing complexity:

1. Scenario analysis with subjective probability;
2. Deterministic modelling with linear probability quantification; and,
3. Stochastic modelling with Bayesian probability.

The first method (scenario analysis with subjective probability) has been applied to this modelling study. This methodology is judged to be appropriate to the analysis of a Seep/W model, which utilises a single set of parameters for each material type

A sensitivity analysis of the CNE model was undertaken as follows:

- The base-case (final CNE) models were used to establish the extent of 5 m drawdown from the edge of the final void to the north, south, east and west of the mining area. The locations of the section models are shown in Figures 3-3 and 3-4, and detail from the models pre and post-mining are shown in Figures 3-5 and 3-6. The sections highlight the relationship between the various groundwater units, including the degree to which faulting and folding compartmentalises the units;
- The base-case model was altered to make changes to specific parameters (discussed below) and to assess the impact that the change in parameters had on the location of the extent of the 5 m drawdown contour at the end of mining.
- The parameters that were selected for the sensitivity analysis are shown in Table 3-4 and include:
    - Scenario 1 - Horizontal hydraulic conductivity (Kh). The Kh of the Triassic and Permian non-coal units (Rewan Group, Interburden 1 and 2, Burngrove Formation) was increased by a factor of 10.

- Scenario 1 - Vertical hydraulic conductivity (Kz). The Kz of the above units was increased by a factor of 10. An increase in the vertical permeability of the coal measures allows an increase in the rate of downward seepage from overlying units and therefore increase the lateral extent to which drawdown of groundwater levels will occur;
- Scenario 3 - Specific yield (Sy) and coefficient of volume compressibility (*mv*), which is related to the specific storage (*Ss*) of the aquifer, were adjusted for the coal seams as follows:
  - the Sy of the coal seams was increased by a factor of 2. The specific yield, which describes the volume of water that can drain under gravity-drainage conditions, is the dominant aquifer storage property in zones that are close to the mine void; and,
  - the coefficient of volume compressibility (*mv*), which is related to specific storage as discussed in Section 3.4.2.2, was increased by a factor of 10 for the Permian coal seams.
- Scenario 4 – the Sy and mv of the overburden/ interburden units (Rewan Group, Interburden 1 and 2, Burngrove Formation) was altered as described above for Scenario 3, i.e. *Sy* was increased by a factor of 2 and *mv* was increased by a factor of 10;
- Scenario 5 – the recharge was doubled from:
  - Tertiary sediments - 0.5% of average annual rainfall to 1% of average annual rainfall; and,
  - Quaternary alluvium – 1% of average annual rainfall to 2% of average annual rainfall.

3.9.2 Results

The results of the sensitivity analysis are discussed below and are presented in Table 3-4 and in Figure 3-11. Figure 3-11 shows the extent of 5 m drawdown contours for each modelled scenario at post-mining equilibrium, over a background of the solid geology. The solid geology map is prepared by removing the Cainozoic cover units, revealing the relationships (including faulted contacts) between older rocks (Permian and Triassic) in the project area. Results are summarised as follows, with reference to the results shown in Figure 3-11:

- Scenario 1 - An increase in the Kh of the Triassic and Permian non-coal units by a factor of 10 results in an increase in the extent of the 5 m drawdown contour at post-mining equilibrium of between 1,250 m (to the east) and 340 m (to the north). The variability in the extent of the 5 m drawdown contour is related to dominant rock type in each direction;
- Scenario 2 - An increase in the Kz of the Triassic and Permian non-coal units by a factor of 10 results in an increase in the extent of the 5 m drawdown contour at post-mining equilibrium of between 2,300 m (to the east) and 1,600 m (to the north). The model is more sensitive to changes in Kz than Kh;
- Scenario 3 - An increase in the specific yield (Sy) of the coal seams by a factor of 2 and an increase in the coefficient of volume compressibility (*mv*) by a factor of 10 results in a decrease in the extent of the 5 m drawdown at post-mining equilibrium (-860 m to the east and -560 m to the north) relative to the base case;
- A low value for *mv* (and *Ss*) indicates a geotechnically stiff (less compressible) aquifer. An increase in the aquifer *mv* (and hence *Ss*) will therefore result in a more compressible aquifer, which will act to decrease the extent of drawdown.
- Scenario 4 - An increase in the specific yield (Sy) of the non-coal Triassic and Permian sediments by a factor of 2 and an increase in the coefficient of volume compressibility (*mv*) by a

factor of 10 results in a decrease in the extent of the 5 m drawdown at post-mining equilibrium (-1490 m to the east and -780 m to the north) relative to the base case;

- Scenario 5 – An increase (doubling) in the rate of recharge results in a decrease in the extent of the 5 m drawdown contour at post-mining equilibrium of -1,150 m to the east and -740 m to the north of the CNE.

The results highlight the sensitivity of the model to changes in key parameters and the need to utilise realistic model inputs (hydraulic parameters, recharge) for the base-case model.

It is noted that the Tertiary sediments at site are dry and that the regional groundwater system is developed within the Permian coal measures and is assessed to be disconnected from the surface water systems and alluvium (refer Section 4.4). Therefore it is concluded that variability in model input parameters from those used in the base-case model will only affect groundwater levels within Permian sediments and is unlikely to have practical impacts on water levels within the shallow groundwater systems in the area (i.e. alluvial aquifers).

Table 3-4: Change in the location of the 5 m Drawdown Contour, Relative to the Base-Case

Modelled Scenario		Base Case	Sensitivity Model	Change (m) in extent of 5 m drawdown contour*
East-West Section				
1	Increase horizontal hydraulic conductivity (Kh) x 10			
	Rewan Group	9.4×10^{-4} m/d	9.4×10^{-3} m/d	1250
	Interburden 1	9.4×10^{-4} m/d	9.4×10^{-3} m/d	
	Interburden 2	3.4×10^{-4} m/d	3.4×10^{-3} m/d	
	Burngrove Formation	4.0×10^{-5} m/d	4.0×10^{-4} m/d	
2	Increase horizontal hydraulic conductivity (Kh) x 10			
	Rewan Group	6.9×10^{-5} m/d	6.9×10^{-4} m/d	2300
	Interburden 1	6.9×10^{-5} m/d	6.9×10^{-4} m/d	
	Interburden 2	1.0×10^{-4} m/d	3.4×10^{-4} m/d**	
	Burngrove Formation	4.0×10^{-5} m/d	4.0×10^{-4} m/d	
3	Increase specific yield (*Sy*) of coal seams x 2	2%	4%	-860
	Increase compressibility (*mv*) of coal seams x 10	1×10^{-5}/kPa	1×10^{-4}/kPa	
4	Increase specific yield (*Sy*) of Rewan Group, Interburden 1&2, Burngrove Formation x 2	1%	2%	-1490
	Increase compressibility (*mv*) of above units x 10	1×10^{-5}/kPa	1×10^{-4}/kPa	
5	Increase Recharge x 2			
	Alluvium	1%	2%	-1150
	Tertiary Sediments	0.5%	1%	
North-South Section				
1	As above			340
2	As above			1600
3	As above			-560
4	As above			-780
5	As above			-740

* Change in the extent of the 5 m drawdown contour for the CNE mining case at post-mining equilibrium.

A positive value indicates an increase in the extent of drawdown, a negative value indicates a decrease in the extent of drawdown.

** Value changed by less than 10x original value, to the value of the Kh of this unit

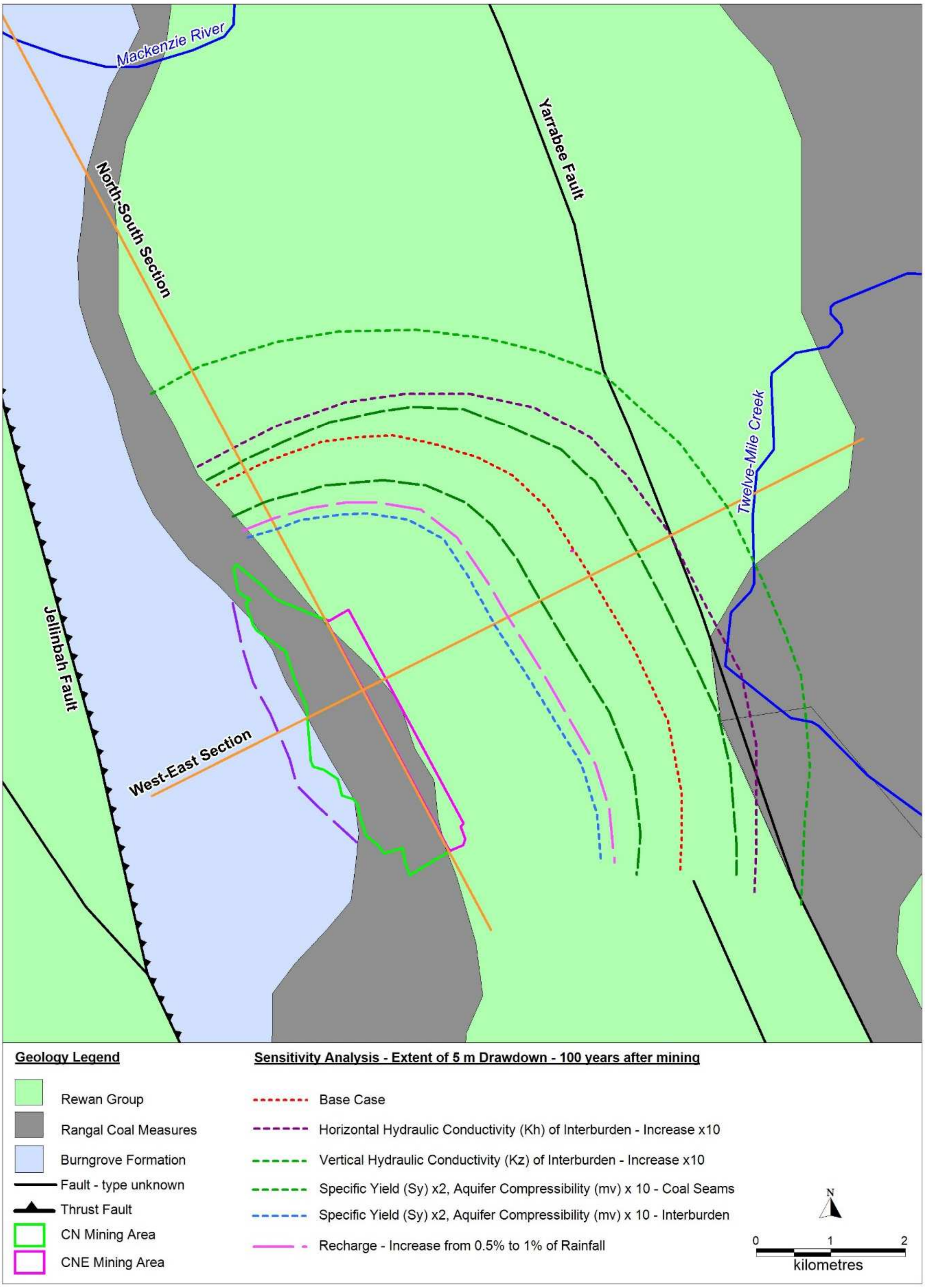

Figure 3-11: Results of Groundwater Model Sensitivity Analysis

4.0 GROUNDWATER IMPACTS FROM MINING

4.1 Impacts on Existing Groundwater Users

4.1.1 Data from DNRME Groundwater Database

The most current version of the Department of Natural Resources, Mines and Energy (DNRME) Groundwater Database (current to July 2020) was reviewed for the location of registered private groundwater bores. From the review it has been determined that there are no existing registered groundwater bores in the area between the Jellinbah and Curragh/Curragh North mining lease areas (i.e. to the west of the CNE) or in the area between the Jellinbah and Yarrabee mining lease areas (i.e. to the east to the CNE). Therefore it is concluded that there are no existing registered groundwater bores that could be impacted by the CNE operation. However, it is possible that not all existing groundwater bores appear in the Groundwater Database; therefore, a bore census was undertaken for properties that are within the predicted area of water level impact of the CNE. This is discussed below in Section 4.1.2.

4.1.2 Landowner Bore Census

A bore census has been undertaken to establish whether bores exist within the predicted area of impact as defined from groundwater modelling (Section 3.8). The census was undertaken as follows:

- The properties that are within the area of predicted impact are shown in Figure 4-1. The landowners of each of the properties, as well as their contact details, were identified from Jellinbah's landowner database;
- The bore census was undertaken between 30 September and 1 October 2020, with all landowners or their representatives contacted within that period;
- The landowners (or in some cases the property leaseholders or managers) were contacted by phone by JBT Consulting and were asked if any groundwater bores existed on their property. As no groundwater bores were identified there was no need to go further with the census, e.g. to obtain bore data and/or undertake bore condition surveys.
- The property owners/managers are not identified in this report for privacy reasons; the full details of the bore census, including contact details and responses, are maintained in the records of JBT Consulting and Jellinbah Mine.

Summary details of the bore census are shown below in Table 4-1.

4.1.3 Requirements for Make-Good and/or Mitigation Measures

As there are no private groundwater bores within the predicted area of impact it is concluded that there is no requirement for make-good and/or mitigation measures.

Table 4-1: Results of Landowner Bore Census

Real Property Description	Nature of Contact	Response
6CLR94	Spoke by phone with manager	No groundwater bores currently located on property
14RP885348	Property is owned by Jellinbah Mining	
13LR102	Spoke by phone with property owner	No groundwater bores currently located on property
50SP257934	Spoke by phone with property lessee. Property is owned by Yarrabee Mine, with contact leasing a portion of the property	No groundwater bores currently located on the leased section of property. Lessee is unaware of any bores on remainder of property
10LR103	Spoke by phone with lessee	No groundwater bores currently located on property
1SP161090	Spoke by phone with property owner	No groundwater bores currently located on property

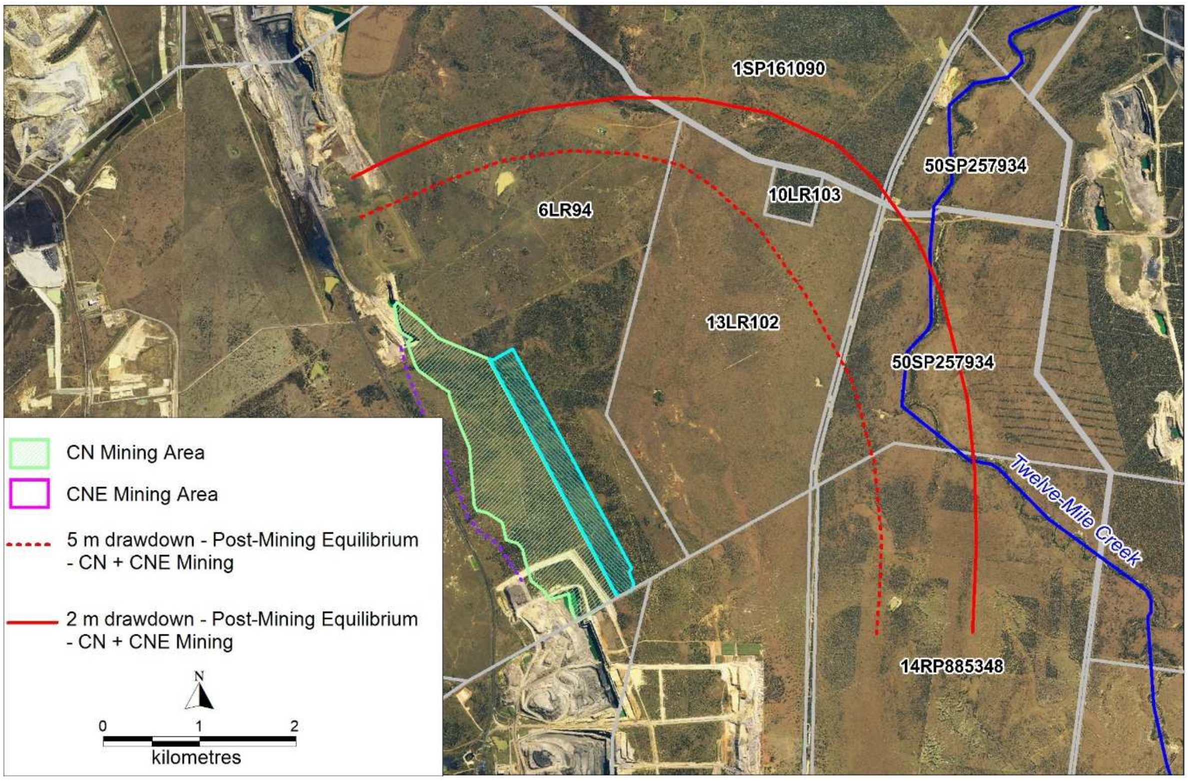

Figure 4-1: Properties where Bore Census was Undertaken

4.2 Cumulative Impacts

Cumulative impact assessments are highly specific to the impact under analysis and may consider, for example, the following (Franks et al 2010):

- Multiple areas of groundwater abstraction (e.g. adjacent mining operations);
- Overlapping cones of drawdown;
- Dewatering discharge locations;
- Distribution of ecosystems around the Project area; and,
- Catchment-scale groundwater levels.

Existing projects that may combine with the Central North Extension to impact groundwater resources have been identified from the following sources:

- The Queensland Coordinated Projects Map (DSDIP 2014);
- Queensland's Mineral, Petroleum and Energy Operations and Resources map (State of Queensland 2012); and,
- Publicly available documentation (e.g. EIS documents that exist within the public domain).

Based on review of the above documentation it is concluded that the projects with the potential to contribute to cumulative groundwater impacts include:

- The existing Jellinbah Central operation that occurs immediately to the south of the CNE;
- The approved but as-yet unmined Central North (CN) operation, of which the CNE will be an extension;
- The existing Jellinbah Plains operation, which occurs to the north of the CN and CNE operations;
- The existing Curragh Central and Curragh North projects, which occur approximately 5 km west of the CNE; and,
- The existing Yarrabee Coal Mine, which is located approximately 6 km to the east of the CNE.

As the CNE is to be developed in the middle of existing Jellinbah mine operations it is taken as given that the drawdown from the CNE will coalesce with drawdown from existing Jellinbah operations to the north and south.

Based on searches undertaken for this study it is concluded that there is no information in the public domain on the extent of groundwater level drawdown due to the adjacent Curragh/Curragh North and Yarrabee operations, therefore it is only possible to discuss the potential for cumulative impacts in general terms.

In Section 3.8.2 (model results) it is noted that the predicted extent of the 2 m drawdown contour at the end of mining extends approximately 5,500 m to the east of the CNE at post-mining equilibrium and by less than 100 m to the west (for base-case hydraulic parameters). The depth of mining at operations to the west of the project (Curragh/Curragh North) and east of the project (Yarrabee) is unknown; however, given the distance of these existing mining projects from the CNE it is concluded that:

- Cumulative impacts to the west of the CNE are judged to be unlikely due to the relatively limited drawdown that is predicted to the west of the CNE (less than 100 m) and the fact that the Curragh/Curragh North operation is located approximately 5 km away. In any case, drawdown to the west from the CNE will be limited by the presence of the CN operation immediately to the west; and,

- There is potential for cumulative impacts between the CNE and the Yarrabee mining area to the east. This is based on the observation that the extent of 2 m drawdown from the CNE is approximately 5,500 m and that the Yarrabee operation occurs approximately 6 km to the east. Therefore there is potential for the cones of depression from these two operations to coalesce.

  It is noted, however, that the drawdown will occur within the Permian coal measures, which are assessed to be hydraulically disconnected from the alluvium (Section 4.4); therefore it is assessed that mining at the CNE, as well as any cumulative impacts with other mining operations, will have no impact on groundwater levels within the alluvium.

4.3 Impacts on Groundwater Quality

Groundwater modelling (Section 3.0) predicts that a permanent cone of depression will develop that will direct groundwater flow towards the final voids; therefore, the risk of the project impacting on water quality (via outflow to the groundwater system) is assessed to be low.

It is, however, assessed that the Project could impact groundwater quality if the water within the final void were able to exit the void via unconsolidated sediments (i.e. the base of Tertiary) and flow via the groundwater system towards sensitive environmental receptors such as 12 Mile Creek. For this reason, an assessment of the potential for water within the final voids to exit the void via the base of Tertiary sediments has been undertaken and is summarised as follows:

- The post-mining final void lake equilibrium level is assessed to be a maximum of 45.3 mAHD (Engeny 2019).
- In the area of the CNE the base of Tertiary is interpreted to be in the order of 120 mAHD, i.e. approximately 70-75 m higher than the final void water level.

It is therefore concluded that there is no possibility of outflow from the final void via the base of Tertiary and that there is a very low risk of the CNE project impacting the water quality of the surrounding groundwater system.

4.4 Potential Impacts to GDE’s

Creeks to the west and east of the project area (Blackwater Creek and Twelve Mile Creek respectively) are ephemeral and available groundwater level data indicates that the regional water table is generally below the base of Tertiary. Groundwater modelling predicts very limited drawdown to the west as the coal seams crop out in this direction and drawdown is limited by the low permeability of the interburden (non-coal) sediments. In addition, the CNE is developed to the east of the already-approved CN operation, therefore any additional drawdown will be to the east rather than to the west in the direction of the CN mine void.

As noted in Section 2.2.2, groundwater levels in the CN and CNE area are below the base of Tertiary, with water levels in the order of 40 m below ground level compared to a Tertiary thickness of approximately 15 m. An assessment has been undertaken of the potential depth of groundwater beneath 12 Mile Creek, which occurs to the east of the CNE and which may contain groundwater dependent ecosystems (GDE’s). Figure 4-2 (below) shows available water level data in the CN and CNE area as well as interpreted water level elevation contours. The contours were developed as follows:

- Depth to groundwater data from geological bores was converted to reduced water level (RWL) data (i.e. the water level elevation in metres relative to the Australian Height Datum (mAHD);
- It is interpreted that the direction of groundwater flow will be from west to east, in the direction of the dip of the coal seams. Based on data from the site geological model and interpretation of

available geological data, it is interpreted that the depth to the top of the uppermost coal seams (Castor/Aries Seams) increases from approximately 40 mbgl in the CN area to approximately 300 mbgl at the location of the Yarrabee Fault, which occurs just to the west of 12 Mile Creek;

- A conservative assumption of a 20 m decrease in water level from west to east, from the CNE area to 12 Mile Creek, was made. This equates to a 20 m reduction in water level over a horizontal distance of approximately 4,000 m, giving a hydraulic gradient of 0.005;
- A number of “dummy” points were generated in the area between the CNE (where water level data exists) and 12 Mile Creek, using topographic contours to guide the location of the points. The resulting data set of measured groundwater elevation data and “dummy” points was contoured to produce the groundwater elevation contours that are shown in Figure 4-2.

The groundwater elevation contours were then utilised to produce depth to groundwater contours, which are shown in Figure 4-3. These contours were developed as follows:

- Figure 4-3 shows available depth to groundwater data from geological bores in the CN and CNE areas, with this data utilised to produce the groundwater elevation contours that are shown in Figure 4-3;
- The grid file for the groundwater elevation contours was subtracted from the grid file for the surface topography contours, to produce a gridded surface of depth to groundwater data;
- The resultant depth to groundwater contours were manually smoothed and re-gridded to provide the depth to groundwater contours that are show in Figure 4-3.

The depth to groundwater contours show an increase in depth to groundwater from approximately 40 mbgl in the CN/CNE area to approximately 60 mbgl in the area of 12 Mile Creek (a 20 m reduction in water level over approximately 4,000 m at a hydraulic gradient of 0.005, as discussed above).

The depth to groundwater contours, while based on interpretation as discussed above, are useful in demonstrating that the depth to groundwater in the area of 12 Mile Creek is likely to be in the order of 60 mbgl, which is beyond the depth that is accessible by vegetation (it is also noted that, if it is accepted that the direction of groundwater flow is down-dip to the east, then the depth to groundwater must at least be greater than the 40 mbgl that has been measured in the CN/CNE areas).

Figure 4-4 shows the location of potential aquatic and terrestrial GDE’s from the BOM groundwater dependent ecosystem atlas, relative to the 5 m and 2 m drawdown predictions at post-mining equilibrium, for mining of the CNE.

From review of the information presented in Figures 4-2 to 4-4 it is concluded that:

- The depth to the regional groundwater level in the area of 12 Mile Creek is greater than 40 mbgl and interpreted to be approximately 60 mbgl;
- Any vegetation along 12 Mile Creek is likely to be dependent on surface water flows and on water that may be periodically stored within alluvium following recharge events;
- Mining at the CNE will have no impact on groundwater levels within the alluvium as mining will only impact on water levels within the Permian sediments and the water level within Permian sediments at the location of 12 Mile Creek is interpreted to significantly below ground level and below the base of alluvium (as any Quaternary alluvium within 12 Mile Creek is interpreted to be thin and of limited extent).

Quaternary alluvium exists to the north of the CNE, associated with the Mackenzie River main channel and flood plains (Figure 4-4). It is noted that the 2 m drawdown contour from CNE operations at post-mining equilibrium is more than 4.5 km from the Mackenzie River and does not extend to within the area of mapped Mackenzie River alluvium (Figure 4-4); therefore, any GDEs that are associated with the Mackenzie River to the north of the CNE are not considered to be at risk from any potential groundwater related impacts corresponding to the CNE.

In summary, it is not expected that the CNE will impact on any GDEs within the vicinity of the CNE project.

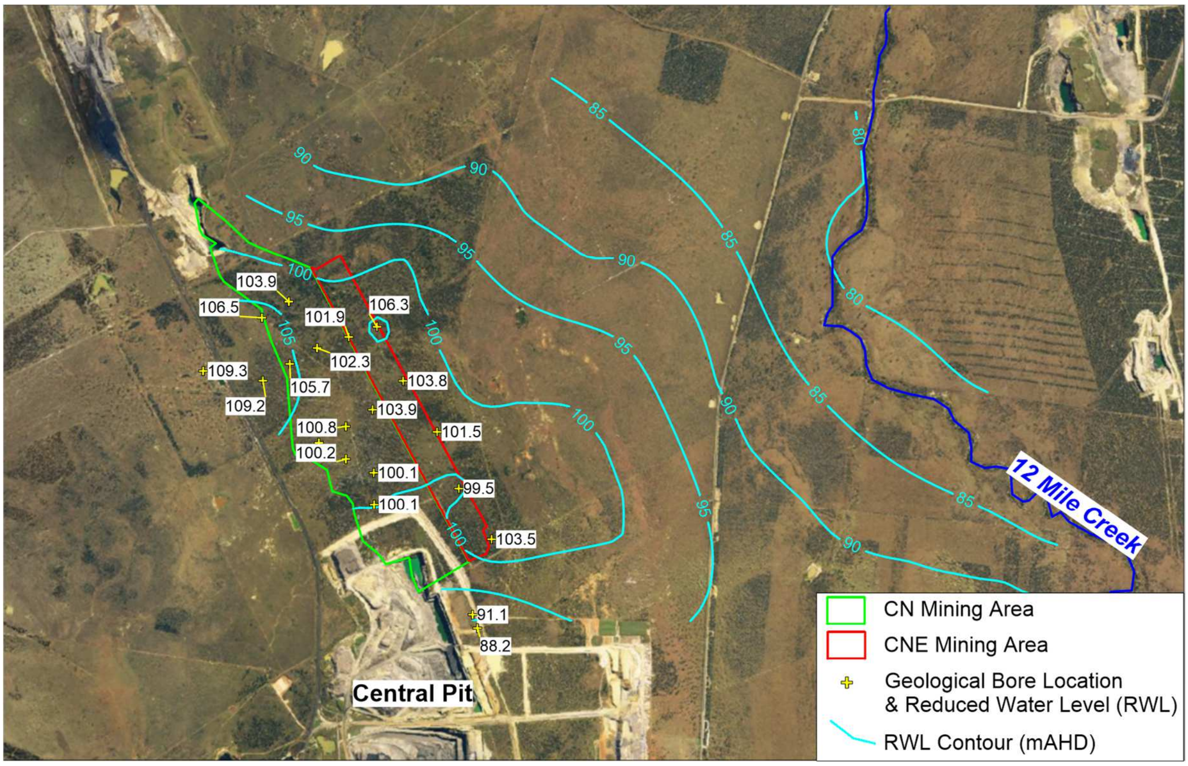

Figure 4-2: Groundwater Elevation Data and Interpretive Contours

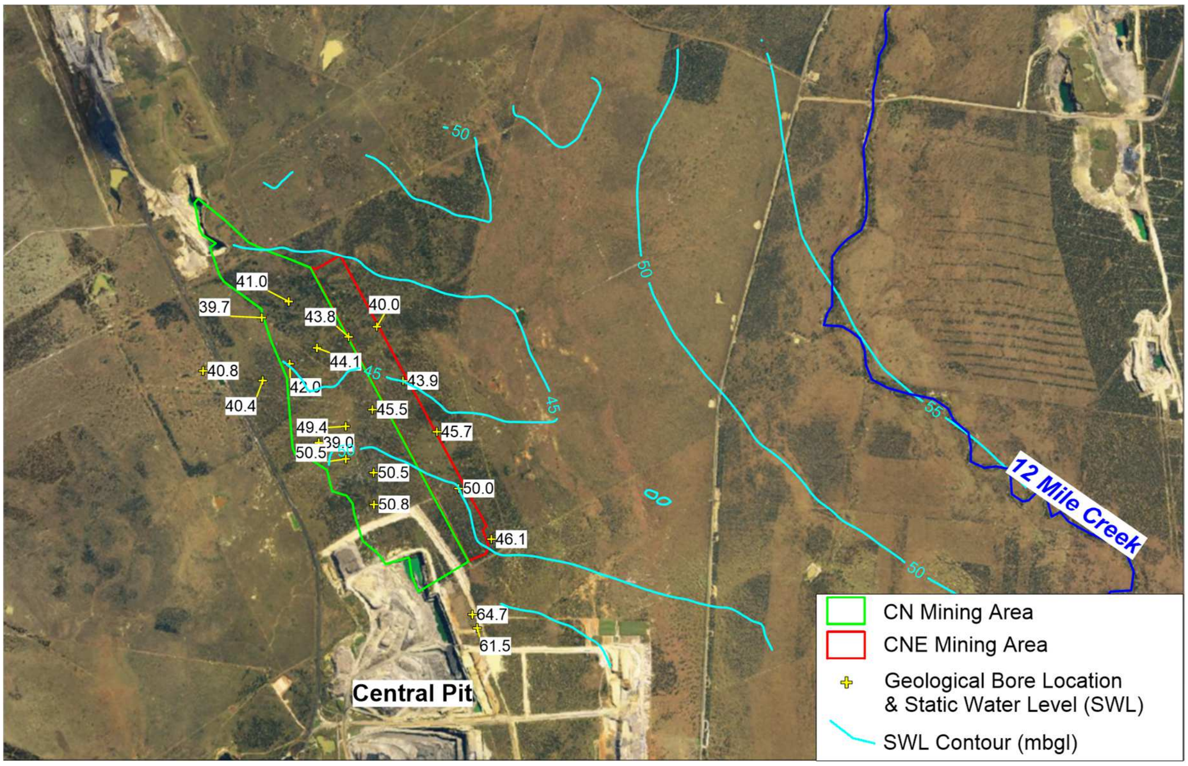

Figure 4-3: Depth to Groundwater Data and Interpretive Contours

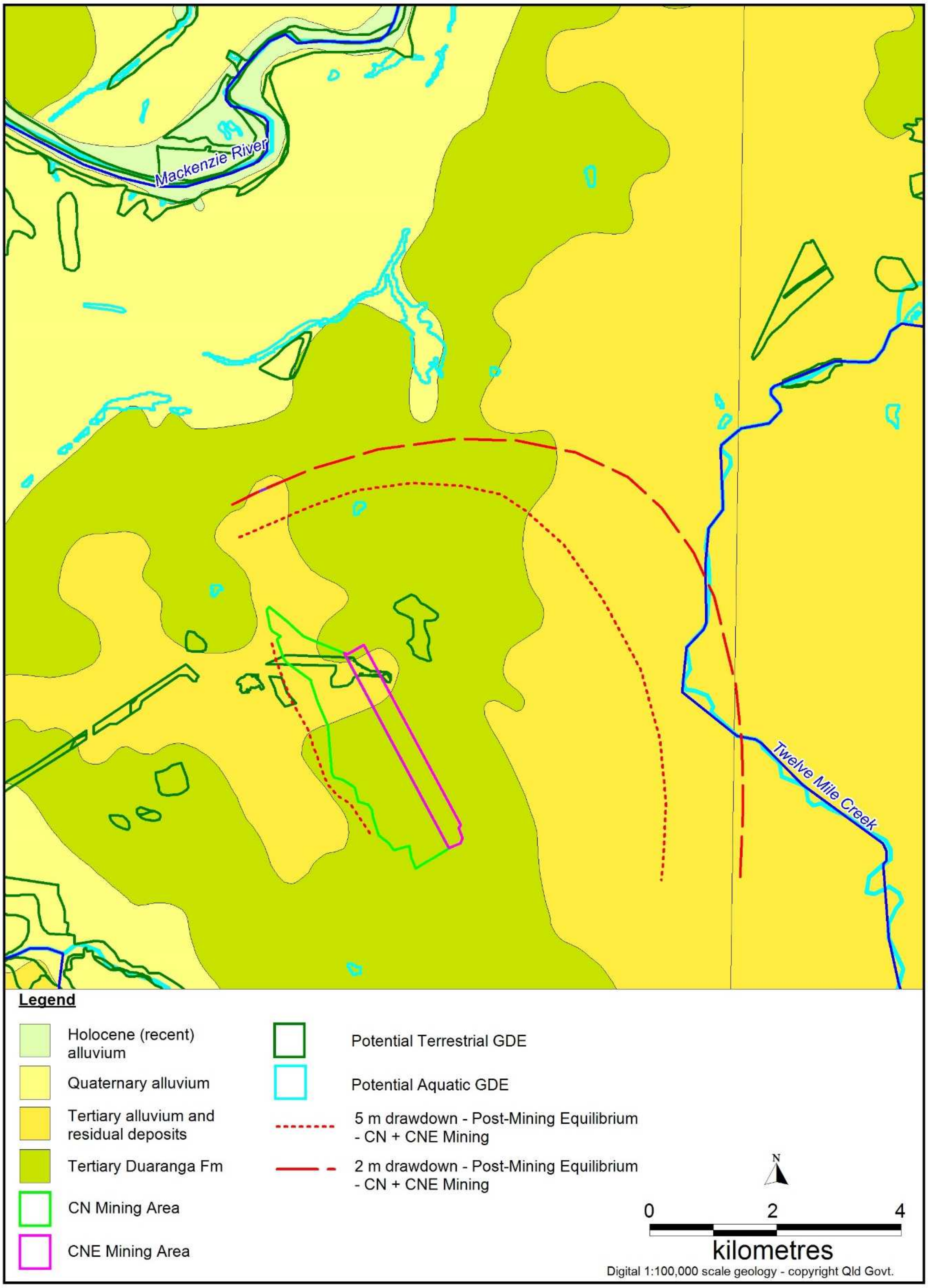

Figure 4-4: Location of Drawdown Contours with Respect to Potential GDE's

5.0 SUMMARY AND CONCUSIONS

The following summary and conclusions are presented following data analysis and modelling undertaken for the CNE Project:

- Groundwater monitoring requirements for the Project were discussed with DNRME prior to the finalisation of the program and are summarised as follows:
  - Three (3) groundwater monitoring bores have been installed to enable monitoring of water levels and potential water level impacts in the Permian coal measures (coal seams and interburden) that are associated with the Project. The bores have been installed as vibrating wire piezometer (VWP) bores and include 5 sensors in each bore that monitor the coal seams and interburden that will be mined by the Project;
  - No bores have been installed within the Tertiary sediments as these are dry within the CNE Project area; and,
  - No Quaternary alluvium exists at the CNE Project site. The alluvium is monitored to the north of the Project area as a requirement of the Jellinbah Plains EA.
- A groundwater model has been developed that predicts the extent of drawdown associated with the CNE Project. The model predicts that, at post-mining equilibrium (150 years post-mining):
  - the 5 m drawdown contour will extend approximately:
    - 3,750 m to the east;
    - 2,400 m to the north;
    - An insignificant distance to the east, as the coal seams do not exist to the east due to the dip of the strata; and,
    - To the south drawdown was not considered due to the existence of the Jellinbah Central pit in that direction; and,
  - the 2 m drawdown contour will extend approximately:
    - 5,500 m to the east;
    - 2,800 m to the north;
    - To the west and east, comments are as per above for the 5 m drawdown contour
- The potential groundwater impacts from mining are summarised as follows:
  - Impacts on existing groundwater users – it is concluded that there will be no impacts on existing groundwater users as, based on review of data from the DNRME groundwater database as well as a landowner bore census that was conducted on 30 September to 1 October 2020, there are no existing private groundwater bores within the area of predicted water level impact (as summarised above and in Section 4.1 of this report);
  - Impacts on groundwater quality are summarised as follows:
    - a permanent cone of depression will develop that will direct groundwater flow towards the final voids;
    - There could be potential for water within the final void to impact on the groundwater system if outflow were possible via unconsolidated sediments (i.e. the base of Tertiary), which could direct flow via the groundwater system towards sensitive environmental receptors such as 12 Mile Creek. This was assessed to be not possible as:

- The post-mining final void lake equilibrium level is assessed to be a maximum of 45.3 mAHD (Engeny 2019); and,
- In the area of the CNE the base of Tertiary is interpreted to be in the order of 120 mAHD, i.e. approximately 70-75 m higher than the final void water level.

It is therefore concluded that there is no possibility of outflow from the final void via the base of Tertiary and that there is a very low risk of the CNE project impacting the water quality of the surrounding groundwater system.

- Cumulative impacts
  - Cumulative impacts to the west of the CNE are judged to be unlikely due to the relatively limited drawdown that is predicted to the west of the CNE (less than 100 m) and the fact that the Curragh/Curragh North operation is located approximately 5 km away. In any case, drawdown to the west from the CNE will be limited by the presence of the CN operation immediately to the west; and,
  - There is potential for cumulative impacts between the CNE and the Yarrabee mining area to the east. This is based on the observation that the extent of 2 m drawdown from the CNE is approximately 5,500 m and that the Yarrabee operation occurs approximately 6 km to the east. Therefore there is potential for the cones of depression from these two operations to coalesce.

    It is noted, however, that the drawdown will occur within the Permian coal measures, which are assessed to be hydraulically disconnected from the alluvium; therefore it is assessed that there is a very low probably that mining at the CNE, as well as any cumulative impacts with other mining operations, will impact on groundwater levels within the alluvium.
- Potential for impacts on GDE's - it is not expected that the CNE project will have any impacts on GDE's as:
  - The depth to the regional groundwater level in the area of 12 Mile Creek is greater than 40 mbgl and interpreted to be approximately 60 mbgl;
  - Any vegetation along 12 Mile Creek is likely to be dependent on surface water flows and on water that may be periodically stored within alluvium following recharge events;
  - Mining at the CNE will have no impact on groundwater levels within the alluvium as mining will only impact on water levels within the Permian sediments and the water level within Permian sediments at the location of 12 Mile Creek is interpreted to significantly below ground level and below the base of alluvium (as any Quaternary alluvium within 12 Mile Creek is interpreted to be thin and of limited extent).
  - Quaternary alluvium exists to the north of the CNE, associated with the Mackenzie River main channel and flood plains (Figure 4-4). It is noted that the 2 m drawdown contour from CNE operations at post-mining equilibrium is more than 4.5 km from the Mackenzie River and does not extend to within the area of mapped Mackenzie River alluvium (Figure 4-4); therefore, any GDEs that are associated with the Mackenzie River to the north of the CNE are not considered to be at risk from any potential groundwater related impacts corresponding to the CNE.

6.0 REFERENCES

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ATTACHMENT A

GROUNDWATER MONITORING BORE CONSTRUCTION DIAGRAMS

Project: Central North Extension **Bore ID: JC0894P**

Installation Date: 15 July 2020

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, brown		0			
CLAY, creamy-brown. Base of Tertiary at 15 mbgl		10	140		
CLAYSTONE, yellowish-brown		20	130		
SILTSTONE, yellowish-brown. Base horizon of weathering at 37 mbgl		30	120		
SANDSTONE, grey, fine to medium grained, black siltstone at bottom 1.78 m		40 50 60 70	110 100 90 80		
COAL, Aries Seam					Vibrating Wire Piezometer @ 75.5 mbgl - s/n 4930
SILTSTONE, interbedded with mudstone and minor coal			70		
COAL, Castor Seam		80			
SILTSTONE, brownish-grey, interbedded with mudstone and minor coal		90	60		Vibrating Wire Piezometer @ 90 mbgl - s/n 4932
COAL, Pollux Upper Seam		100	50		Vibrating Wire Piezometer @ 102 mbgl - s/n 4933
SILTSTONE, interbedded with mudstone and minor coal		110	40		
SANDSTONE, fine to medium-grained, light grey		120 130	30 20		
COAL, Pollux Lower Seam		140	10		Vibrating Wire Piezometer @ 141.4 m - s/n 4937
SILTSTONE, brownish-grey					Vibrating Wire Piezometer @ 145 m - s/n 4936
		150	0		

JBT consulting

Easting: 700352

Northing: 7415159

Collar RL (mAHD): 148.58

Co-ord System: GDA94

Drilling Company:

Drill Rig:

Hole Diameter (mm): 100

Total Depth (m): 146.0

Project: Central North Extension

Bore ID: JPS0197P

Installation Date: 16 July 2020

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes

Lithological Description

- SOIL, brown
- CLAY, light brown, base of Tertiary at 6 mbgl
- SILTSTONE, yellowish-brown, occasional sandstone bands, Base of Weathering at 19.5 mgl
- SANDSTONE, fine to medium-grained, light-grey, siltstone at base
- COAL, fault repeat of Aries Seam
- SILTSTONE, brownish-grey
- COAL, fault repeat of Castor Seam
- SANDSTONE, light grey
- SILTSTONE, brownish-grey
- SANDSTONE, light grey
- COAL, Aries Seam
- SILTSTONE, brownish-grey with black mudstone bands
- COAL, Castor Seam
- SANDSTONE, fine to medium-grained, light-grey, siltstone bands throughout
- COAL, Pollux Upper Seam
- SILTSTONE, dark grey, bands of mudstone and sandstone
- COAL, Pollux Lower Seam
- SILTSTONE, dark grey

Depth (m): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180

Elevation (mAHD): 140, 130, 120, 110, 100, 90, 80, 70, 60, 50, 40, 30, 20, 10, 0, -10, -20, -30

Bore Construction/General Drilling Notes

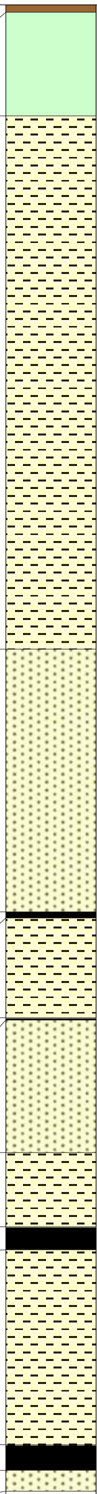
- Vibrating Wire Piezometer @ 90.5 m - s/n 4920
- Vibrating Wire Piezometer @ 104 m - s/n 4931
- Vibrating Wire Piezometer @ 137 m - s/n 4935
- Vibrating Wire Piezometer @ 163 m - s/n 4938
- Vibrating Wire Piezometer @ 165.5 m - s/n 4939

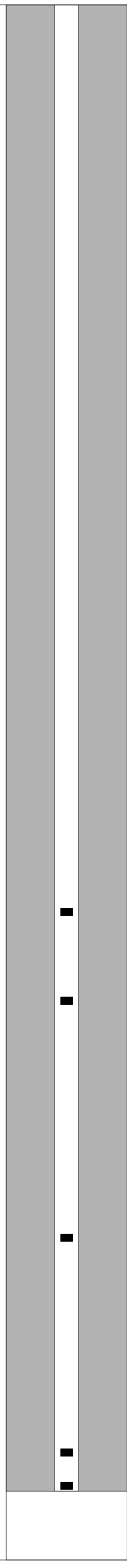
Easting: 699602	Drilling Company:
Northing: 7416893	Drill Rig:
Collar RL (mAHD): 146.95	Hole Diameter (mm): 100
Co-ord System: GDA94	Total Depth (m): 166.5

Project: Central North Extension **Bore ID: JP0963P**

Installation Date: 4 August 2020

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes





Lithological Description:

SOIL, brown

CLAY, orange-brown

SILTSTONE, brownish-grey, interbedded with fine to medium-grained sandstone

SANDSTONE, fine-grained, light grey, 1 m of siltstone at base

COAL, Aries Seam

SILTSTONE, brownish-grey

COAL, Castor Seam

SANDSTONE, fine to medium grained, light grey

SILTSTONE, brownish-grey

COAL, Pollux Upper Seam

SILTSTONE, brownish-grey

COAL, Pollux Lower Seam

SANDSTONE, fine-grained, light grey

Depth (m)	Elevation (mAHD)
0	
10	130
20	120
30	110
40	100
50	90
60	80
70	70
80	60
90	50
100	40
110	30
120	20
130	10
140	0
150	-10
160	-20
170	-30
180	-40
190	-50
200	-60
210	-70

Bore Construction/ General Drilling Notes:

Vibrating Wire Piezometer @ 123 m - s/n 4934

Vibrating Wire Piezometer @ 135 m - s/n 8696

Vibrating Wire Piezometer @ 167 m - s/n 4971

Vibrating Wire Piezometer @ 196 m - s/n 8776

Vibrating Wire Piezometer @ 200.5 m - s/n 4940

JBT consulting

Easting: 697508

Northing: 7420035

Collar RL (mAHD): 138.94

Co-ord System: GDA94

Drilling Company:

Drill Rig:

Hole Diameter (mm): 100

Total Depth (m): 200.7

ATTACHMENT B

CENTRAL NORTH EXTENSION (CNE)

UNDERGROUND WATER MONITORING PROGRAM

Report Prepared for Jellinbah Group Pty Ltd

JELLINBAH MINE – CENTRAL NORTH EXTENSION

UNDERGROUND WATER MONITORING PROGRAM

October 2020

JBT01-061-006

RECORD OF ISSUE

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JBT Consulting Pty Ltd

John Bradley
PRINCIPAL HYDROGEOLOGIST

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1.0 INTRODUCTION

This Underground Water Monitoring Program (UWMP) for the Jellinbah Central North Extension (CNE – the Project) has been prepared by JBT Consulting, on behalf of the Jellinbah Group Pty Ltd (Jellinbah), to support the application for the Project's Associated Water Licence (AWL). The UWMP is required to meet, but not be limited to, the objectives[1] that are shown below in Table 1-1. Table 1-1 also includes comments that relate to the specific objectives.

Table 1-1: AWL Monitoring Plan Objectives and Comments

AWL Monitoring Plan Objective	Comment
Provide for the monitoring of impacts on any springs and watercourses dependent on underground water flow	The groundwater impact assessment [2] has concluded that the project will not impact on any springs or watercourses that are dependent on underground water flow.
Provide for the monitoring of impacts on other underground water users	The groundwater impact assessment[2] has identified that there are no existing underground water users within the area of predicted impact of the project.
Provide for underground water level monitoring in all identified geological units across and adjacent to the mine site	Groundwater monitoring bores have been installed that allow for the monitoring of the groundwater units across and adjacent to the mine site. However it is noted that: • The Tertiary sediments are dry in the area of the CNE; therefore, no groundwater monitoring bores have been constructed within the Tertiary sediments • Quaternary alluvium does not exist in the area of the CNE. The alluvium is monitored under the Environmental Authority for the adjacent Jellinbah Plains mine.
Estimate underground water inflow to, and take from, mine workings	Data from the CNE groundwater monitoring bores will allow for estimation of inflow to the CNE mine workings.
Provide for the refinement and validation of the numerical underground water model used to assess impacts	Data from the CNE groundwater monitoring bores will allow for refinement and validation of the numerical underground water model that has been used to assess impacts.

This UWMP has been prepared to satisfy the requirements outlined above in Table 1-1.

1 Application for an associated water licence, Part E Minimum Requirements Checklist. Form W2F154-v4, Department of Natural Mines and Resources, Queensland Government, 2019.

2 Groundwater Report for Associated Water Licence (AWL) Application, Jellinbah Central North Extension (CNE) Area. Report prepared by JBT Consulting for Jellinbah Group Pty Ltd, Report No. JBT01-061-005, October 2020.

2.0 GEOLOGY AND HYDROGEOLOGY

Regional and site geology is described below and is summarised in Table 2-1. Figure 2-1 shows the project location in relation to 1:100,000-scale surface geology. Figure 2-2 shows the project location in relation to the underlying Bowen Basin solid geology (i.e. the surficial unconsolidated Quaternary and Tertiary units have been removed, revealing the relationship between the underlying Triassic and Permian sediments as well as the prevalence of regional-scale faults). With reference to Figures 2-1 and 2-2 it is observed that:

- The open cut mines are developed in areas where the Rangal Coal Measures subcrop beneath the Tertiary cover, i.e. mining is undertaken in areas where the coal measures are shallowest. The dip of the coal seams is to the east or southeast, so that the CNE extends mining down-dip from the CN mining area;
- The Jellinbah mines are situated within the Jellinbah Thrust Belt, which lies between the Jellinbah fault to the west and the Yarrabee Fault to the east; the faults act to compartmentalise the various groundwater units in the project area.

Site and regional stratigraphy includes:

- Quaternary-age alluvium associated with current surface drainage features such as Blackwater Creek, Twelve Mile Creek and the Mackenzie River;
- Tertiary deposits comprising mudstone, sandstone, siltstone and conglomerate of the Duaringa Formation, as well as sediments that are derived from Tertiary weathering and remobilisation of older units. Drilling data indicates that the Tertiary sediments are dry in the location of the CNE;
- Triassic sediments of the Rewan Group, which comprise lithic sandstone and green to reddish brown mudstone and which occur in the eastern area of the CNE; and,
- Coal-bearing sediments of the Late Permian Blackwater Group, including the Rangal Coal Measures, which contains the target coal seam for mining within the CNE (Pollux Seam).

Table 2-1: Summary of Regional Geology

Age	Unit	Description	Thickness (m)
Quaternary	-	Unconsolidated soil, silt clay, sand and gravel associated with current surface drainage systems, e.g. Blackwater Creek and Mackenzie River	0 to 50 m
Tertiary	Duaringa Formation and residual units	Mudstone, sandstone, conglomerate, siltstone	0 to 30 m
Triassic	Rewan Group	Lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanilithic pebble conglomerate at base	0 to 100 m+
Late Permian Blackwater Group	Rangal Coal Measures	Feldspathic and lithic sandstone, carbonaceous mudstone, siltstone, tuff and coal seams. Includes the Pollux Coal Seam, which is the target coal seam for mining within the CNE	0 to 100 m+ Aries Seam – 0 to 1 m Castor Seam – 0 to 1 m Pollux Seam - ~10 m
	Burngrove Formation	Mudstone, siltstone, sandstone, coal, tuff	0 to 90 m
	Gyranda Formation	Siltstone and shale with minor tuff and volcanilithic sandstone and rare coal (lower part - Banana Formation); calcareous sandstone, mudstone and siltstone (upper part - Wiseman Formation)	0 to 500 m+

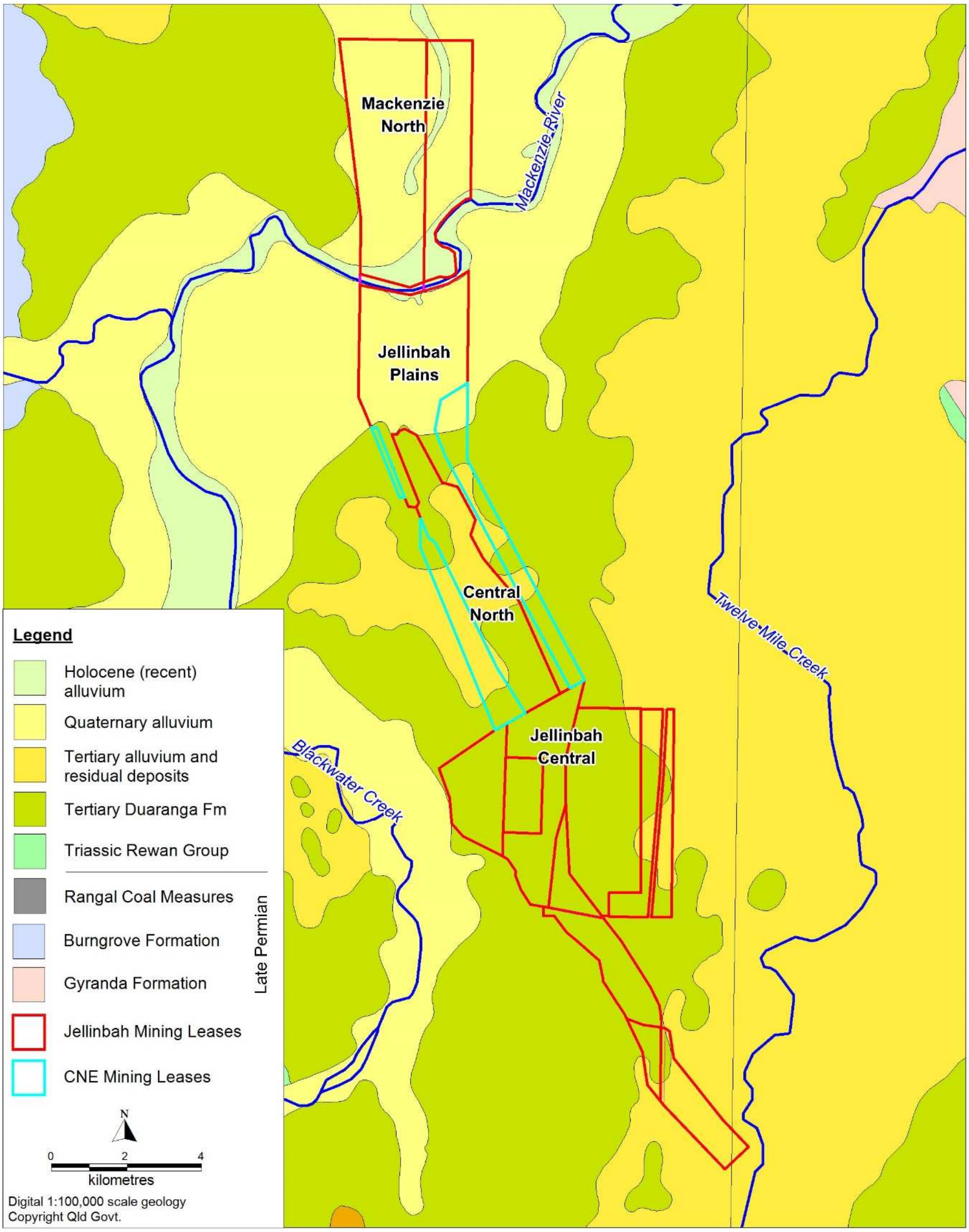

Figure 2-1: Project Location and Surface Geology (1:100,000 Scale Digital Geology)

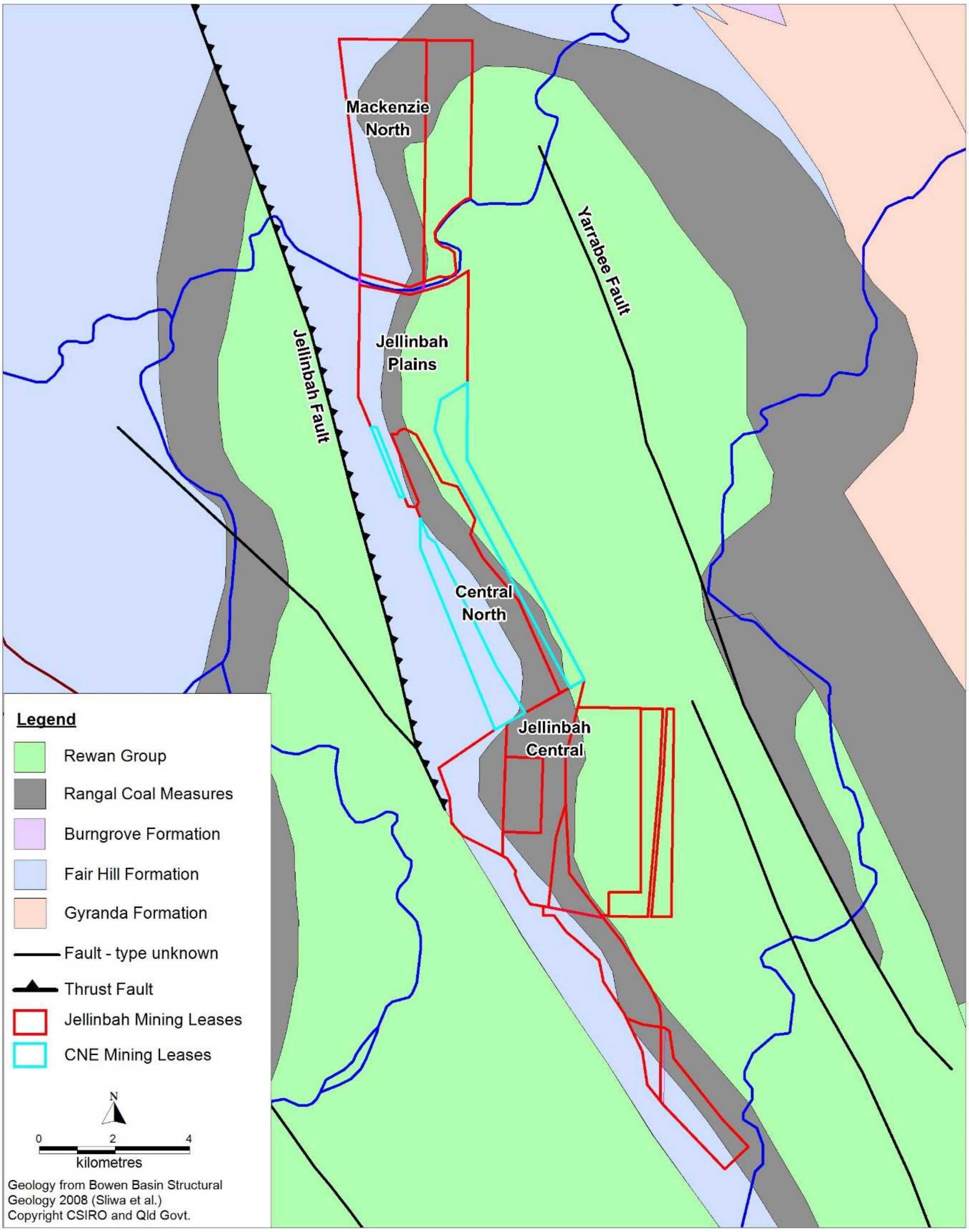

Figure 2-2: Project Location and Bowen Basin Solid Geology

3.0 GROUNDWATER MONITORING BORES

Following liaison with DNRME with respect to the groundwater monitoring requirements for the Project, groundwater monitoring bores were drilled and constructed at three locations adjacent to the CNE project area. The bores have been constructed as vibrating wire piezometer (VWP) bores, which allow the recording of groundwater level data at a number of vertical locations within the same bore. All bores include five VWP sensors and the same intervals are targeted in each bore, i.e.:

- The Aries coal seam
- The interburden between the Aries Seam and the Pollux Upper Seam
- The Pollux Upper seam
- The Pollux Lower Seam; and,
- The sandstone/siltstone immediately below the floor of the Pollux Lower Seam

As noted in Table 1-1, the Tertiary sediments are dry in the location of the CNE, therefore no groundwater monitoring bores have been constructed within the Tertiary sediments.

All bores have been fitted with a datalogger to allow logging of VWP water level data at daily intervals.

Bore construction details are shown below in Table 3-1, with bore locations shown in Figure 3-1. Bore construction logs are included in Attachment A.

Table 3-1: Groundwater Monitoring Bore Construction Details

Bore Number	Easting (GDA94	Northing (GDA94)	Collar Elevation (mAHD)	Sensor Depth (mbgl)	Target Unit
JC0894P	700352	7415159	148.58	75.5	Aries Seam
				90	Interburden between Aries Seam and Pollux Upper Seam
				102	Pollux Upper Seam
				141.5	Pollux Lower Seam
				145	Siltstone below Pollux Lower Seam floor
JPS0197P	699602	7416893	146.95	90.5	Aries Seam
				104	Interburden between Aries Seam and Pollux Upper Seam
				137	Pollux Upper Seam
				163	Pollux Lower Seam
				165.5	Siltstone below Pollux Lower Seam floor
JP0963P	697508	7420035	138.94	123	Aries Seam
				135	Interburden between Aries Seam and Pollux Upper Seam
				167	Pollux Upper Seam
				196	Pollux Lower Seam
				200.5	Siltstone below Pollux Lower Seam floor

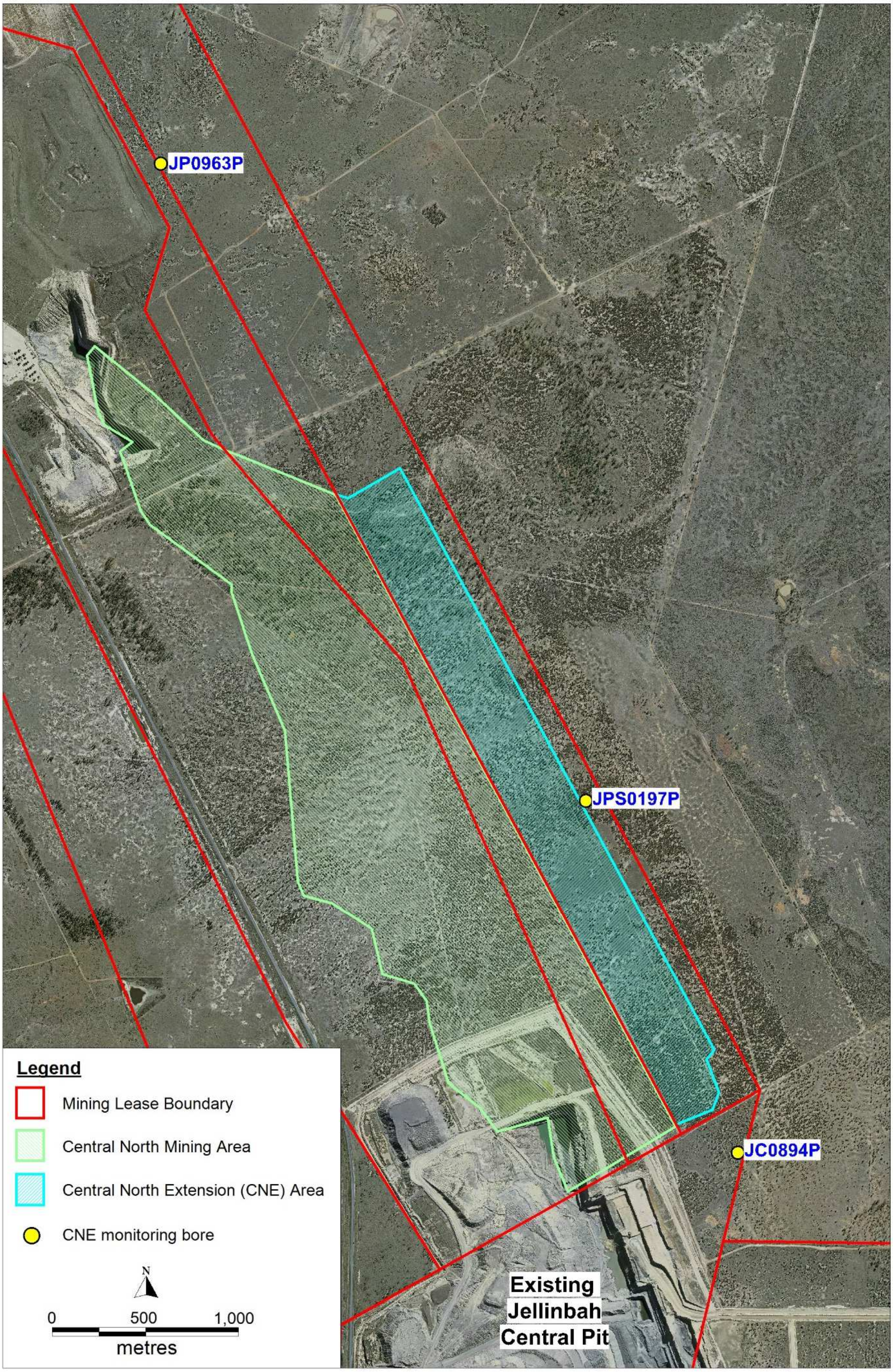

Figure 3-1: Groundwater Monitoring Bore Locations

4.0 GROUNDWATER LEVEL MONITORING

Groundwater level monitoring will be undertaken at all sites at a minimum of 3-monthly readings.

However, it is noted that all monitoring bores are currently equipped with dataloggers to allow daily recording of data, therefore the nominated collection of data at 3-monthly intervals is to be regarded as a minimum requirement.

5.0 STORAGE AND PUBLISHING OF MONITORING DATA

With respect to the storage and publishing of monitoring data:

- All monitoring results will be compiled and kept for a minimum of at least five years; and,
- In accordance with the general AWL requirements, it is proposed that groundwater level monitoring data that are collected under the UWMP will be published within 10 business days from measurement

6.0 REPORTING

An Annual Monitoring Report will be prepared by an appropriately qualified person and will include, as a minimum:

(a) the underground water levels in the monitoring bores identified in the approved Underground Water Monitoring Program;

(b) any changes in water quality in the monitoring bores, recorded in accordance with the approved Underground Water Monitoring Program;

(c) maps showing the actual water level drawdown contours for each aquifer;

(d) details of the numerical underground water model and any review undertaken of the numerical underground water model since the previous Annual Monitoring Report;

(e) an assessment of any differences between the actual water level impact and the impact predicted for the same period by the numerical underground water model;

(f) details of any bores which are predicted by the numerical underground water model to be located in the affected area; and

(g) raw data provided in a format as requested by the chief executive.

ATTACHMENT A

GROUNDWATER MONITORING BORE CONSTRUCTION DIAGRAMS

Project: Central North Extension

Bore ID: JC0894P

Installation Date: 15 July 2020

Lithological Description	Bore Construction/ General Drilling Notes
SOIL, brown	
CLAY, creamy-brown. Base of Tertiary at 15 mbgl	
CLAYSTONE, yellowish-brown	
SILTSTONE, yellowish-brown. Base horizon of weathering at 37 mbgl	
SANDSTONE, grey, fine to medium grained, black siltstone at bottom 1.78 m	
COAL, Aries Seam	Vibrating Wire Piezometer @ 75.5 mbgl - s/n 4930
SILTSTONE, interbedded with mudstone and minor coal	
COAL, Castor Seam	
SILTSTONE, brownish-grey, interbedded with mudstone and minor coal	Vibrating Wire Piezometer @ 90 mbgl - s/n 4932
COAL, Pollux Upper Seam	Vibrating Wire Piezometer @ 102 mbgl - s/n 4933
SILTSTONE, interbedded with mudstone and minor coal	
SANDSTONE, fine to medium-grained, light grey	
COAL, Pollux Lower Seam	Vibrating Wire Piezometer @ 141.4 m - s/n 4937
SILTSTONE, brownish-grey	Vibrating Wire Piezometer @ 145 m - s/n 4936

Graphic Log | Depth (m): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150 | Elevation (mAHD): 140, 130, 120, 110, 100, 90, 80, 70, 60, 50, 40, 30, 20, 10, 0 | Bore Design

Easting: 700352	Drilling Company:
Northing: 7415159	Drill Rig:
Collar RL (mAHD): 148.58	Hole Diameter (mm): 100
Co-ord System: GDA94	Total Depth (m): 146.0

Project: Central North Extension

Bore ID: JPS0197P

Installation Date: 16 July 2020

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes

Lithological Description

- SOIL, brown
- CLAY, light brown, base of Tertiary at 6 mbgl
- SILTSTONE, yellowish-brown, occasional sandstone bands, Base of Weathering at 19.5 mgl
- SANDSTONE, fine to medium-grained, light-grey, siltstone at base
- COAL, fault repeat of Aries Seam
- SILTSTONE, brownish-grey
- COAL, fault repeat of Castor Seam
- SANDSTONE, light grey
- SILTSTONE, brownish-grey
- SANDSTONE, light grey
- COAL, Aries Seam
- SILTSTONE, brownish-grey with black mudstone bands
- COAL, Castor Seam
- SANDSTONE, fine to medium-grained, light-grey, siltstone bands throughout
- COAL, Pollux Upper Seam
- SILTSTONE, dark grey, bands of mudstone and sandstone
- COAL, Pollux Lower Seam
- SILTSTONE, dark grey

Depth (m): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180

Elevation (mAHD): 140, 130, 120, 110, 100, 90, 80, 70, 60, 50, 40, 30, 20, 10, 0, -10, -20, -30

Bore Construction/General Drilling Notes

- Vibrating Wire Piezometer @ 90.5 m - s/n 4920
- Vibrating Wire Piezometer @ 104 m - s/n 4931
- Vibrating Wire Piezometer @ 137 m - s/n 4935
- Vibrating Wire Piezometer @ 163 m - s/n 4938
- Vibrating Wire Piezometer @ 165.5 m - s/n 4939

JBT consulting

Easting: 699602	Drilling Company:
Northing: 7416893	Drill Rig:
Collar RL (mAHD): 146.95	Hole Diameter (mm): 100
Co-ord System: GDA94	Total Depth (m): 166.5

Project: Central North Extension

Bore ID: JP0963P

Installation Date: 4 August 2020

Lithological Description
SOIL, brown
CLAY, orange-brown
SILTSTONE, brownish-grey, interbedded with fine to medium-grained sandstone
SANDSTONE, fine-grained, light grey, 1 m of siltstone at base
COAL, Aries Seam
SILTSTONE, brownish-grey
COAL, Castor Seam
SANDSTONE, fine to medium grained, light grey
SILTSTONE, brownish-grey
COAL, Pollux Upper Seam
SILTSTONE, brownish-grey
COAL, Pollux Lower Seam
SANDSTONE, fine-grained, light grey

Bore Construction/ General Drilling Notes

- Vibrating Wire Piezometer @ 123 m - s/n 4934
- Vibrating Wire Piezometer @ 135 m - s/n 8696
- Vibrating Wire Piezometer @ 167 m - s/n 4971
- Vibrating Wire Piezometer @ 196 m - s/n 8776
- Vibrating Wire Piezometer @ 200.5 m - s/n 4940

Easting: 697508

Northing: 7420035

Collar RL (mAHD): 138.94

Co-ord System: GDA94

Drilling Company:

Drill Rig:

Hole Diameter (mm): 100

Total Depth (m): 200.7