# CS ENERGY LTD

**Kogan Creek Mine PRCP**

**Groundwater Aspects**

**May 2021**



**ENVIRONMENTAL MANAGEMENT STRATEGIES**

A. B. N. 68 732 302 155

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# 1.0 INTRODUCTION

CS Energy is in the process of developing a transitional Progressive Rehabilitation and Closure Plan (PRCP) in accordance with the requirements of the *Environmental Protection Act 1994* (EP Act) at Kogan Creek Mine (the Project). The Project is owned by Aberdare Collieries Pty Ltd (Aberdare), a subsidiary of CS Energy Limited (CS Energy).

The transitional PRCP is applicable to Mining Lease (ML) ML50074 and the Project's Environmental Authority (EA) (EPML00417213) issued on 10 August 2018. The resource activity EA authorises the environmentally relevant activity (ERA) of mining black coal under Schedule 3 of the Environmental Protection Regulation 2019.

This report describes groundwater conditions in the pit area as they relate to mine closure.

The report includes an assessment on the site and all connected strata, and a conceptual model of the mine site's groundwater systems. Comments have been provided on any impacts the proposed landform (particularly the final void proposal) and PMLU may have on groundwater and vice-versa, as applicable. The report includes an assessment of:

- Groundwater occurrence including the presence and depth of aquifers and aquitards
- Local and regional groundwater recharge and discharge locations
- Groundwater quality of aquifers, and from any surface expressions
- Current and future uses of groundwater in the area including existing groundwater extraction bores
- Groundwater flow direction and velocity including any information relating to field tests to determine hydraulic conductivity
- Potentiometric mapping and hydro stratigraphic cross sections
- Contaminant transport mechanisms and potential changes to groundwater level from dewatering or waste storage.

Sections 2 to 6 provide information on mine and ash disposal infrastructure history and site scientific and technical background data.

Section 2 provides a brief outline of mine and ash disposal infrastructure and mine and ash storage development and related groundwater monitoring infrastructure history on ML 50074.

Section 3 provides an outline of catchment topography and drainage; climatic conditions and mine area soils, vegetation, land use and groundwater usage.

Section 4 provides information on the mine and local and regional geological conditions and mine waste geochemistry.

Section 5 is a summary outline of hydrogeology, groundwater conditions, groundwater hydraulics and groundwater chemistry in the mine and ash disposal areas and sub-regionally within the northern part of the Condamine Valley catchment.

Section 6 provides a discussion on local riverine vegetation and potential Groundwater Dependent Ecosystem presence.

Section 7 outlines the inferred surface water groundwater interaction between Kogan Creek and Condamine River and underlying Walloon Coal Measures strata.

Section 8 discusses the development of conceptual groundwater flow models associated with existing and future ash disposal areas on the mine lease.

Section 9 discusses ash management in IPAC cells and considers potential seepage contaminant indicators and seepage risk.

Section 10 considers potential hydraulic connectivity between alluvium and underlying Walloons strata that could be influenced by groundwater depressurisation of the Walloon Coal Measures in the vicinity of the mine and associated risks.

Section 11 discusses groundwater impacts at the final void.

Throughout this report, various abbreviations and acronyms are used. These are defined throughout the report, however, for ease of reference they are summarised below.

| ABBREVIATION | MEANING |
|---|---|
| **AHD** | Australian Height Datum |
| **bgl** | Below ground level |
| **btoc** | Below top of casing |
| **DERM/EHP/DES** | (former) Department of Resource Management and Department of Environment and Heritage Protection now Department of Environment and Science |
| **DNRM** | Department of Natural Resources and Mining |
| **DO** | Dissolved oxygen |
| **EA** | Environmental Authority |
| **EMS** | Environmental Management Strategies |
| **GDE** | Groundwater Dependent Ecosystem |
| **IADA** | Initial Ash Disposal Area |
| **IPAC** | In Pit Ash Cell |
| **OPAC** | Out of Pit Ash Cell |
| **OGIA** | Office of Groundwater Impact Assessment |
| **RL** | Reduced Level |
| **UWIR** | Underground Water Impact Report |
| **WCM** | Walloon Coal Measures |
| **WMPB** | Water Management Plan Bores |

# 2.0 KOGAN CREEK MINE AND ASH DISPOSAL INFRASTRUCTURE

This section provides a brief outline of mine and ash disposal infrastructure which is located on ML 50074. Kogan Creek Coal Mine is an open cut operation that has been delivering approximately 2.8Mtpa of Run-of-Mine (ROM) raw coal to the power station since 2007. The coal is not washed and subsequently no wash plant is required, and no coal reject or tailing is produced. Figure 1 is an oblique drone photo taken above the southeast corner of the mining area looking towards the north west in March 2019. It highlights the areas of coal extraction, and key mine area features. Key mine and ash disposal features are also shown on Figure 2.

The main infrastructure on the mining lease includes:

- Open cut mine pit including backfilled overburden and interburden spoil areas
- Run of Mine (ROM) Coal stockpile, crusher and conveyor
- Office and vehicle and machinery workshop maintenance and fuelling facilities
- Various water management dams and related stormwater diversion works
- Perimeter levees to prevent flood water inflows to the mine.
- The Initial Ash Disposal Area (IADA) on the western side of Kogan Creek
- The Out of Pit Ash Cell (OPAC) located to the east of the ROM Stockpile and north of the pit
- In Pit Ash Cell 1 (IPAC 1) and associated ash slurry delivery lines.


**Figure 1 Mine Pit Looking Northwest to Kogan Creek PS March 2019**

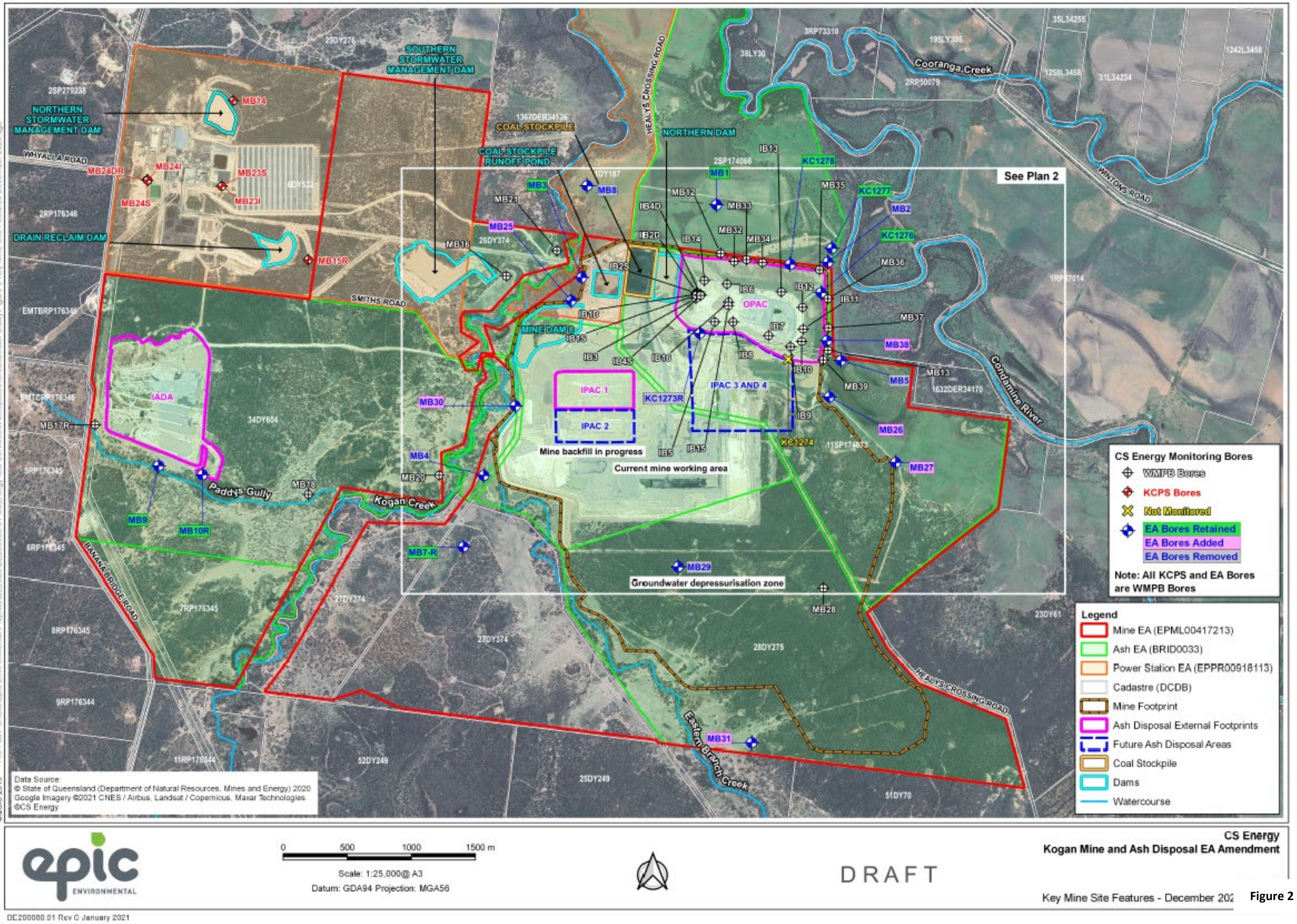



**Figure 2 Key Mine Site Features December 2020**

Figure 2 highlights mine water management storages. Each of the ash disposal areas IADA, OPAC and IPAC 1 is operated as a regulated storage, as are the ROM Pond and the various flood protection levee banks at the mine.

## 2.1 Mine Development

The mining development is principally based on mining three (3) seams, namely the M, N and O seams (refer Figure 3) in the Upper Juandah Coal Measures of the Walloons Subgroup. These seams vary in thickness and are separated by layers of silty mudstones and sandstones. The average combined seam thickness is 10 to 12m, with a maximum of 15.8 m in the mining area. The coal seams in the mine area have been informally named into major seams, in descending order K, M, N, O, R, S, T and U. The M, N and O seams correlate to the Upper Juandah Macalister and Nangram seams; whereas the R, S and T seams correlate to the Lower Juandah Wambo Seam. (RGS, 2017). Figure 4 shows a recent 2020 as-mined west to east cross-section developed from recent geological modelling (Xenith, 2020).

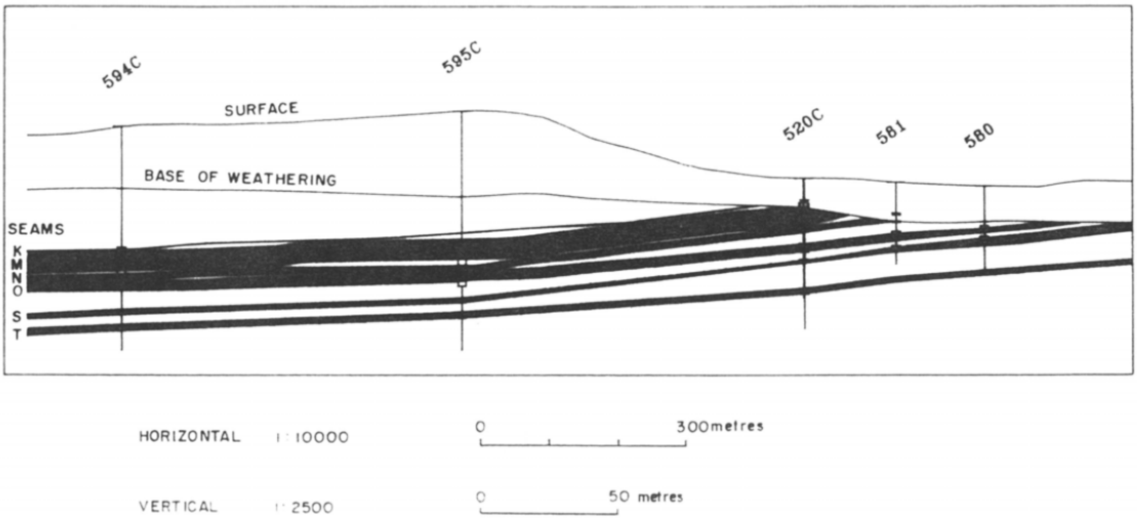
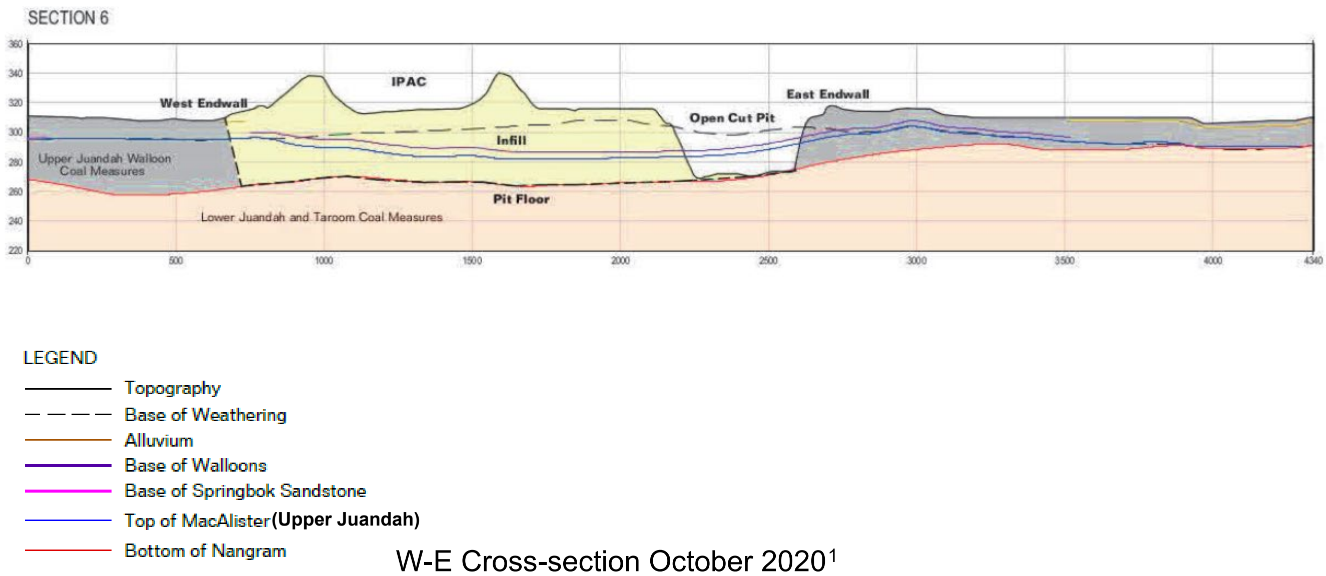



**Figure 3 Coal Seam Distribution Kogan Creek Mine**

Pre-Mining Cross-section




W-E Cross-section October 2020[1]

**Figure 4a Kogan Creek Mine West East Cross Section October 2020**

The coal sits in relatively flat 0.1 metre to 3 metre thick seams with parting layers of rock and clay between each coal seam. The coal is selectively mined from the parting and transported to the Run of Mine (ROM) pad, where it is loaded into the crusher and conveyed directly to the power station. The waste parting bands (interburden) are hauled to the spoil dumps which are located within the footprint of mined out areas. Initial overburden was used to form the base of and walls of the OPAC, located to the north of the open cut pit and adjacent to ML50074. The initial mine floor area beneath ash cell IPAC 1 was around RL 270 m.

The maximum depth of mine development is expected to be 60+m to around RL 260 m at the southern limit of mining.

[1] For location refer to Section 6 Figure 4b

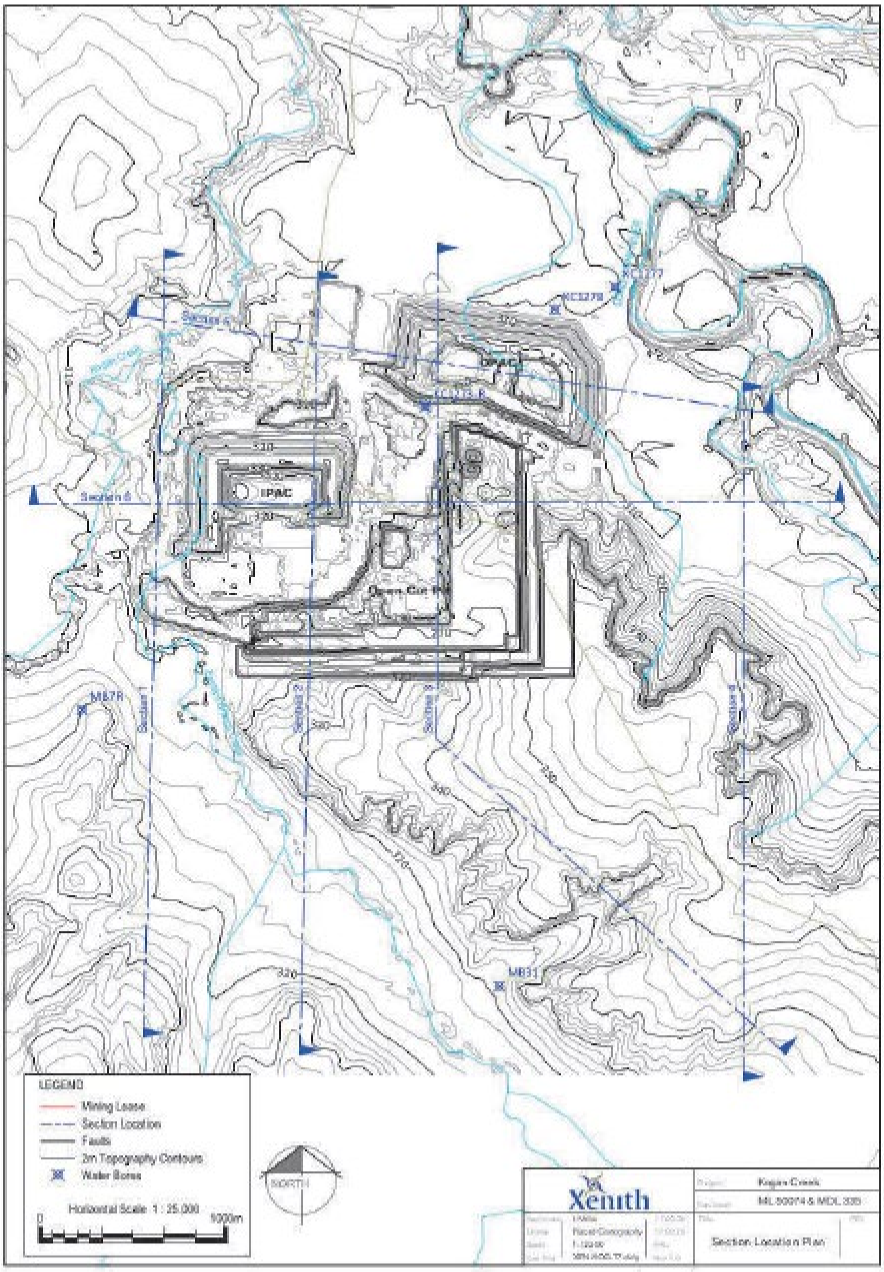



**Figure 4b Kogan Creek Mine West East Cross Section Location October 2020**

## 2.2 Ash Storage Development History

Fly ash and bottom ash generated from the burning of coal are contained in regulated waste storage areas. Over the 13-year life of the Kogan Creek mine/power station complex, ash has been managed in three EA approved storage areas: IADA, OPAC and IPAC 1 which all lie on ML 50074. Key events in the history of the development of ash storages are summarised below.

**Table 1 Ash Disposal History Key Dates**

| | |
|---|---|
| 2006 | Mine overburden transfer to OPAC area |
| Mid 2007 | IADA operations commenced |
| 2010 | Overburden dumping at OPAC complete<br>Liner placement on OPAC floor and walls |
| Late 2010 | Ash deposition in OPAC commenced |
| Early 2011 | Ash deposition IADA ceased |
| 2016 to 2018 | Occasional ashing and transfer of saline OPAC ash slurry water to the IADA (2016 to 2018) |
| 2018 to 2019 | Development of IPAC 1 cell |
| 2019 | Ash deposition IPAC 1 commenced<br>Final stage ashing and progressive final cover placement at OPAC ongoing. |

The current ash disposal EA allows for the future development of three additional in-pit ash cells: In Pit Ash Cell 2, In Pit Ash Cell 3 and In Pit Ash Cell 4. These are planned to be developed either to the south (IPAC 2) or east (IPAC 3, IPAC 4) of IPAC 1. Maximum approved ash cell surface areas and capacities are summarised below.

| Ash Storage | Maximum Approved Surface Area of Cell (ha) | Maximum Capacity of Cell ($m3 \times 10^6$) |
|---|---|---|
| Initial Ash Disposal Area (IADA) | 80 | 5 |
| Out of Pit Ash Cell (OPAC) | 72 | 7 |
| In-Pit West Ash Cell(s) each | 40 | 5 |
| In-Pit East Ash Cell(s) each | 40 | 5 |

# 3.0 SITE CHARACTERISTICS

The Kogan Creek mine is located on relatively low-lying ground associated with valley floor alluvium and shallow weathered sedimentary strata which steadily rises to the south between Kogan and Eastern Branch Creeks on its western/southern sides, and the Condamine River to the east. Floodwaters from both these waterways have the potential to flood the mine operational area, consequently flood diversion levees have been located on the western, northern and eastern sides of the mine area.

To the south and west of the mine, the topography steadily rises and reaches a maximum altitude of around RL 400 m to the south. To the east and north of the OPAC, ground elevations on the Condamine River floodplain are below RL 310 m, whilst Condamine River invert levels are inferred to be below RL 300 m to the east of the OPAC. Pre-mining topographical contours are shown at Figure 5.

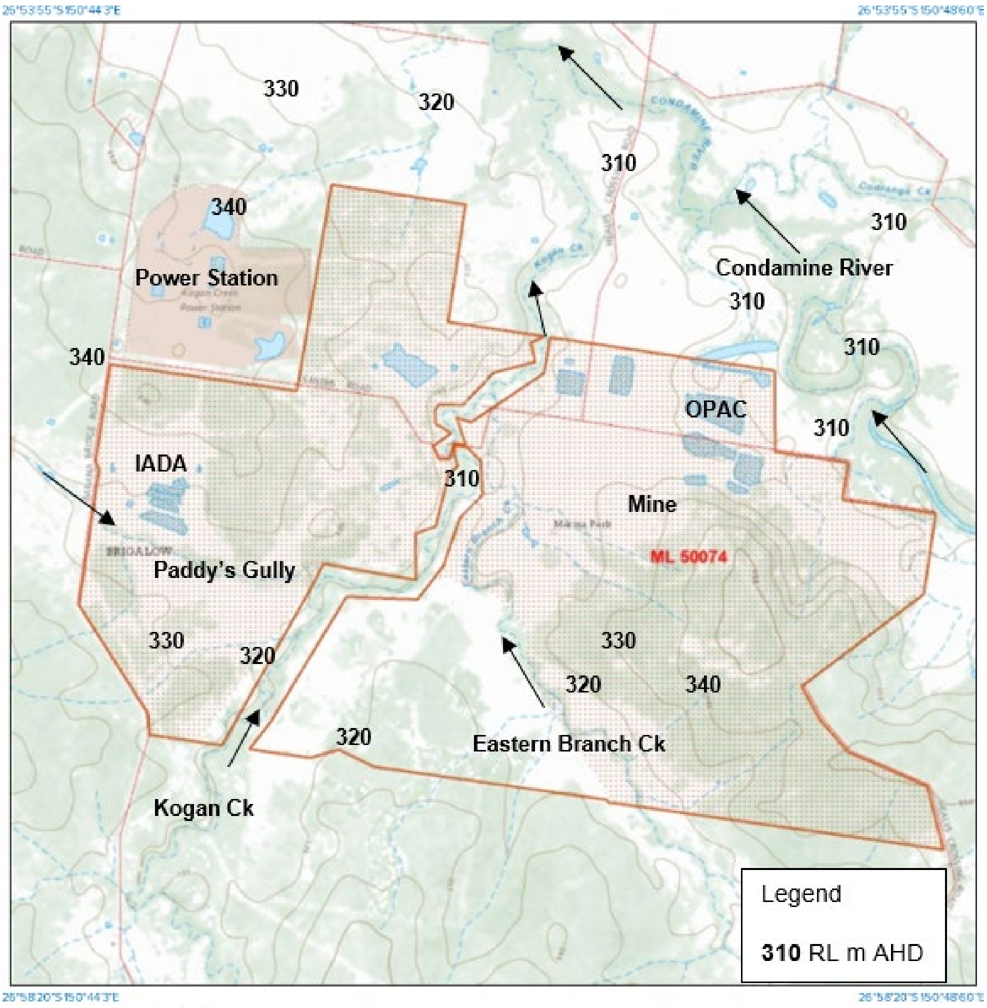



**Figure 5 Site Topography**

Source: Base Map Queensland Globe DNRME 2020

## 3.1 Catchment Characteristics

The mine and power station are located within the Condamine River catchment (Figure 6) which is located west of the Great Dividing Range in southern Queensland. The Condamine Catchment is at the headwater of the Murray-Darling Basin. Creeks to the east flow away from the Great Dividing Range through undulating basaltic landscapes with flood flows spreading across the landscape as they approach the Condamine River. Kogan Creek drains elevated Surat Basin sediments to the south.

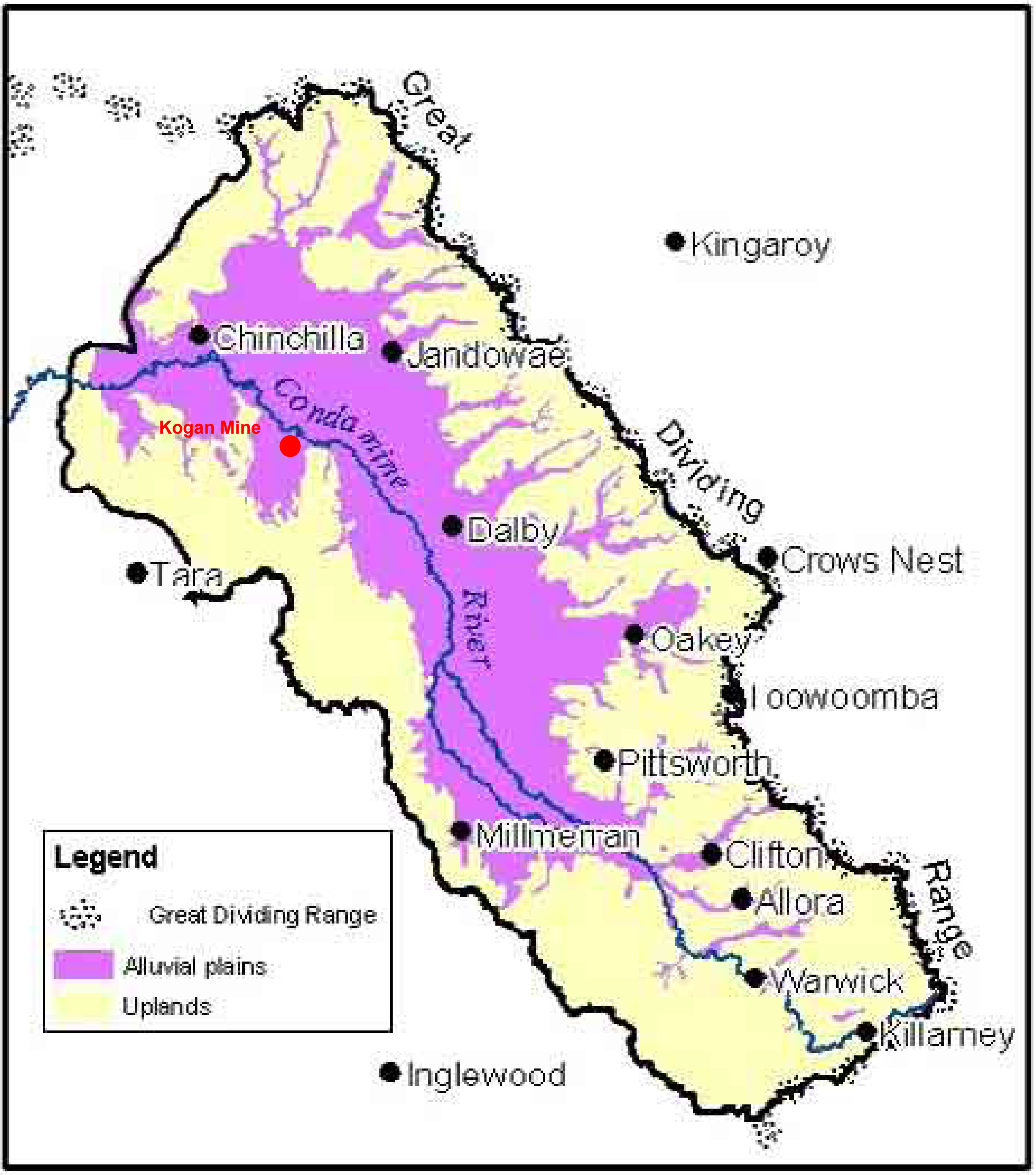



**Figure 6 Condamine River Catchment**

## 3.2 Climate

The area has a highly variable subtropical climate with summer dominant rainfall and a distinct dry season during the winter months, with an annual average rainfall in the order of 610 mm (data obtained from Bureau of Meteorology, Dalby Airport). Average temperatures in the region range between 6.4°C and 33.7°C and prevailing winds are from the southeast although northwest winds occur in spring and early summer (Golding, 2008).

## 3.3 Soils

Topsoil depth is very shallow and the area has been subject to long periods of weathering and leaching. The soil at the site is of low fertility, lacking major nutrients, alkaline and highly sodic in nature with no evidence of potential acid generation (Sinclair Knight Merz, 1999). The subsoils (overburden) are unlikely to be acid forming as they are characterized by a low sulphur content and high inherent acid neutralizing capacity (Golding, 2008). Soils are also prone to erosion.

## 3.3 Vegetation

From a groundwater management perspective for the Kogan Creek mine, the main vegetation assemblages of interest are those associated with alluvium of Kogan Creek and the Condamine River. In both cases this is predominantly RE 11.3.2 *Eucalyptus populnea* woodlands on floodplains with variable presence of 11.3.18 (*Callitris glaucophylla, Allocauasuarina luehmannii*), 11.3.17(*Acacia harpophylla* and/or *Casuarina cristata*) and 11.3.4 *Eucalyptus tereticornis* woodland.

These terrestrial systems are reportedly dominated by *Eucalyptus camaldulensis* (river red gum). Remnant regional ecosystems based on vegetation assemblages are shown at Figure 7. Such communities represent high potential (the most likely) Groundwater Dependent Ecosystem (GDE) areas that exist proximal to CS Energy mining and ash disposal activities.

## 3.4 Land Use

Local land use in proximity to the site is predominantly broadacre cropping (cereals, legumes) with some grazing (cattle, pigs, sheep) in areas north of the site, with grazing and forestry in more elevated areas to the south.

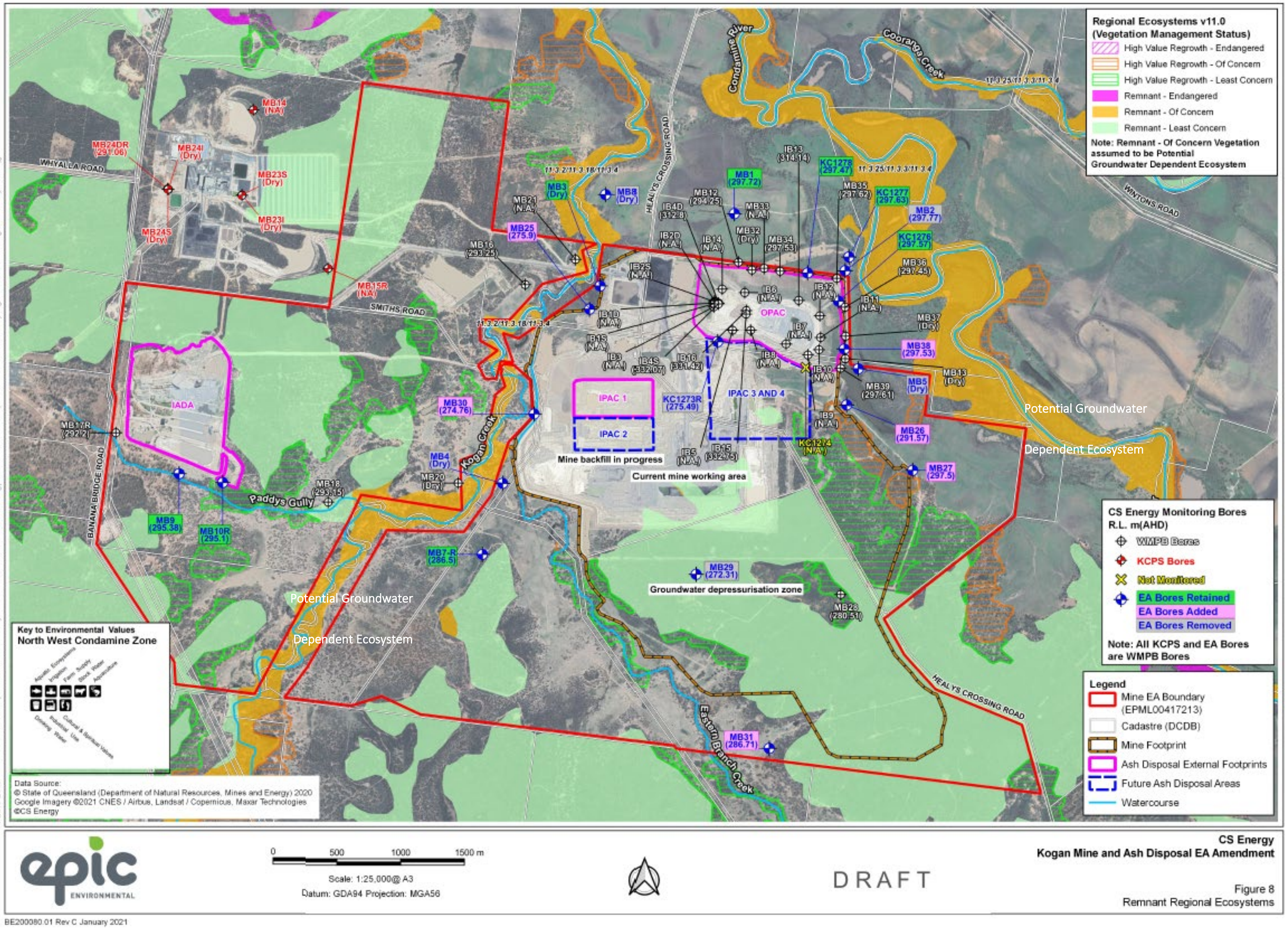
The site is located within the Surat Basin, with numerous Petroleum Leases mapped in areas surrounding the site. Coal seam gas extraction occurs to the south and south west of the site with former Underground Coal Gasification (UCG) pilot plants located approximately 6.5 km west (former Linc Energy) and 22 km south (former Carbon Energy) of the site.

## 3.5 Groundwater Usage

Groundwater usage in the vicinity of the site is expected to be limited to domestic and stock watering from Condamine River alluvium and stock watering only from underlying Springbok Sandstone/Walloon Coal Measures bores due to quality constraints. Registered water bores within a 5 km radius of the power station/mine are shown at Figure 8.

The Springbok Sandstone is not considered to be a major aquifer of the Great Artesian Basin. The most significant aquifer units of the eastern Darling Downs are the Gubberamunda Sandstone (not present beneath the site) and the deeper Hutton and Precipice Sandstones.

The power stations main make-up water supply is sourced from the Hutton Sandstone approximately 1 km north of the site and has also historically been sourced from the Precipice Sandstone approximately 20 km to the south of the site.




## Figure 7 Remnant Regional Ecosystems

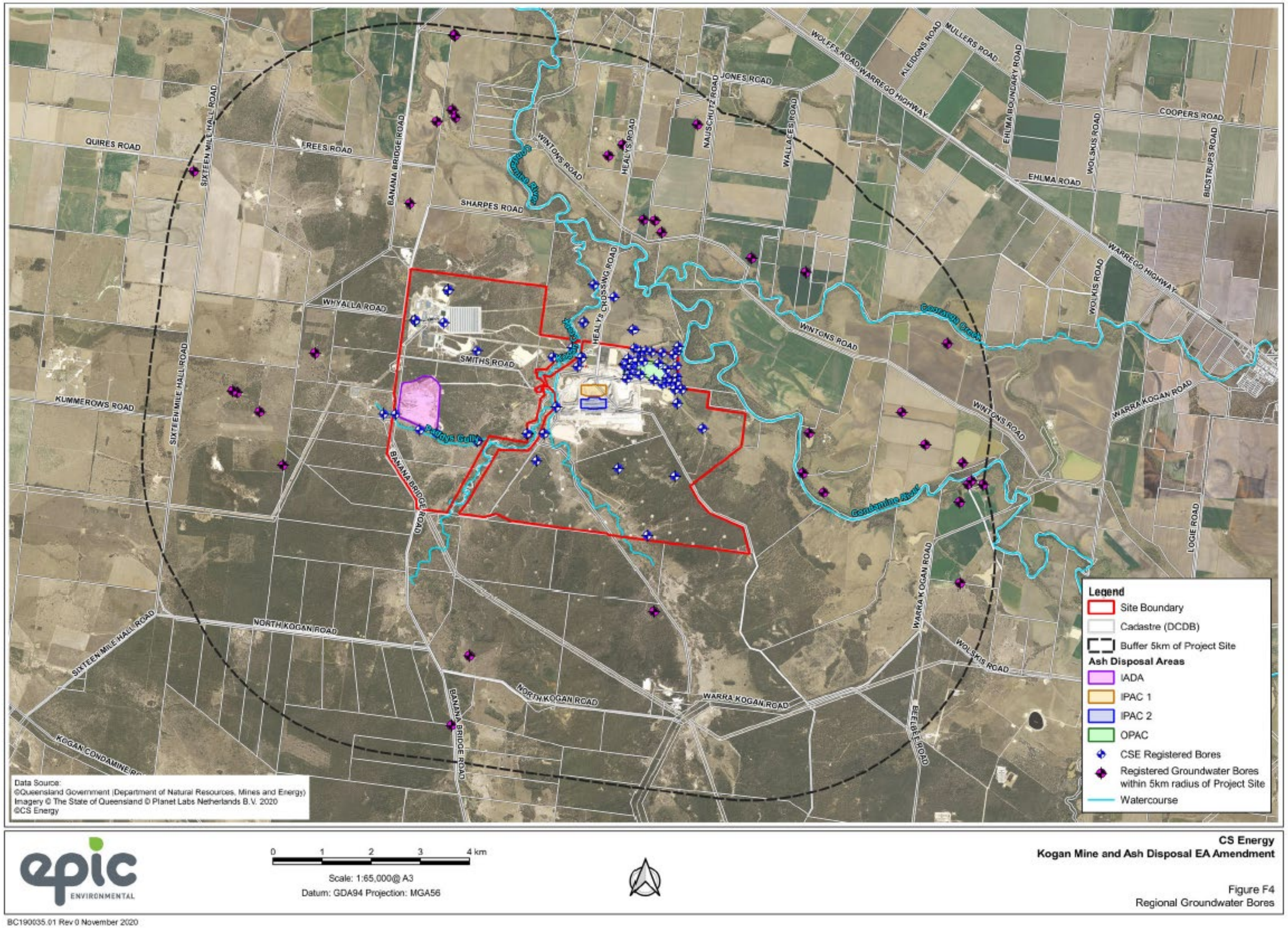



**Figure 8 Registered Groundwater Bores Within 5 Km of Kogan Creek Power Station/Mine**

# 4.0 GEOLOGY

Geologically, the site overlies sedimentary rock strata of the Surat Basin which is part of the Great Artesian Basin and an important water resource. The site lies within the Surat Basin Coal Seam Gas Cumulative Impact Zone established by the Office of Groundwater Impact Assessment (OGIA) for the Queensland Government. The OGIA has developed a regional groundwater model of the Surat Basin as a tool to manage and mitigate potential impacts on groundwater users of the coal seam gas and major coal mining industries groundwater abstractions from the Walloon Coal Measures.

The regional stratigraphy of the Surat Basin is shown in Figure 9.

The general geology of the power station/mine sites as drawn from recent Queensland Geological survey mapping (and from which the mine geology modelling[2] (Xenith 2020) is based) is shown in Figure 10a. Mine area geology and Water Management Bores are shown in Figure 10b.

Topsoil depth at the mine is very shallow and the area has been subject to long periods of weathering and leaching.

The main geological units in the area are:

- Alluvium associated with Condamine River, Kogan and Eastern Branch Creeks;
- Springbok Sandstone. Cross bedded clayey lithic to very lithic sandstone, some porous; siltstone, mudstone
- Upper Juandah Coal Measures of the Walloon Subgroup. Carbonaceous mudstone and siltstone; some sandstone and coal.

Geological modelling (Xenith 2020) indicates the mine area and surrounds including Kogan Creek, Eastern Branch Creek and Condamine River are underlain by Walloons Coal Measures strata which is inferred to directly subcrop beneath the Kogan Creek and Condamine River alluvium. The geology of the mine site is well established from geological drilling and logging.

The Kogan Creek coal deposit forms the shallowest part of the Walloon Coal Measures which were deposited in the Surat Basin during mid-Jurassic times. The Upper Juandah Walloon Coal Measures were formed in freshwater swamps, lakes and low velocity streams. They comprise of medium to very fine sandstones, siltstones, mudstones, claystones and banded coal seams.

Figure11[3] shows modelled geological cross-sections of the Condamine Valley alluvium upstream and downstream of the Kogan Creek mine.

[2] *Conceptual Groundwater Models* Xenith Consulting October 2020

[3] Groundwater Connectivity between the Condamine Alluvium and the Walloon Coal Measures OGIA August 2016 Figure 4.4 p. 34

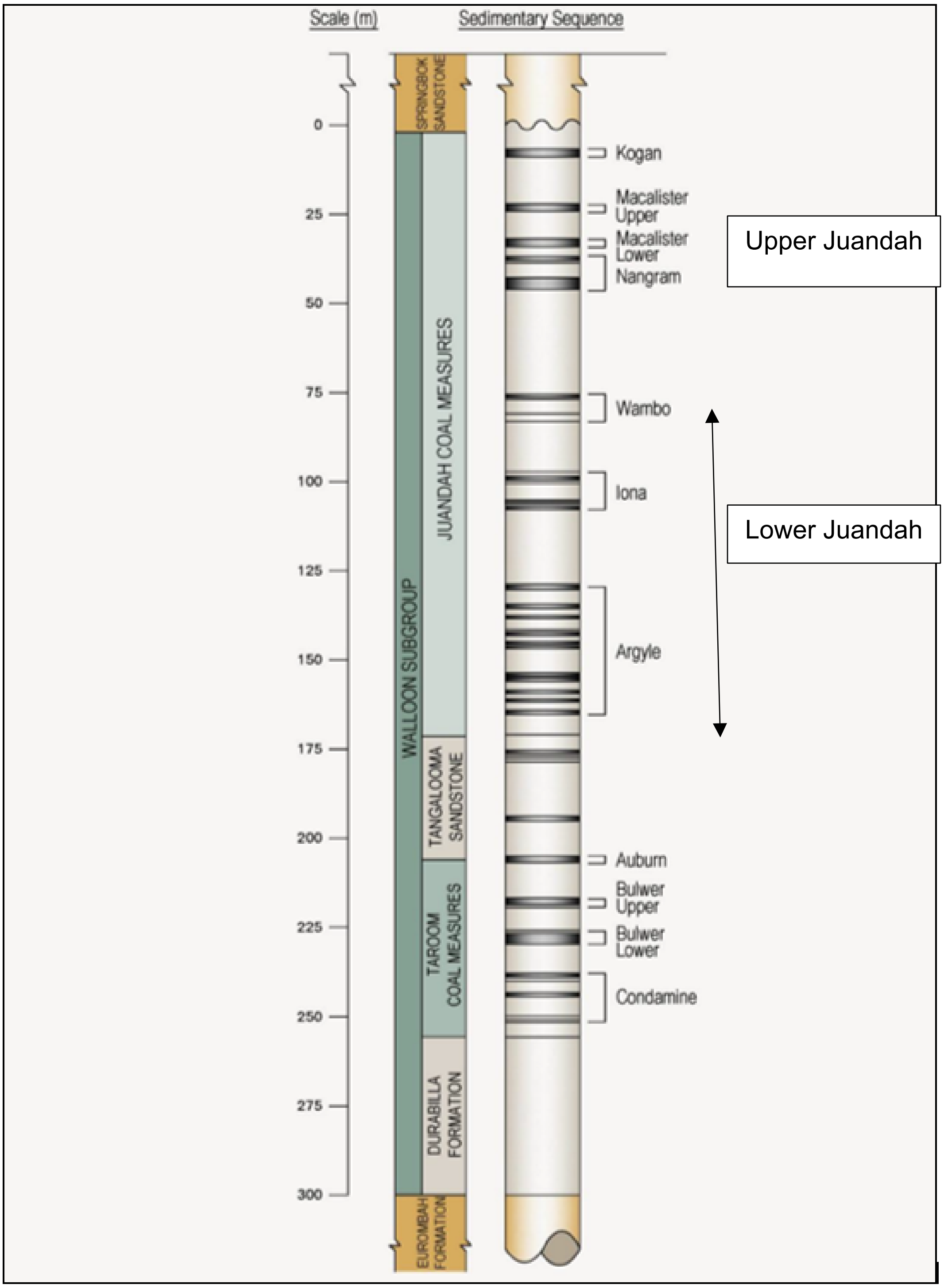



**Figure 9 Regional Stratigraphy of the Surat Basin**

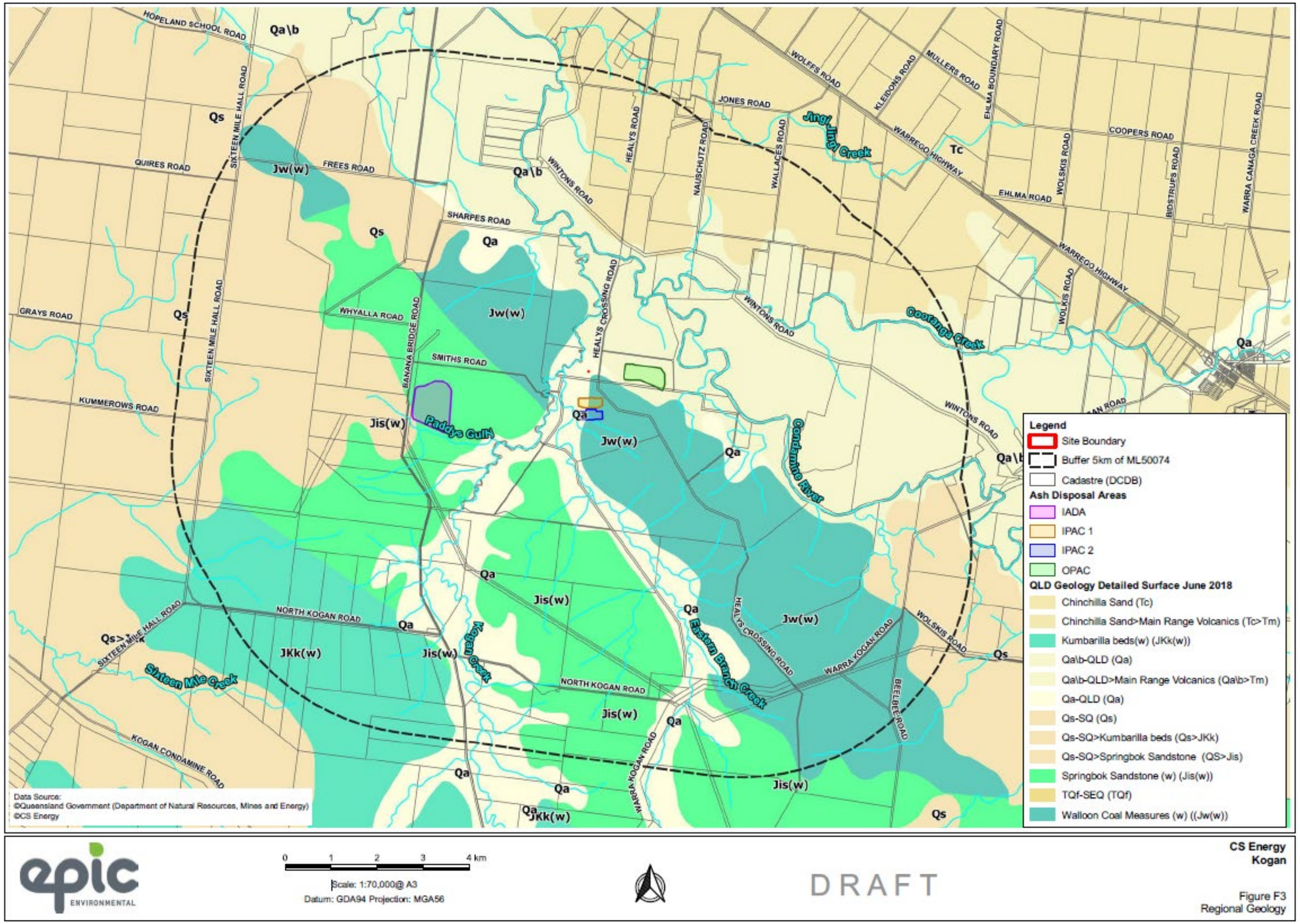



**Figure 10a Regional Geology**

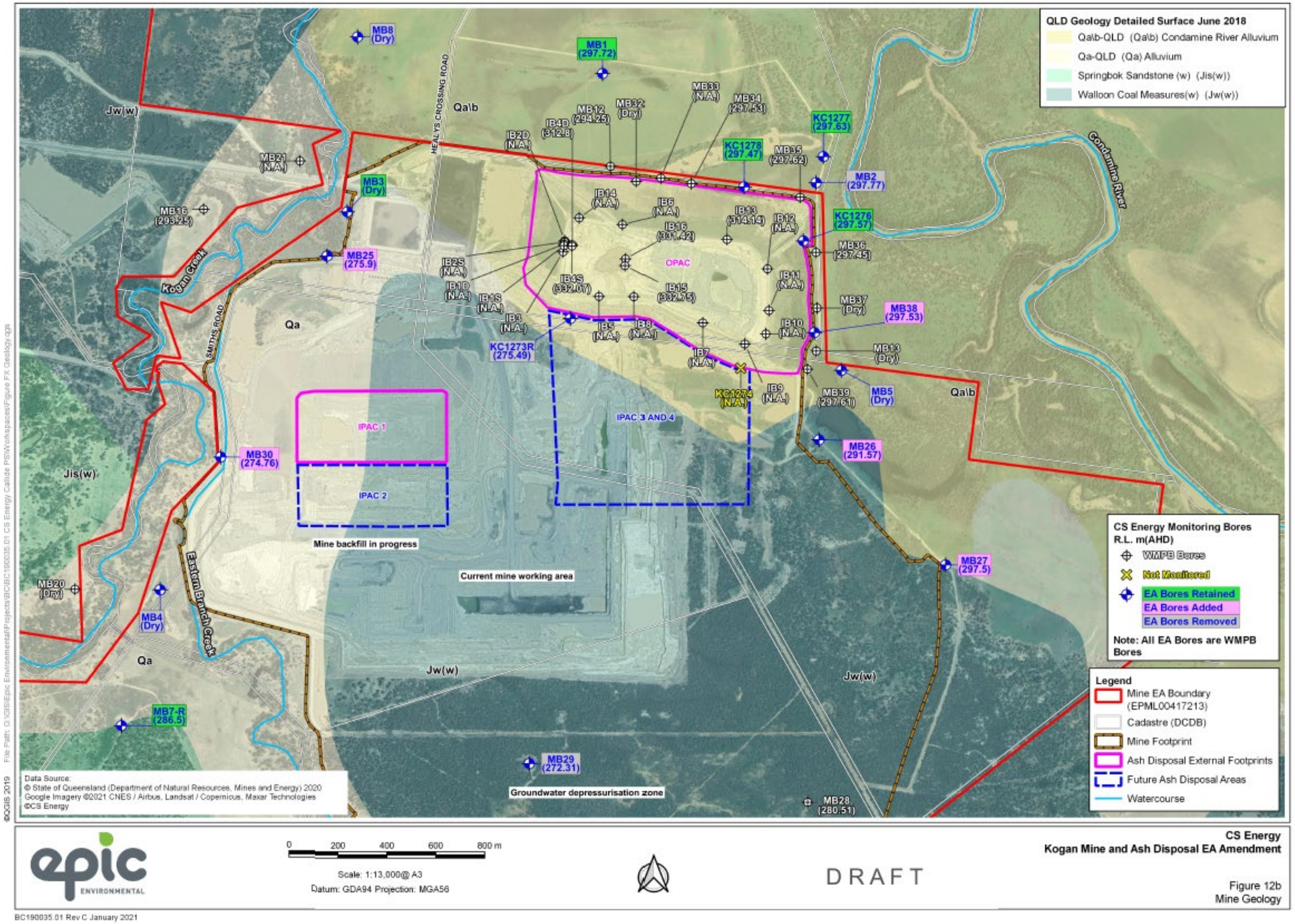



**Figure 10b Mine Geology**

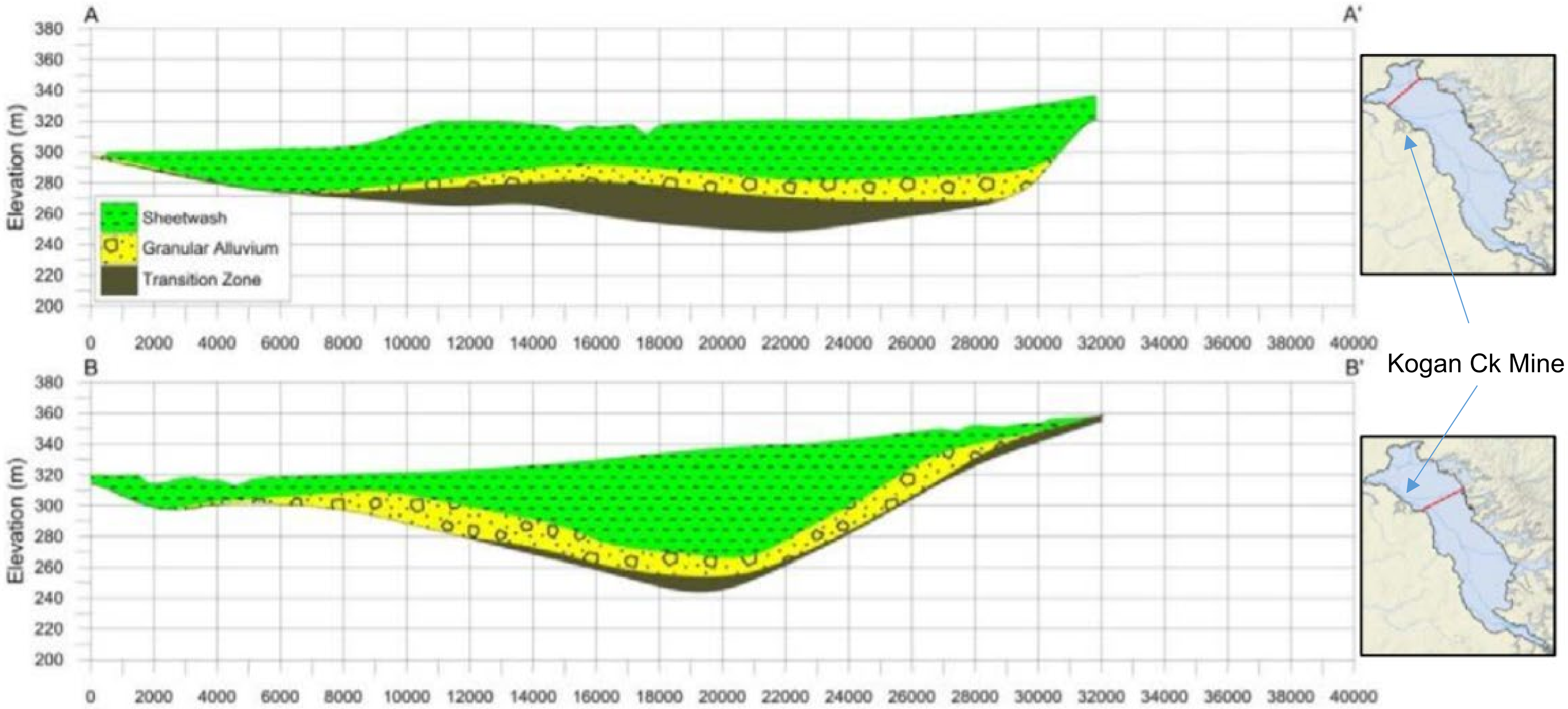



**Figure 11 Regional Geological Cross-sections Condamine Valley Alluvium**

## 4.1 Structural Geology

Kogan Creek Coal Mine is located to the west of and adjacent to the alignment of the N-E striking basement Wambo Fault. Faults affecting the Walloon Coal Measures (WCM) have in general small displacement (less than 50 m). The majority of faulting or folding observed in the WCM is associated with "keystone" structures which are often narrow, down-drop graben blocks that are tightly folded. Primary bounding faults of these features are found to often offset base Condamine alluvium.

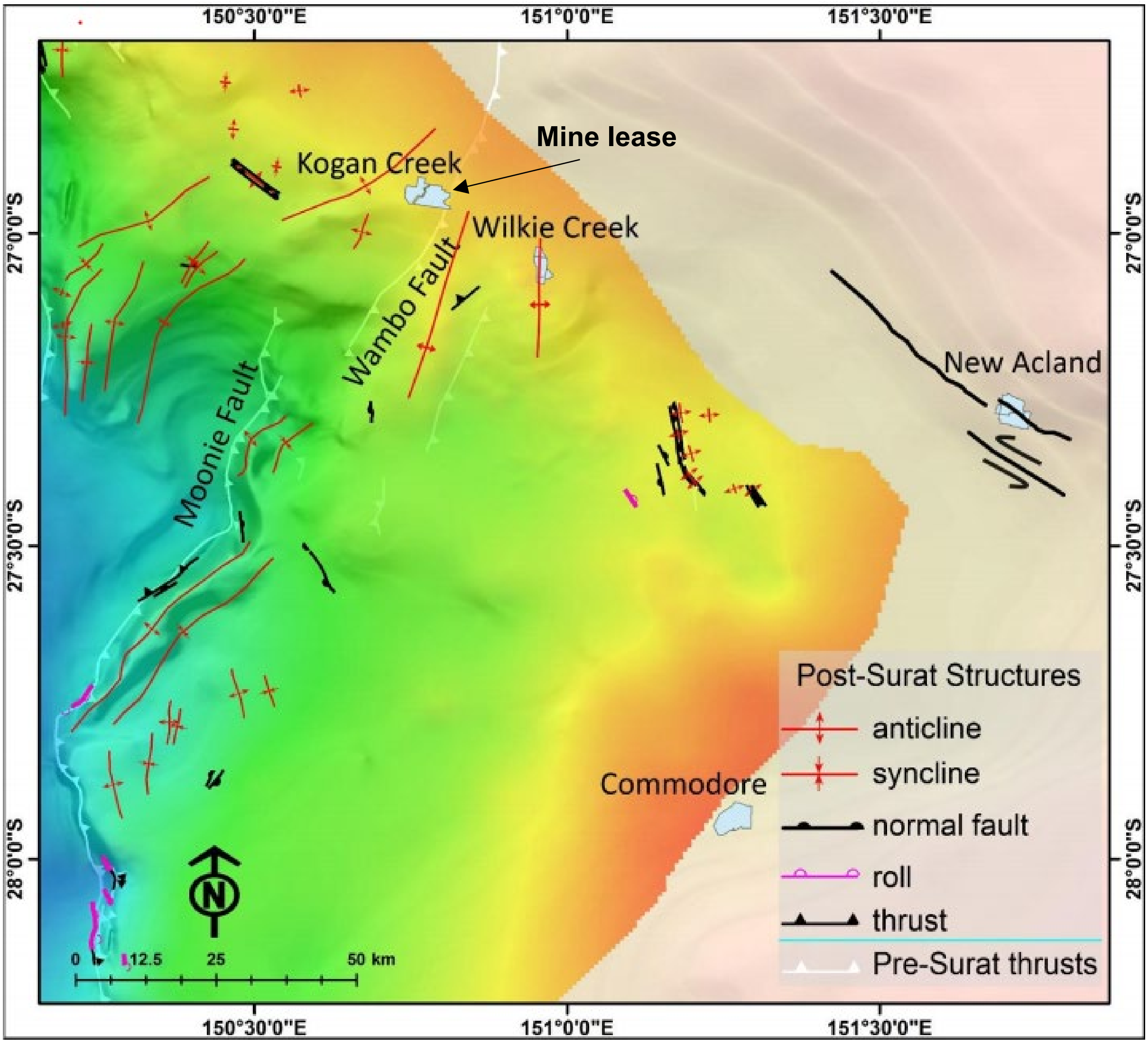



**Figure 12 Structural Geology**

Anticlinal structures are present in Walloons strata and minor reverse faulting is present in the mine (Figure 13a).


**Figure 13a Thrust Fault Kogan Creek Coal Mine**

Thrust faults have been identifed at the western edge of the mine adjacent to Kogan Creek (Figure 13b). The coals show two dominant joint sets , striking NW-SE and NE-SW.[4]

### 4.2 Mine Waste Geochemistry

Geochemical and physical characterisation test programs (RGS, 2016, 2019) were undertaken to assess overburden, interburden and uneconomical coal seam (parting, roof and floor) spoil materials from the mine in accordance with relevant industry guidelines (COA, 2016a, b) and the degree of risk from the presence of reactive sulphides, acid generation, and leaching of soluble metals/metalloids and salts. The assessment also included characterisation of standard soil parameters including salinity, cation exchange capacity and exchangeable sodium percentage to assess the suitability of mine spoil for rehabilitation purposes.

The results from geochemical testing of the overburden and interburden materials sampled from the Eastern Area of the mine indicate that:

- Most materials have negligible sulphur, low to high Acid Neutralising Capacity, and are classified as Non Acid Forming – Barren (NAF-Barren). There is therefore a high factor of safety and low risk of acid generation from most of these materials;
- Some of the weathered claystone overburden material may initially release some existing acidity into contact water;
- All materials have low concentrations of metal(loid)s that do not present a significant risk to the environment with respect to total metal(loid) concentrations in solids;

[4] Faults and Fractures in the Surat Basin- Relationships with Permeability Copley J., S. Mukherjee, A. Babaahmadi, F. Zhou, K. Barbosa, S. Hurter, S. Tyson School of Earth and Environmental Sciences Queensland University September 2017

- Most materials generate pH neutral to slightly alkaline contact water with low salinity and low concentrations of dissolved metals/metalloids and therefore poses negligible risk of potential impact on the quality of surface and groundwater resources;
- Some of the weathered claystone overburden material may initially generate slightly acidic pH contact water; however, leachate salinity and dissolved metal(loid)s concentrations are likely to be low.

Overall, Kogan Creek spoil material is considered to be Non Acid Forming and have a high factor of safety with respect to potential for Acid Mine Drainage, Neutral Mine Drainage and/or saline drainage. The spoil material also contains low concentrations total and leachable metals/metalloids (RGS, 2019).

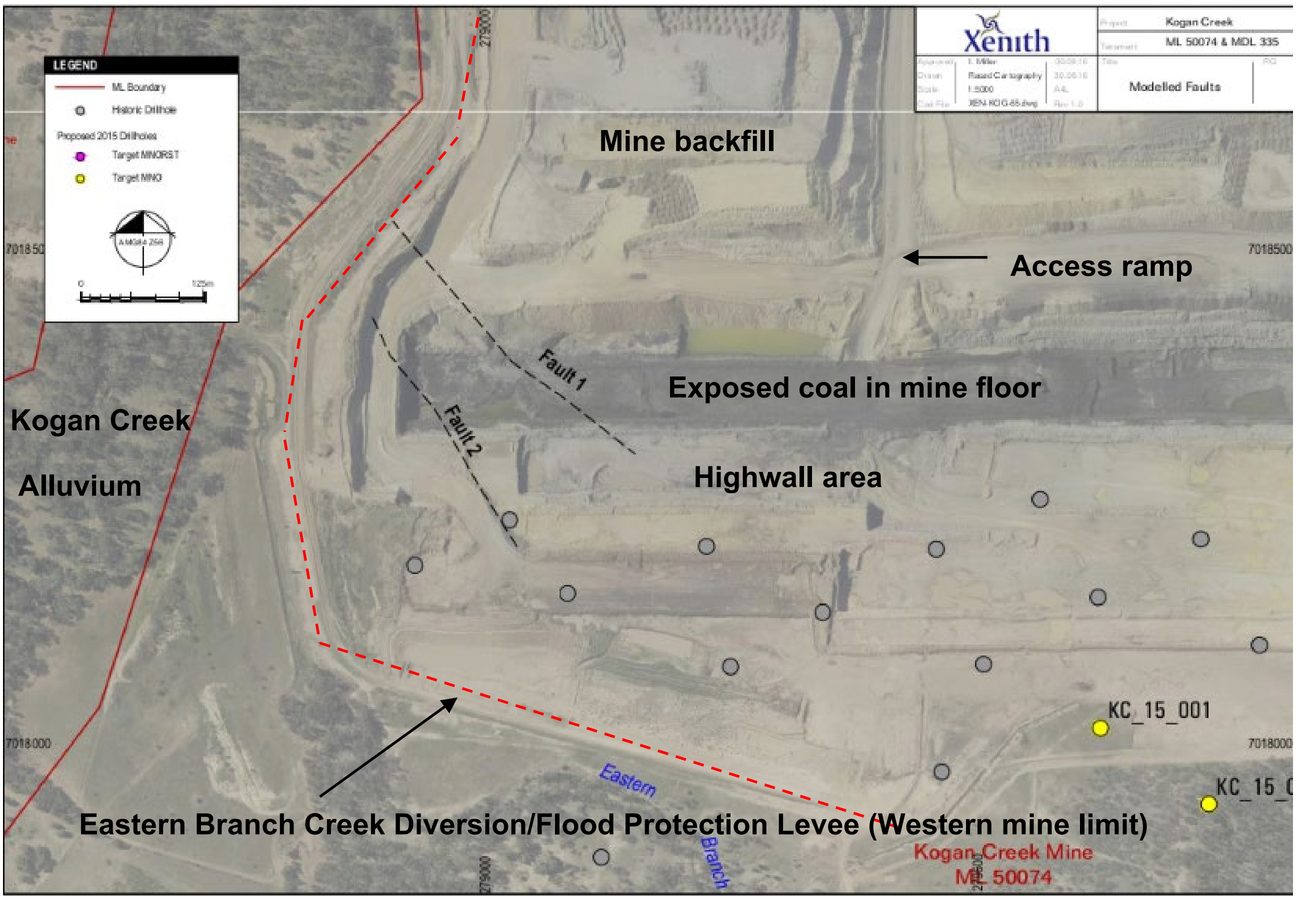



**Figure 13b Thrust Fault Kogan Creek Coal Mine**

# 5.0 HYDROGEOLOGY

## 5.1 Background Groundwater Conditions

Groundwater in the vicinity of the mine and adjacent areas is present in:

- Unconsolidated alluvial sediments of the Condamine River and Kogan Creek;
- Sediments associated with bedrock weathering;
- Possible higher permeability zones within sandstone bedrock (referred to as Springbok Formation) associated with fractures and joints below approximately 15 m depth; and
- Coal seams and sandstones of the Walloon Coal Measures. Groundwater is associated with coal seams and associated bedding plane partings and is likely associated with fractures, joints and open faults where present in sandstones.

Groundwater usage for agricultural purposes from aquifers within the Condamine Alluvium is widespread in the Condamine River valley, although limited in the vicinity of the Kogan Creek Power Station/Mine. Groundwater from the Walloon Coal Measures is used for stock watering and also extracted as part of coal seam methane gas production to the west and south. A conceptual hydrogeological model of the power station/mine area is shown in Figure 14. Groundwater elevations in bores are a function of topography, depth of bore and geology intersected. Bores drilled into alluvium may have higher or similar standing water elevations to bores that monitor groundwater elevations in underlying sedimentary rock aquifers. Standing groundwater elevations in rock aquifers beneath the power station site are estimated to be 15-45 m below ground elevation, depending on bore location and land elevation. Condamine River alluvium has low salinity indicating local rainfall and streamflow recharge.

The model shows conceptualised groundwater flow directions in Condamine Alluvium, Springbok Sandstone and the Upper Juandah sequence of the Walloon Coal Measures, highlighting a groundwater depressurisation zone that has developed around the mine pit and potential leakage from Springbok Sandstone to Walloons and Kogan Creek and Condamine Alluvium to the Walloons. Inferred groundwater flow directions in alluvium, Springbok Sandstone and Walloons are shown in Figures 16,17, 19 and 20.

## 5.2 Formation Thicknesses

Geological modelling indicates that much of the power station area and IADA are underlain by Springbok Sandstone whilst the current mine area is underlain by Walloon Coal Measures strata with outcrops of Springbok Sandstone on elevated terrain.

Kogan Creek alluvium consists of fine to medium-grained sands and coarse sands and gravels and is in the order of 13 to 14 m thick at bores MB1, MB3 and MB8. On the eastern side of the planned extent of mining, Condamine River Alluvium is only 4 m thick at bore MB26 but is present at depths of up to 15 m in bores further to the north of the OPAC. At bore KC1277, up to 9 m of medium grey clay was intersected below coarse-grained alluvial sands.

Only a thin layer of surficial clay overlies weathered sandstone in Walloon Coal Measures bores MB25 and MB30 on the eastern side of Kogan Creek, between it and the mine. Weathered Walloons strata with thicknesses of 23 and 32 m respectively are present in bores MB25 and MB30. Weathered sandstones are present to 15 m depth in MB25 with slightly weathered coals from 22 to 23 m depth and fresh coal from 25 to 26 m overlying coarse grained grey sandstone.

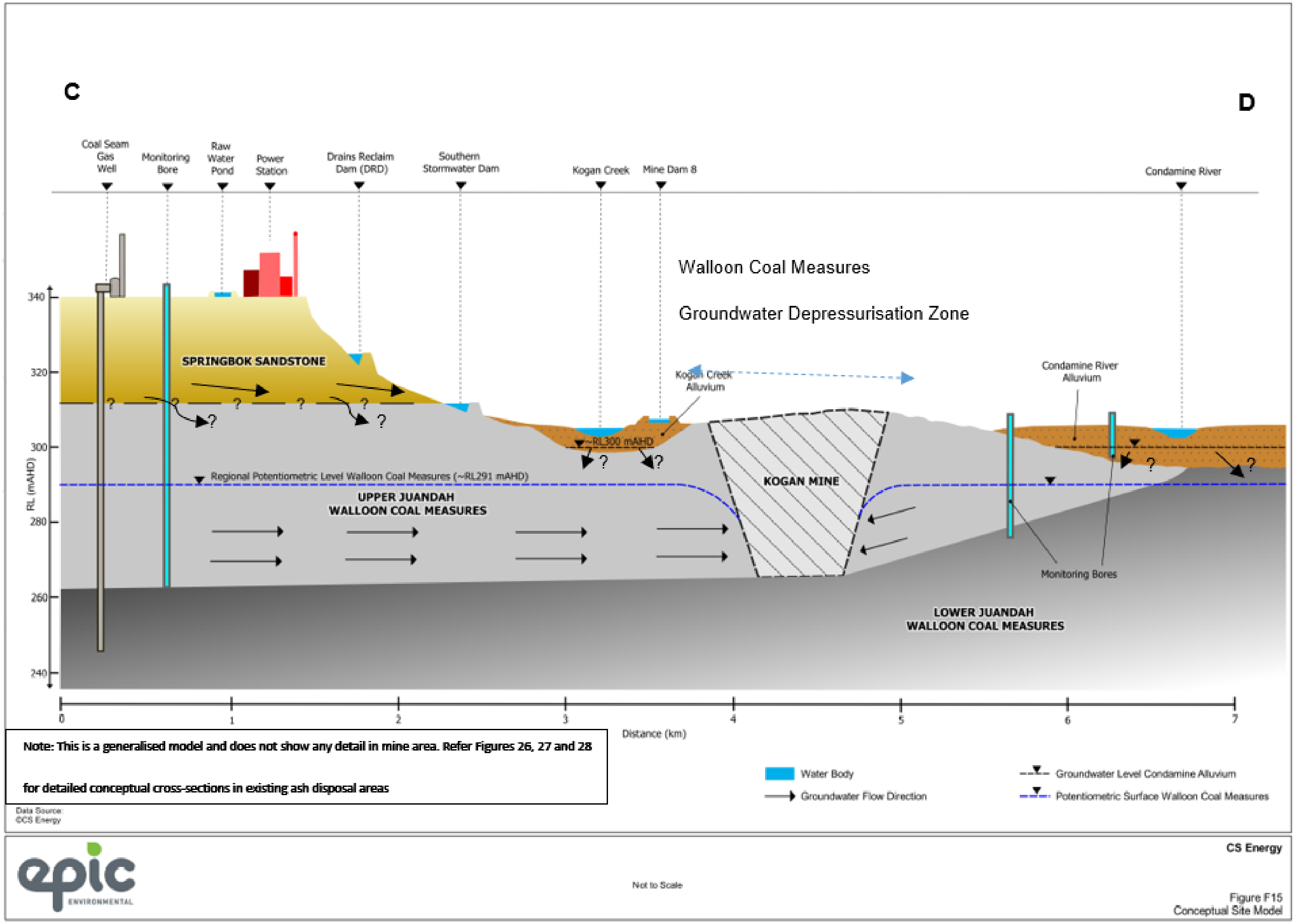



**Figure 14 Generalised Conceptual Hydrogeological Model**

At MB30 weathered sandstones, siltstones and mudstones are present to 32 m overlying fresh grey siltstone with fresh coal first intersected at 36 m bgl. At bore MB26 on the eastern side of the mine, the depth of weathering in the Walloon Coal Measures was 12 m and several coal seams were intersected above the first inflow zone, in a sandstone at 24 m depth. Damp coals were intersected at 33 to 35 m.

## 5.3 Monitoring Bore Construction

Walloons monitoring bores range in depth from 15 to 20 to in excess of 80 m depending on mine area location. Monitoring bores have been constructed by licensed water bore drillers and generally in accordance with standard industry practise.[5] Bores are typically drilled with blade bit/air hammer to target depth and constructed with 50 mm diameter Class 12 or 18 uPVC casing, with slotted/or screened casing and associated sand/gravel pack fill in annular spacing opposite target formation monitoring zones. These are isolated from surface inflows by bentonite seal zones with in some cases cementing back to surface. Bores are generally completed to around 0.5 to 1 m ground surface with galvanised steel covers set in concrete collars. Protection works around bores in trafficable areas are installed where necessary.

## 5.4 Groundwater Monitoring – Mine and Ash Disposal Area

CS Energy maintains a network of Water Management Plan Bores (WMPB) for the mine and power station complex. The overall network contains 67 bores, with 21 required for EA compliance purposes (including the separate power station EA – EPPR00918113). Current WMPB (including existing and proposed future EA bores) locations are shown at Figure 15.

Bores monitor various geological formations:

- Alluvium of Kogan Creek and Condamine River
- Springbok Sandstone
- Walloon Coal Measures including surficial weathered Walloons (e.g bore MB4).

The original mine EA (MIM800345805) and ash disposal approval (DA IPDE00173405A11) came into effect in July 2005. The mine EA monitoring bores were MB1 to MB10. Of these, MB1 to MB5 and MB8 to MB10 were constructed specifically as monitoring bores. MB6 and MB7 were open geological investigation holes in the mine area that were cased and completed to monitor the O seam (Ison, 2006).

Bores MB25 to MB32 were constructed in 2015 to augment the groundwater network in the mine area and specifically to monitor future in-pit ash disposal areas and the extension of the mine area to the south.

Over the years several bores have been either destroyed due to mine development activities (MB6, MB7) or have become unserviceable e.g. due to casing failure (MB10). These have been replaced by bores MB29, MB7-R, and MB10-R in the mine EA.

[5] *Minimum Construction Requirements for Water Bores in Australia* National Uniform Drillers Licensing Committee 2020

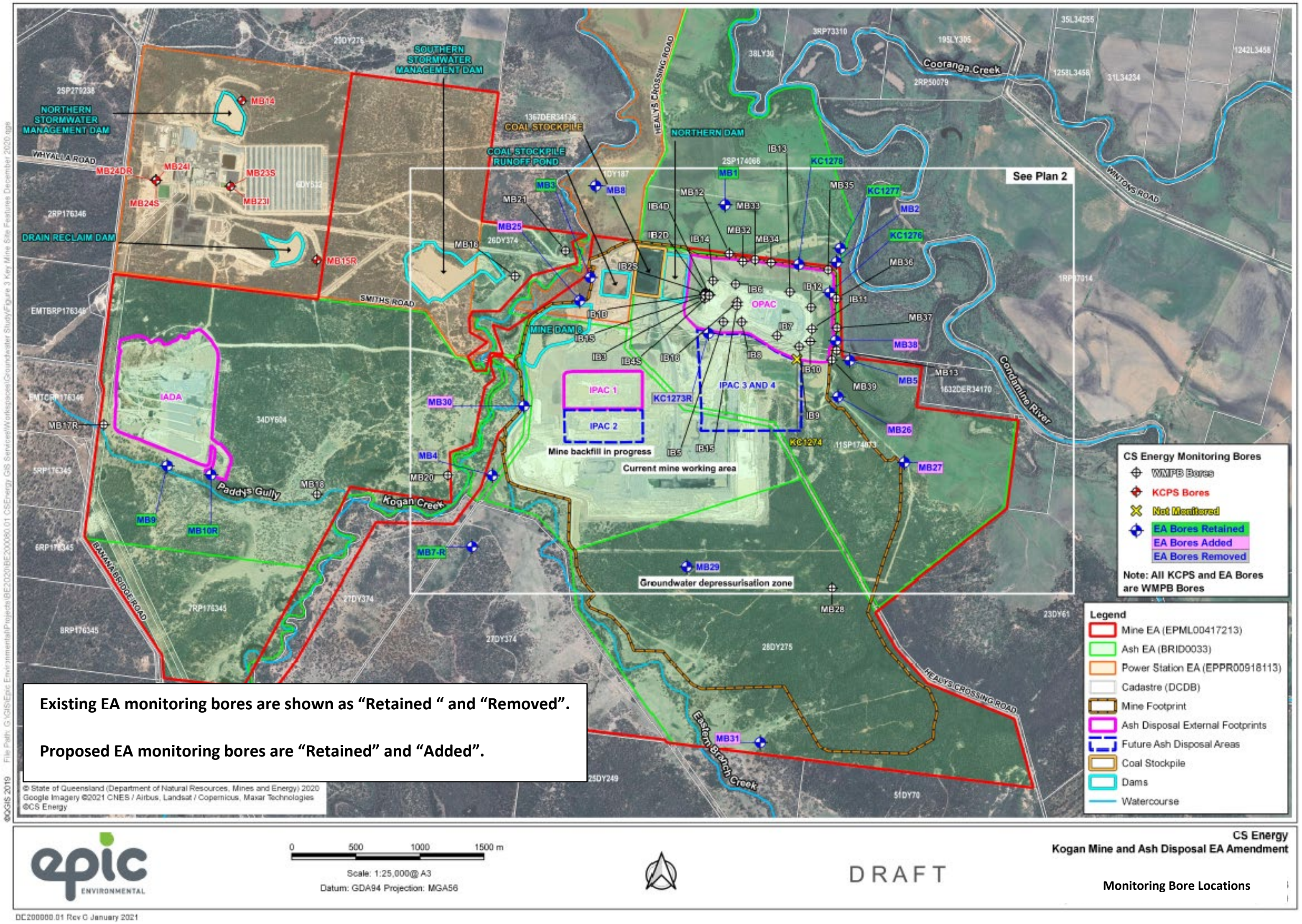
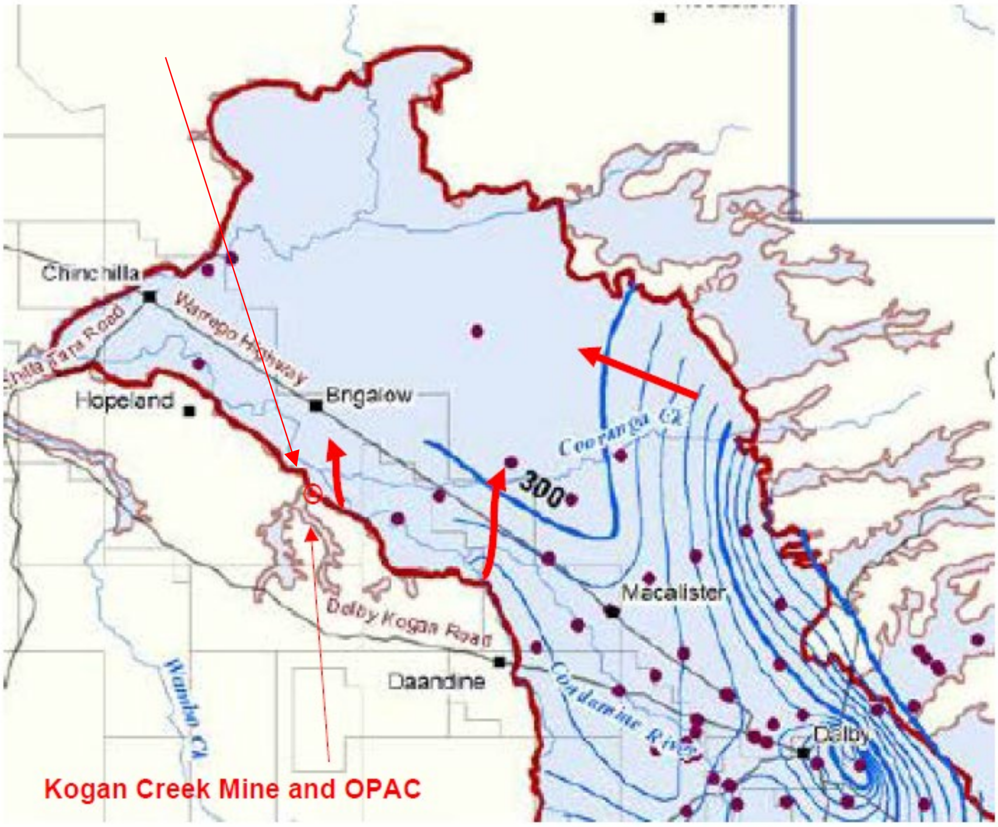



**Figure 15 EA and Water Monitoring Plan Bore Locations Kogan Creek Mine and Power Station**

## 5.5 Condamine Alluvium

Regional groundwater contours in the Condamine Alluvium have been developed in DNRME Office of Groundwater Impact Assessment (OGIA) studies as shown in Figure 16. The inferred background regional groundwater flow direction in the Condamine Valley is in a north westerly direction. Groundwater levels in OPAC Condamine Alluvium bores have ranged between RL 296.9 m and RL 298.6 m AHD between December 2016 and March 2020. This range of groundwater heads is consistent with the distribution of the inferred contours of Figure 16.




Regional Groundwater flow direction in Condamine Alluvium

Contours from 2013 -2014

Source: Groundwater Connectivity Between the Condamine Alluvium and the Walloon Coal Measures Office of Groundwater Impact Assessment August 2016

**Figure 16 Regional Potentiometric Levels for the Condamine Alluvium**

### 5.6 Walloon Coal Measures

Groundwater studies undertaken for the Queensland government (Klohn Krippen Berger 2011) demonstrate that groundwater pressures in the Walloon Coal Measures (WCM) within the north western end of the Condamine Valley also decrease in a north-westerly direction. A regional potentiometric surface map for the WCM in the Condamine Valley is shown at Figure 17. The figure indicates background groundwater pressures in the WCM in the vicinity of the Kogan Creek Coal Mine and Power Station have been between RL 290 - 300 m AHD which is consistent with the inferred background head conditions and current groundwater pressures in bores and at locations not affected by pit depressurisation.

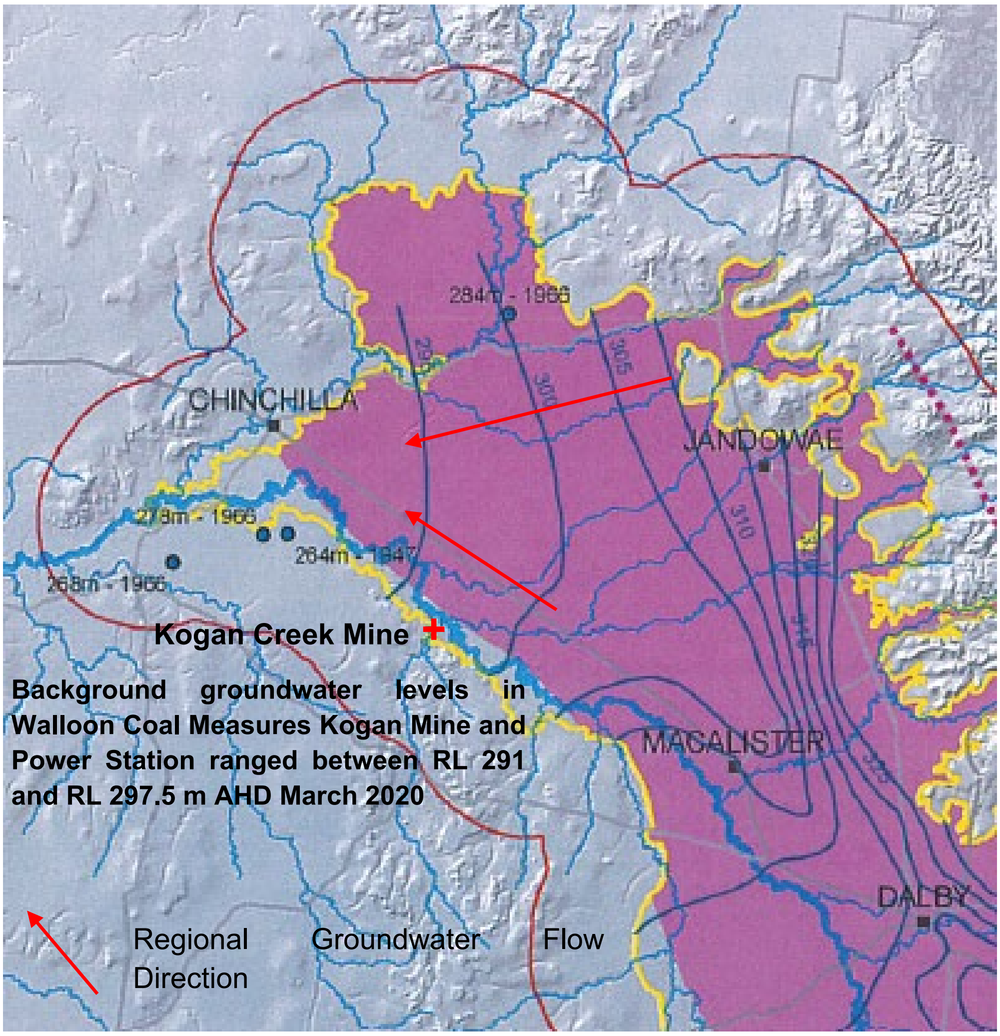



**Figure 17 Regional Potentiometric Levels for the Walloon Coal Measures Condamine River Valley**

Source: Figure 13 "Conceptualisation of the Walloon Coal Measures beneath the Condamine Alluvium" Final Report Klohn Krippen Berger July 2011.

## 5.7 Groundwater Flow

### 5.7.1 Hydraulic Characteristics

The two key hydraulic properties that influence groundwater flow are hydraulic conductivity (related to intrinsic permeability) and specific storage/specific yield. Estimates of these properties can be derived from field and laboratory tests.

No hydraulic data has been collected at the site as historically there has been no regulatory requirement or operational need to do so. The pit floor is essentially dry apart from following rainfall periods and is easily managed during dry periods.

OGIA have completed an exhaustive assessment of field and laboratory hydraulic conductivity/permeability testing undertaken primarily for the coal seam gas industry in the UWIR 2019 report (OGIA 2019). This included some 7700 drill stem field tests and more than 100 aquifer pumping tests across the Surat CMA. The bulk of drill stem tests would have been undertaken across various Walloons strata including Upper and Lower Juandah coals. The range of horizontal hydraulic conductivity values for the major Surat Basin formations is shown at Figure 18. For the Walloon Coal Measures, measured hydraulic conductivities have ranged between approximately $10^{-12}$ m/d to in excess of 100 m/d. Coal seams typically have hydraulic conductivities in the range $10^{-3}$ to 1 m/d. For modelling purposes, OGIA have used values in the range $5 \times 10^{-7}$ m/d to 0.1 m/d.

With respect to specific storage ($S_s$) and specific yield ($S_y$), OGIA have noted that relatively few actual measurements are available and indirect estimates are commonly used for modelling purposes (OGIA, 2019). These are typically based on literature values. Typical values for the Walloon Coal Measures coal are $4.9 \times 10^{-6}$ and 0.01 and for interburden $1.6 \times 10^{-7}$ to$9.06 \times 10^{-6}$ and 0.01 (OGIA, 2019).

Whilst groundwater pressure declines around Kogan Creek Mine have been observed, the horizontal permeability of the exposed coal seams is of a magnitude that little free groundwater discharges to the pit floor. Consequently, no pit dewatering to specifically manage groundwater inflows is carried out.

The most recent reported estimate of water volume attributed to groundwater ingress is 22 ML/year (Golding, 2020), equivalent to a continuous flow of around 0.7 L/sec. However this is not a direct measurement but the difference between estimated pit inflows from rainfall/runoff and estimated outflows (pumpage and evaporation) and consequently there is a high degree of uncertainty in the estimate, as groundwater inflow would be a very small component of the overall mine pit water balance and there can be a relatively high degree of inaccuracy (relative to the groundwater inflow estimate) in the estimates of other water balance parameters, in particular runoff and evaporation.

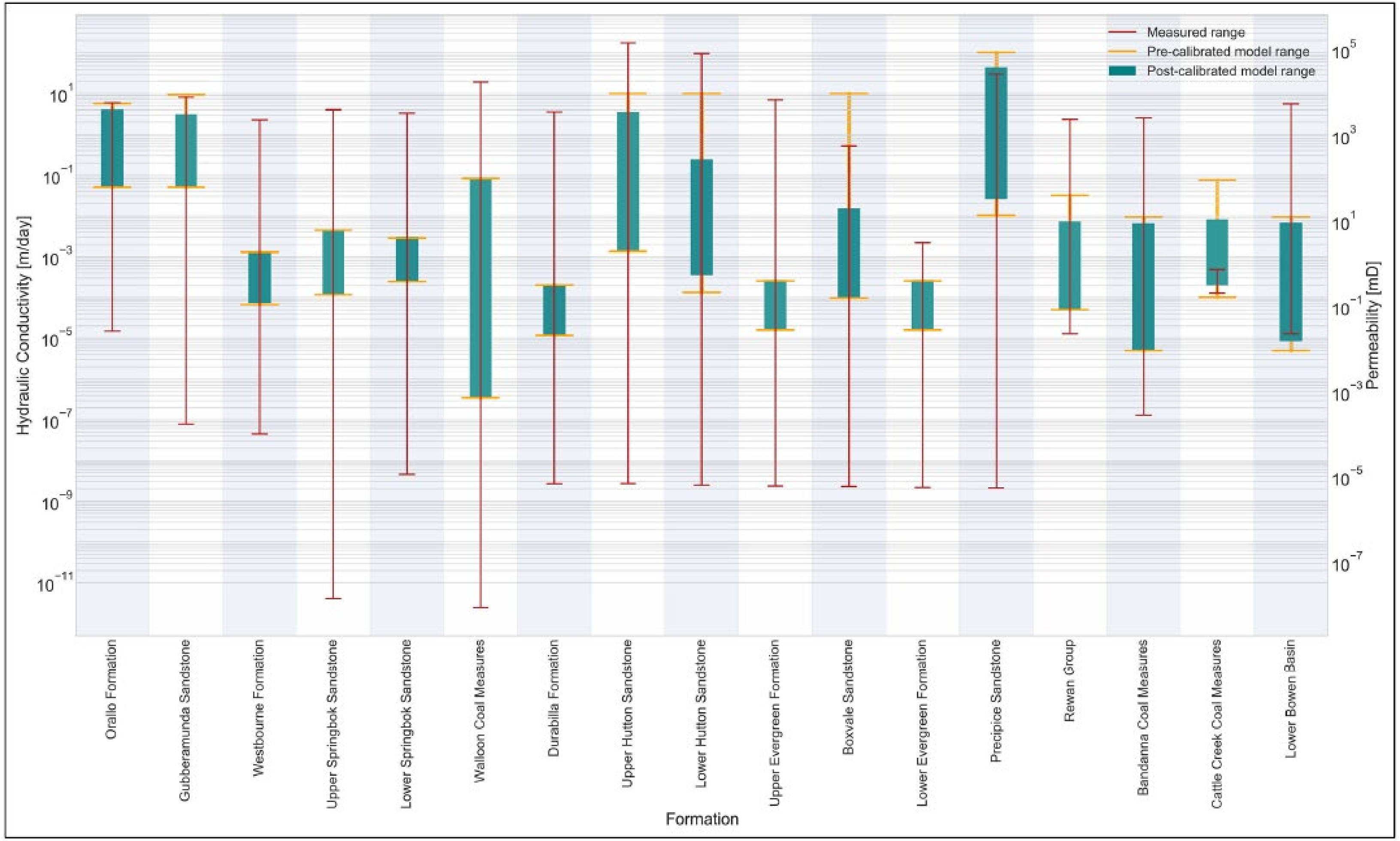



**Figure 18 Horizontal Hydraulic Conductivity Ranges in the Surat CMA[6]**

[6] Source Underground Water Impact Report for the Surat Cumulative Management Area OGIA 2019

### 5.7.2 Groundwater Heads

Groundwater elevations in most bores have been generally recorded on either a monthly or in recent years quarterly basis as part of the groundwater sampling and analysis program. Continuous data loggers have been installed in several bores in the mine area (MB6, MB7-R, MB25 and MB31). Numerous bores often record no groundwater presence which is a function of bore depth, historical water tables and possibly bore sampling procedures.

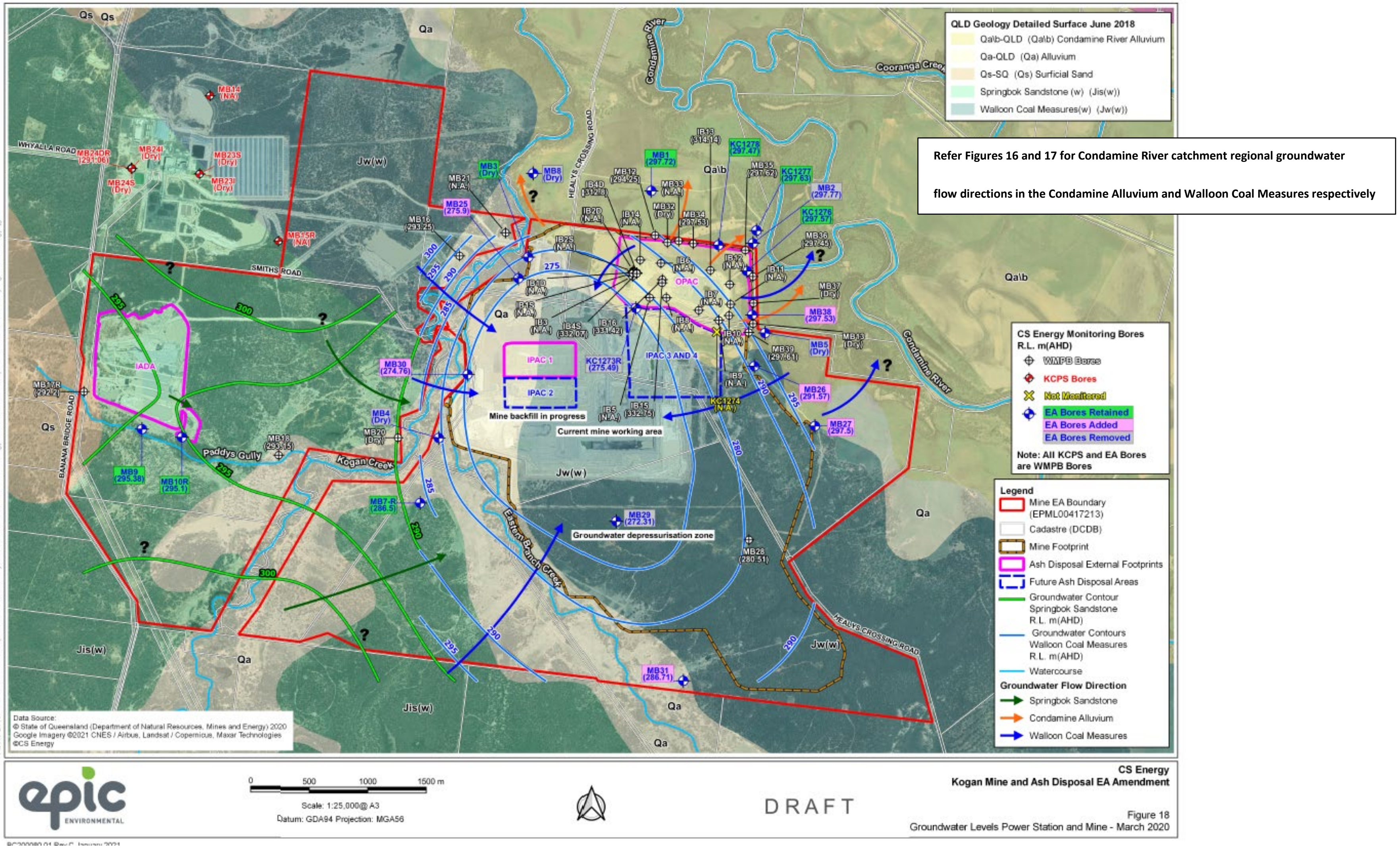
Groundwater flow conditions in the vicinity of the site are thought to be complex, given the site's location relative to the course of Kogan Creek and the Condamine River and within the Surat Basin.

Groundwater pressures (heads) and contours and inferred groundwater flow directions in various formations in March 2020 are shown at Figure 19. Separate figures highlighting inferred groundwater flow directions for Condamine Alluvium and Springbok Sandstone are shown in Figure 20 and for Walloon Coal Measures are shown in Figure 21.

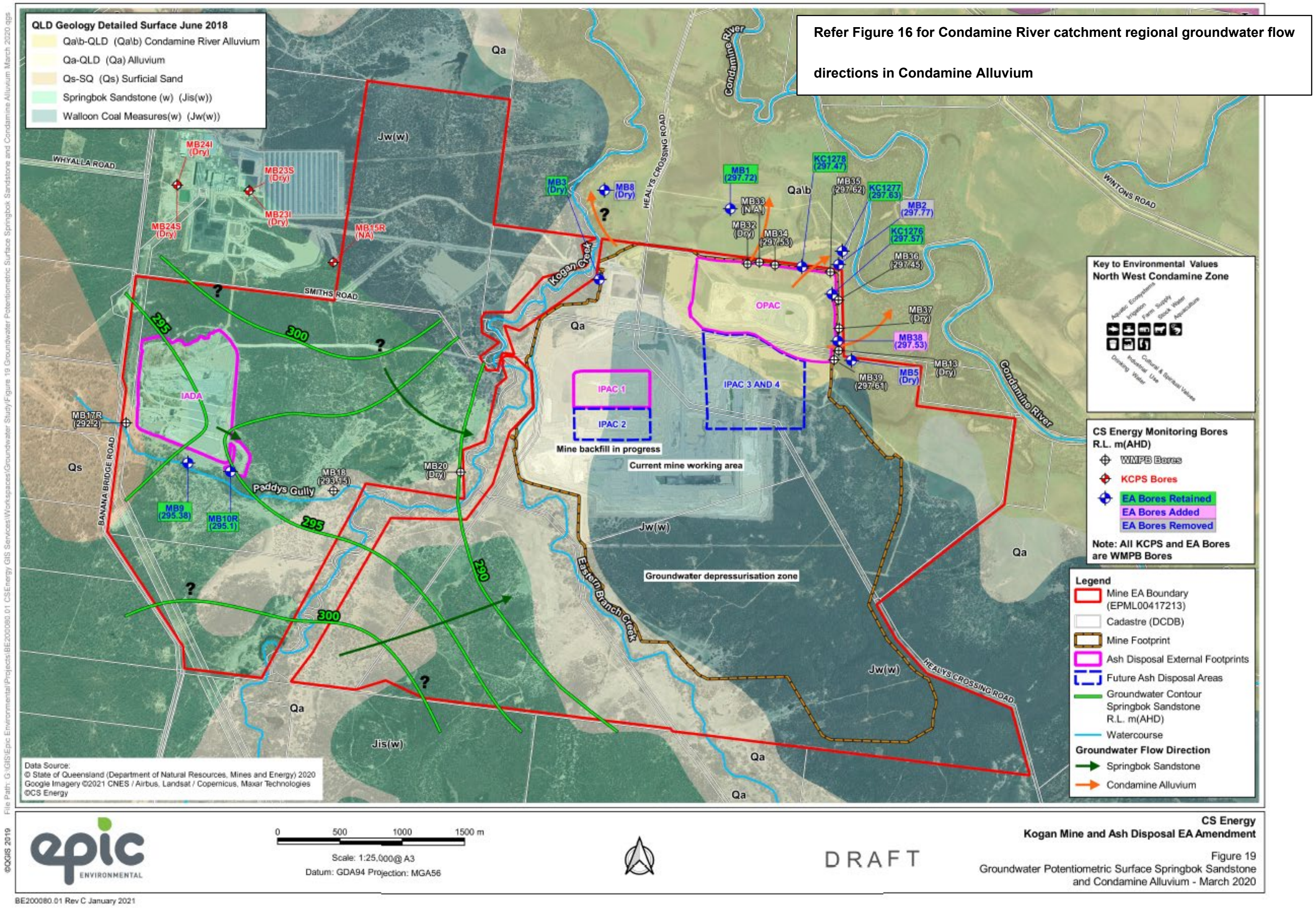
Groundwater pressure contours for Walloon Coal Measures and Springbok Sandstone bores in Figures 19, 20 and 21 have been developed using the ARCGIS geoprocessing Spline tool which uses an interpolation method that estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points.

The technique is considered suitable to define the inferred conceptual groundwater depressurisation zone in the Walloon Coal Measures around the Kogan Mine pit, as well as groundwater flow directions from the limited areal extent of monitoring of the Springbok Sandstone.

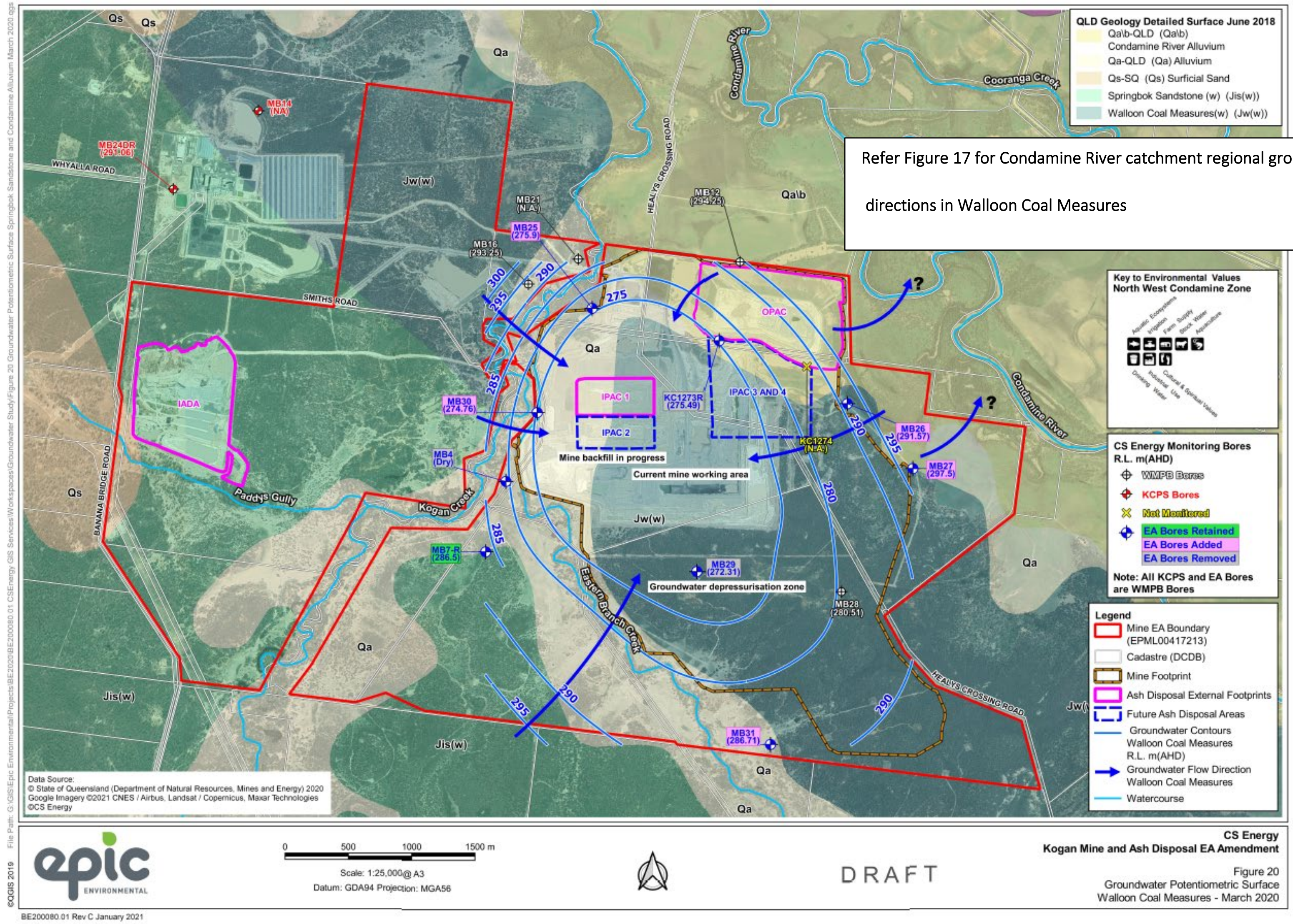
The technique could not be used for Condamine Alluvium bores due to the limited range of groundwater head data available, with all bores reporting groundwater heads in the range RL 297.45 to RL 297.92 m in March 2020.




## Figure 19 Groundwater Levels Mine Area March 2020




## Figure 20 Groundwater Potentiometric Surface Condamine Alluvium and Springbok Sandstone




Refer Figure 17 for Condamine River catchment regional groundwater flow directions in Walloon Coal Measures

**Figure 21 Groundwater Potentiometric Surface Walloon Coal Measures**

### 5.7.3 Alluvium

Groundwater elevations in alluvium/weathered rock are monitored in several bores (MB1, MB2, MB5 and MB12). Since March 2012 groundwater elevations have been measured manually on a quarterly basis. Groundwater elevations in alluvium from bores located to the north and east of the mine/OPAC have been generally between RL 297 m and RL 298 m. Bores MB1 and MB2 are located to the north and northeast of the OPAC respectively, and elevations have slowly declined since mid-2013 due to the mostly below average rainfall years since 2011. In May 2019 MB1 was reported as dry.

### 5.7.4 Springbok Sandstone

Recent geological modelling (Xenith, 2020) indicates that the Springbok Sandstone is limited to the western side of Kogan Creek in the mine area. The upper Springbok Sandstone is essentially dry/unsaturated in the area as indicated by historical data from monitoring bore MB15 at the power station. Groundwater elevations in weathered to fresh sedimentary strata are monitored in several inferred Springbok bores on the western side of Kogan Creek (MB9, MB10- R, MB17 R, MB18, and MB20). Data indicate that groundwater elevations generally lie between RL 292 m and RL 296 m. Regionally to the west of the site where the topography is lower, groundwater in the Springbok Sandstone and Walloon Coal Measures is likely to flow in a more south-westerly direction in the general direction of the Condamine Balonne catchment drainage and the dip of the strata.

### 5.7.5 Walloon Coal Measures

Groundwater elevations in WCM bores are influenced by their proximity to the mining operation, the coal plys monitored and the extent to which groundwater depressurization has occurred. Bores which report inferred background levels include:

| Bore | Location | Date | Groundwater Level (RL m AHD) |
|---|---|---|---|
| MB24-DR | Power Station | 24/06/20 | 291.86 |
| MB26 | East of mine area/Condamine Levee | 26/06/20 | 291.81 |
| MB27 | East of mine area/Condamine Levee | 26/06/20 | 297.54 |
| MB21 | West of Kogan Ck | 26/06/20 | 287.99 |

Coal extraction from the Walloons is carried out at a depth of around 50 m with regional standing water elevations in water-bearing strata (predominantly coal seams in the Walloon Subgroup) in the mine area in the range RL 274.7 m to RL 286.5 m. Bores that are considered to be influenced by groundwater depressurization include:

| Bore | Location | Date | Groundwater Level (RL m AHD) |
|---|---|---|---|
| MB30 | Between Kogan Ck and mine backfilled area west | 24/06/20 | 275.03 |
| MB25 | Between Kogan Ck and mine backfilled area west | 24/06/20 | 275.97 |
| KC1273-R | Mine area south of OPAC | 26/06/20 | 275.97 |
| MB28 | Southeast of mine | 25/06/20 | 280.16 |
| MB29 | South of mine | 25/06/20 | 271.05 |
| MB7-R | Southwest of mine | 25/06/20 | 286.64 |

In summary, inferred groundwater flow directions in the vicinity of the power station/mine complex are:

- Condamine River alluvium: north to east towards the river depending on bore location.
- Kogan and Eastern Branch Creeks alluvium: to north (in direction of creek flow). Potentially some influence of drainage from Kogan Creek and at the confluence with Eastern Branch Ck towards the mine pit; and
- Springbok Sandstone. Uncertain but possibly locally to the east/northeast
- Walloon Coal Measures. Locally towards the mine pit within the mine's groundwater depressurisation zone and elsewhere sub-regionally towards the north/northeast.

## 5.8 Groundwater in Riverine Vegetation Communities

Groundwater levels in Condamine River alluvium bores are generally about 12 m to 13 m below ground level. No data for existing bores in Kogan Creek alluvium (MB3, MB8) are available as the bores have always been dry. Both bores are on the eastern margin of the Kogan Creek alluvium and may not be representative of alluvial groundwater conditions within the main alluvial channel, where it could be expected that shallow groundwater would be present for a period of time following streamflow recharge events.

Groundwater levels in Springbok Sandstone are generally about 20 to 21 m below ground level.

In the mine area the WCM potentiometric surface was approximately 33 to 40 m bgl in March 2020. On the eastern side of the mine the potentiometric surface in the Walloons was around 19.5 m bgl in bore MB26.

**Table 2 Depth to Standing Water Mine and OPAC Area**

| | | March 2020 Depth Below Top of Casing (m) | Bore Stickup (m) | Depth Below Ground Level (m) |
|---|---|---|---|---|
| MB16 W | Walloons | 15.62 Dec 19 | 0.43 | 15.19 |
| MB18 Sp | Springbok | 18.64 Dec 19 | 0.46 | 18.18 |
| MB21 W | Walloons | 21.07 | 0.37 | 20.7 |
| MB25 W | Walloons | 33.61 | 0.86 | 32.75 |
| MB30 W | Walloons | 35.86 | 0.79 | 35.07 |
| MB7-R | Walloons | 34.56 | 0.75 | 33.81 |
| MB1 CA | Alluvium | 13.52 | 0.45 | 13.07 |
| KC1277 CA | Alluvium | 12.34 | 0.38 | 11.96 |
| MB2 CA | Alluvium | 13.33 | 0.48 | 12.85 |
| MB5 CA? | Alluvium | >15.33 | 0.46 | >14.87 |
| KC1273-R | Walloons | 41.19 | 1.02 | 40.17 |
| MB26 W | Walloons | 20.2 | 0.75 | 19.45 |
| MB27 W | Walloons | 20.9 | 0.58 | 20.32 |

Note recent regional geological mapping (Figure 11), suggests that bores MB16 and MB21 could be inferred to be in Walloon Coal Measures strata and not Springbok Sandstone as previously inferred. Current depths to standing water in Walloons strata beneath Kogan Creek to the west of the mine could be expected to be in the range of approximately 20 to 30 m.

## 5.9 Groundwater Chemistry

### 5.9.1 Background Groundwater Quality

Groundwater quality type can be categorised on the basis of available salinity data as follows:

| Strata | Salinity |
|---|---|
| Condamine River alluvial sediments | Low salinity (<2000 mg/L TDS) |
| Shallow bedrock (<20 m) Springbok Sandstone | High salinity (> 8000 mg/L TDS) |
| Walloon Coal Measures weathered surficial strata mine area | Very high salinity (> 30000 mg/L TDS) in surficial clays overlying sandstone in bore MB4 to east of Kogan Creek |
| Deep bedrock (>40 m)<br><br>Walloon Coal Measures mine area | Moderate salinity (1000 – 9000 mg/L TDS) |
| Deep bedrock (>50 m)<br><br>Walloon Coal Measures mine and power station area | High salinity (9000 – 15000 mg/L TDS) |

Salinity in Condamine River and Kogan Creek alluvials is likely to be highly variable and will depend on bore location and depth of the water-bearing horizon from which groundwater is drawn (i.e. depth of screen/slotted casing).

Groundwater quality in sedimentary rock strata will also be influenced by local geology and hydrogeochemical interactions in the weathered zone, particularly where coal seams are shallow and have been oxidised. Such conditions can cause the oxidation of sulphides associated with the coal and potentially influence the concentrations of sulphate. The mobility of coal-related trace elements such as boron, molybdenum, fluoride, selenium and vanadium will be influenced by groundwater pH conditions. Data from leachate analysis on coal samples from Kogan Creek Mine M, N and O Seams recorded sulphate, boron and molybdenum concentrations of 70 - 110 mg/L, 1.5 – 3 mg/L and 0.11 – 0.15 mg/L respectively (AGEE, 1999).

### 5.9.2 Groundwater Quality Types

Groundwater quality is characterised by a range of various types depending on geology and location. Water types (as represented by a spatial range of bores including the proposed EA monitoring bores) are shown on the Piper Diagrams in Figures 22a and 22b. These diagrams represent the distribution of major cations and anions to characterise the different water types.

Condamine Alluvium bores are generally of low salinity and of sodium chloride sulphate type with secondary calcium and magnesium. pH is around neutral. There are two groupings:

- Sodium chloride sulphate dominant waters as in MB34, MB38 and MB39 which is the same water type as mine backfill pore water as observed in bores IB4D (OPAC basal fill) and IB13 (OPAC north wall fill);
- Bores less Na-Cl dominant with increasing bicarbonate concentrations (KC1276, KC1278, MB5, MB35 and MB36).

Springbok Sandstone bores are of sodium chloride type with some sulphate.

Water quality in Walloons bores falls into three distinct types:

- Sodium chloride with little or no calcium, magnesium or sulphate in the power station area (MB24D-R) and upstream or west of the mine (MB31, MB7-R, MB30);
- Sodium chloride with variable bicarbonate waters in the mine area and between the mine and Condamine River (MB25, MB26, MB27)
- Sodium bicarbonate water in the mine area at KC1273-R.

The latter two categories have probably been influenced by localised recharge from flood flows in Kogan Creek and the Condamine River.

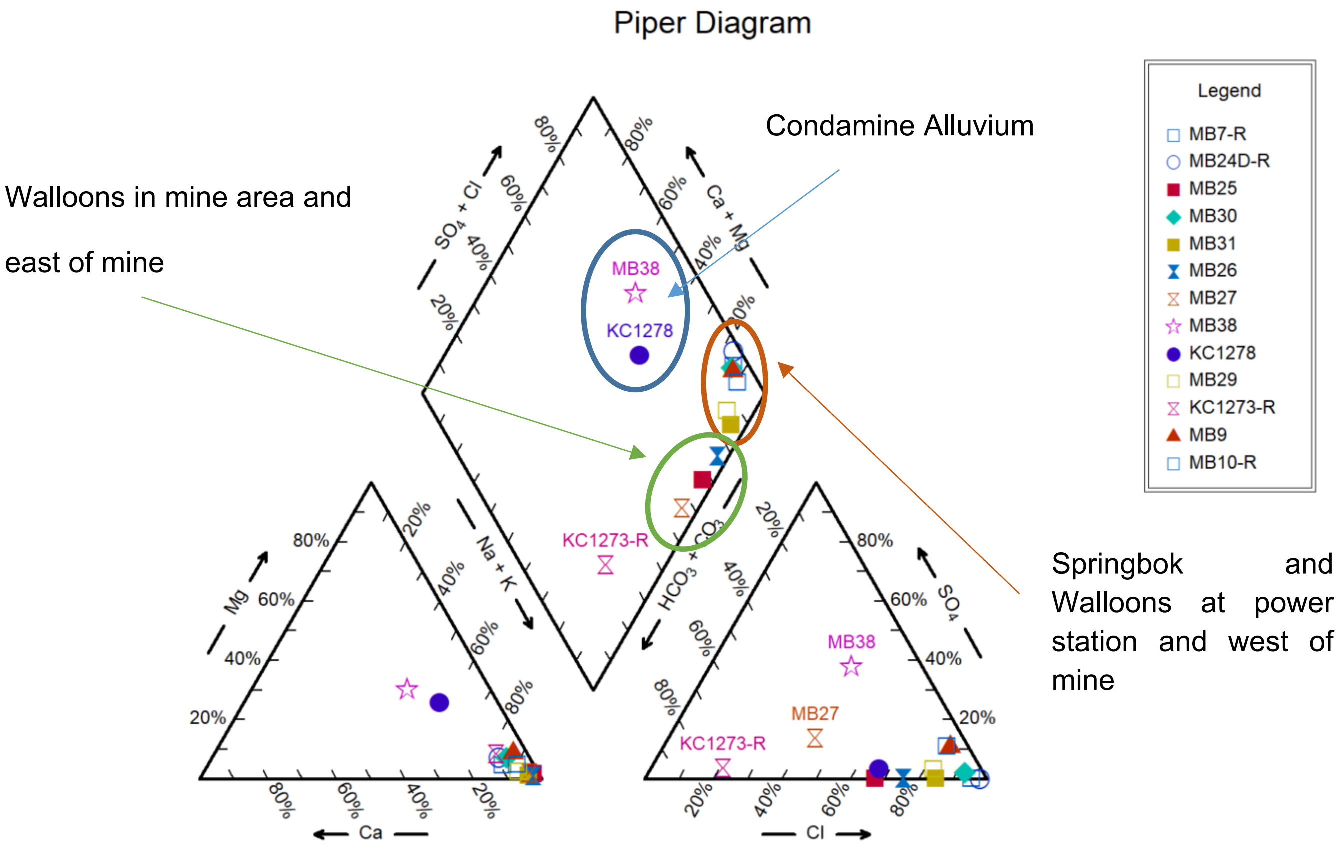



**Figure 22a Groundwater Quality Types Kogan Mine and Power Station**

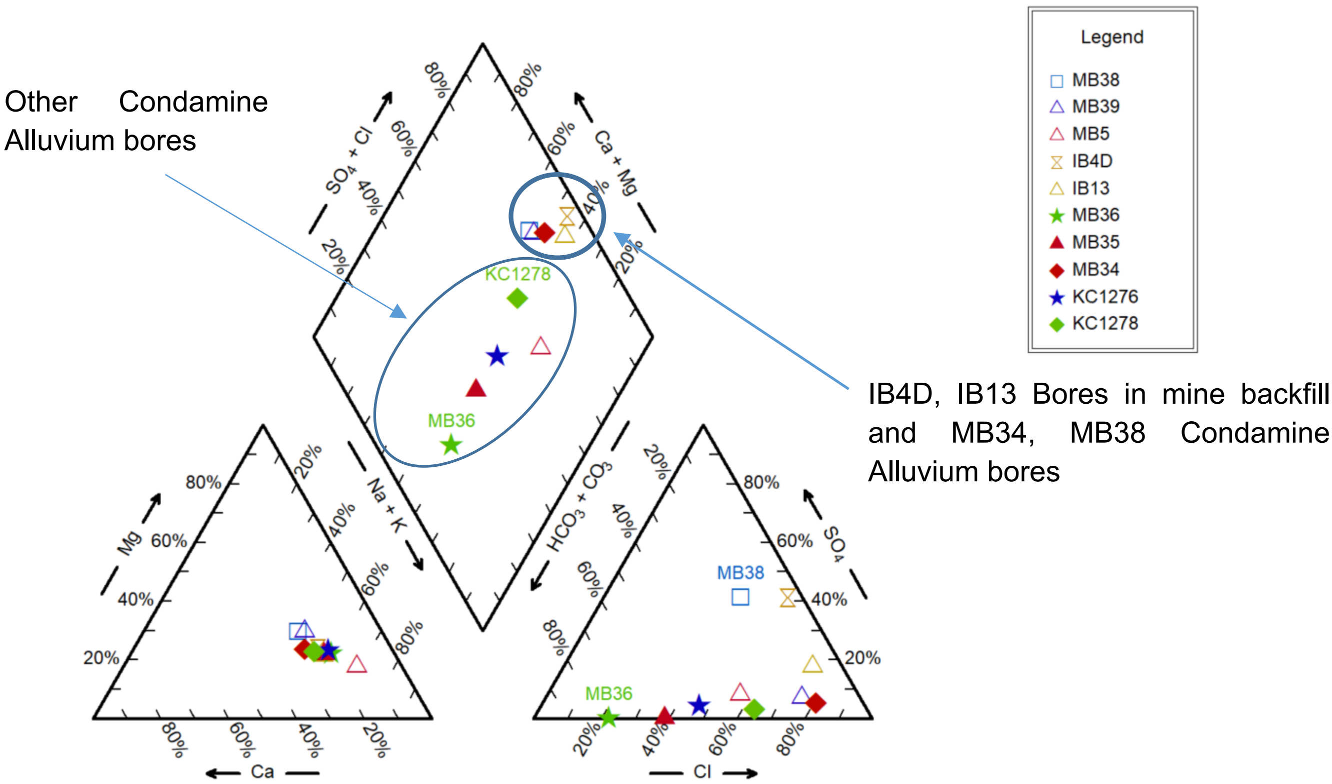



**Figure 22b Groundwater Quality Condamine Alluvium and Mine Backfill Pore Water**

# 6.0 GROUNDWATER DEPENDENT ECOSYSTEMS

GDE require access to groundwater intermittently or permanently to maintain ecological assemblages, processes and ecosystem services (Eamus *et al*. 2006). Three types of GDE are broadly recognised:

- Ecosystems dependent on the surface expression of groundwater: associated with wetlands, lakes, seeps, springs and river baseflow
- Ecosystems dependent on the sub-surface presence of groundwater: associated with terrestrial vegetation accessing the water table
- Cave and aquifer ecosystems: located within the pores or void spaces of caves and aquifers.

## 6.1 Terrestrial GDE

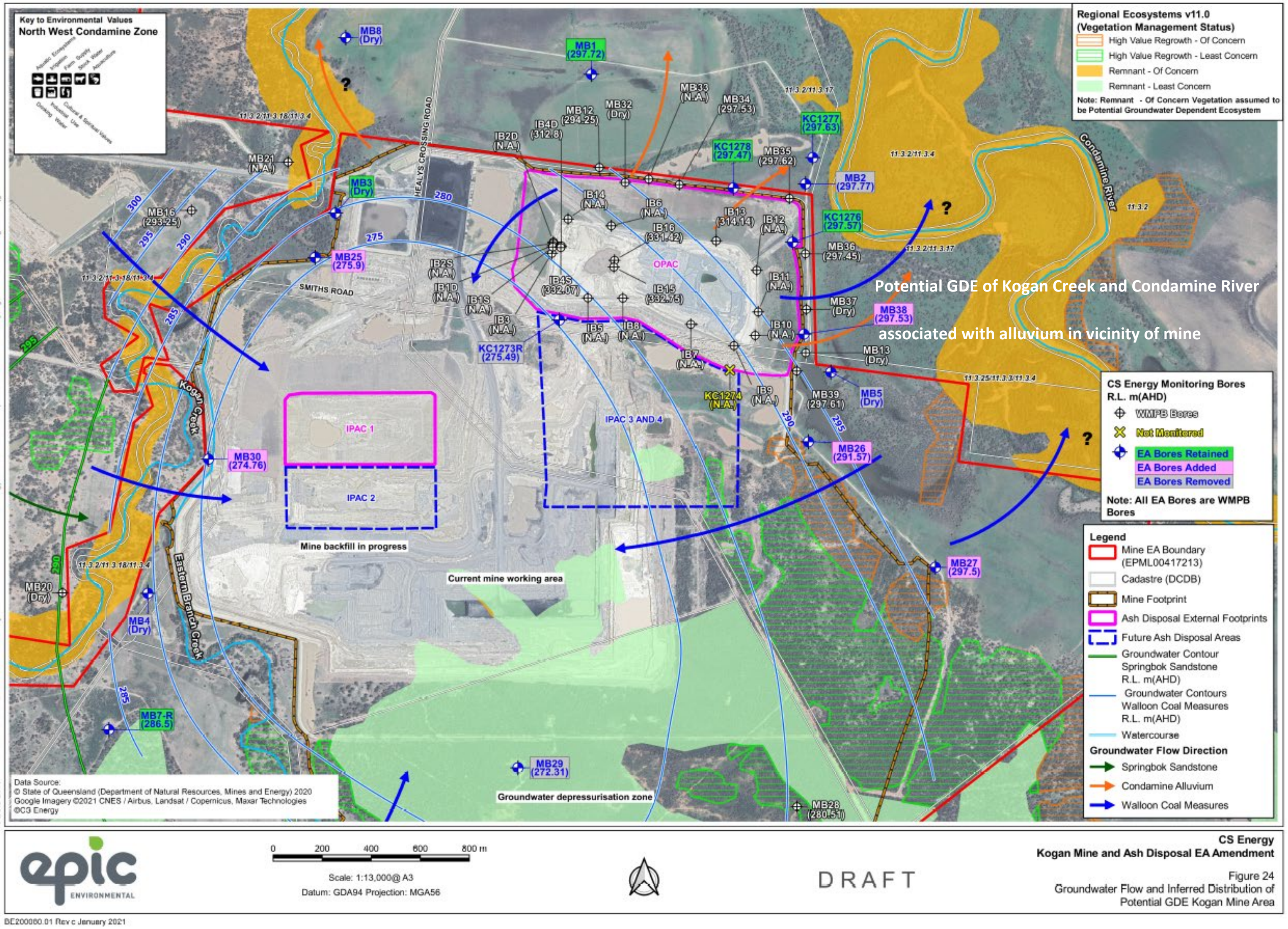
Riverine vegetation assemblages such as is present at Kogan Creek and Condamine River are considered to be surface ecosystems potentially dependent on the sub-surface presence of groundwater.

Terrestrial GDE occur in areas where aquifers outcrop at the surface or where the water table is shallow enough for vegetation to access when needed and where water quality is suitable.

A widely adopted rule of thumb is that vegetation use of groundwater is likely where the depth -to-water is less than 10 m below ground level (mbgl), possible at 10 to 20 m and unlikely at 20m+ bgl (Eamus *et al.* 2009).

In the vicinity of the Kogan Creek Mine potential GDE are associated with alluvial deposits that host riverine vegetation and regional ecosystems of Kogan Creek and Condamine River. Inferred mapped distributions are shown at Figure 23.

Riverine vegetation areas are mapped as ecosystems intermittently connected to aquifers with saline salinity and neutral pH in unconsolidated Quaternary alluvia in the Condamine River drainage basin sub-area. These terrestrial systems are dominated by *Eucalyptus camaldulensis* (river red gum), *Eucalyptus intertexta* (gum coolibah) and or *Corymbia Tessellaris* (Moreton Bay Ash).




## Figure 23 Groundwater Flow and Inferred Distribution of Potential GDE Kogan Mine Area

# 7.0 SURFACE WATER GROUNDWATER INTERACTION

Surface water groundwater interaction in the vicinity of the Kogan Creek mine will be influenced by the hydraulic connectivity between the alluvium of Kogan Creek and Condamine River and the underlying Springbok Sandstone/Walloons Coal Measures strata. Groundwater is expected to be present in Kogan Creek alluvium and could be present for some months in high permeability sand and gravel zones following streamflow events. Notably, however, no groundwater levels have been recorded in alluvial bores MB3 and MB8 since monitoring commenced in 2007. The bores are completed in alluvium on the eastern side of Kogan Creek.

Groundwater is also present in Walloons strata underlying Kogan Creek alluvium at depth and is particularly associated with coal seams and associated bedding plane partings. Groundwater may also be present in fractures, joints and open faults if they are present.

Groundwater pressures in both the alluvium and underlying Springbok/Walloon Subgroup strata reflect topographical influences in the Kogan Creek and Condamine River catchment. Groundwater in the alluvium would be unconfined to semi-unconfined but becomes confined in the underlying sedimentary strata. Regionally groundwater in alluvium and sedimentary strata flows towards the northeast to north, however there will be locally variable flow directions, particularly within the groundwater depressurisation zone associated with mine development in the Walloons.

## 7.1 Kogan Creek

For Kogan Creek, alluvium consisting of fine to medium-grained sands and coarse sands and gravels is in the order of 13 to 14 m thick based on drillers logs for bores MB1, MB3 and MB8.

Walloon Coal Measures bores MB25 and MB30 are located on the eastern side of Kogan Creek, between it and the mine. Only a thin layer of surficial clay overlies weathered sandstone at these sites. Weathered Walloons strata with thicknesses of 23 and 32 m respectively are present in bores MB25 and MB30. Weathered sandstones are present to 15 m depth in MB25 with slightly weathered coals from 22 to 23 m depth and fresh coal from 25 to 26 m overlying coarse-grained grey sandstone. MB25 permeability is low with a small inflow zone observed at around 37 m depth observed during drilling. The standing water level has fluctuated between 31 and 32.7 m bgl in the sandstone.

At MB30 weathered sandstones, siltstones and mudstones are present to 32 m overlying fresh grey siltstone with fresh coal first intersected at 36 m bgl. As with MB25 a small soak was intersected at around 30.2 m during drilling. Standing water level has varied between approximately 33.9 to 35.8 m bgl and is likely associated with the coal and/or underlying grey coarse sandstone.

The data suggests that in the vicinity of Kogan Creek, alluvial groundwater and Walloon groundwater are disconnected with water levels (if present) in alluvium from approximately 17 to 28 m higher than has been recently observed in bore MB25 (ie around RL 279 m). This indicates that groundwater in the Walloons does not directly discharge into the alluvium. Groundwater chemistry data from bore MB25 (which has low salinity TDS 1680 mg/L March 2020) indicates that there may however be a limited amount of recharge to the Walloons, although this is not the case at bore MB30 where salinity is much higher (TDS 8470 mg/L March 2020).

The inferred relationship between Kogan Creek alluvium and underlying Walloons water levels is shown at Figure 24.

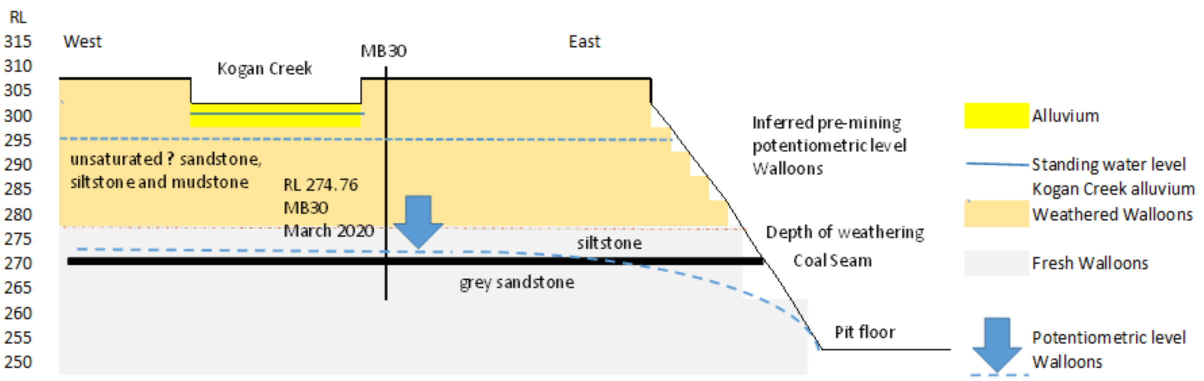



**Figure 24 Kogan Creek Surface Water Groundwater Interaction**

## 7.2 Condamine River

On the eastern side of the planned extent of mining, Condamine River Alluvium is only 4 m thick at bore MB26 but is present at depths of up to 15 m in bores further to the north of the OPAC. At bore KC1277, up to 9 m of medium grey clay was intersected below coarse-grained alluvial sands.

At bore MB26 the depth of weathering was 12 m and several coal seams were intersected above the first inflow zone, in a sandstone at 24 m depth. Damp coals were intersected at 33 to 35 m.

Groundwater pressure in the Walloons at MB26 has been stable since monitoring commenced in 2015 between RL 291.5 and RL 292.7 with the potentiometric level generally around 18.7 to 19.3 m bgl.

Groundwater pressure data indicates that there is around a positive 6 m head difference between the Condamine Alluvium (as measured at MB39) and the Walloons (as measured at MB26). This head difference is consistent with OGIA findings. (Figure 25). OGIA notes that "*the pattern of groundwater level differences …continues to suggest overall low connectivity between the two formations.*"[7]

No hydrogeological data is available for alluvium or Walloons strata adjacent to CS Energy tenure and in the main Condamine floodplain. However, a generalised model can be developed based on OGIA work (OGIA, 2016) (Figure 26).

[7] Underground Water Impact Report 2019, p. 75

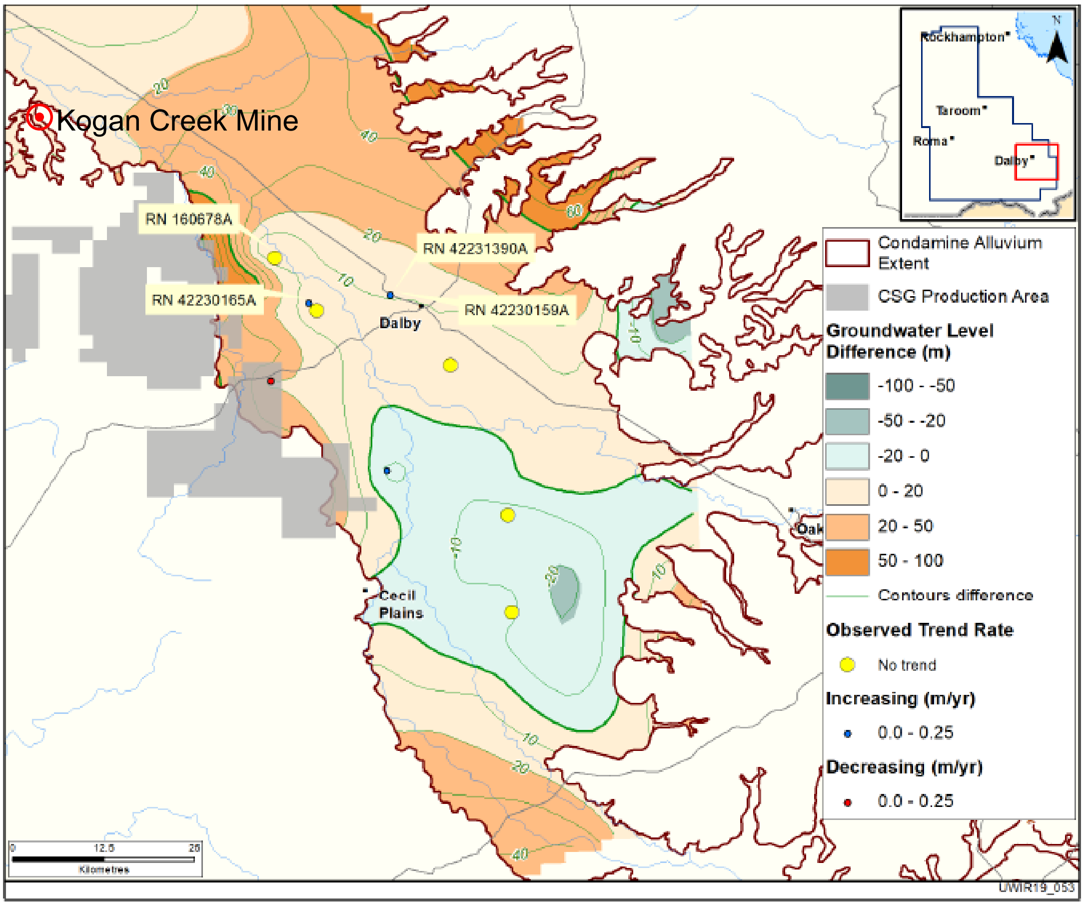



**Figure 25 Regional Groundwater Head Difference Walloons and Condamine Alluvium**

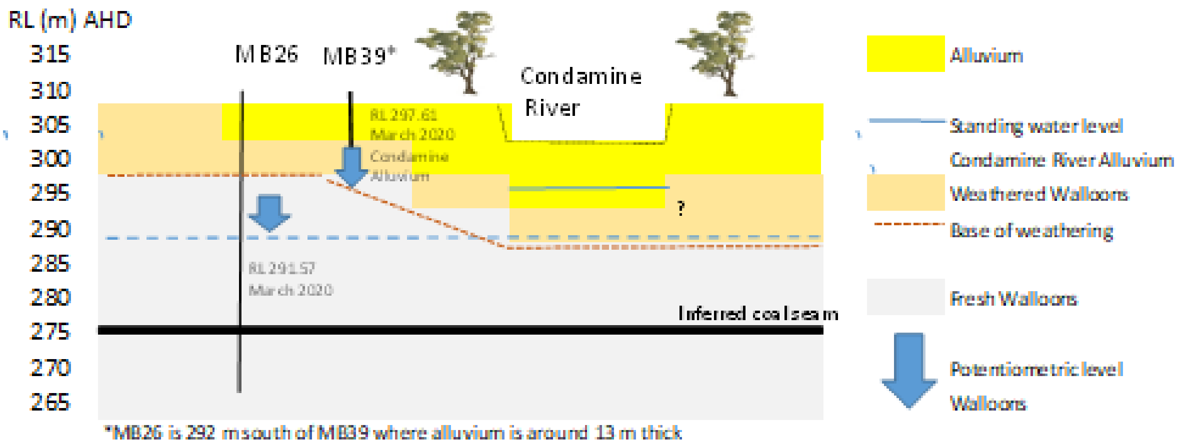



**Figure 26 Condamine Alluvium Surface Water Groundwater Interaction**

# 8.0 PRELIMINARY CONCEPTUAL SITE MODELS

The two main areas of environmental risk on the mining lease for which groundwater is the potential pathway are:

- Seepage from mine regulated structures including dams, levees, ash cells and ash disposal areas
- Groundwater level declines in alluvium impacting potential GDE as a result of groundwater depressurisation in Walloons Coal Measures

Conceptual site groundwater flow models have been developed to address each of these issues.

## 8.1 Mine Dams and Levees

The Kogan Creek mine has a number of regulated water management structures which are managed under conditions H1 to H37 of EA EPML00417213 Kogan Creek Coal Mine. These structures include:

- the Coal Stockpile Runoff Pond (CSRP)
- the various levee structures that form the flood protection works for the mine from Eastern Branch Creek, Kogan Creek and the Condamine River. Some of these act as mine site stormwater retention ponds.

The original structures built around 2006 to 2007 were not required to be designed or built to manage a “failure to contain – seepage” consequence category requirement. However, it is understood the CSRP was constructed with a select fill engineered floor[8].

Mine site stormwater retention ponds (Figure 2) are not considered to be regulated storages and have not been considered as part of this assessment.

Only the CSRP has been subject to risk assessment. Groundwater monitoring has been undertaken at MB3 to monitor potential seepage from CSRP to Kogan Creek. No seepage has been detected over 13 years of monitoring since 2007.

## 8.2 Ash Cells and Disposal Areas

From a regulatory perspective the risk management of potential seepage from waste disposal facilities is a key issue for environmental licensing. Risk issues in the design of waste storage facilities that are commonly considered include:

- facility geometry, height and storage capacity;
- hazardous nature of wastes (solid, liquid) stored;
- proximity to drainage lines;
- potential for leakage to underlying aquifers and impact on beneficial groundwater use;
- potential to cause emergent seepage at ground surface such as surface salt outbreaks; and
- storage facility decommissioning and post-closure land use.

[8] ARUP Drawing AUS377-VH00-U-069151 dated 15 April 2005

Shallow seepage from waste disposal facilities is a key focus. Shallow seepage is normally controlled and managed by engineering works associated with water/waste storage embankment design and construction (e.g. cutoff trenches to low permeability strata beneath embankments, floor blanketing/liners, seepage collection works).

Three conceptual groundwater flow scenarios have been developed to describe potential migration of solutes from ash disposal areas - the IADA, OPAC and IPAC cells. Subsurface conditions and potential seepage migration paths are different for each case. The models are shown as cross-sections with locations shown on Figure 27. Cross-sectional models are located at (Figures 29 to 31).

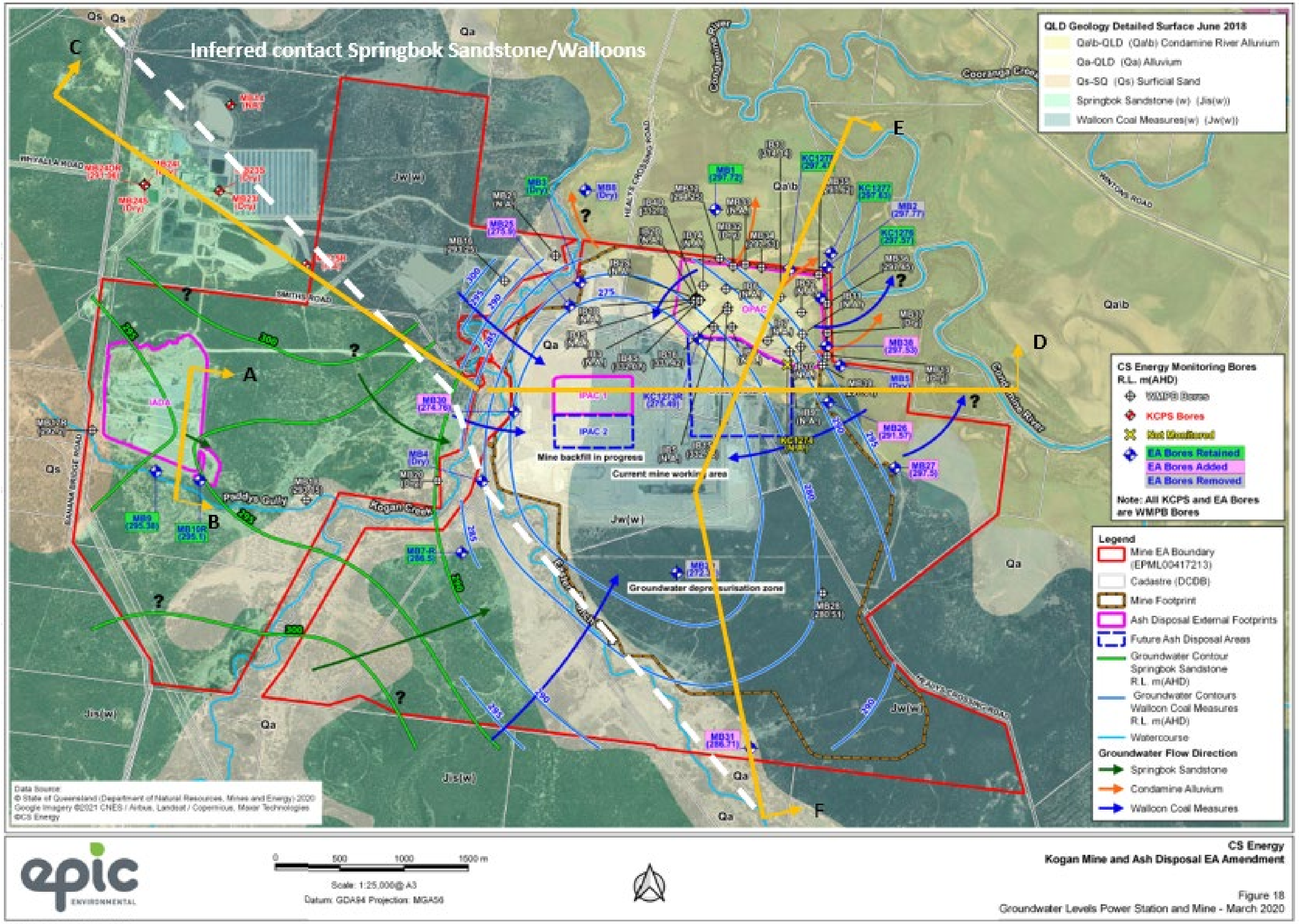



Figure 27 Conceptual Seepage Migration Model Locations

## 8.3 IADA

The IADA commenced operations with power generation in mid 2007 and ceased initial dense phase ashing in early 2011. Occasional ashing and transfer of saline OPAC ash slurry water to the IADA (2016 to 2018) has subsequently taken place.

The IADA was constructed on land which slopes to the south towards Paddys Gully, a small tributary of Kogan Creek (Figure 28). Ground elevations at the site range from around RL316 to RL 335. The ash disposal area was built on natural ground which consisted of a shallow soil layer overlying weathered sedimentary rock strata of the Springbok Sandstone which overlies Walloons Coal Measures strata.


**Figure 28 IADA Bore Locations**

The ground surface within the IADA footprint was compacted to meet EA requirements (ARUP, 2007). A low level embankment and spillway were constructed at the southern end of the IADA to capture runoff slurry water from the dense phase ash piles. The embankment is located approximately 300 to 400+ m from the ash storage area. Due to the sloping nature of the site, a number of internal bunded areas were developed to control ash deposition, water management and ash beach development.

Groundwater monitoring has focused on two potential seepage pathways:

- Shallow seepage beneath the IADA embankment that would flow towards Paddy's Gully.
- Deeper seepage through the base of the storage to the Springbok Sandstone.

Three shallow bores (KG04, KG05, KG06), approximately 7.5 to 8.5 m deep were constructed at the downstream toe of the IADA embankment circa 2007. These are monitored quarterly and have been dry on all but one occasion (moisture recorded at base of KG06 13/12/2012) since monitoring commenced in December 2007.

Two deeper bores MB9 and MB10 were constructed in early 2007 to monitor the Springbok Sandstone. Monitoring of these bores commenced in April 2007 and apart from MB10 has continued through the period of this report. Subsequently MB17 and MB18 were established with monitoring commencing in July 2009. In 2015 MB10-R and MB17-R were drilled as replacements for MB10 and MB17 which had been found to be unsuitable for ongoing sampling. In both cases the opportunity was taken to construct the replacement bores closer to the IADA.

Groundwater elevations are currently monitored at four Springbok Sandstone bores (MB9, MB10-R, MB17-R, and MB18) in the vicinity of the IADA.

Figure 30 shows a south – north conceptual cross-section through the IADA. Water intersections recorded in the drillers logs in the initial bores drilled in the area, MB9 and MB10, were at 19 m and 14 m depth respectively, associated with soaks in sandstone. The regional groundwater potentiometric surface in the vicinity of the IADA is around 20 to 25 m below ground surface in this area, based on groundwater elevation responses at bores MB9, MB10- R and MB17-R. The interface between the Springbok Sandstone and the WCM is expected to be about 30 m below ground level in the vicinity of Paddys Creek.

Bores MB9, MB10 and MB10-R have shown no influence of groundwater mounding from potential seepage through the floor of the IADA.

Given the age of the facility and the results of groundwater monitoring over the past thirteen years, the risks of seepage from the IADA migrating to alluvium or to deeper strata are considered to be low to moderate.

## 8.4 Mine Site

In the mine area ash disposal has taken place in the OPAC since late 2010. The OPAC is nearing the end of its useful life, with ash disposal expected to cease in 2023. Progressive capping of the OPAC is ongoing. Ash disposal commenced in the first in-pit ash cell, IPAC 1 in 2019.

Once the OPAC has been filled, in the longer term and for the remainder of the current mine life, all future ash disposal (authorised by SPDE 04947312) will take place in engineered in-pit ash cells (similar in design to IPAC Cell 1) located in backfilled areas of the mine pit.

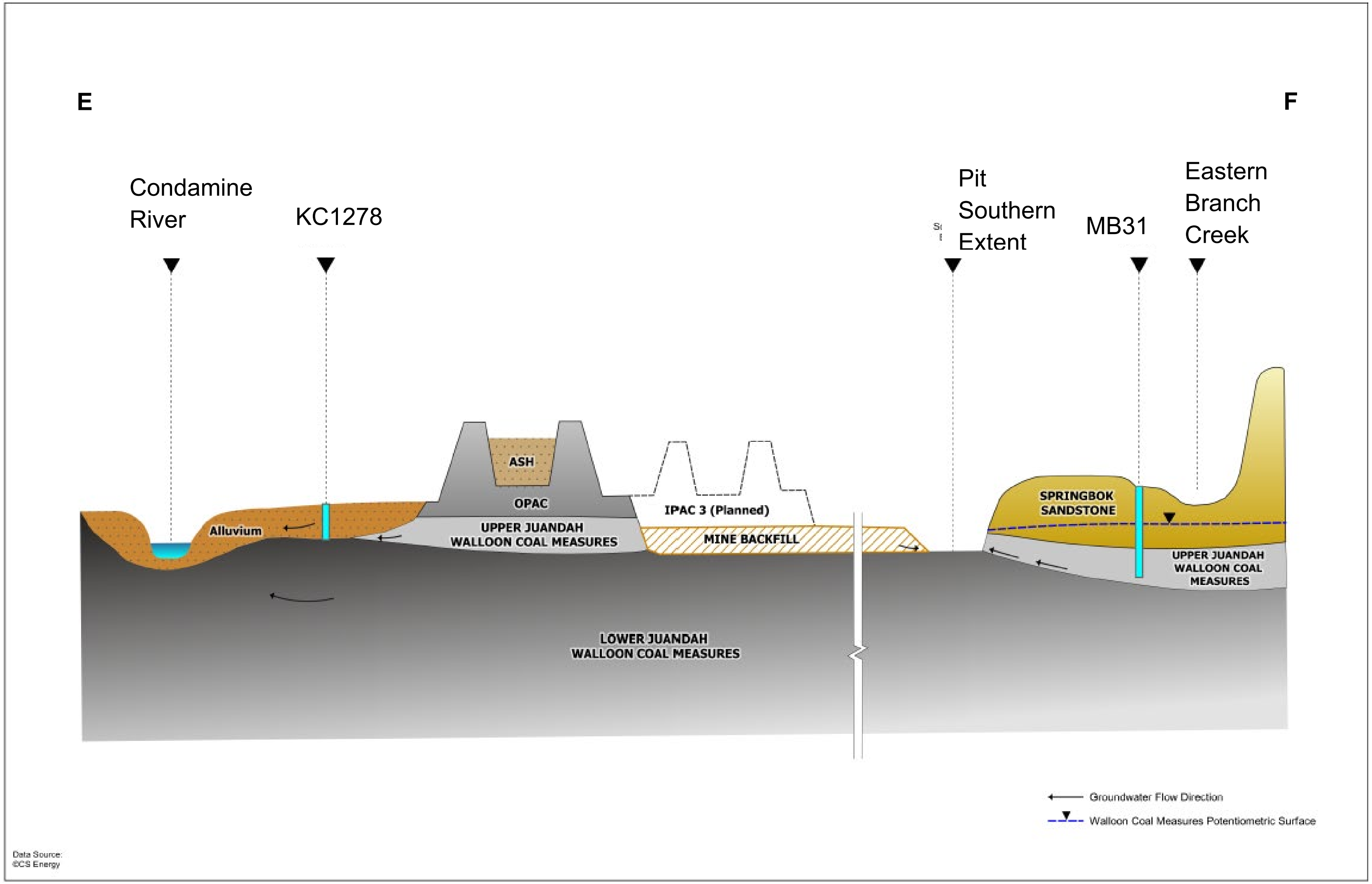



**Figure 29 Conceptual Seepage Migration Model Mine and OPAC/IPAC Cells**

## 8.5 IPAC Cells

The first IPAC Cell, IPAC 1 has been constructed in the following manner.

Mine overburden was used to construct the bulk earthworks beneath IPAC 1. Overburden thickness is up to 40 m above the former mine floor (approximately RL 270). The bulk earthworks were placed by truck end dumping in generally 3 m lifts to floor level and generally 1.5 m maximum lifts within IPAC embankment walls. Crest height of the cell embankment walls is RL 340 m.

Prior to placement of a 1.5 mm thick LLDPE geomembrane liner, the liner floor (RL310 to RL 316 m) was initially compacted with impact rolling, subgrade defects removed and replaced with compacted engineered fill prior to proof rolling using a smooth vibratory compactor.

IPAC 2 will be constructed in a similar manner.

Figure 32 shows a conceptual west-east cross-section of the mine pit and highlights IPAC 1 and the proposed future lined ash cells IPAC 3 and IPAC 4.

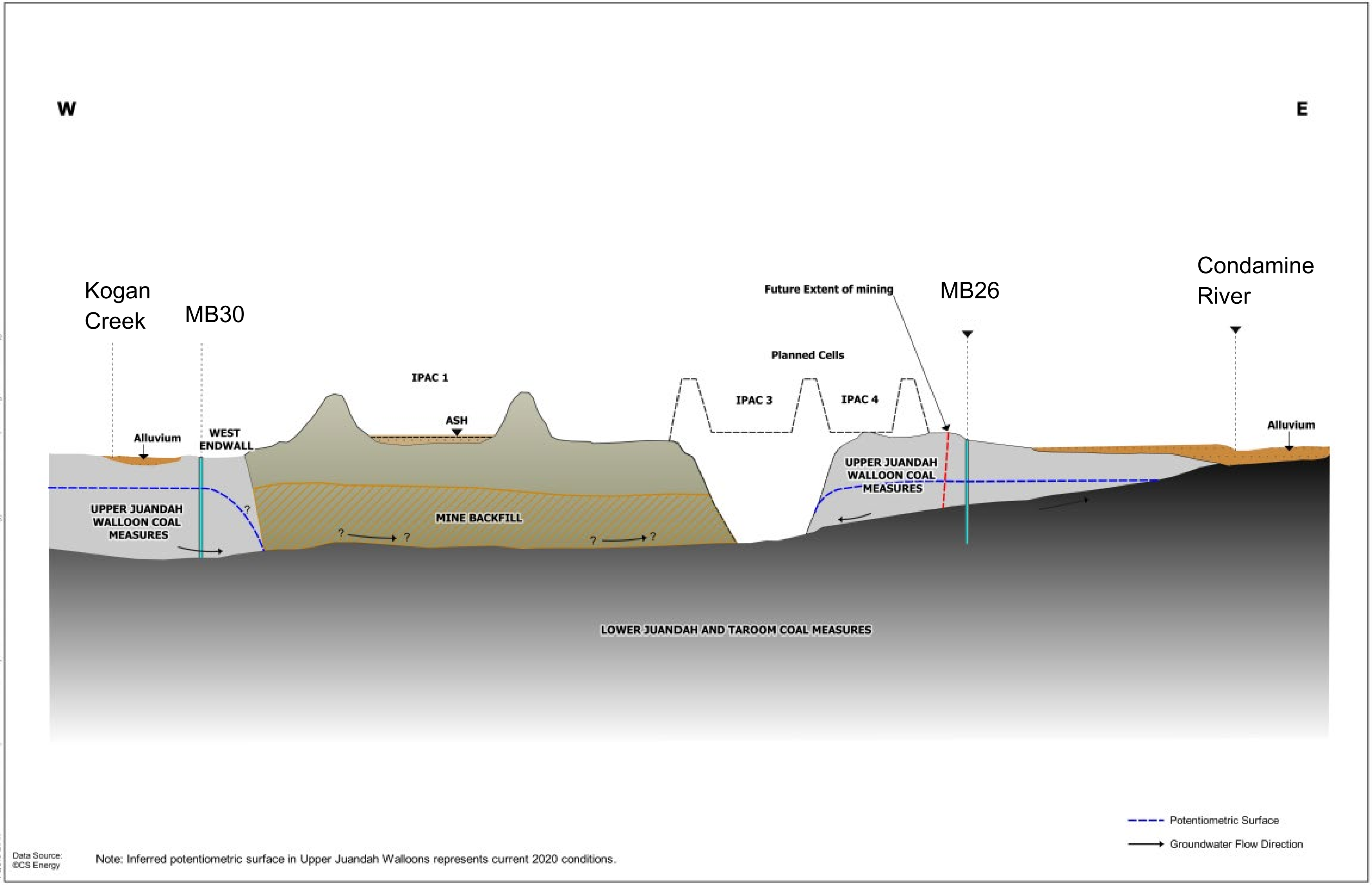



**Figure 30 Conceptual Seepage Migration Model Mine and IPAC Cells**

# 9.0 ASH STORAGE SEEPAGE MANAGEMENT

## 9.1 Ash Storage and Mine Backfill Water Quality

Dense phase ash slurry is stored in the various ash disposal areas. During the operational life of ash cells ash pore water will be retained such that a layer of saturated ash will be present in the ash cells until such time as dewatering of the ash cells takes place. The water pressure developed in the ash cells in backfilled mine areas will be sufficient to potentially result in seepage through the low permeability liner into the underlying/adjacent mine backfill.

Typical OPAC ash slurry and pore water quality which could potentially be present in IPAC cells is summarised below in Table 3.

The data highlights the following points for the time periods shown:

- Water quality in the OPAC is consistently quite alkaline which is indicative of ash slurry water.
- OPAC-contained decant water has pH levels and concentrations of proposed EA indicators $SO_4$ and As, Mo and Se trigger concentrations that exceed proposed EA alluvium contaminant trigger levels;
- Free water in the mine overburden layer in the base of the OPAC reports significantly higher concentrations of salts Na, Cl, $SO_4$ than in ash slurry pore water, but much lower trace elements due to its near neutral pH.

## 9.2 Seepage Indicators and Potential Seepage Migration

It is expected that any ash cell seepage to mine backfill would be indicated by an increase in salinity and major cations and anions such as sodium, chloride and potentially sulphate. Other indicators could be change in pH and trace element concentrations such as aluminium, arsenic, boron and molybdenum.

Potential seepage rates to backfill will depend on the liner permeability, presence of any imperfections or punctures in the liner and the permeability of the backfill, but could be expected to be very low (in the order of litres/day). The risk of IPAC seepage beyond the mine backfill footprint to the external environment during the life of the mine is considered to be low to very low.

The extent to which groundwater levels will recover over time in the Walloons and backfill material will depend on the relative magnitude and distribution of the hydraulic conductivities of the two strata and the storativity of the backfill.

## Table 3 Ash Storage Water Quality

| | Measured OPAC Ash Decant Water Quality Range (Feb 2019- Jan 2020) | OPAC Ash Pore Water (June 2017 to Dec 2019) Bore IB4S | OPAC Mine Overburden (Nov 2017 to March 2020) Bore IB4D | Proposed EA Alluvium Contaminant Trigger Limits or *Typical Water Quality Trigger Level* |
|---|---|---|---|---|
| $pH_{field}$ | 9.18 – 12.04 | 11.59 – 12.0 | 6.46 - 8.25 | 6 to 8.5 |
| Electrical conductivity (EC) | 6176 - 12250 | 4500 - 5000 | 11000 -13900 | |
| Sodium | 1260 - 1560 | 870 - 1030 | 1880 -2100 | |
| Chloride | 901 - 1170 | 950 - 1130 | 2860 - 3250 | |
| Sulphate | 365 - 454 | 256 - 385 | 2940 - 3370 | 241 |
| Key Trace Elements[1] | | | | |
| Aluminium | 34.4 – 37.9 | 13.1 – 19.2 | <0.1 – 0.14 | *xx*[2] |
| Boron | 3.68 – 4.98 | 2.60 – 4.02 | 0.14 – 0.37 | *xx*[3] |
| Molybdenum | 6.38 – 10.6 | 6.30 – 8.48 | <0.001 – 0.13 | 0.034 |
| Fluoride | 4 – 6.2 | 0.7 – 1.4 | <0.1 - 0.1 | *2*[4] |
| Arsenic | 0.26 – 0.47 | 0.25 - 0.41 | <0.001 – 0.006 | 0.013 |
| Selenium | 0.49 – 0.73 | 0.28 – 0.38 | <0.01 | 0.11 |
| Vanadium | | 4.07 – 5.64 | | *xx*[5] |
| Other Trace Elements[1] | | | | |
| Beryllium | <0.001 | <0.001 | <0.001 | |
| Barium | 0.014 – 0.038 | 0.004 – 0.063 | 0.019 - 0.106 | |
| Cadmium | 0.0018 – 0.004 | 0.002 – 0.004 | 0.0002 – 0.0016 | |
| Chromium | 0.029 – 0.045 | <0.001 | <0.001 | |
| Cobalt | <0.001 – 0.001 | <0.001 | 0.001 – 0.509 | |
| Copper | 0.004 – 0.017 | <0.001 – 0.002 | <0.001 – 0.003 | |
| Iron | <0.05 | <0.05 | <0.05 | |
| Lead | <0.001 -0.01 | <0.001 | <0.001 - 0.001 | |
| Manganese | <0.001 -0.004 | <0.001 | 0.085 – 5.89 | |
| Mercury | <0.0001 | <0.0001 | <0.0001 | |
| Nickel | 0.002 -0.005 | <0.001 | 0.078 – 0.322 | |
| Strontium | | 0.046 – 0.452 | 15 – 24.8 | |
| Zinc | <0.005 -0.006 | <0.005 – 0.033 | 0.07 - 0.7 | |

Note all units mg/L except pH 1 Dissolved concentrations 2, 3 ANZECC Freshwater Guideline 95% Protection

4 Stockwater Drinking Guideline 5 ANZECC Freshwater Guideline 95% Protection Low Reliability

# 10.0 GROUNDWATER DEPRESSURISATION

Mining of the Walloon Coal Measures has resulted in dewatering and depressurisation of water-bearing strata associated with sandstones and coal plys within the Walloons. The magnitude of depressurisation has been monitored on a quarterly basis at several Walloons bores variously located around the pit.

Groundwater elevation data collection commenced in 2007. Pre-mining groundwater elevations in the Walloon Coal Measures in the current pit area would have been less than RL 300 m inclusive of any seasonal or other natural fluctuations or at least 10 m below ground elevation, assuming an average ground elevation of RL 310 m. The pit floor level varies depending on the stage of mining and in 2019 was around RL 254 or approximately 40 m below the inferred pre-mining potentiometric surface. Current groundwater level data (to March 2021) for bores in Walloon Coal Measures in the mine area are shown in Figure 31.

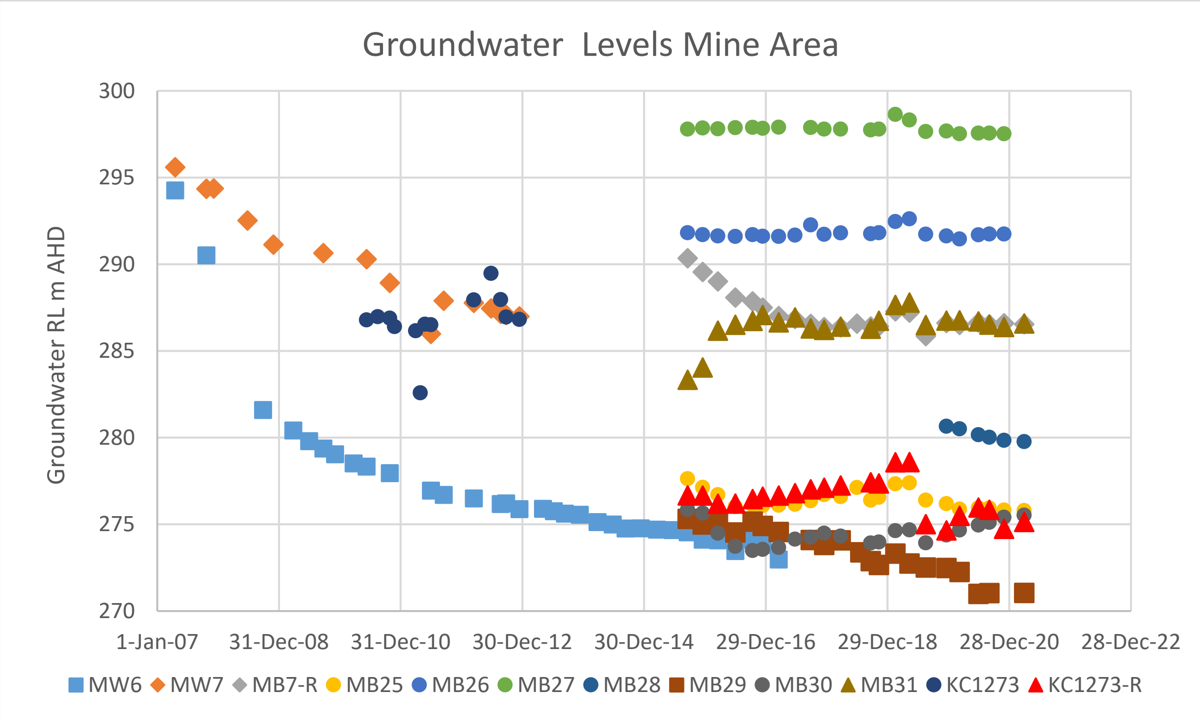



**Figure 31 Groundwater Levels in Walloon Coal Measures Mine Area**

A conceptual cross-section of groundwater elevations in the vicinity of the mine pit is shown at Figure 32, which shows;

- the inferred initial potentiometric surface falling from around RL 298 south of MB7R on the southern side of the pit to around RL 291 on the eastern side of the OPAC;
- the inferred potentiometric surface as at March 2020, with the pit floor at around RL 254
- on the eastern side of the mine, bore MB26 has recorded relatively stable water levels at around RL291.5 since monitoring commenced at the bore in September 2015, indicating that the depressurisation zone has not extended to the bore (as at March 2020). The nearby shallow Condamine Alluvium bore records a pressure approximately 6 m higher than the Walloons bore,

indicating that direct hydraulic connectivity between the alluvium and the deeper Walloons strata is unlikely in that area.

Estimated groundwater pressure declines from inferred background to March 2020 in bores MB7, MB7R, MB6, KC1273R, MB25 and MB26 are shown at Table 4.

**Table 4 Estimated Background Groundwater Elevations in Mine Area Bores**

| Bore | Inferred Background Potentiometric Elevation 2006 (RL m AHD) | Potentiometric Elevation March 2020 (RL m AHD) | Groundwater Head Decline (m) |
|---|---|---|---|
| MB7* | 297 | 288.24 | 8.76 |
| MB7-R | 298 | 286.5 | 11.5 |
| MB6** | 296 | 273.54* | 22.46 |
| KC1273-R | 293 | 277.30 | 15.70 |
| MB25 | 295.5 | 275.90 | 19.6 |
| MB30 | 296 | 274.76 | 21.24 |

*At December 2012. Subsequently destroyed

**At March 2017. Subsequently destroyed

The estimated spatial extent of depressurisation to March 2020 is shown on Figure 20, and it appears that drawdown in Walloons strata has been occurring at bores up to 700 m from the nearest working pit face on the south eastern side of the mine. This would suggest that pressure declines in Walloons strata beneath Kogan Creek could be expected. Three bores on the western side of the mine have gone dry since May 2013.

These are:

- MB4 a shallow bore monitoring weathered Walloon strata[9] on the eastern side of Kogan Creek has been dry since May 2013.
- MB20, a Springbok Sandstone monitoring bore on the western side of Kogan Creek has been dry since June 2015.
- MB18, a Springbok Sandstone monitoring bore on the western side of Kogan Creek approximately 1.1 km west of MB20 has been effectively dry (unable to be sampled) since December 2019.

Groundwater declines in these bores can be potentially attributed to regional groundwater decline or potentially groundwater level lowering due to mining. Whilst groundwater pressure declines have been observed, the low horizontal permeability of the exposed coal seams is of a magnitude that little free groundwater discharges to the pit floor.

[9] Historically this bore has been referred to as an alluvial bore but has been reinterpreted as a weathered Springbok/Walloons bore as no alluvial sands or gravels were recorded during drilling of the bore.

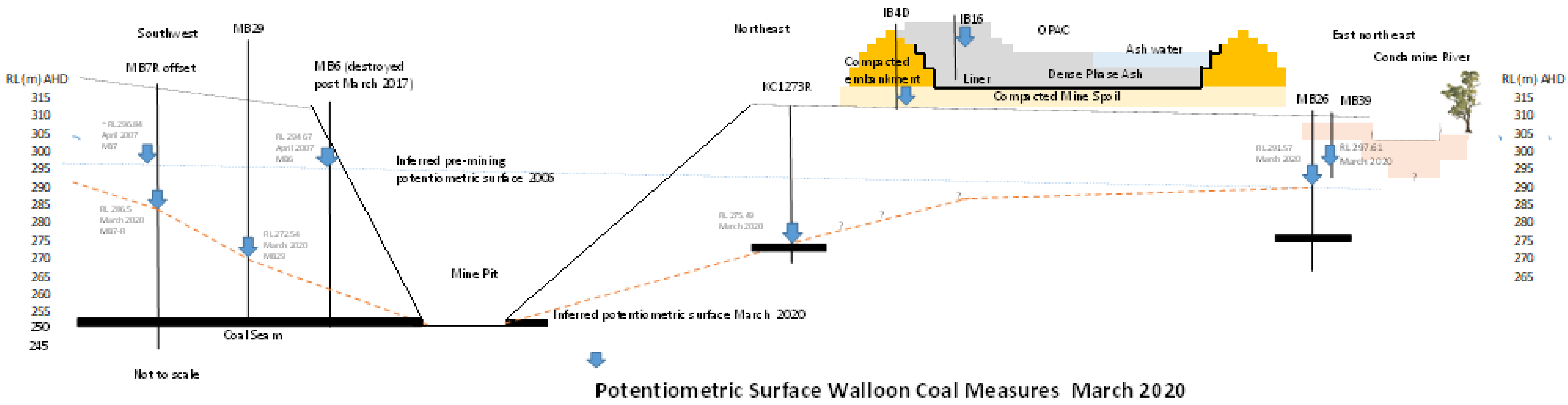



**Figure 32 Groundwater Depressurisation Pit Area March 2020**

# 11.0 FINAL VOID GROUNDWATER CONDITIONS

The final void will act as a sink for local area Walloons groundwaters and potentially groundwater in adjacent Springbok Sandstone strata on nearby outcrops, where hydraulic connectivity between Springbok and Walloons strata might exist.

Estimates of future groundwater levels in the vicinity of the final void have been made based on the historical response to groundwater depressurisation in bores monitoring Walloons strata on the south side of the mine (Figure 33). The floor of the final pit is assumed to be at RL 260 m AHD. Hydrological modelling (Figure 19, AARC 2021) indicates that “steady state” water level conditions in the pit could be achieved at about RL 265 m AHD after about 10+ years.

Water levels at background bore MB31 are currently relatively stable at above RL 286 m AHD , but could potentially drop to RL 265+ as mining proceeds to the south.

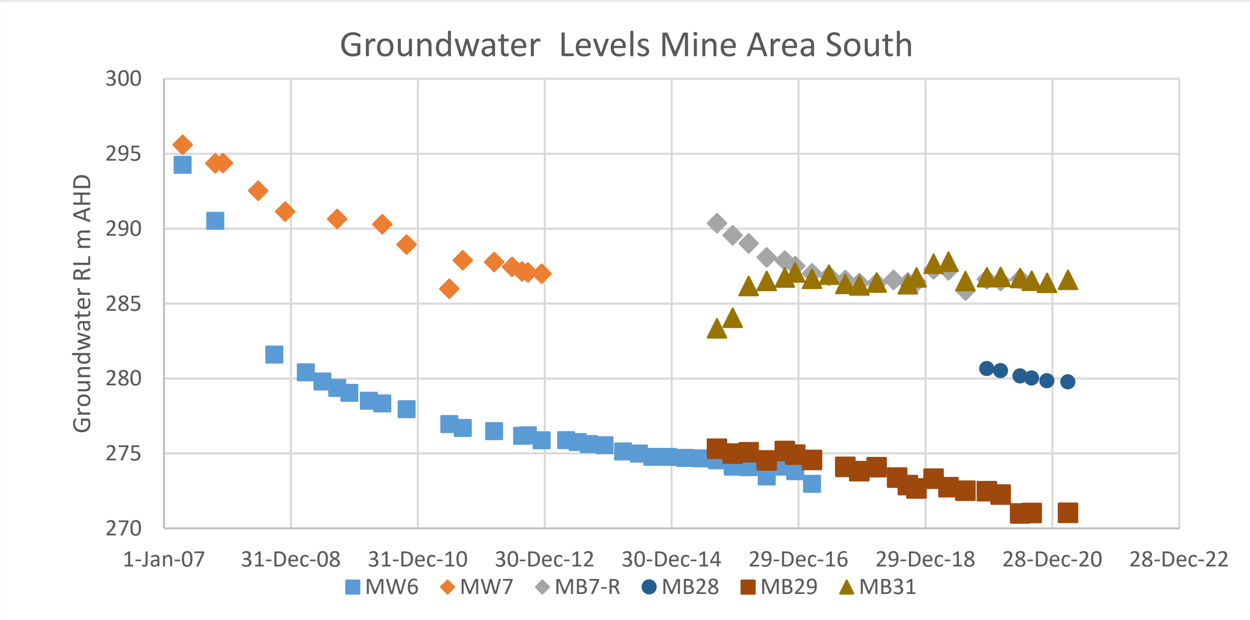



**Figure 33 Groundwater Levels in Walloon Coal Measures Mine Area South**

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# 13.0 LIMITATIONS

EMS has prepared this report for the use of CS Energy Ltd in accordance with generally accepted consulting practice. EMS has relied upon third party reports for the compilation of this report. No other warranty, expressed or implied, is made as to the professional advice included in this report.

This report does not encompass verification of the efficacy of data provided by third parties, or in particular, an audit of sampling or laboratory analytical procedures or protocols. EMS has relied on the water quality data presented in reports and water quality and related data provided by CS Energy and other parties for assessment and interpretation purposes. In particular, it is an implicit assumption of this report that data presented in third party spreadsheets and reports are an accurate collation of data from the original field sheets and laboratory certificates. From time to time, potential data anomalies can be inferred from time series data sets. EMS has used its best endeavours to advise CS Energy of potentially significant anomalies in data sets when considered appropriate.

This report has not been prepared for use of parties other than the client, the owner and their respective consulting advisers and DES. It may not contain sufficient information, nor should it be relied upon, for the purposes of other parties or for other uses. To the best of our knowledge, information contained in this report is accurate at the date data was originally reported. However, conditions including climate, site activities, regional development and water usage and surface and groundwater quality can change, limiting use of the report over time.

**FOR ENVIRONMENTAL MANAGEMENT STRATEGIES**

**REPORT PREPARED BY:**

**JOHN GROUNDS**

**PRINCIPAL**