Douglas Partners
Geotechnics / Environment / Groundwater

Integrated Practical Solutions

Report on

S Pit Groundwater Study Review
Curragh Coal Mine
via Blackwater, Central Queensland

Prepared for
Wesfarmers Curragh Pty Ltd

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Curragh S Pit Groundwater Review
Curragh Coal Mine
Blackwater, Central Queensland

1. Introduction

The Curragh Mine Project (Curragh Mine) is an independent open-cut coal mine operated by Wesfarmers Curragh Pty Ltd (WCPL) near Blackwater approximately 2 hours West of Rockhampton. Coal at the Curragh Mine is sourced from four major seams within the Rangal Coal Measures, namely the Aries, Caster, Pollux and Pisces seams. Annually, the mine produces over 11 million tonnes of coal of which 8.5 million tonnes is exported for coking use and 3 million tonnes sold for domestic steaming. The Curragh Mine Project consists of the Curragh, Curragh East and Curragh North Mines (Drawing 1).

Mining has recently commenced at the previously unmined “S” Pit at the Curragh North Mine via a boxcut which straddles Strip 1 and 2 of the planned S Pit. Groundwater seepage is impacting on mining conditions, and need to be correctly constrained for future mining plans.

Wesfamers Curragh Pty Ltd requires an external desktop review of existing documents and reports with a view to providing an updated Conceptual Hydrogeological Model (CHM), including assessment of groundwater storage volumes, flow rates and recharge. The study is required to include broad-based recommendations on methods to control groundwater inflow into the pit.

This report should be read in conjunction with the attached notes entitled ‘About This Report’ in Appendix A. The geographic coordinate base for this project is AGD 84 Zone 55.

2. Project Objectives & Scope of Work

Douglas Partners Pty Ltd (DP) was engaged by WCPL to complete a review of the Phase 1 WCPL desktop study which characterised the groundwater conditions of the Quaternary Alluvium in S Pit at Curragh North. In addition, WCPL requested that DP determine more accurate estimates of aquifer parameters for the Quaternary Alluvium and provide recommendations on workable management options for controlling groundwater inflows at S Pit. These scope items were completed as Phase 2 of the overall groundwater study. The results of this review may be utilised in the longer term as a basis for the construction of a numerical model of the aquifer, which would constitute Phase 3.

This report includes:

- A review of the Phase 1 S Pit Groundwater Review – Quaternary Sediments (WCPL 2014), its source documents and data;
- An update of the S Pit Quaternary Sediments CHM with refined understanding of aquifer distribution, volume, recharge and discharge rates and overall flow directions;

- Provisional recommendations on workable management options for controlling groundwater seepages in relation to the operational open cut; and
- Recommendations regarding subsequent numerical modelling or predictions required for Phase 3 work.

Table 1 presents a matrix of the scope of work, and key processes required to complete the study.

Table 1: Objectives and Key processes required to complete S Pit Seepage Review

Project Element	Project Objective	Key Processes
Phase 1 Review	Review of existing Phase 1 desktop study	**Review**: of Phase 1 work and other relevant studies **Collation and analysis**: of Available Datasets **3D surface generation:** of the Quaternary aquifer for subsequent analysis of aquifer volumes
CHM Update	Estimates of aquifer distribution, volume, flow rates and flow directions	**Confirm Extents:** of the Quaternary aquifer **Piezometric analysis**: of groundwater data, with view to produce a realistic contour set (adjacent to the 'S' Pit) **Download and analysis:** of SILO climate data **Hydrograph analysis:** determination of aquifer recharge (subject to data availability) **Chloride Mass Balance:** determination of aquifer recharge (subject to data availability) **Assessment**: of groundwater storage volumes **Determine:** Groundwater flow directions and rates (if possible)
S Pit Recommendations	Provide workable management options for controlling groundwater inflows into S Pit	**Provision:** of recommendations based upon Phase 1 review and CHM update
Numerical Modelling Recommendations	Recommend methods to complete numerical modelling / predictions required for Phase 3 work	**Provision:** of recommendations based upon Phase 1 review and CHM update

3. Curragh Mine and S Pit – Site Description

Curragh Mine is a series of open-cut mines within the Bowen Basin located approximately 160 km west of Rockhampton and 14 km north of Blackwater and covers a total area of 12,600 ha. Curragh Mine began operations within ML1878 (Curragh) in 1983 and have progressed down dip in an easterly direction through ML80086 (Curragh East) and operates in ML80110 (Curragh North). Coal is mined from four major seams within the Rangal Coal Measures: the Aries, Castor, Pollux, and Pisces seams, which have average thicknesses of 2.5 m, 1.8 m, 2.8 m and 6.5 m respectively. The S Pit at Curragh Mine North is located two-thirds of the way down the ML80110 mining lease close and adjacent to the Mackenzie River.

Drawing 1 shows that current open-cut operations are undertaken within a number of mining leases:

- ML1878 (Curragh);
- ML80086 (Curragh East);
- ML80110 (Curragh North); and
- ML80171 (Curragh West) and ML80178 (Curragh West Extended).

Drawing 2 shows the surface geology at ML80110, which is dominated by Quaternary Alluvium associated with the current Mackenzie River. Towards the south of ML80110, a tertiary ridge forms a topographic high, which is known locally as Duaringa Formation. The planned S Pit straddles the Tertiary Ridge to the north and south.

Drawing 3 shows the current mining layout in ML80110, with LIDAR data obtained from WCPL which is presumed to be acquired in September 2014. The initial boxcut which has commenced mining operations in The S Pit, can be seen clearly, with maximum depths reaching down to approximately 89 mAHD.

Drawing 4 shows the S Pit Mineplan against aerial imagery which is presumed to have been acquired in August 2014. The S Pit boxcut is clearly visible on this drawing, as are the haul roads and Mackenzie River. The distance from the Mackenzie River to the edge of Strip 1 is routinely between 250 – 350 m, but at its closest point is approximately 240 m.

Drawing 5 shows a zoomed in extent of the S Pit boxcut, with Block Numbering shown, together with the locations of site photographs recorded by the site Resource Geologist. Appendix B contains the site photographs, together with 2 screen captures from videos recorded by the Resource Geologist.

Drawing 6 shows the 100K mapsheet surface geology overlaid over the S Pit mineplan and aerial imagery. The Tertiary Ridge (coloured green) defines the approximate extent of the Quaternary deposits towards the south of the mine plan. Appendix C shows the generalised geological section compiled by the Minserve Group (1998a), together with an alluvial cross section which was completed by Mineserve. The locations of the holes used on the cross section are shown on Drawing 6 (as per Table 10.2 of MG 1998a) however DP notes that the locations do not correspond with either a cross section or a fence diagram, which may be why they had difficulties joining the dots.

4. Data and Literature Review

4.1 Data Supplied

To complete the Phase 1 Report and Data Review, WCPL provided DP with a number of existing data sets, together with a pack of historic reports. Data provided by WCPL included:

- Vulcan Triangulations and CSV files of Geological Surfaces, and S Pit Blocks
- Groundwater Monitoring Data for the period 2006 through to 2008;
- 50cm Aerial Imagery;
- 2 X LIDAR Datasets, covering the majority of Curragh North and a strip along the Mackenzie River (presumed to be acquired in September 2014 and December 2013 respectively);
- Interpolated cross sections (A to D) generated using Vulcan Software through the existing boxcut;
- 7 X Site photographs taken from Blocks 29 and 30;
- 2 X Site videos recorded at Block 30 after period of wetter weather;
- Airlift yield data obtained from exploration hole data, generally which covers deeper units including coal seams;
- Water strike information from exploration holes near S Pit;
- Downhole geophysical data from exploration holes near S Pit, including inferred Standing Water Level from the Neutron Log.

The data supplied is discussed throughout the remainder of this document and presented in Drawings 1 to 20.

4.2 Supplied Documents

Source documents from the Phase 1 review provided by WCPL are detailed below in chronological order:

Geological Survey of Queensland (GSQ), 1980: Curragh Coal Aquifer Testing – Report on Hydrogeological Investigations, Record 1980 / 39, Ref E205, October 1980.

Geological Survey of Queensland (GSQ), 1987: Hydrogeology of Coal Seams at Curragh, Central Queensland, Record 1987 / 20, Ref E205, May 1987.

The Mineserve Group Pty Ltd (MG), 1998a: Task No. 10 - Geotechncial Services. Report on the Feasibility Study for the Development of the Jellinbah Station Coal Deposit. Prepared for Stanwell Corporation, Project number ASE01M, August 1998.

The Mineserve Group Pty Ltd (MG), 1998b: Task No. 11 - Hydrogeology. Report on the Feasibility Study for the Development of the Jellinbah Station Coal Deposit. Prepared for Stanwell Corporation, Project number ASE01M, August 1998.

PKK Environment & Infrastructure (PKK), 2001: Jellinbah Station Coal Project “Pisces” – Hydrogeological Review. Prepared for Stanwell Corporation, Project Number 82p006b, July 2001.

Coffey Geosciences Pty Ltd (Coffey), 2004: Review of the potential for groundwater ingress through quaternary strata to Curragh North open cut mine, Letter Number B17892/01-A, 30 March 2004.

Parsons Brinkerhoff Australia Pty Ltd (PB), 2003: Curragh North Coal Mine – Hydrology, Flooding and Groundwater Report. Prepared for Wesfarmers, Project Number 2132105A – PR001Cbt, July 2003.

O2 Environmental (OE), 2010: Water Management and Erosion and Sediment Control Plan – Water Balance Report. Wesfarmers Curragh Pty Ltd, Project Number SC09-0021 / SC-RO00677a, February 2010.

Douglas Partners Pty Ltd (DP), 2012b: Report on Conceptual Groundwater Model – Curragh Coal Mine, Project Number 79869.01, 26 October 2012.

Douglas Partners Pty Ltd (DP), 2014: Groundwater Monitoring Assessment – Curragh Mine, Project Number 79869.02, 14 May 2014.

Wesfarmers Curragh Pty Ltd (WCPL), 2014a: S Pit Groundwater Review – Quaternary Sediments. Curragh mine, April 2014.

Wesfarmers Curragh Pty Ltd (WCPL), 2014b: Curragh North Groundwater Review – Executive Summary, 2014

4.3 Douglas Partners Sourced Documents

In addition to the Reports supplied by WCPL, DP has been able to find and review the following additional reports relating to groundwater conditions at the Curragh Mine (in chronological order):

Groundwater Environmental (GES), 2008: Review of Groundwater Monitoring Network, November 2008 (Draft).

Douglas Partners Pty Ltd (DP), 2010a: Preliminary Groundwater Appraisal for Curragh Ponds, March 2010 (Draft).

Douglas Partners Pty Ltd (DP), 2010b: Report on Geotechnical Investigation – Curragh North 'S' Pit Development near Blackwater, Central Queensland, Project Number 74387, 27 May 2010.

Douglas Partners Pty Ltd (DP), 2012a: Report on Assessment of Trigger Levels for Groundwater Quality – Curragh Mine, Blackwater, Central Queensland, Project Number 79869.00, 10 May 2012.

Wesfarmers Curragh Pty Ltd (WCPL), 2013a: Water Management Plan – EM Plan 2.0, Revision 1, 26 November 2013.

Wesfarmers Curragh Pty Ltd (WCPL), 2013b: Groundwater Monitoring Procedure – EMS Proc 2.4, Revision 2, 2 December 2013.

Where finalised versions of the additional reports have been available, these will be made available to Wesfarmers Curragh Pty Ltd, for future reference.

After reviewing the Phase 1 work completed by WCPL, DP reviewed all documents in entirety, for information pertaining to this study. Due to the large volume of material reviewed, and for simplicity, a matrix of findings is presented below (Table 2), which presents key findings against each of the reference material.

As conceptual hydrogeological models are generally refined as new information comes to hand, Table 2 is presented in chronological order.

Review of the Phase 1 work is presented subsequent to this analysis.

Table 2: Desktop Review with respect to the S Pit Groundwater Seepage Review

Reference	Summary	Pertinent Information to This Study
GSQ (1980)	Detailed Investigation of Hydrogeological characteristics of coal seams obtained through Aquifer Testing at 2 sites at Curragh.	Does not contain any significant information concerning hydrogeology of the Quaternary Sequence at Curragh.
GSQ (1987)	Extended duration Aquifer Testing of coal seams at Curragh.	Does not contain any significant information concerning hydrogeology of the Quaternary Sequence at Curragh.
MG (1998a)	Geotechnical Assessment to provide design criteria related to pit excavations.	• P10.3 & 10.0 Locations of Obs bores and Standing Water Levels; • P10.12 Summary of PPK major findings relating to Quaternary Sediments; • P10.13 Hydraulic properties of Units; • P10.16 Quaternary Alluvium Description; • P10.27 & 10.29 Cutoffs and embankment recommendations for the Quaternary; • Figure 10.4 Generalised Geological Section; • Figure 10.9 Alluvium Cross Section; and • Figure 10.28 & 10.29 Isopachs. This report contains a reasonable amount of information which is pertinent to this study and can be used for benchmarking purposes, such as the cross section found in Figure 10.9
MG (1998b)	Groundwater investigations including a review of previous data, aquifer characterisation and assessment of likely impact.	• P11.2 General description of Quaternary Sediments; • Groundwater Monitoring Bores Table 11.1 (does not include SWL); • P11.4 Evidence of Quaternary being unsaturated (unconfined) and ***monitoring network dry, hence needs upgrading;*** • P11.5 Comments regarding compartmentalisation in pockets of drainable alluvium; • P11.5 Details Tertiary Sediments; • P11.11 Concludes poor connection to the Mackenzie river; and • Hydrology information concerning the Mackenzie River found in P12.1, 12.2, 12.4 and 12.5. This report contains many contradictions and multiple statements which are not hydrogeologically astute. Furthermore, many questionable statements are made without any scientific evidence to support the statement.

Reference	Summary	Pertinent Information to This Study
PPK (2001)	Review and recommendations concerning risks of pit inflows through the Quaternary Sequence.	• All bores were found to be dry suggesting Quaternary sequence is not fully saturated; • P4 suggests average thickness of Quaternary units is 18.3m; • P5 Details the Tertiary unit; • Table 3.3 details known monitoring bores but does not include any information on measured water levels; • P9 sites recharge as being the biggest unknown in the hydrogeological system and must be resolved; • Figure 3.1 on P10 presents a very simple conceptual model of the system; and • P11 ***Recommends bores drilled in the southern section of the resource area.*** This is essentially a desktop review of earlier work completed by PPK. There is no new information in this reference which is of value to this study.
PB (2003)	Hydrological and Hydrogeological studies completed for the Curragh North Coal Mine Development.	• P28 & 29 Geological descriptions; • P31 Drainage patterns; • P73 / 74 Geomorphology of the Mackenzie; • P83 Existing Groundwater User Search; • P85 Notes regarding Obs Bores; • Figure 4.32 Groundwater Hydrograph; • P88 Finds correlation between observed hydrograph and rainfall; • P87 - 90 ***Monitoring is sparse;*** • Figure 4.34 Groundwater Hydrograph; • P96 to 98 Conceptual Model; and • P135 to 142 Flow calculations. The conceptual model "describes a groundwater system that has potential for very high flow rates, but due to the shallow saturated interval, the aquifer has low storage. Inflows to the mine from the Quaternary sequence are likely in the initial stages of mining. Potentially high continuous inflows via paleochannels are possible on the northern section of South Pit. There are no groundwater monitoring bores in this area currently, and it is recommended that monitoring bores be installed in this area". Overall this is a reasonably sound piece of work, although some questionably hydrogeological components completed in earlier work have followed through into this document. Flow calculations are however not valid. Appendix A titled Groundwater Monitoring Data doesn't include any monitoring data.

Reference	Summary	Pertinent Information to This Study
Coffey (2004)	Concise review of the potential ingress of ground water from the Mackenzie River via Quaternary alluvial sediments into Curragh north	• P2 Found that a limited amount of hydraulic testing had been completed for the Quaternary sediments; • P2 Finds that there is a limited amount of data on groundwater levels in the Quaternary alluvial sequence; • P2 Refutes some of the earlier work by Mineserve and suggests some degree of hydraulic connection with the Mackenzie River; • P3 ***No groundwater monitoring bores have been installed in the alignment of the palaeochannel which crosses South Pit****;* • P3 Concludes that seepage from the Quaternary is likely to be greater along the low wall of the northern half of South Pit; • P3 Indicates that groundwater inflows of approximately 25 L/s may occur over a 900 m width of the inferred palaeochannel; and • Figure 2 presents the inferred base of the Quaternary sequence and potential location of palaeochannels.
GES (2008)	A draft report covering the desktop review of hydrogeological datasets at Curragh.	• DP does not have much confidence in the findings of this draft report. Section 4.5 (P9) commences with the statement 'Due to limited data, the major aquifers that underlie the Curragh mine site have not been identified'; • P15 Contains some useful data regarding chloride ion measurement; • P18 Conceptual Hydrogeological Model is reasonably generic and requires review; and • P20 Groundwater Monitoring Wells section is largely speculation. • P21 ***Due to limited hydrogeologic information the existing monitoring well network does not provided sufficient hydrogeologic information at the Curragh mine site.***
OE (2010)	As per the title, this document covers an assessment of water management of connected storages and erosions and sediment control for Curragh and Curragh North	• Pii Long term rainfall record analysis; • P3 Detailed Project background; and • P41 Contains a useful summary of groundwater quality information as well as hydrograph response.
DP (2010a)	Hydrogeological characterisation of temporary mine water storage pond locations	• Contains some useful observations pertaining to the Tertiary sequence sediments; and • Does not contain any significant information concerning hydrogeology of the Quaternary Sequence.

Reference	Summary	Pertinent Information to This Study
DP (2010b)	Geotechnical investigations carried out for the proposed infrastructure upgrade at Curragh North S Pit. Undertaken at the request of Wave Engineering.	Does not contain any significant information concerning hydrogeology of the Quaternary Sequence at Curragh.
DP (2012a)	Covers the review of the groundwater monitoring program and establishment of groundwater trigger levels as required by the Environmental Authority.	• P1 Monitoring network described covers only the Permian units; • P2 WCPL have previously provided groundwater level data in spreadsheet format; • P4 Some comments regarding general groundwater quality parameters; and • P6 ***Concludes monitoring network is not of a high standard and needs rectifying.***
DP (2012b)	Development of the Conceptual Hydrogeological Model for Curragh	• P2 – 5 Reasonable summary of previous investigations; • P9 suggests the alluvium attains a maximum thickness in excess of 30m adjacent S Pit; • P9 – 11 Various CHM elements; • P11 Finds a 'complex alluvial aquifer system with spatial variability in recharge; • P16 ***Groundwater monitoring at Curragh North has been undertaken on an ad-hoc basis.*** Recommendations made for additional monitoring in the Quaternary; and • Drawing 7 – Groundwater levels in the alluvial aquifer.
WCPL (2013a)	Curragh Mine Water Management Plan aims at reducing potential risk to the environment whilst facilitating operational objectives	Does not contain any significant information concerning hydrogeology of the Quaternary Sequence at Curragh.
WCPL (2013b)	Procedure to provide guidance for the ongoing monitoring and management of groundwater at Curragh Mine.	• Table 1 – Groundwater monitoring locations
DP (2014)	Provides an assessment of the current groundwater monitoring program and its effectiveness in relation to monitoring the EA conditions set	• P4 Useful hydrology summary; • P6 There is very little information concerning the alluvial aquifer; • P11 Defines the 2 bores which have been completed in the alluvium; • Table 4 Groundwater level data; • Drawings 1/2A/2B/3 & 4; and • P29 ***Recommendations to drill monitoring bores based on inadequate network***.

4.4 Preliminary Phase 1 Review Findings

After reviewing all historic literature available, Douglas Partners completed a review of both the Phase 1 reference material, concurrently with an analysis of data supplied by WCPL. Prior to completing detailed hydrogeological analysis, Douglas Partners would make the following comments regarding the WCPL Phase 1 report:

- Douglas Partners have been informed and acknowledge that the WCPL Phase 1 report is a very brief summary which was produced very quickly and as an initial guide for site operations personnel, as part of an exercise to collate all known data on Curraghs hydrogeological setting with specific reference to the Quaternary alluvial aquifer. The report satisfies this need and has been deliberately simplified to convey only the necessary detail to the target audience, with the necessary qualifications on data being communicated verbally in presentations and personal communications. The report was completed prior to having all relevant data to hand due to the previously scattered nature of site data storage. Where the report appears subjective, the author has used personal experience and simple estimates to serve the purpose of providing an indicative picture to the mine operations;
- The current work serves to build on this view and provide a path to a better informed mine site; and
- The S Pit review completed by the Resource Geologist characterises the geology of the system in sufficient detail for both the technical and non technical audience.

The Phase 1 review completed by WCPL is thorough and provides an adequate description of the risks associated with mining to be completed at the S Pit. Some of the hydrogeological advice is quite subjective, partially due to contradictions made in previous reports, and partially due to the lack of verifiable data at the site.

In addition to the review of Phase 1 work, DP has interrogated the data sets provided in order to refine the conceptual understanding of the system.

Drawings 7 & 8 show the geological datasets provided, as presented in colour flood, and against both the mine plan and approximate extent of identified gravels. Blocks 28 to 30 are also marked as a reference point. It can be seen from Drawing 7 that the base of the Quaternary is approaching its lowest elevation (for Strip 1) near Blocks 29 and 30 which is where the problems are occurring at site.

5. Physiography & Climate

5.1 Topography & Drainage

Surface topography is generally flat across the mining lease area, with the surface elevations at their lowest at approximately 120 mAHD in the northeast corner and at the highest levels of 170 mAHD near the southwest corner of the lease area. The overall fall in elevation and drainage direction across Curragh leases is to the northeast.

The two most significant water courses are the Mackenzie River and Blackwater Creek. Blackwater Creek originates from an area about 15 km southeast of the mine and drains through the mine towards

the north and northeast. It discharges into the Mackenzie River some 9 km north of Curragh at an elevation of approximately 120 mAHD.

The Mackenzie River, a major stream within the Fitzroy catchment, trends along the western boundary of the Curragh North lease, towards the north and then northeast. The catchments of Blackwater Creek and the Mackenzie River are occasionally subjected to flooding during significant rainfall events.

5.2 Climate

Curragh Mine is located at an approximate latitude of 23.4°S, some 190 km inland from the Queensland coast. Several weather stations are located nearby, with Blackwater Airport located approximately 15 km southeast of Curragh Mine South and Wilpeena approximately 20 km north of Curragh North.

Climate data for the site was collated from the Queensland Department of Science, Information Technology, Innovation and the Arts (SITIA), SILO database, which interpolates data from point observations to generate a more representative dataset for a given location. On 2 April 2014, data was harvested from the SILO database from 1900 to 2013 and indicates a long-term annual average rainfall of approximately 560 mm per year for Curragh Mine (Drawing 9). Average monthly data indicates a seasonal climate, with the Wet Season summer months of December to March accounting for ~47% of annual total rainfall. In contrast, only ~16% of annual rainfall occurs during the Dry Season months of June to September.

Average evaporation for the year is in excess of 2,000 mm, approximately 3.5 times the average total rainfall, which generally peaks in the summer months. The ratio of evaporation to rainfall is lowest during December and January, suggesting that high rainfalls during these months may provide the bulk of recharge to the groundwater system.

Average daily maximum temperatures range from 33.8°C for the months of January and December down to 23.3°C for July. Average daily minimum temperatures are 12°C to 16°C lower than average daily maxima.

Table 3 summarises the monthly average climate statistics for the Curragh Mine region.

Table 3: Long-Term Average Monthly Climate Statistics

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (mm)	87	34	58	30	29	29	24	16	20	39	57	85	557
Evaporation (mm)	230	188	195	154	119	96	103	130	170	209	221	236	2051
Max. Daily Temp (°C)	33.8	33.1	32.1	29.6	26.3	23.5	23.3	25.2	28.3	30.9	32.5	33.8	29.4
Min. Daily Temp (°C)	21.8	21.6	20.2	16.6	12.4	9.4	8.0	9.4	12.9	16.6	19.1	20.9	15.7

The climate in the area can be classified as sub-humid and sub-tropical. Temperatures are relatively moderate throughout the year. Average daily maximum temperatures range from 34°C for the month of January down to 23°C for July. Average daily minimum temperatures are 12°C to 16°C lower than average daily maxima.

6. Geology & Hydrogeology Summary

DP (2012b) described in detail the geology and conceptual hydrogeological model of the Curragh mine site and surrounding area. The geology and hydrogeology are summarised in the following sections.

6.1 Geology

The geology of Curragh Mine and surrounding region generally comprises Permian sedimentary units overlain by surficial deposits of Tertiary and Quaternary age, and is re-produced on Drawing 2. The regional geology is characterised by the following stratigraphic units (from youngest to oldest):

- Quaternary alluvium and colluvium;
- Tertiary Emerald and Duaringa Formations;
- Triassic Rewan Group; and
- Permian Blackwater Group containing the Rangal Coal Measures.

The alluvium at Curragh North is described as a fining upward sequence where clay soils and silty clay units overlie sandy sediments that coarsen with depth to gravel (PB, 2003). The fluvial channel fill deposition of this alluvium results in a sequence with significant lateral variability. Coarser sediments are found in the streambeds of Blackwater Creek and Mackenzie River.

The Rangal Coal Measures of Late Permian age comprise grey mudstone and siltstone, fine-grained lithic sandstone, tuff, carbonaceous shale and coal seams. The Rangal Coal Measures represent the final development of coal forming conditions in the Bowen Basin. The Aries, Castor, Pollux and Pisces Seams are the coal seams of economic significance at Curragh.

6.2 Hydrogeology

6.2.1 Aquifers & Hydraulic Properties

DP (2012b) reported that the hydrogeology of Curragh Mine and adjacent areas is characterised by two distinctly different groundwater systems comprising:

1. Coal seams of the Permian Rangal Coal Measures; and

2. Tertiary / Quaternary alluvium associated with Blackwater Creek and the Mackenzie River.

DP (2012b) reported that the coal seams were the primary aquifers of the Rangal Coal Measures sequence. The coal seams behave as confined fractured rock aquifers and a program of hydraulic testing reported the hydraulic conductivity (K) of coal seams to be ~1.2 x 10^{-1} m/day. Interseam sediments (siltstones and sandstones) were found to be 1 to 2 orders of magnitude less permeable than the coal seams (average K: ~9.7 x 10^{-3} m/day). Results of the analysis of test pumping data show that Transmissivity (T) of coal seam aquifers is of the order of 3.8 x 10^{-1} m^2/day, and that storativity (S) values average 1.7 x 10^{-4}. The coal seam aquifers are significantly anisotropic, with a principal direction of enhanced Transmissivity and hydraulic conductivity aligned (approximately) with regional structure.

Geological mapping (Drawing 2) shows the extent of alluvial deposits associated with Blackwater Creek and the Mackenzie River. These deposits are thicker and better developed in close proximity to the Mackenzie River where (on the basis of drilling records) they are characterised by a water bearing basal sand / gravel unit. Consequently, this aquifer is of greater significance at Curragh North, than at Curragh and Curragh East.

6.2.2 Permian Groundwater Levels & Flow Directions

Groundwater levels within the Permian strata prior to mining were in a generally north-easterly direction at a gradient of approximately 1 in 400. The Aries-Castor and Pollux aquifers maintained separate potentiometric levels over the period 1980 to 1982.

DP (2012b) reported that very little information is available in regard to groundwater levels in the Tertiary / Quaternary alluvial sequence associated with Blackwater Creek and the Mackenzie River. PB (2003) assessed groundwater level monitoring data for the alluvial aquifer over the periods November 1996 to June 1997, and November 2001 to June 2003. Many of the monitoring bores were found to be dry.

6.2.3 Groundwater Quality

DP (2012b) reported that the water quality of groundwater from the Permian fractured rock aquifers can be characterised as follows:

- Groundwater is moderately saline to saline and dominated by the sodium (Na) and chloride (Cl) ions;

- pH of groundwater is neutral;
- Levels of nutrients are low; and
- There is evidence of some elevated levels of hydrocarbons, although the data is inconclusive.

A search of the DNR&M Groundwater Database shows that the average salinity (EC) of groundwater in the Curragh region is ~14,500 µS/cm (DP2012).

In 2012, DP reported that there was no information available in regarding the quality of groundwater from the alluvial aquifer associated with Blackwater Creek and the Mackenzie River. In 2014 however, DP completed a Groundwater Monitoring Assessment which included groundwater chemistry data from at least 2 bores completed in the Quaternary Alluvium, bores 1309MB and 1312MB.

Groundwater quality data from the 2 bores known to be completed in the Quaternary Alluvium are presented in Appendix D. Groundwater quality from these bores could be characterised as brackish (Fetter, 2001) with an average TDS of approximately 1800 mg/L. Further to the suite of results presented in Appendix D, results measured for chloride ion concentration for these 2 bores are shown in Section 9.

7. Quaternary Groundwater Monitoring

7.1 Monitoring Network

Curragh Mine has implemented a groundwater monitoring network comprising 29 monitoring bores that are currently being monitored as a condition of the EA. The monitoring system, bores, sampling parameters and methodology are outlined in Curragh Mine's EMS PROC 2.4 Groundwater Monitoring Procedure.

The majority of the monitoring bores are installed appropriately within the Permian strata to monitor the potential impacts from mining and the draining of water from the coal seams. The Permian bore network provides good coverage across the whole mine site and includes some background bores which are located upgradient of the active mine pits, such as BH5, 1322MB, and 1323MB.

The network also includes two alluvium monitoring bores between Curragh North and the Mackenzie River which will allow the detection of any quality or level impacts on the shallow groundwater system. As part of the literature review of this study, DP collated every bore that had been reported to have been completed in the Quaternary sediments, for the construction of a piezometric surface.

All bores found to have been completed in the Quaternary sediments are shown in Drawing 10. It is assumed that most of the 39 bores shown on this drawing have been made historic.

From Drawing 10, it can be inferred that:

- The Quaternary bores have historically been installed in 2 clustered areas, some in the north-east near the U Pit extension, and some to the west of T Pit;
- All bores have been completed between the open cuts and the Mackenzie River; and
- There have been no bores installed in the Quaternary near S Pit;

8. Quaternary Monitoring Results

8.1 Groundwater Levels and Flow Direction

Drawing 11 shows an interpolated groundwater contour plan which has been hand drawn and digitised, based on the temporally composite set of hydraulic head data which was collated during the desktop study. Where data were not available for use, Douglas Partners digitised previously reported hydrographs by hand, in order to maximise the number of data points which could be used to produce a reliable contour set. Drawing 11 should be considered the most comprehensive representation of Quaternary data available at the time of reporting.

In a subsequent part of this study DP used the LIDAR and geological data to identify where the current open cuts had mined through the Quaternary unit. The area of the Quaternary which had been mined out is displayed on Drawing 11 in a light blue colour. As this information was compiled post contouring, it can be seen there are a couple of areas where contour lines exist at the edge of mined out areas, but apart from this, the groundwater contours match the general open cut pit trend quite well.

Douglas Partners notes that through completing the literature review, no other previous groundwater contour sets have been acquired, for any of the hydrogeological units.

From the interpolated groundwater contour plan, it can be inferred that:

- Groundwater flow occurs from the Mackenzie river towards the open cut pits;
- A small mound has formed near the water storages at 1309MB;
- Hydraulic heads recorded near the Mackenzie River are between 104 and 108 mAHD;
- Hydraulic heads recorded near the open cuts are between 94 and 97 mAHD;
- The head in the Mackenzie river (or river stage) is generally around 108.5 mAHD based on the LIDAR data provided, although historic hydrographs suggest it may routinely fluctuate between 107.5 and 109 mAHD, and up to 111 mAHD during flood;
- The range in hydraulic heads would mean that the groundwater system would largely behave in an unconfined manner, given the base of the surficial clays has been nominated at approximately 112 to 120 mAHD (WCPL, 2014a); and
- The calculated hydraulic gradient towards the pits varies approximately from 0.0057 (4m fall over 700m) up to approximately 0.026 (8m fall over 300m), generally depending on the distance from the river to the open cut.

Drawing 12 infers the approximate location and extension of the interpolated contours in the north, to that area which is currently being mined at S Pit. The absolute levels are of a similar order than those calculated by WMPL (2014a), but do not extend above the base of the current boxcut. Without any dedicated monitoring wells in the Quaternary unit, the inferred contour set can not be verified, however they are intuitive, given the observed behaviour around existing pits, and the structure contours which the Wesfarmer's Resource Geologist has previously established.

It can be inferred from Drawing 12:

- Groundwater flow will and is occurring towards the completed boxcut; and

- Throughout mining of Strip 1 and 2, groundwater gradients will continue to develop towards the open cut, and groundwater will drain to the lowest levels of topography.

Drawings 13 to 16 show a compilation of hydrographs which DP has been able to reproduce in part by digitising some of the older reports hydrographs, together with the latter datasets which are available in spreadsheet format.

Historically, there have been some very loose comments made with respect to hydrogaphs, and how they have responded against both rainfall and rises in the Mackenzie River. Douglas Partners notes that none of these comments have been quantified, and none have used specific examples. Section 9 below looks at one example in detail, with a view to providing a better understanding of the hydrogeological system. Douglas Partners would also reiterate that any historical inferences between the hydrograph response, and the transmissivity of the sand / gravel unit, should be ignored.

9. Recharge Estimation

9.1 Cumulative Rainfall Departure Recharge Estimate

Douglas Partners has used the Cumulative Rainfall Departure (CRD) method for estimating the amount of recharge which the groundwater system may be receiving through rainfall. The CRD method is based on the relationship between rainfall and observed groundwater levels and can be used for calculating estimates of recharge rates and storativity / specific yields.

The general equation relating CRD to groundwater level fluctuations (Wenzel, 1936) takes the form:

$$h_i = h_{(i-1)} + F(P_i - C)/S + (I_i - O_i)/SA - Q_i/SA$$

Where;

h_i = Groundwater level in month$_i$ (m);

$h_{(i-1)}$ = Groundwater level in previous month (m);

F = Fraction;

P_i = Precipitation in month$_i$ (m);

C = Cutoff monthly rainfall, below which no recharge occurs (m);

S = Specific yield;

I_i = Inflow to the aquifer during month$_i$ (m^3);

O_i = Outflow to the aquifer during month$_i$ (m^3);

A = Area (m^2); and

Q_i = Withdrawal (pumping) from the aquifer during $month_i$ (m^3).

Note: R_i = effective monthly recharge (m) is represented as $F(P_i-C)$

The CRD technique is a lumped parameter method. That is, the hydrological status of the aquifer is integrated into a composite hydrograph that simulates saturated volume fluctuations derived from water level records in the studied area.

For the purposes of this assessment it is assumed that groundwater levels in observation bores are representative of an aquifer surface with area (A) of 40 km^2. This area correlates roughly with the area of Quaternary sediments in Mining Lease 80110. The method ideally requires monthly water level, abstraction and rainfall data for the simulated period. The assessment was undertaken using a spreadsheet model that allows for optimisation of input parameters by matching observed water levels with computed groundwater levels (h_i). Due to the frequency of observations made at Curragh, a script was used to interpolate monthly observations where the frequency of monitoring was not conducive for the analysis. Given these constraints, this should not be considered a definitive assessment, but it should yield an order of magnitude estimate of recharge and storage, as well as identify locations where the relative recharge is comparably higher or lower.

Drawing 17 shows probably the best match between the CRD-modelled and observed water levels, which were required to achieve the greatest correlation at site PSMB 05B. This site was selected as it was the site with the longest record of continuous data and exhibited clear peaks and troughs within the dataset. Douglas Partners notes that the hydrograph for PSMB 06 is essentially a subdued version when compared to PSMB 05B, in terms of the amplitude of response, and could have been used just as easily.

Based on the analysis, it was possible to achieve an approximate fit for the data using a recharge rate of 28% of rainfall. Table 4 presents the results of the recharge analysis.

Table 4: Results of CRD Recharge Analysis

Site	Location	Recharge (% of Rainfall)	Specific Yield	Cutoff (mm rainfall per month)
PSMB 05B	Adjacent T Pit	28	0.07	33

Given the lithology at the site (thin capping of clays over an unsaturated sand profile) the CRD estimate of recharge does seem at the higher end of what Douglas Partners would have expected. It should be noted though, that this estimate has been based on the longest record of data available, which when applied in the model, considers 16 months of rainfall data. It has been DP's experience that much better matches can generally be made with frequent monthly measurements over much longer periods (multiple years ideally). The input dataset for this hydrograph was also digitised from Figure 4.34 of the PB (2003) Report, in lieu of raw data being available.

Anecdotal evidence from site does however show that discharge from the basal gravels does vary after significant rainfall events, hence it is plausible that recharge rates to the Quaternary tend towards the higher end of the spectrum as calculated.

As part of the present study WCPL provided DP with 2 X 1 second videos, which have been converted to photo stills and shown in Appendix B (Photographs 4 and 9). Photograph 4 (taken from Video 4) was taken from the eastern high wall in block 30, while Photograph 9 (taken from Video 3) was filmed of the western low wall in block 30. Douglas Partners has estimated the groundwater flow rates from these 2 videos (in lieu of any physical measurements) to be:

- Western low wall block 30 – Video 3 – Approximately 4 to 5 L/s
- Eastern high wall block 30 – Video 4 – Marginally less than to the west, approximately 4 L/s.

Information from WCPL suggests that a couple of weeks prior to filming the described videos, flow rates from the same 2 locations were significantly less, of the order of 1 L/s. Therefore it can be assumed that recharge to the Quaternary system is significant.

Other comments relating to the CRD recharge analysis;

- It is a possibility that recharge occurring from the Mackenzie River into the Quaternary system does increase the total amount of recharge occurring to the system, which limits the reliability of this approach in isolating that component of recharge which occurs solely from rainfall precipitation;
- Having noted the above, it can be seen from Drawing 17 that from the period between February 2002 and May 2002, the river gauge in the Mackenzie continues to rise, while the recorded groundwater hydrograph at PSMB05 05B (some 800 – 900 metres from the river) is in decline. The hydrograph at PSMB 05B experiences a relatively big jump at the end of May and start of June 2002, just preceding the very wet month of June (some 94.3mm). The PSMB 05B response in February 2002 was not as large as that in June, even though 87.3 mm of rain fell in February, following a couple of reasonably wet months. One could postulate that the rising river level had a delayed effect, witnessed at PSMB 05B some 2 months after the river began rising. This is plausible, given we believe the system behaves in an unconfined manner, and the propagation of pressures are not as rapid as opposed to a confined groundwater system; and
- If we look at the digitised response shown in Drawing 14, a rise in groundwater levels is noticeable at PSMB 02B from April to May, almost a month earlier to the rise observed at PSMB 05B. Given PSMB 02B is located at approximately 220m from the Mackenzie River, this makes sense conceptually.

9.2 Chloride Mass Balance Recharge Estimate

To provide a cross check against the CRD recharge estimate, DP has completed a chloride mass balance recharge estimate for Curragh North. Douglas Partners has been provided groundwater quality results for 2 Quaternary monitoring bores at Curragh North, 1309MB, and 1312MB.

The groundwater quality results for chloride at both bores are listed in Table 5 below. Crosbie et al (2012) presents results for the chloride concentration in rainfall at 21 sites across Australia. Douglas Partners triangulated the results from the average of all raw results presented for the Townsville, Rockhampton and Charleville stations, in order to derive an estimated chloride concentration of rainfall at Curragh (Cl_{eff}).

Table 5: Chloride Present in Groundwater

Site	Average Chloride (mg/L)
1309MB	420 (based on 3 samples with range from 350 to 470)
1312MB	420 (based on 3 samples with range from 300 to 590)
Average	420
Geometric Mean of all Samples	410

The Chloride Mass Balance is widely used by hydrogeologists and was reported by Wood & Sanford (1999). The equation for the Chloride Mass Balance takes the form:

$$R = P \times Cl_{eff} / Cl_{GW}$$

Where;

R = Recharge per year in mm (mm/yr);

P = Mean annual Precipitation in mm (mm/yr);

Cl_{eff} = Effective chloride concentration of infiltration water (mg/L); and

Cl_{GW} = Chloride concentration of groundwater (mg/L)

If it is assumed that the effective chloride concentration is that of the chloride concentration of rainfall, and that the chloride concentration of rainfall is relatively unchanged since the time that recharge occurred, then the above method may be used for the estimation of recharge. Table 6 below reports the chloride mass balance estimates of recharge, using a combination of parameters.

Table 6: Recharge Estimate Based on Chloride Mass Balance Method

Assumption	Recharge (% of Rainfall)
Cl_{GW} = Minimum Cl concentration of sites Cl_{eff} = Triangulated raw average	1.6
Cl_{GW} = Maximum Cl concentration of sites Cl_{eff} = Triangulated raw average	0.8
Cl_{GW} = Average Cl concentration of sites Cl_{eff} = Triangulated raw average	1.2
Cl_{GW} = Geometric Mean Cl concentration of sites Cl_{eff} = Triangulated raw average	1.2

Results presented in Table 5 suggest that the recharge which is occurring at Curragh is approximately 1 to 2% of annual rainfall. Given what we know from site, a recharge rate of 1 to 2% of rainfall seems appropriate or possibly lower than we might have expected, especially when compared with the CRD estimate of 28%.

With reference to the interpolated groundwater contour plan in Drawing 11, it is quite clear that the Mackenzie River is at very least a minor source of recharge to the Quaternary system at Curragh North, and most likely a reasonable contributor to the overall water balance. The water quality within the Mackenzie River obviously therefore becomes a key component within the chloride mass balance. If the salinity of the River tends much higher than native rainfall runoff (which can occur for a number of reasons depending on upstream conditions), then the chloride concentration of the water which recharges into the Quaternary groundwater system will be higher than local rainfall precipitation, and subsequently yield a lower recharge estimate.

In summary, Douglas Partners can make the following observations regarding recharge:

- Based on the CRD method, recharge rates may be of the order of up to 28% of rainfall which seems higher than what we may have expected;
- Anecdotal evidence from site suggests that discharge from the basal Quaternary sediments does fluctuate in time, specifically post significant rainfall events which suggests that rainfall recharge can not be negated;
- Results from the CMD method imply that recharge rates may be of the order of 1-2 % of rainfall, which seems appropriate, or possibly lower than what DP may have expected;
- Recharge from the Mackenzie River may artificially lower the CMD recharge estimate, by virtue of the water quality entering the system; therefore
- Recharge is thought to occur from both rainfall and leakage from the Mackenzie River. Further modelling would be required to further unpack these 2 components, but in the interim, it could be hypothesised that the total amount of recharge entering the Quaternary system per annum lies somewhere between 2 and 28% of the annual rainfall. The geometric mean of these 2 estimates is 7.5%, and would equate to a long term recharge rate (over the approximate 40 km^2 of 52 L/s.

Recommendations with respect to ongoing refinement of recharge estimation:

1. Water samples should be collected from the Mackenzie river quarterly for one year adjacent the S and T Pits, and analysed for major and minor ions, including chloride;
2. Groundwater samples should be continued to be collected from 1309MB and 1312MB, and analysed with the same suite as has been provided previously; and
3. Periodic samples should be collected from the problem discharge areas and analysed for the same water quality suite as is being conducted from the groundwater monitoring bores nominated in point 2. Samples should be collected after prolonged dry periods, and shortly following a significant rainfall event.

10. S Pit Inflows

With the commencement of the boxcut at S Pit, groundwater discharge from the basal gravels occurring at the base of the Quaternary unit have been causing issues for mining operations.

Evidence from the U Pit Extension has shown that groundwater discharge from the same unit has been occurring consistently at similar rates over a number of years and has been speculated to have drained more groundwater than what could have solely drained from the unit, inferring that a hydraulic connection exists with the Mackenzie River, or that the amount of recharge which the aquifer is receiving, is enough to maintain a steady flow to the pit.

Douglas Partners has estimated that at present, groundwater discharge is occurring into the S Pit at blocks 29 & 30, at the following approximate rates:

- On the western side: 1-2 L/s baseflow with increases up to 4-5 L/s after wetter periods; and
- On the eastern side: 1-2 L/s baseflow with increases up to 4 L/s after wetter periods.

The literature review completed in this study found that a few estimates of inflows had been completed historically, but the methods used for calculating these inflows are probably not appropriate, especially given the analytical solutions have been based on confined aquifer flow, where it is reasonably well understood the Quaternary system is not well confined, nay it is likely to behave in a semi-confined to unconfined manner.

PB (2003) estimated that the likely inflow rates would be somewhere between 9 and 23 L/s. Douglas Partners view is that WCPL have mined into block 29 and 30 and are already experiencing close to 9 L/s.

Obviously there are a number of variables which will govern the calculated inflow to the S Pit, and for higher accuracy WCPL would need to consider construction of a 3 Dimensional Numerical Groundwater Model to better understand these relationships. For simplicity, DP has used an analytical method, to identify the likely inflow rates which may be realised through mining Strip 1 & 2 of the S Pit.

Given the interpolated and inferred groundwater contour sets shown in Drawing 11 & 12, together with other existing open cuts, and the extent of Quaternary sediments, DP has defined 2 approximate capture zones which would roughly define the surface area of aquifer which would drain towards the open cut. Drawing 18 shows the capture zones as defined in both the East and West.

After defining the approximate capture zones, the geological model supplied by WCPL and the groundwater contours developed by DP were used to calculate the unconfined Quaternary aquifer volume.

Drawing 19 shows the capture zones as calculated, and the saturated extent due to hydraulic heads being above the base of the Quaternary unit. It can be inferred from comparing Drawing 19 with Drawing 7, that inflows to Strip 1 & 2 should have commenced by block 28 or 29 and are likely to persist in accordance with the development of more gravelly zones, right through to blocks 42 or 43.

As the main extent of gravels encompasses Strip 1, it is likely that inflows on the western side of the pit will decrease as the pit expands to the east.

Dupuit approximated steady flow through an unconfined aquifer where the slope of the water table is small and the velocities should be considered to be horizontal. The following expression is defined:

$$Q = -\frac{K}{2}\left(\frac{h_B^2 - h_A^2}{L}\right)$$

Where;

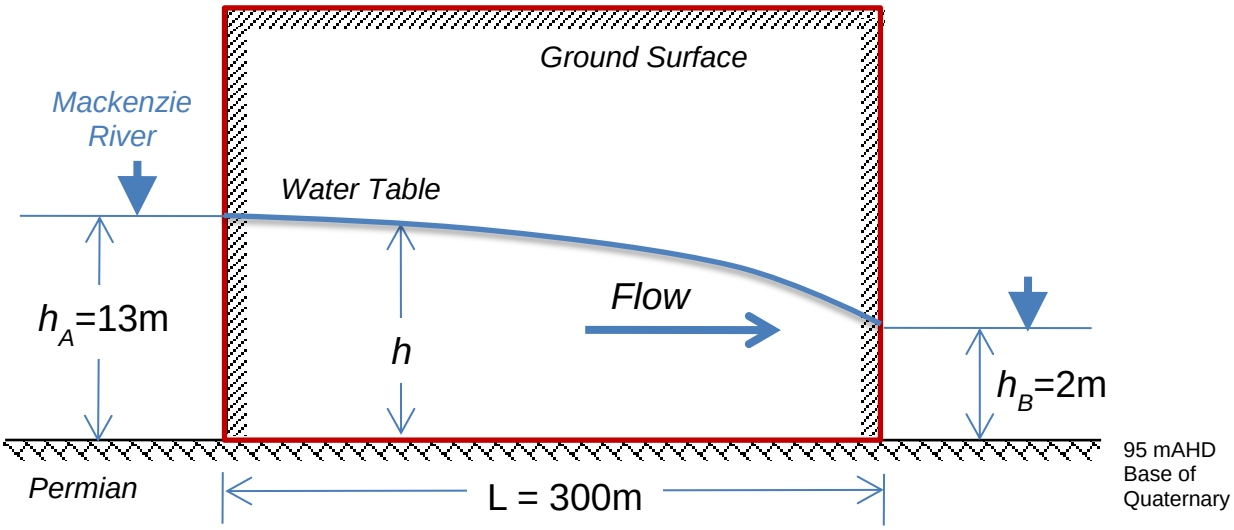
Q = Discharge (m^3/d/unit width);

K = Hydraulic Conductivity of the unconfined aquifer (m/d);

h = Hydraulic head as measured at point a and b (m); and

L = Horizontal distance between head measurements (m).

Figure 1: Dupuit Approximation of Steady Flow in an Unconfined Aquifer



Based on the Dupuit approximation, as shown in Figure 1, and assuming a Hydraulic Conductivity of 10 m/d (marginally higher than the inferred estimate for the sands, and factoring up due to the gravel component), the calculated flow per unit width is estimated to be:

$$Q = -\frac{K}{2}\left(\frac{h_B^2 - h_A^2}{L}\right) = -\frac{10\,m/d}{2}\left(\frac{13^2 - 2^2}{300}\right) = 2.75\,m^3/day/m$$

If we consider the length of a mining block is 100 meters, and the current problems being encountered at site are occurring at the end of block 29 and block 30, then we could assume this distance is 1.5 blocks or 150m. A transect distance of 150m would yield 412.5 m^3/d which equates to a groundwater discharge of approximately 4.8 L/s. This estimate is consistent with what is currently being observed at site from the western side of the pit. While the estimate assumes a diffuse flow across the full 150m, what will occur in reality is the bulk of the groundwater will follow the easiest route to the lowest point of elevation, which in this environment, would mean following the most permeable gravel zones to the point of discharge. Seepage will likely still occur through the less permeable zones, and be at rates which may be easily evaporated. This is evident in Photograph 1 and 2 in Appendix B.

The distance from the start of block 28 to the end of Strip 1 is approximately 1800m. Based on the calculated unit flux, this would equate to a total flux of 57 L/s from the western capture zone. Hydraulic head gradients are not well known on the eastern side, and the extent of the gravel zone is known to pinch out further to the east, which will mean that groundwater discharge should become more manageable as the pit extends to the east. That said, at present the groundwater inflows from the eastern side have been estimated to be only marginally less than those from the west (possibly around 80% from purely visual estimation, no measurement). If this trend continued along the eastern side of Strip 1 and 2, then the total groundwater inflows could be of the order of 100 L/s. This is a significant amount of water, and WCPL will need to plan for this management accordingly.

Further to the calculations completed by WCPL, DP checked the 3-Dimensional volume of the capture zones as shown in Drawing 19. These are given in Table 7 below.

Table 7: Results of Capture Zone Storage

Capture Zone	Unconfined Aquifer Volume (m^3 of Aquifer Material)	Specific Yield	Volume of Groundwater (ML)
Western	3,030,766	0.1	303
Eastern	23,514,214	0.1	2351

The estimates above equate to less than 3 gigalitres of stored groundwater, which is less than the calculated 18 gigalitres calculated in the WCPL Phase 1 work, but these calculations were not well understood by DP.

Based on the above storage volumes and the calculated inflow rates (without assuming recharge is occurring) the Eastern capture zone would take approximately 1.6 years to drain, while the Western capture zone would take just a couple of months to drain, however it is understood that the Western capture zone is likely to be recharged by the Mackenzie River, and may never cease to flow without mitigation.

11. Update of S Pit CHM

Douglas Partners has completed a thorough review of the Phase 1 work completed by WCPL, and revisited all Quaternary groundwater datasets available. Analysis completed in this study, which has not been completed before includes:

- Piezometric contouring;
- Cumulative rainfall departure recharge estimate;
- Chloride mass balance recharge estimate; and
- Unconfined flow analytical modelling

Through completing the literature review and additional data analysis, DP has refined the Conceptual Hydrogeological Model of the Quaternary Aquifer, specifically at Curragh North. Main components of the CHM are summarised below:

- The extent of saturated Quaternary exists from approximately block 24 northwards, tending away from the southern Tertiary ridge;
- A significant gravel layer sits at the base of the Quaternary (fluvial palaeochannel) directly over the harder Permian units. The extent of this higher permeability unit pinches out to the west;
- Groundwater flow directions are clearly perpendicular to the existing open cut pits;
- Groundwater is recharged through a combination of rainfall recharge and recharge occurring from the Mackenzie River;
- The geometric mean of calculated recharge mechanisms is 7.5% of annual rainfall, however recharge needs to be further unpacked to delineate the proportion from each source. Numerical modelling could assist with this process;
- The Quaternary aquifer is most likely to behave in an unconfined to semi-confined manner based on the available datasets. It should be noted that no bore completion reports have been made available for individual bore reconciliation of RSWL against lithology.

Drawing 20 shows 2 previous conceptual models provided by PPK (2002) and PB (2003), which have been re-digitised by DP. The conceptual model drawn by PPK (2002) perhaps best illustrates the Quaternary system, although it would be best modified with the fine grained surface clays (QC) as shown in Appendix C.

12. Conclusions and Recommendations

Douglas Partners has completed a comprehensive review of the Phase 1 work completed by WCPL, and revisited all Quaternary groundwater datasets available.

The Phase 1 work is of a high standard but some components of the analysis should be considered as indicative only due to a legacy of history resulting in many previously published hydrogeological contradictions. The author's personal experience has been required to address some immediate issues at the site, where other data was not available at the time. Douglas Partners acknowledge that the author is a geologist with over a decade of experience in groundwater management but is not a qualified hydrogeologist.

Based on observations from site, review of the Phase 1 work, further data analysis and analytical modelling, groundwater inflows are likely to continue being a problem at S Pit, particularly along Strip 1 & 2 where basal gravels provide the permeability required to discharge groundwater at rates which will continue to cause operational issues.

The Phase 1 work recommends the continued approach of dewatering, which is to pump from trenches and sumps based on assumed poor well yield and costs of dewatering from bores. Douglas Partners has not seen results from any pumping tests from the Quaternary unit at Curragh, so can not confirm if this is a valid assumption.

Given the ongoing risks to mining efficiency, and potential ingress rates of the order of 100 L/s, Douglas Partners would make the following recommendations:

1. Installation of dedicated Quaternary monitoring bores at S Pit. These bores should be designed to be permanent infrastructure, and include bores to both the east and west of S Pit. Douglas Partners notes that this recommendation has been made repeatedly and as far back as 1998 by the Mineserve Group, and should be considered as a priority;
2. Short term slug tests should be completed at the completion of the monitoring bores, and analysed for hydraulic properties;
3. Groundwater samples should be collected from the Quaternary monitoring bores, together with selected samples from the Mackenzie River, and groundwater discharge points at the S Pit;
4. A monitoring program should be designed for the Quaternary network, which considers the short and longer term needs of the monitoring, including any requirements for numerical modelling calibration;
5. At least one production bore should be completed on the western side of the S Pit, to establish whether dewatering is a viable option. Saturated aquifer thickness and feasibility could be assessed prior by a hydrogeologist, perhaps opportunistically during supervision of the monitoring wells;
6. A multirate pumping test and a constant rate discharge rate test should be conducted and analysed by an appropriately qualified hydrogeologist;
7. Advice regarding potential discharge options from either pumping from trenches or dewatering bores should be sought from the regulator;
8. Based on the findings of point 6, a decision should be made with respect to the completion of a cost benefit analysis; and
9. If required, a trade off study should be completed which identifies the Capex and Opex costs of the various options.

One of the objectives of this study, was to provide some recommendations regarding the numerical modelling which could be completed, with a view to being used by mine planning and modelling of possible dewatering strategies.

Perhaps the biggest challenge of completing a groundwater model which will be of significant value to WCPL (above simpler and more cost effective approaches) will be the lack of calibration data. As per the Dupuit Approximation shown in Figure 1, the geology at the site is reasonably well known. The hydraulic gradients and the hydraulic properties of the Quaternary materials however are still largely unknown. Simple 3D models can be built to test particular dewatering scenarios, but these will be

hard to verify at present without any valid monitoring data. For this reason, multiple layer models representing coal seams as well as the Quaternary system are probably best avoided. Either MLU, a multilayer analytical model, or MODFLOW could be used to complete this component of work.
Douglas Partners has the capability to assist WCPL, should they wish to progress any of the recommendations made above.

13. Limitations

DP has prepared this report for Curragh Mine in accordance with DP's Proposal BNE140631 dated 4 August 2014. This report is provided for the exclusive use of WCPL Curragh Pty Ltd for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

This report must be read in conjunction with the notes entitled 'About This Report' in Appendix A and any other explanatory notes and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion given in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards that may be contained in this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the groundwater components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Douglas Partners Pty Ltd

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Drawings

Drawing 1: Location of Curragh Mine & Leases

Drawing 2: Geology of Curragh Mine and Surrounding Region

Drawing 3: Site LIDAR Data

Drawing 4: S Pit Mineplan

Drawing 5: S Pit Initial Boxcut

Drawing 6: S Pit Surface Geology

Drawing 7: Base of Quaternary S Pit Data

Drawing 8: Base of Quaternary Geological Model Data

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Drawing 13: Quaternary Hydrograph 1 (Nov 96 – Jun 97)

Drawing 14: Quaternary Hydrograph 2 (Nov 01 – Jun 03)

Drawing 15: Quaternary Hydrograph 3 (Oct 11 – Feb 12)

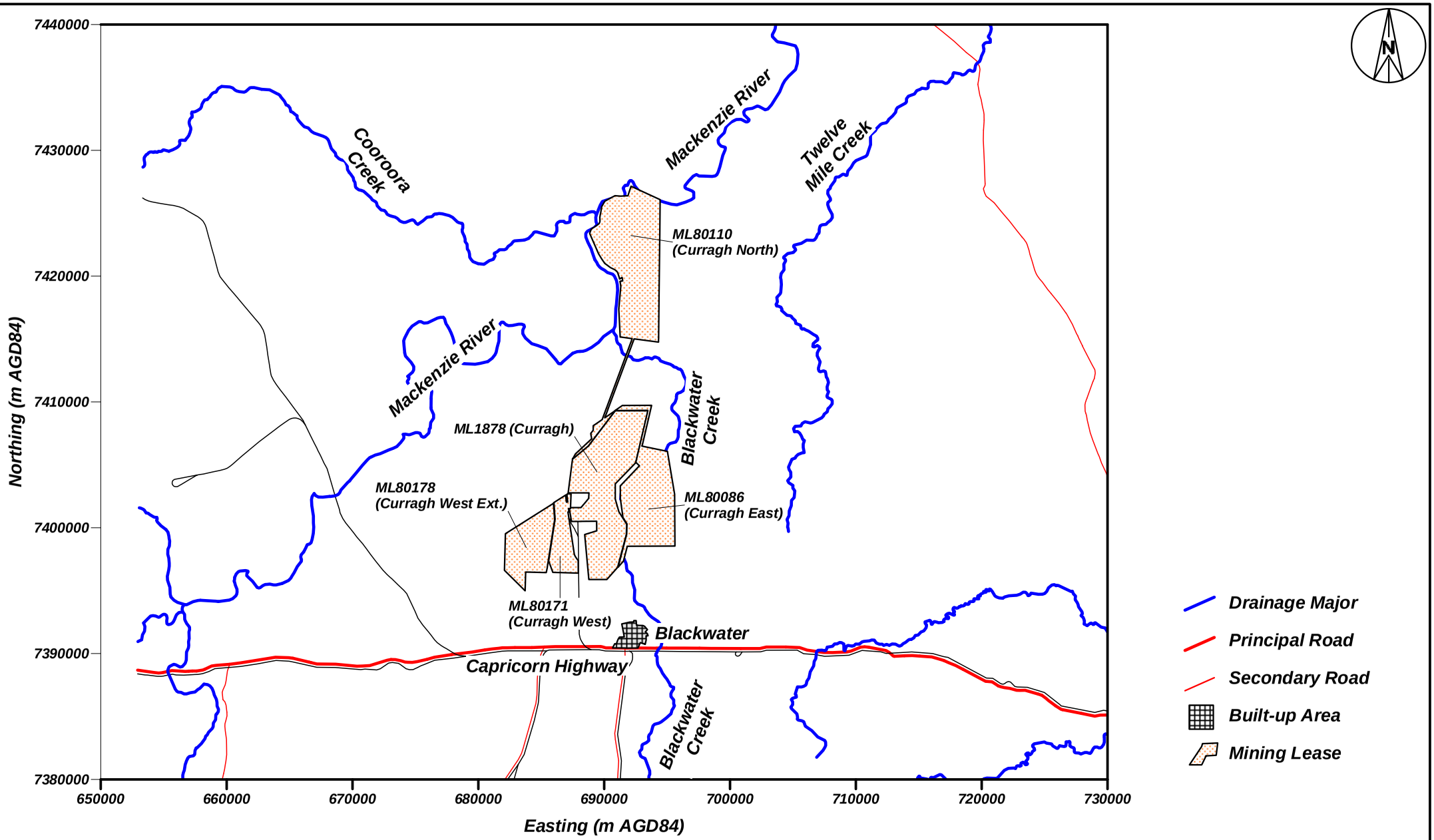
Drawing 16: Quaternary Hydrograph 4 (Sep 13 – Mar 14)

Drawing 17: CRD Recharge Estimate PSMB 05B

Drawing 18: Approximate Quaternary Capture Zone

Drawing 19: Quaternary Capture Volumes

Drawing 20: Previous Conceptual Hydrogeological Models



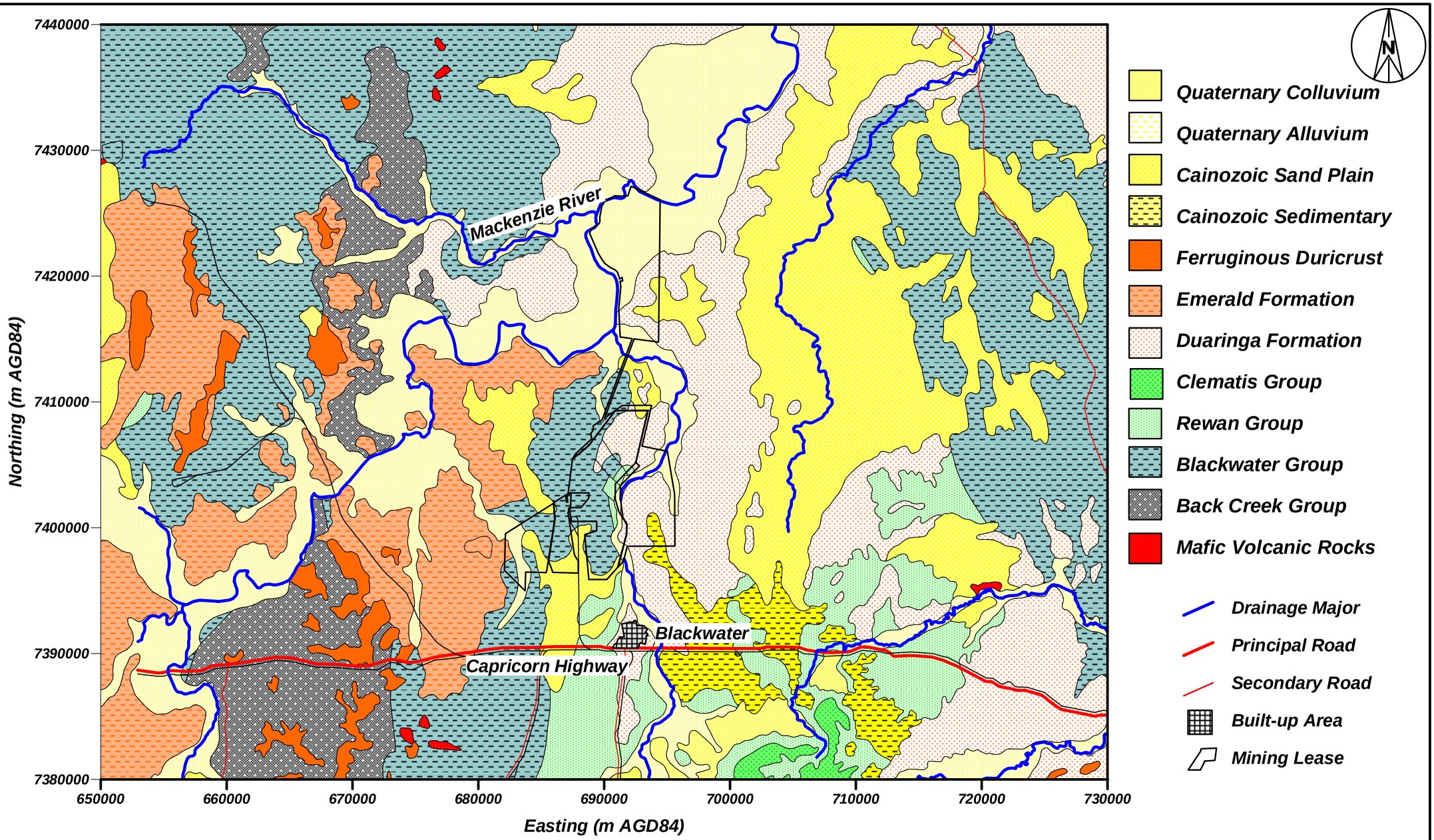
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Geotechnics / Environment / Groundwater

CLIENT: Wesfarmers Curragh Pty Ltd	
DRAWN BY: BN	DATE: Sept 2014
APPROVED BY: MS	OFFICE: Brisbane

LOCATION OF CURRAGH MINE & LEASES
S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

PROJECT No:	80724.00
DRAWING No:	1
REVISION:	A



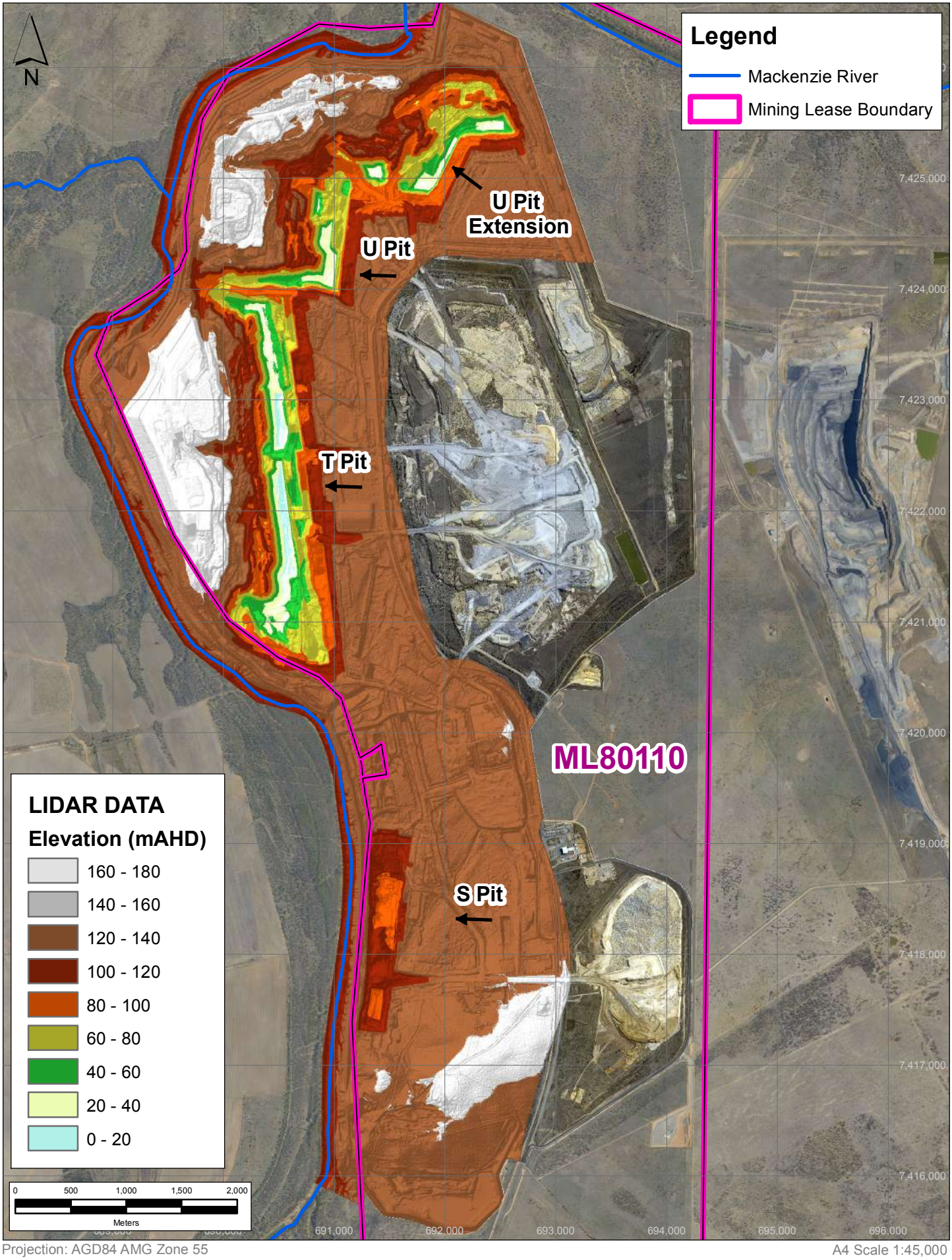
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APPROVED BY: MS	OFFICE: Brisbane	

GEOLOGY OF CURRAGH MINE & SURROUNDING REGION
S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

PROJECT No: 80724.00	
DRAWING No:	2
REVISION:	A



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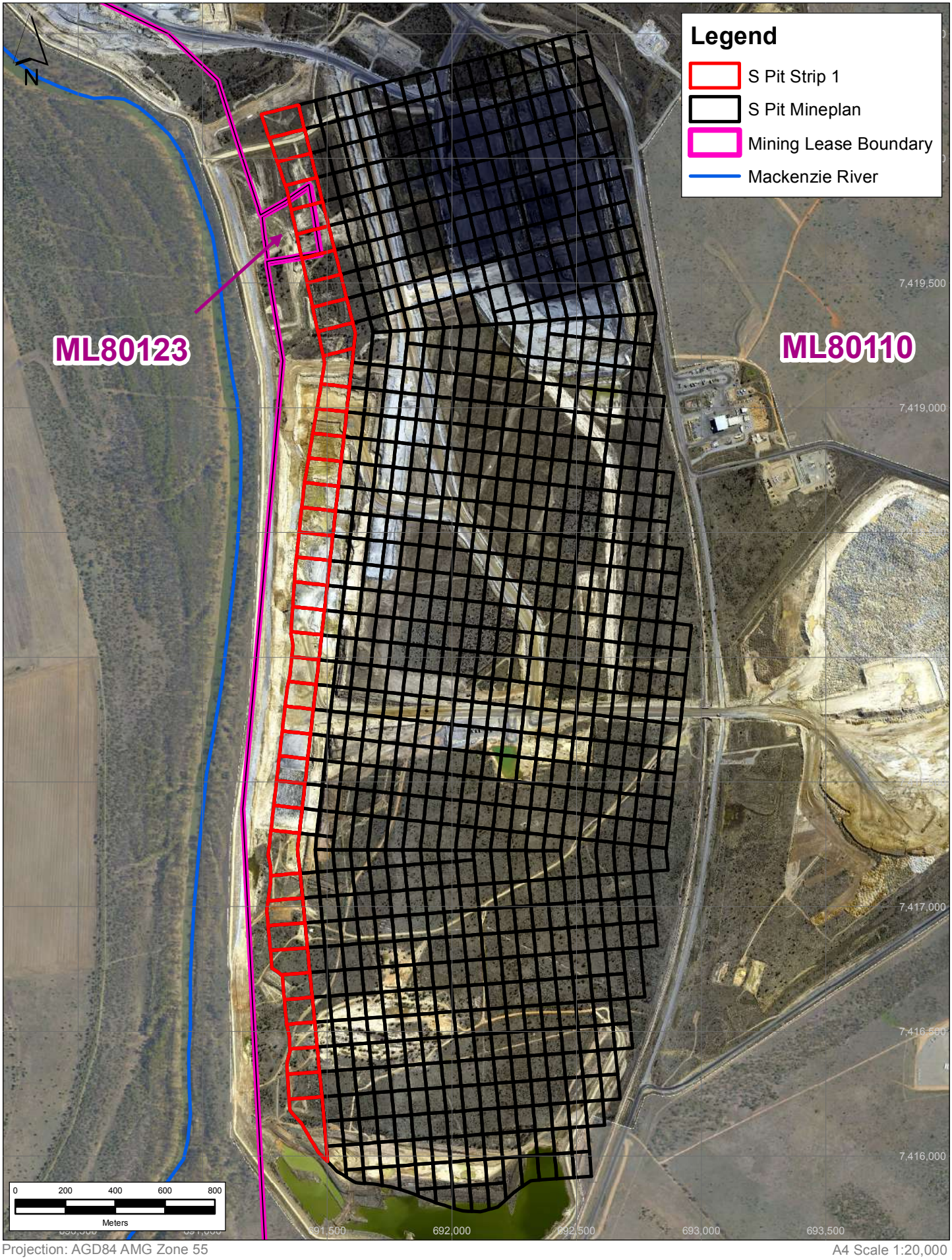
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SITE LIDAR DATA

S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

CLIENT: Wesfarmers Curragh Pty Ltd

PROJECT No:	80724.00
DRAWING No:	3
REVISION:	A
DATE:	Oct 2014



Projection: AGD84 AMG Zone 55

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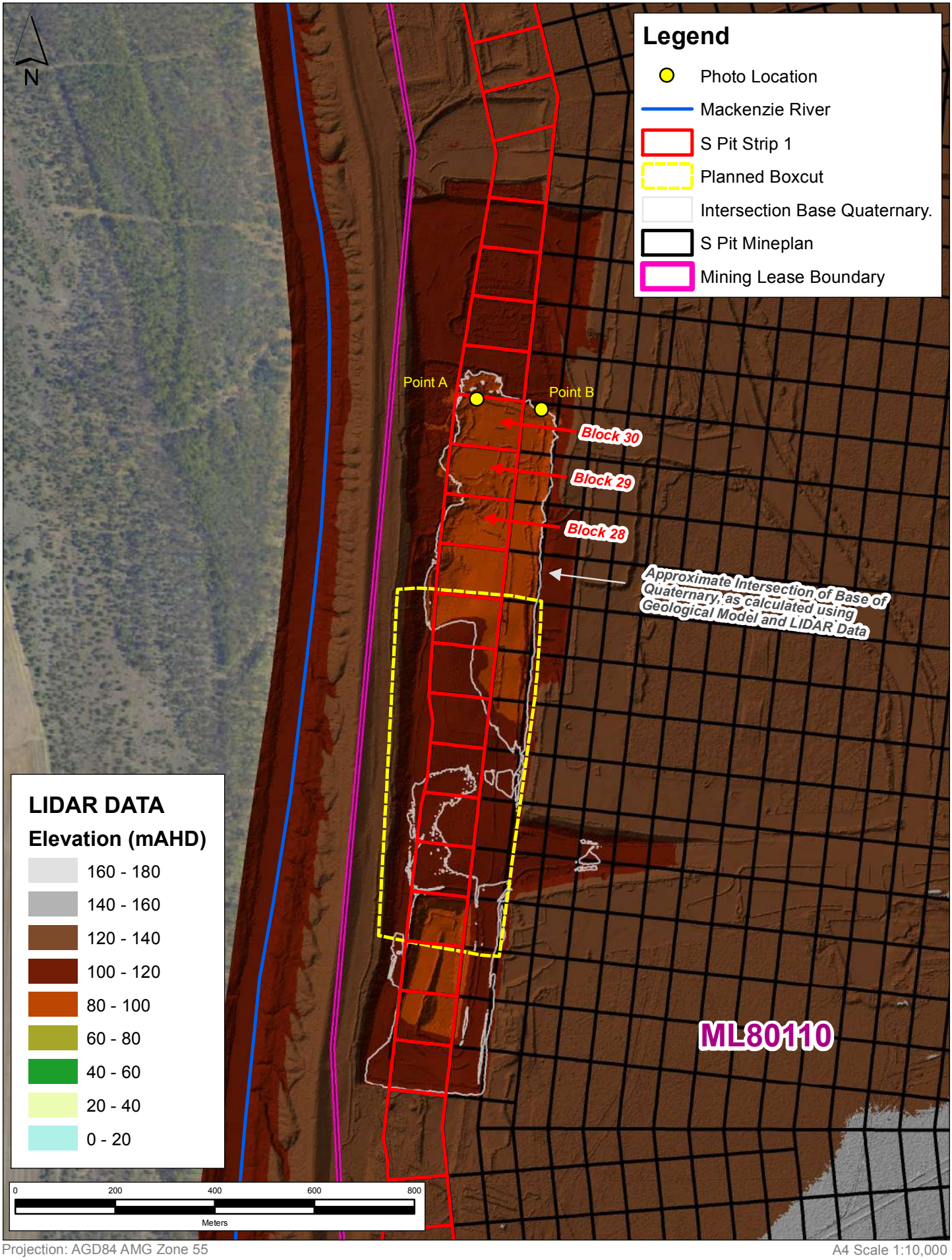
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S PIT MINEPLAN

S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

CLIENT: Wesfarmers Curragh Pty Ltd

PROJECT No:	80724.00
DRAWING No:	4
REVISION:	A
DATE:	Oct 2014



Projection: AGD84 AMG Zone 55

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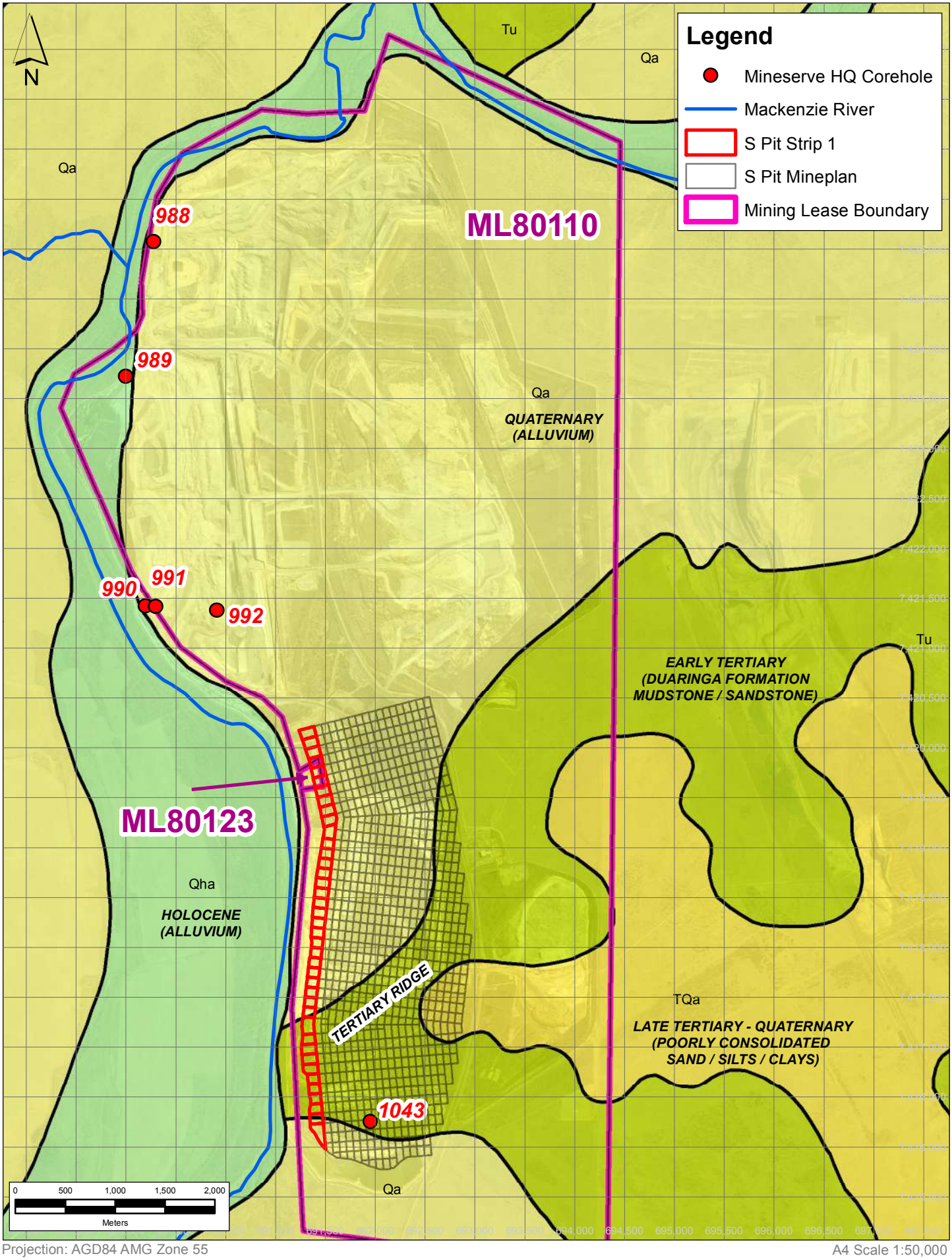
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S PIT INITIAL BOXCUT

S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

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PROJECT No:	80724.00
DRAWING No:	5
REVISION:	A
DATE:	Oct 2014



Projection: AGD84 AMG Zone 55

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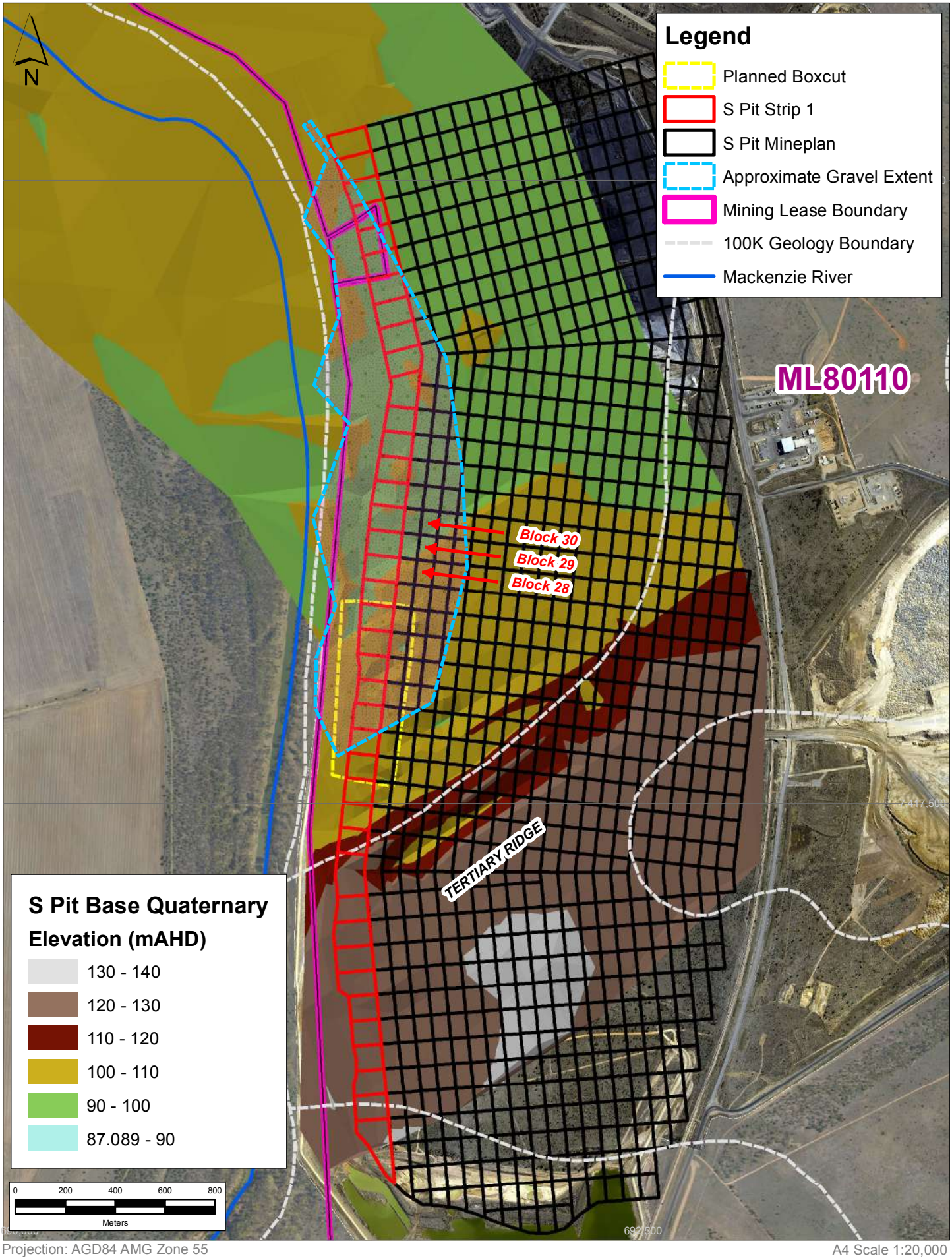
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S PIT SURFACE GEOLOGY

S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

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PROJECT No:	80724.00
DRAWING No:	6
REVISION:	A
DATE:	Oct 2014



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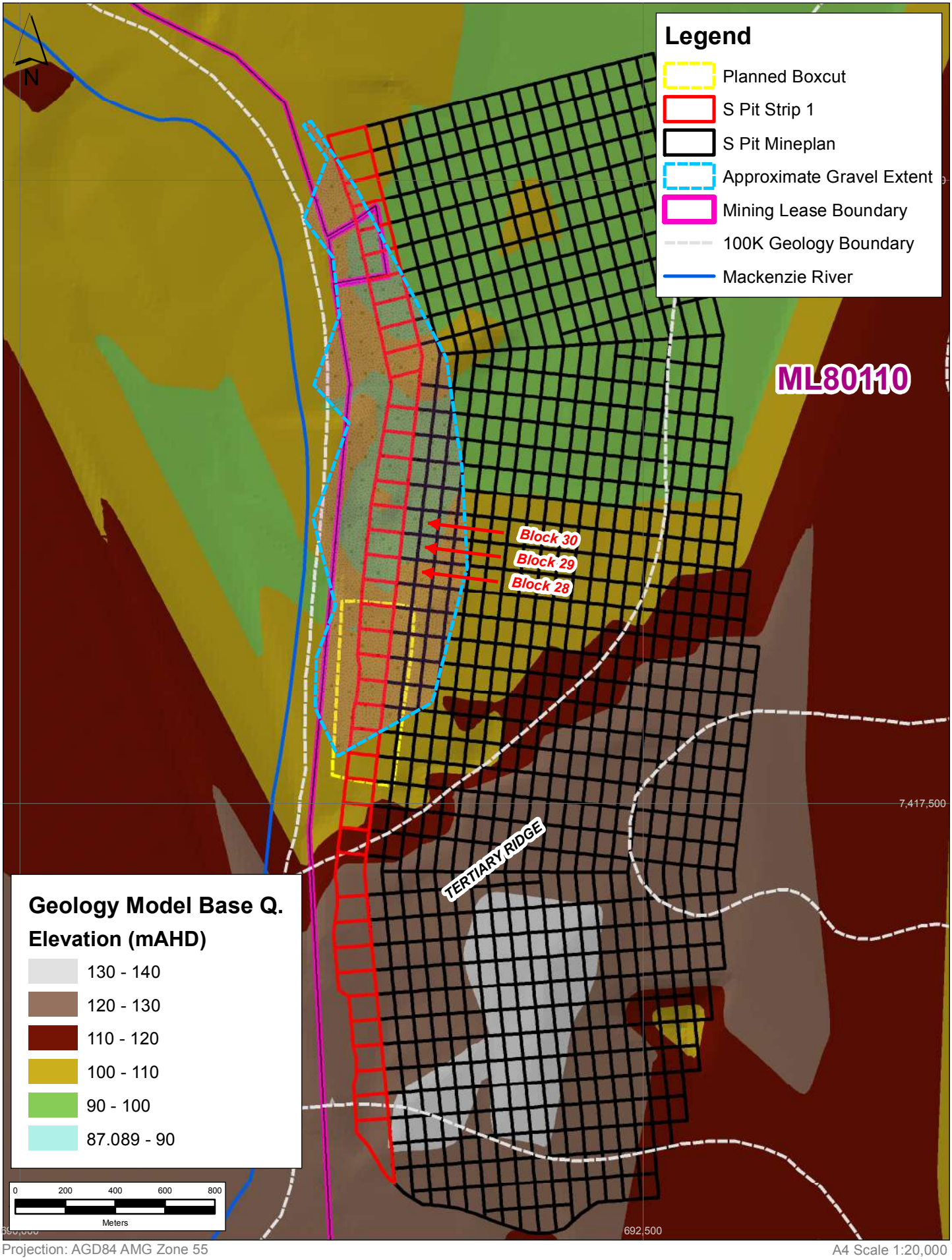
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BASE QUATERNARY S PIT DATA

S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

CLIENT: Wesfarmers Curragh Pty Ltd

PROJECT No:	80724.00
DRAWING No:	7
REVISION:	A
DATE:	Oct 2014



Projection: AGD84 AMG Zone 55

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BASE QUATERNARY GEOLOGY MODEL DATA

S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

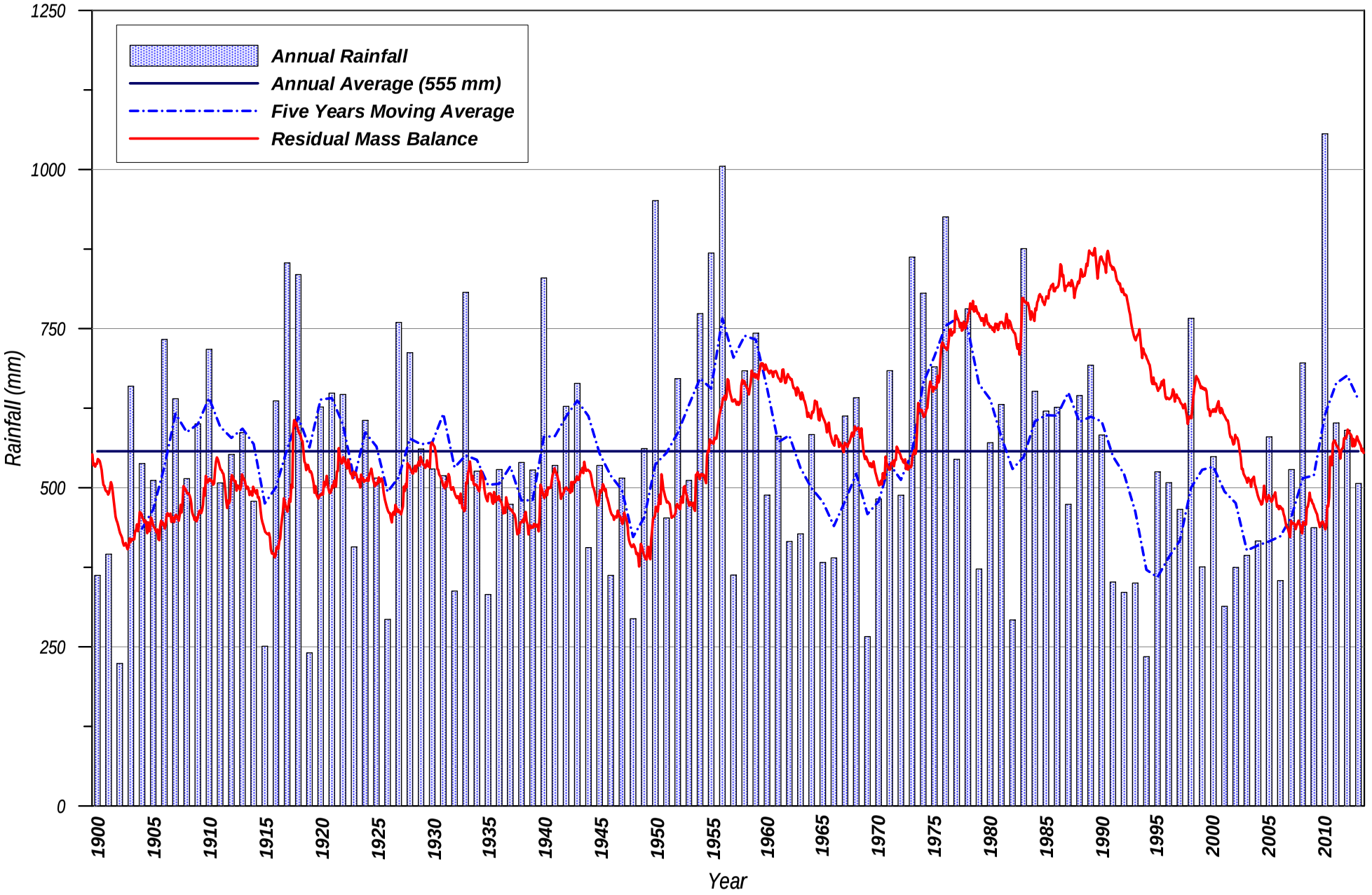
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PROJECT No: 80724.00

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REVISION: A

DATE: Oct 2014



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CLIENT: Wesfarmers Curragh Pty Ltd		
DRAWN BY: PED	DATE: Sep 2014	
APPROVED BY: MS	OFFICE: Brisbane	

LONG TERM ANNUAL RAINFALL TRENDS
S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

PROJECT No: 80724.00
DRAWING No: 9
REVISION: 1



Projection: AGD84 AMG Zone 55

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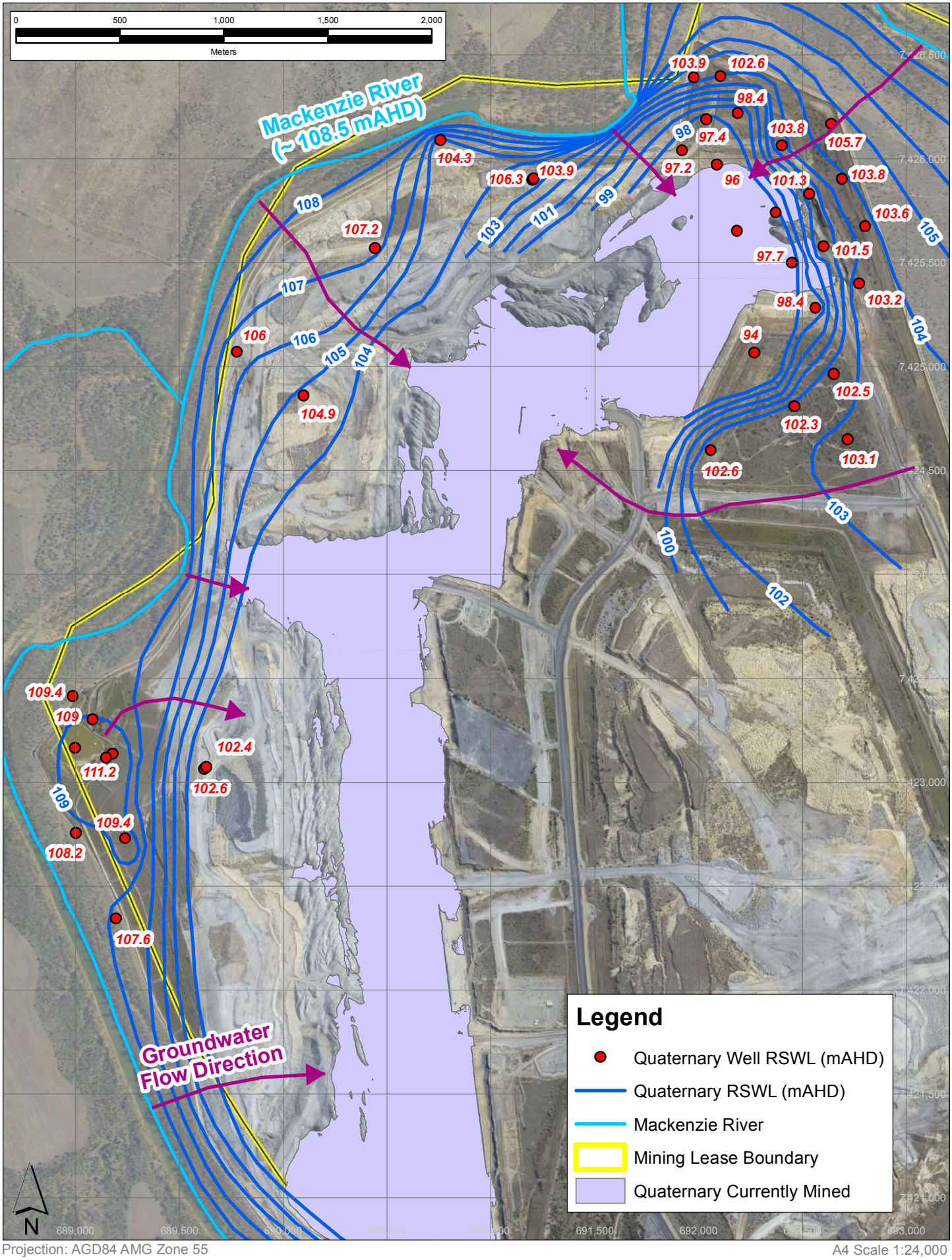
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QUATERNARY MONITORING NETWORK

S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

CLIENT: Wesfarmers Curragh Pty Ltd

PROJECT No:	80724.00
DRAWING No:	10
REVISION:	A
DATE:	Oct 2014



Projection: AGD84 AMG Zone 55

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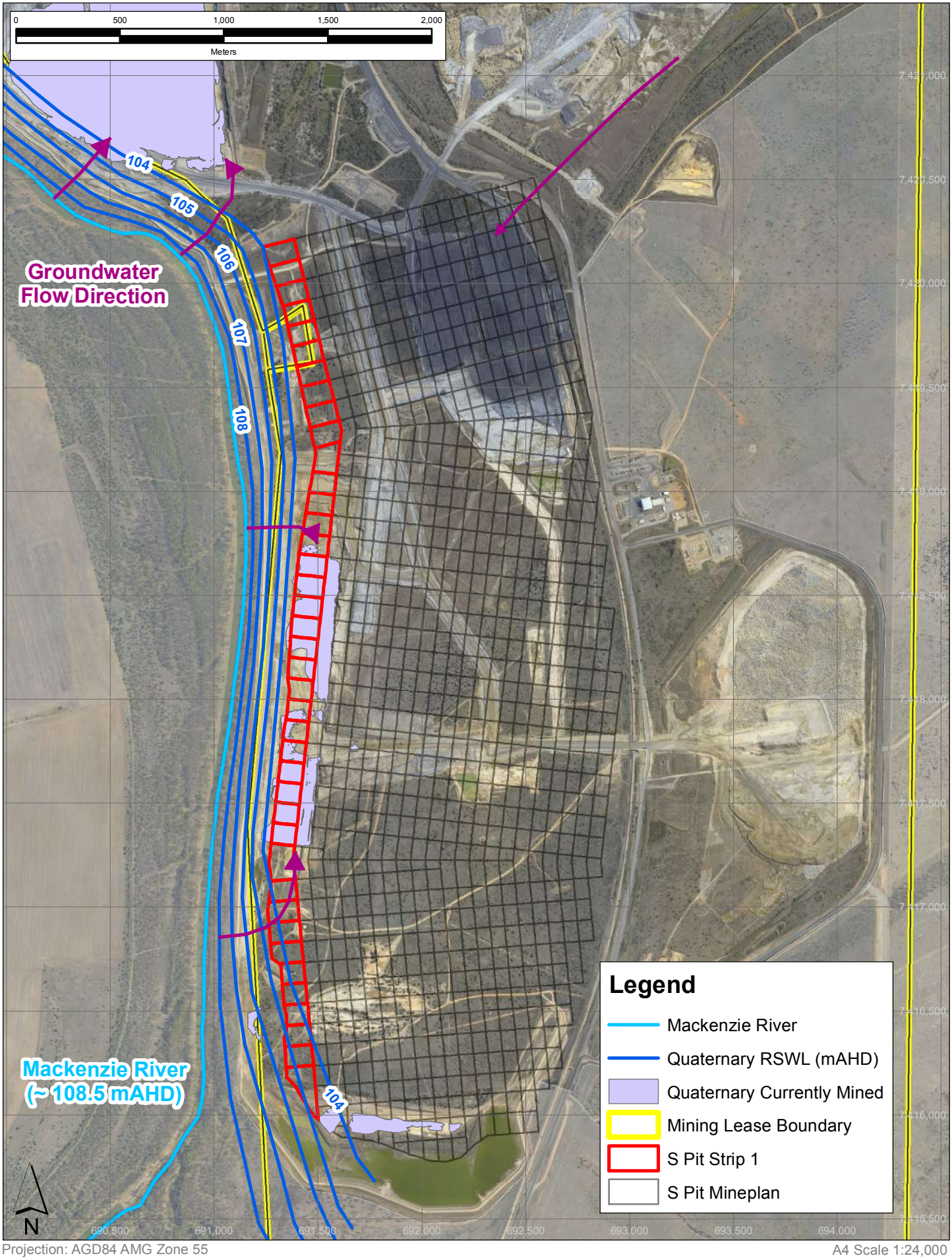
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QUATERNARY GROUNDWATER CONTOUR PLAN - INTERPOLATED (NORTH)

S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

CLIENT: Wesfarmers Curragh Pty Ltd

PROJECT No:	80724.00
DRAWING No:	11
REVISION:	A
DATE:	Oct 2014



Projection: AGD84 AMG Zone 55

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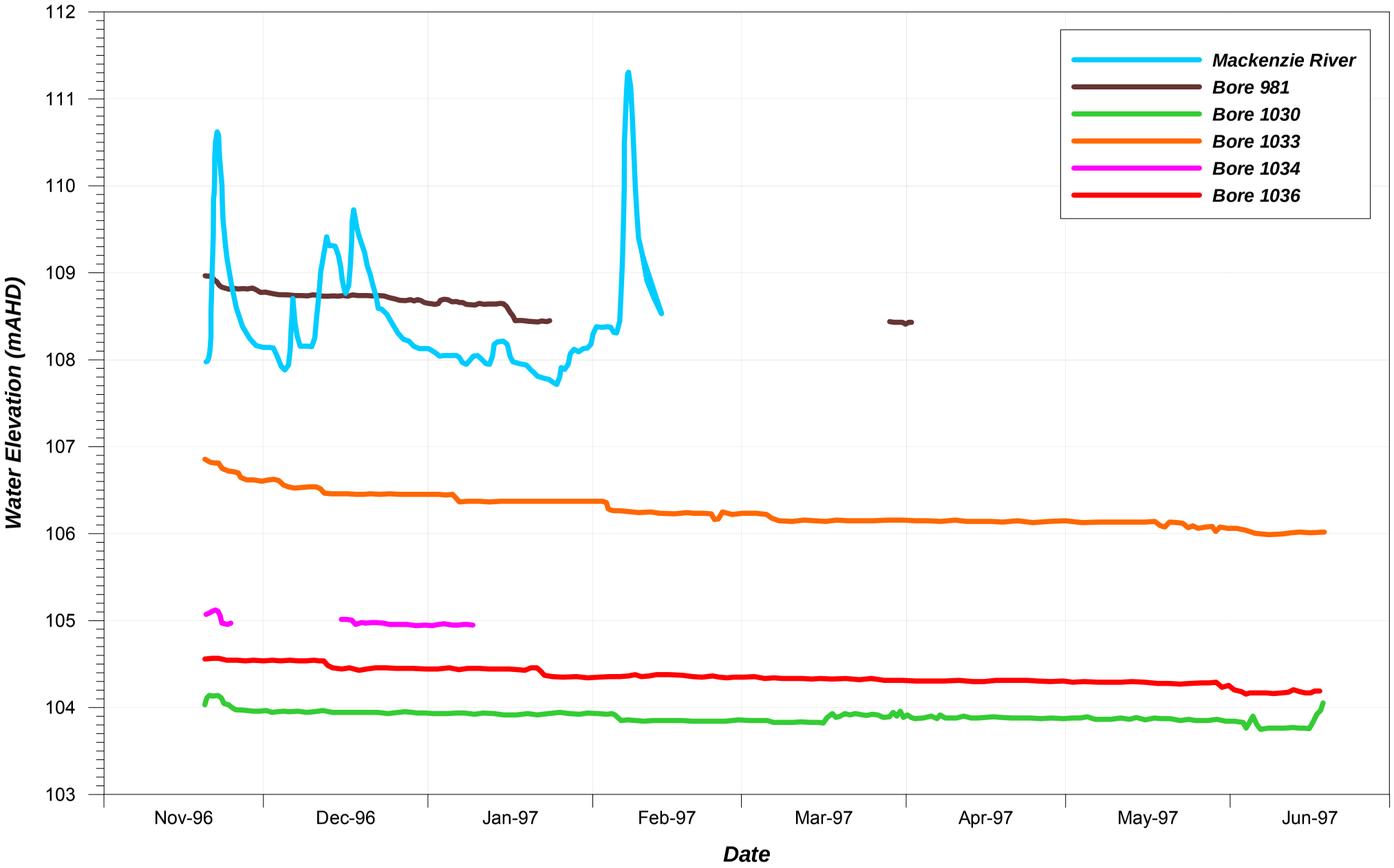
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QUATERNARY GROUNDWATER CONTOUR PLAN - INFERRED (SOUTH)

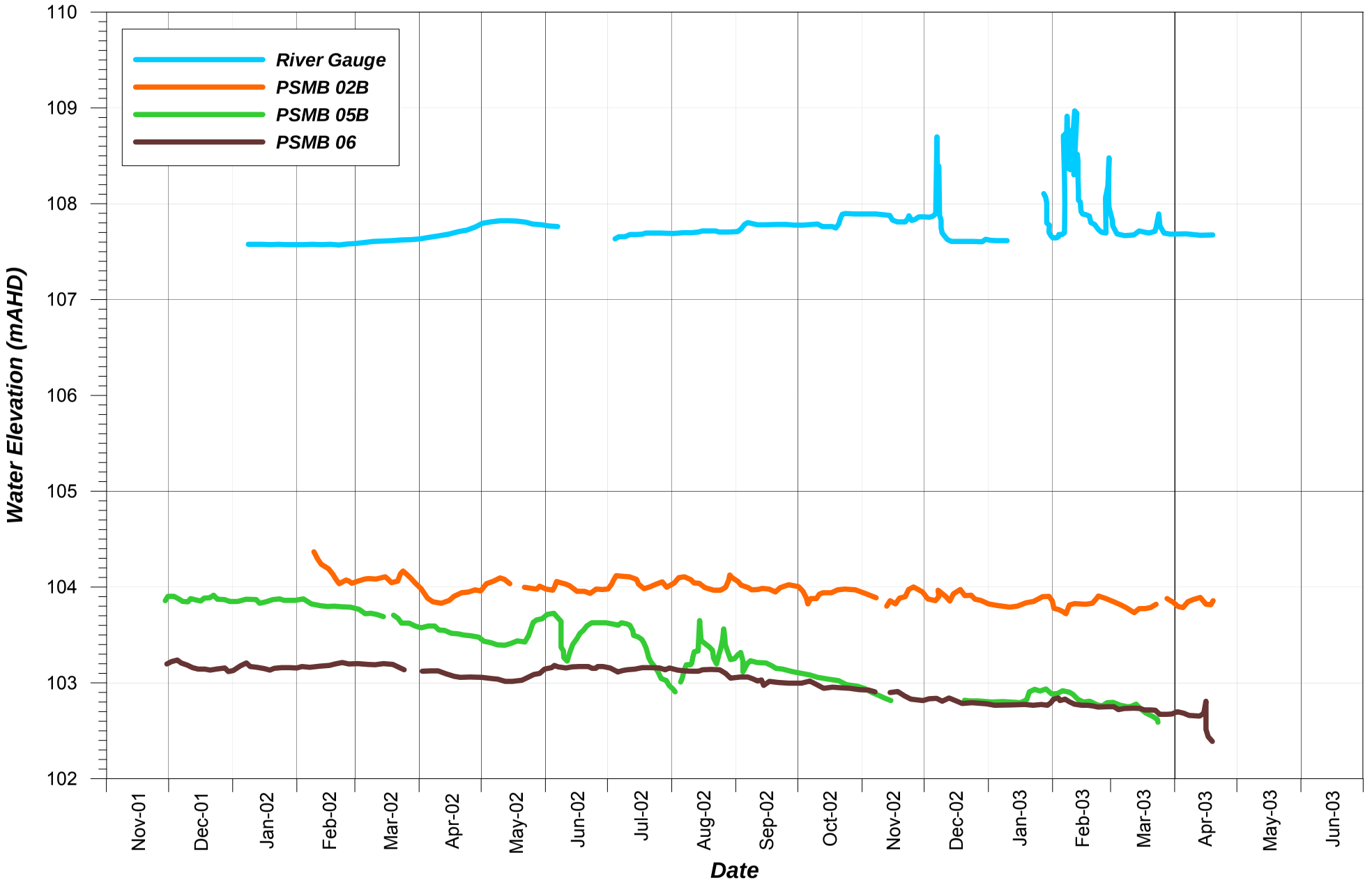
S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

CLIENT: Wesfarmers Curragh Pty Ltd

PROJECT No:	80724.00
DRAWING No:	12
REVISION:	A
DATE:	Oct 2014



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	DRAWN BY: PED / DATE: Sep 2014		DRAWING No: 13
	APPROVED BY: MS / OFFICE: Brisbane		REVISION: 0

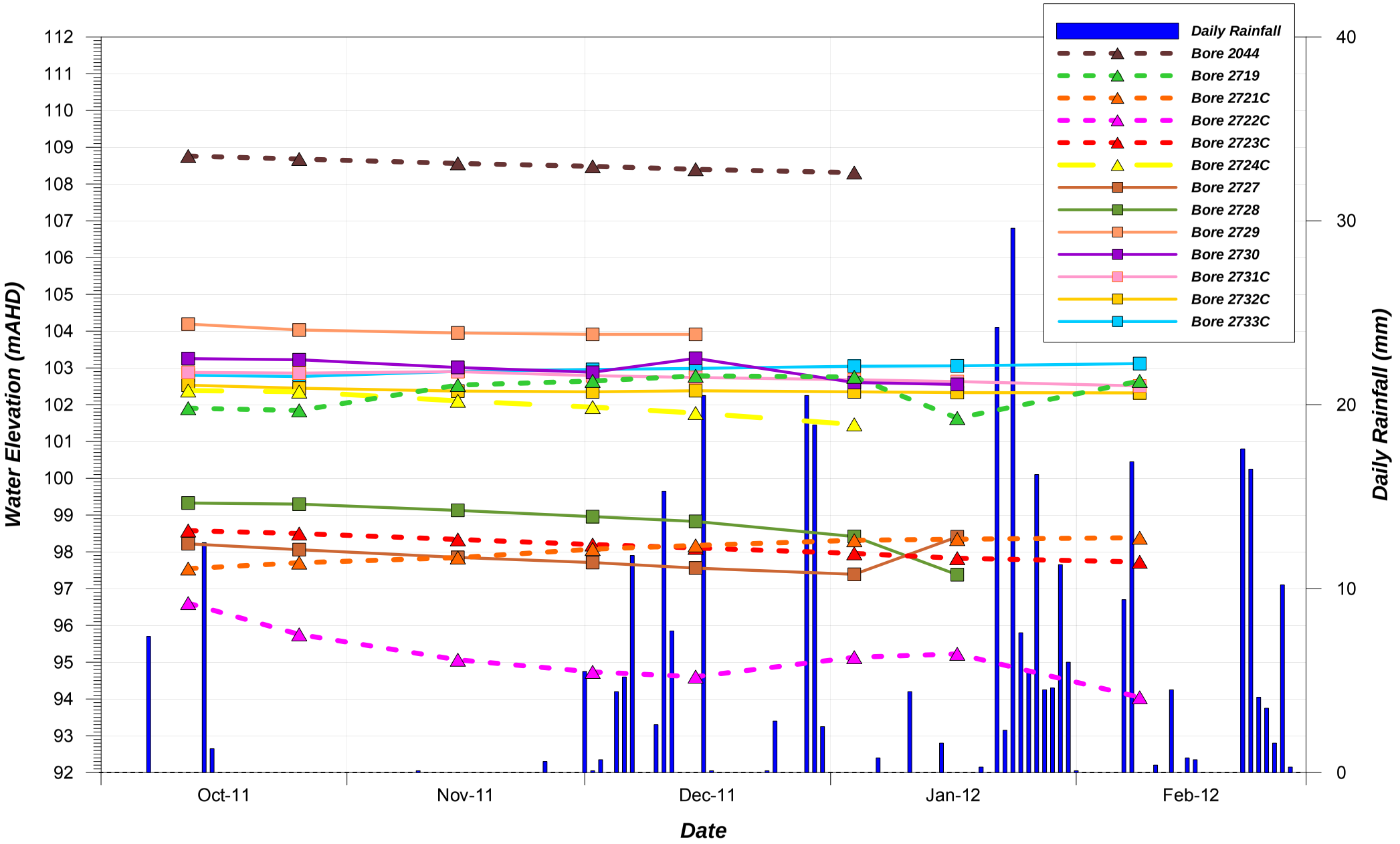


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APPROVED BY: MS	OFFICE: Brisbane	

QUATERNARY HYDROGRAPH 2 (Nov 2001 - Jun 2003)
S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

PROJECT No:	80724.00
DRAWING No:	14
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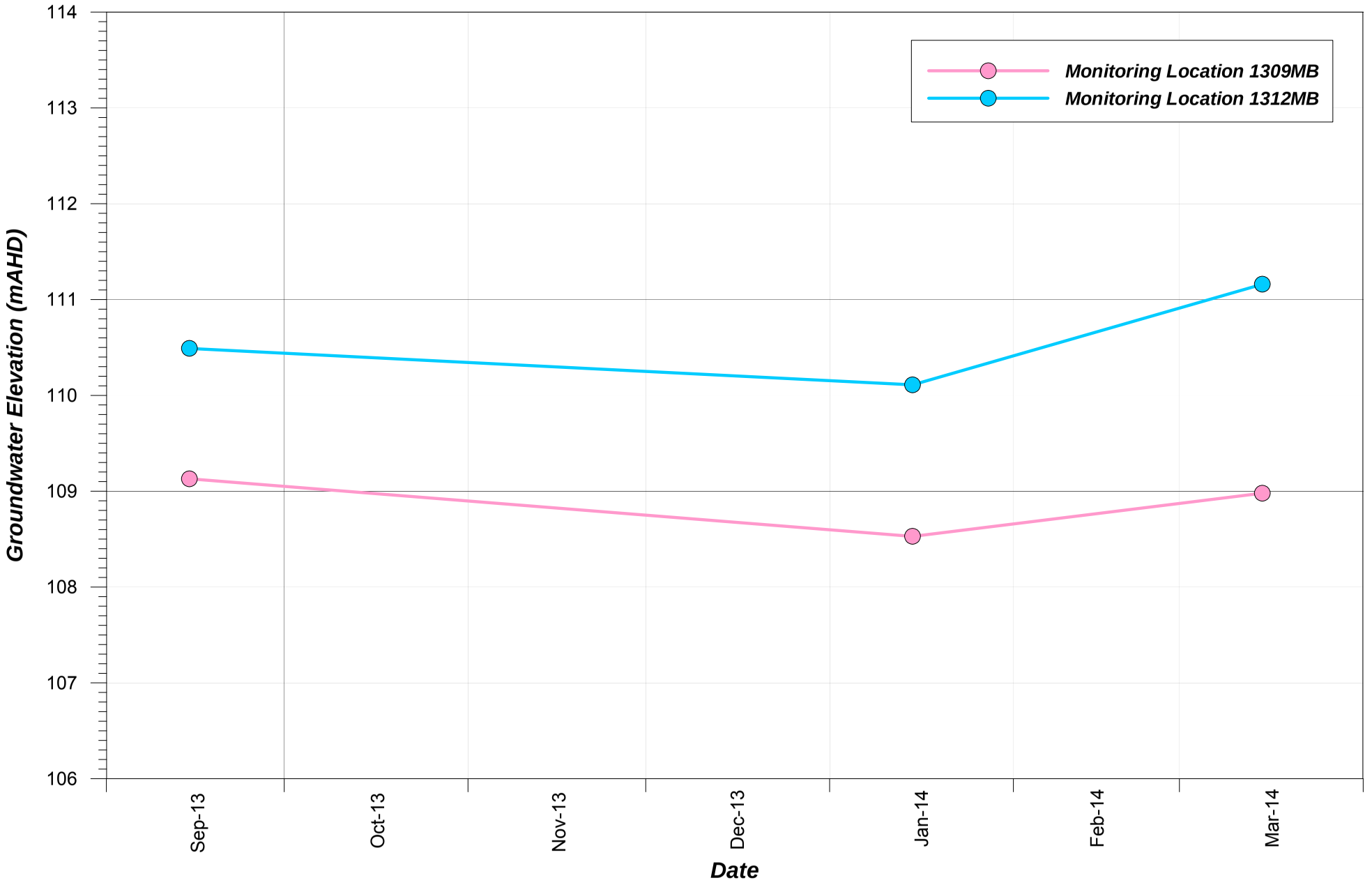


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QUATERNARY HYDROGRAPH 3 (Oct 2011 - Feb 2012)
S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

PROJECT No:	80724.00
DRAWING No:	15
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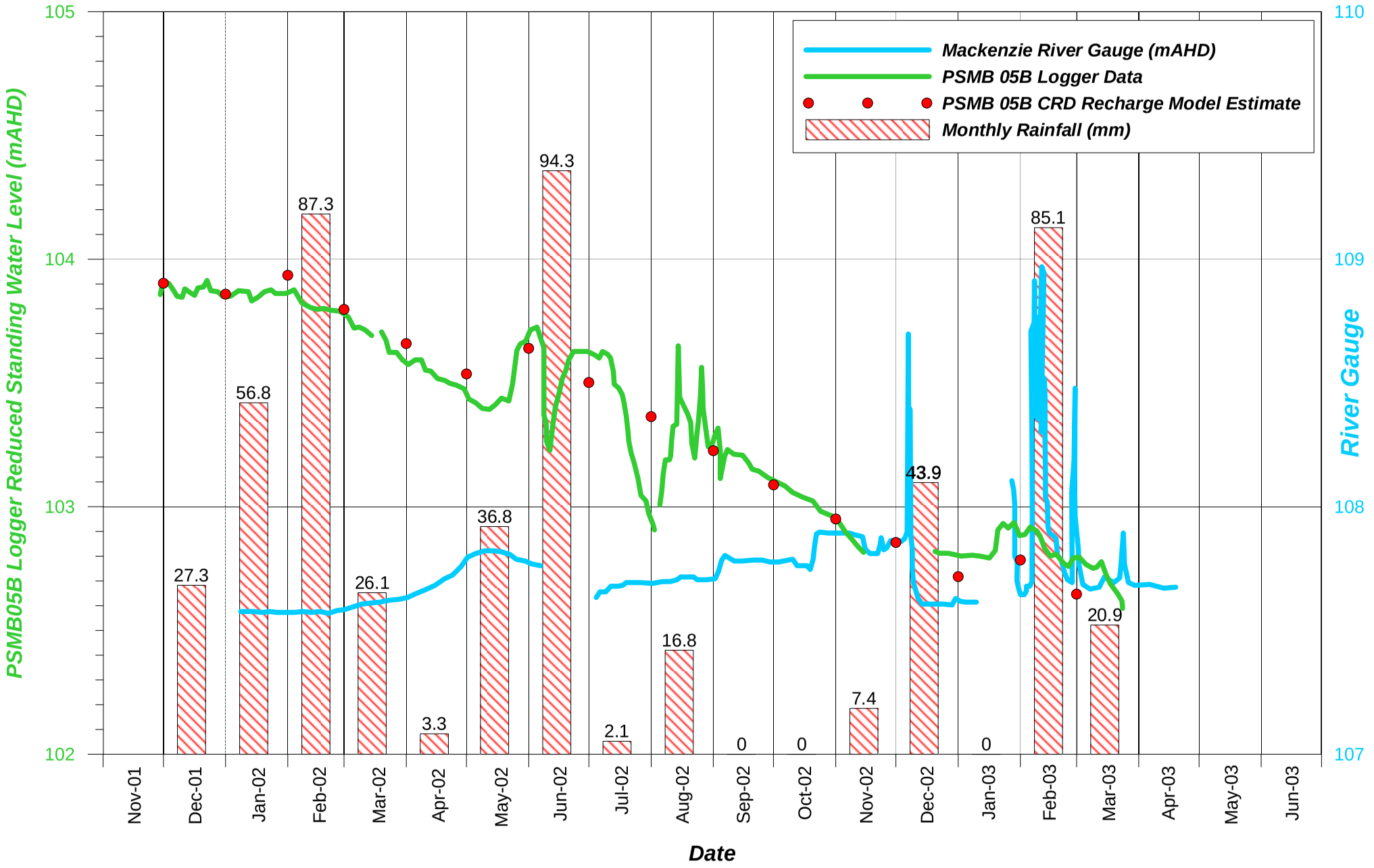


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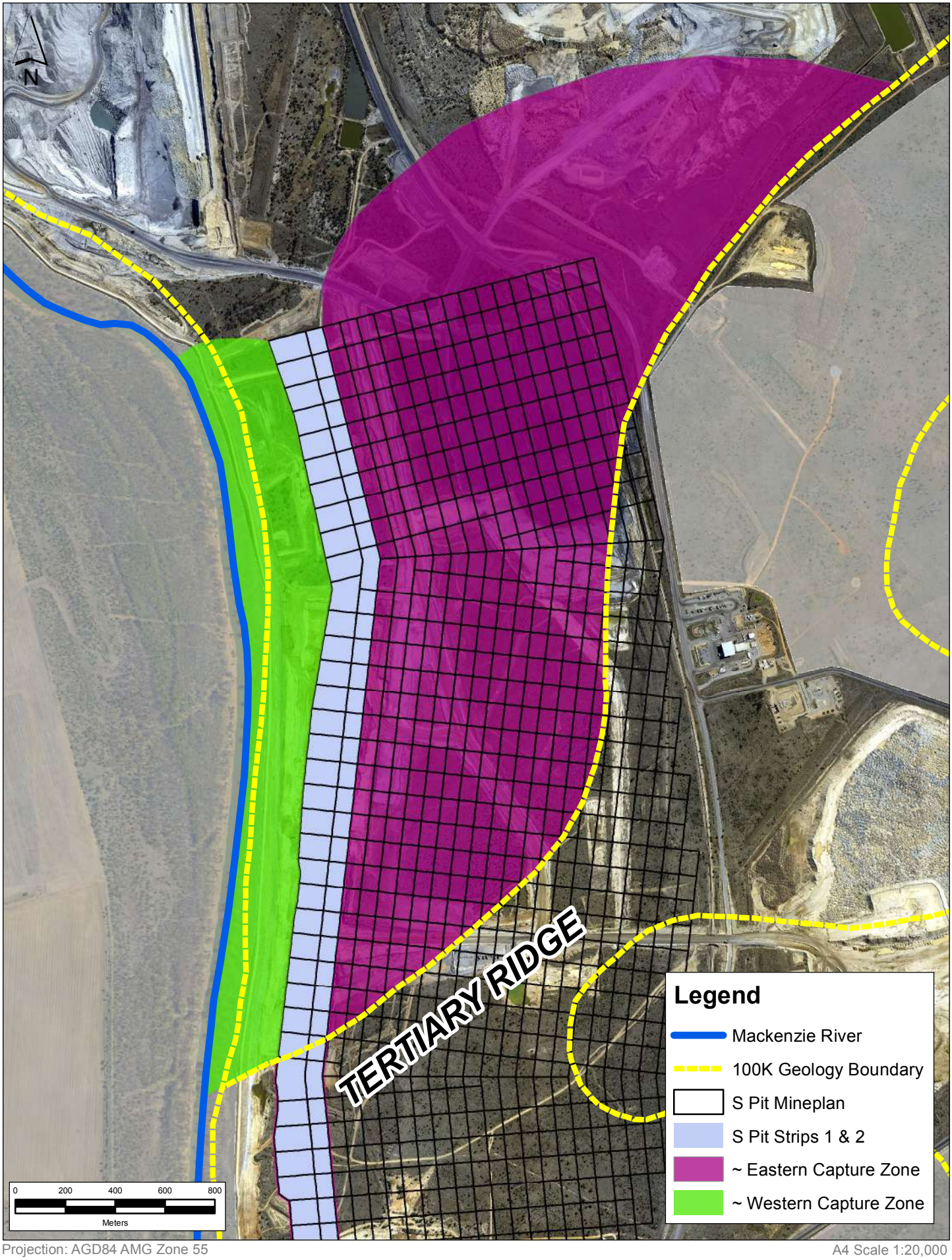
CLIENT: Wesfarmers Curragh Pty Ltd		
DRAWN BY: PED	DATE: Sep 2014	
APPROVED BY: MS	OFFICE: Brisbane	

QUATERNARY HYDROGRAPH 4 (Sep 2013 - Mar 2014)
S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

PROJECT No:	80724.00
DRAWING No:	16
REVISION:	0



Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Wesfarmers Curragh Pty Ltd	**CRD RECHARGE ESTIMATE PSMB 05B (Nov 2001 - Jun 2003)** S Pit Groundwater Study Review Curragh Coal Mine, Blackwater, Central Queensland	PROJECT No: 80724.00
	DRAWN BY: MS / DATE: Oct 2014		DRAWING No: 17
	APPROVED BY: MS / OFFICE: Brisbane		REVISION: 0



Projection: AGD84 AMG Zone 55

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APPROXIMATE QUATERNARY CAPTURE ZONE

S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

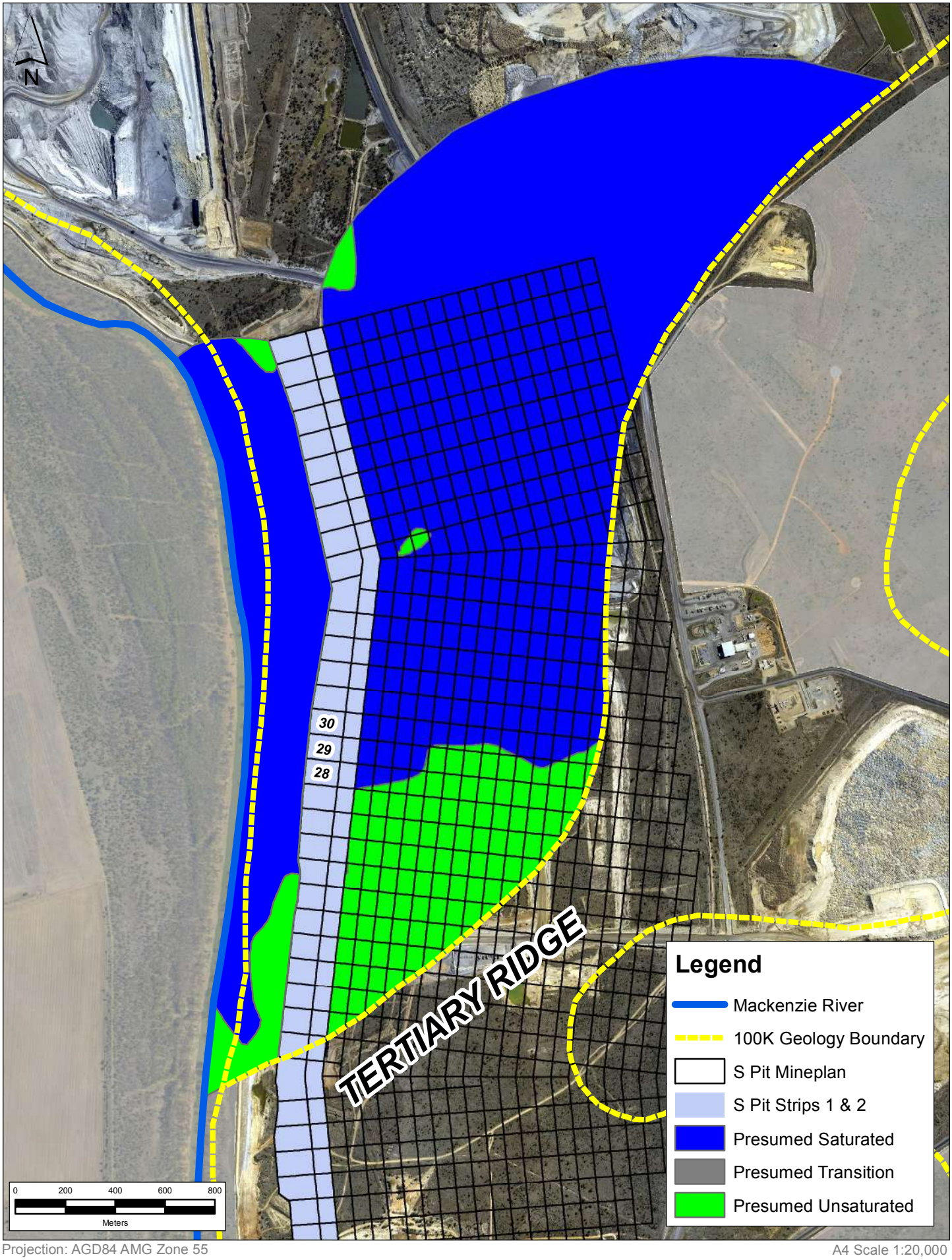
CLIENT: Wesfarmers Curragh Pty Ltd

PROJECT No: 80724.00

DRAWING No: 18

REVISION: A

DATE: Oct 2014



Projection: AGD84 AMG Zone 55

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QUATERNARY CAPTURE VOLUMES

S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

CLIENT: Wesfarmers Curragh Pty Ltd

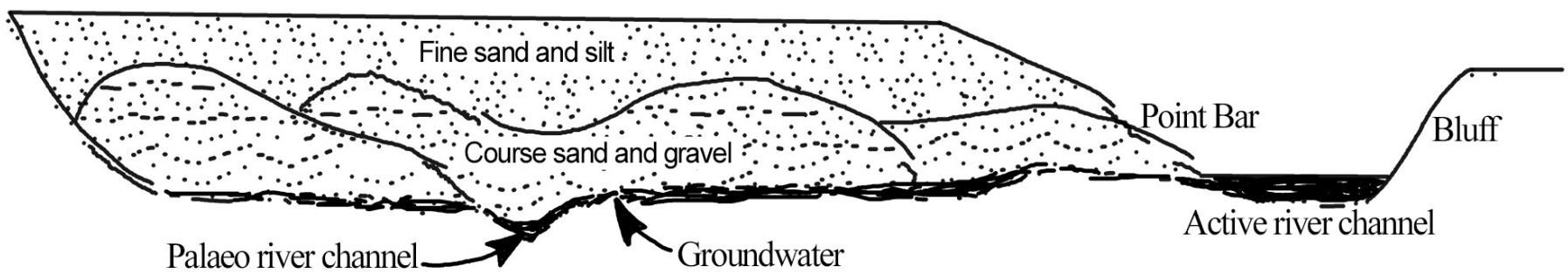
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DRAWING No: 19

REVISION: A

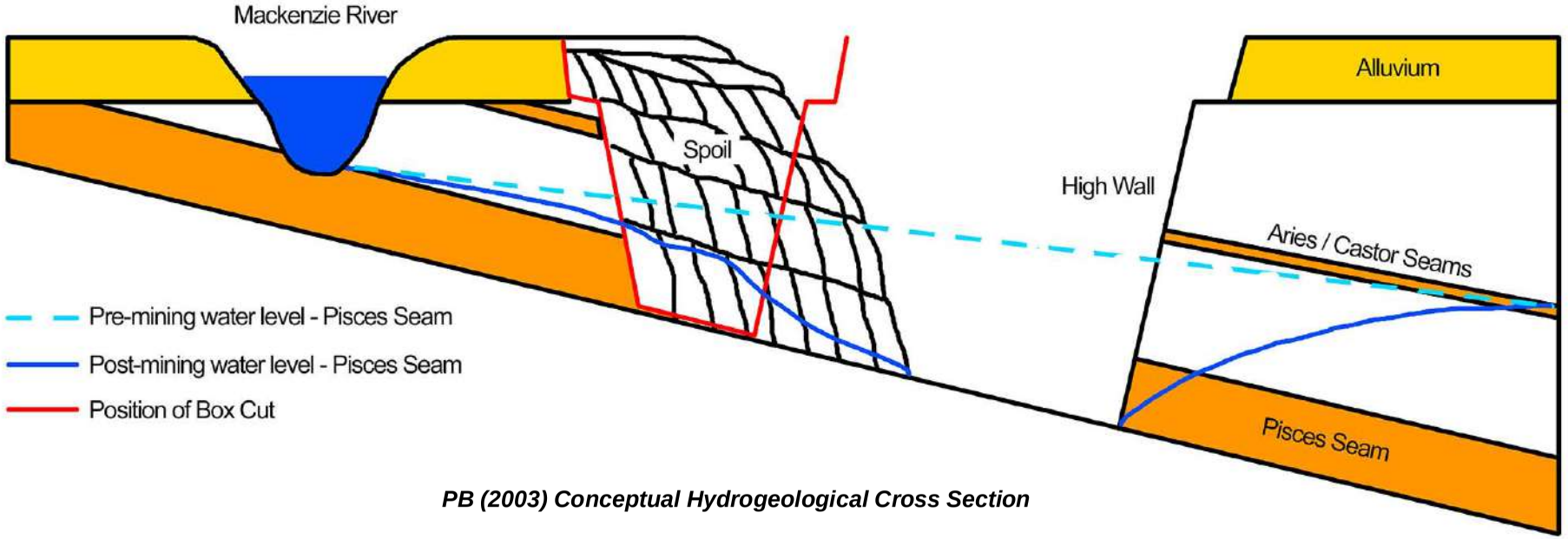
DATE: Oct 2014

EAST WEST



PPK (2002) Conceptual Hydrogeological Cross Section

WEST EAST



PB (2003) Conceptual Hydrogeological Cross Section

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Wesfarmers Curragh Pty Ltd	**PREVIOUS CONCEPTUAL HYDROGEOLOGICAL MODELS** S Pit Groundwater Study Review Curragh Coal Mine, Blackwater, Central Queensland	PROJECT No: 80724.00
	DRAWN BY: MS / DATE: Oct 2014		DRAWING No: 20
	APPROVED BY: IDH / OFFICE: Brisbane		REVISION: 0

Appendix A

Notes About This report

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

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Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Appendix B

Site Photograph Plates



Photograph 1: Imag0252: Eastern High Wall Block 30



Photograph 2: Imag0253: Eastern High Wall Block 30

Douglas Partners Geotechnics / Environment / Groundwater	**EASTERN HIGH WALL PHOTOS BLOCK 30** **S Pit Groundwater Study Review** **Curragh Coal Mine, Central QLD**	PROJECT: 80724.00 PLATE No: 1 REV: A
	CLIENT: Wesfarmers Curragh Pty Ltd	DATE: Oct-14



Photograph 3: Imag0253: Eastern High Wall Block 30



Photograph 4: Video004 Screengrab: Eastern High Wall Block 30

Douglas Partners Geotechnics / Environment / Groundwater	**EASTERN HIGH WALL PHOTOS BLOCK 30** **S Pit Groundwater Study Review** **Curragh Coal Mine, Central QLD**	PROJECT: 80724.00 PLATE No: 2 REV: A
	CLIENT: Wesfarmers Curragh Pty Ltd	DATE: Oct-14



Photograph 5: Imag0259: Northern Face of Block 30



Photograph 6: Imag0263: Northern Face of Block 30

Douglas Partners Geotechnics / Environment / Groundwater	**NORTHERN FACE PHOTOS BLOCK 30**	PROJECT: 80724.00
	S Pit Groundwater Study Review	PLATE No: 3
	Curragh Coal Mine, Central QLD	REV: A
	CLIENT: Wesfarmers Curragh Pty Ltd	DATE: Oct-14



Photograph 7: Imag0260: Western Low Wall Block 29/30



Photograph 8: Imag0261: Western Low Wall Block 29/30

Douglas Partners Geotechnics / Environment / Groundwater	**WESTERN LOW WALL PHOTOS BLOCK 30** **S Pit Groundwater Study Review** **Curragh Coal Mine, Central QLD**	PROJECT: 80724.00 PLATE No: 4 REV: A
	CLIENT: Wesfarmers Curragh Pty Ltd	DATE: Oct-14

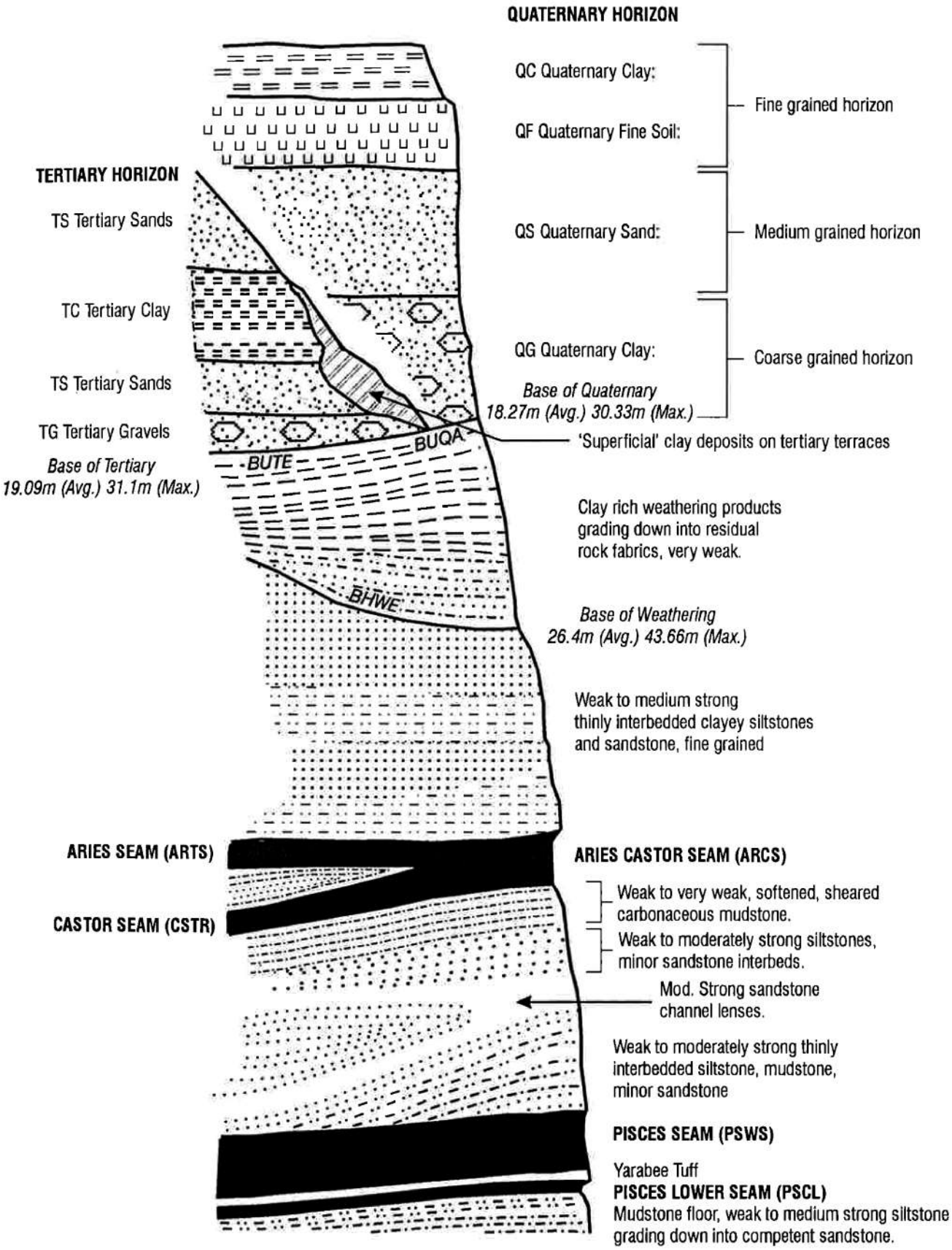


Photograph 9: Video003 Screengrab: Western Low Wall Block 30

Douglas Partners Geotechnics / Environment / Groundwater	**WESTERN LOW WALL PHOTOS BLOCK 30**	PROJECT:	80724.00
	S Pit Groundwater Study Review	PLATE No:	5
	Curragh Coal Mine, Central QLD	REV:	A
	CLIENT: Wesfarmers Curragh Pty Ltd	DATE:	Oct-14

Appendix C

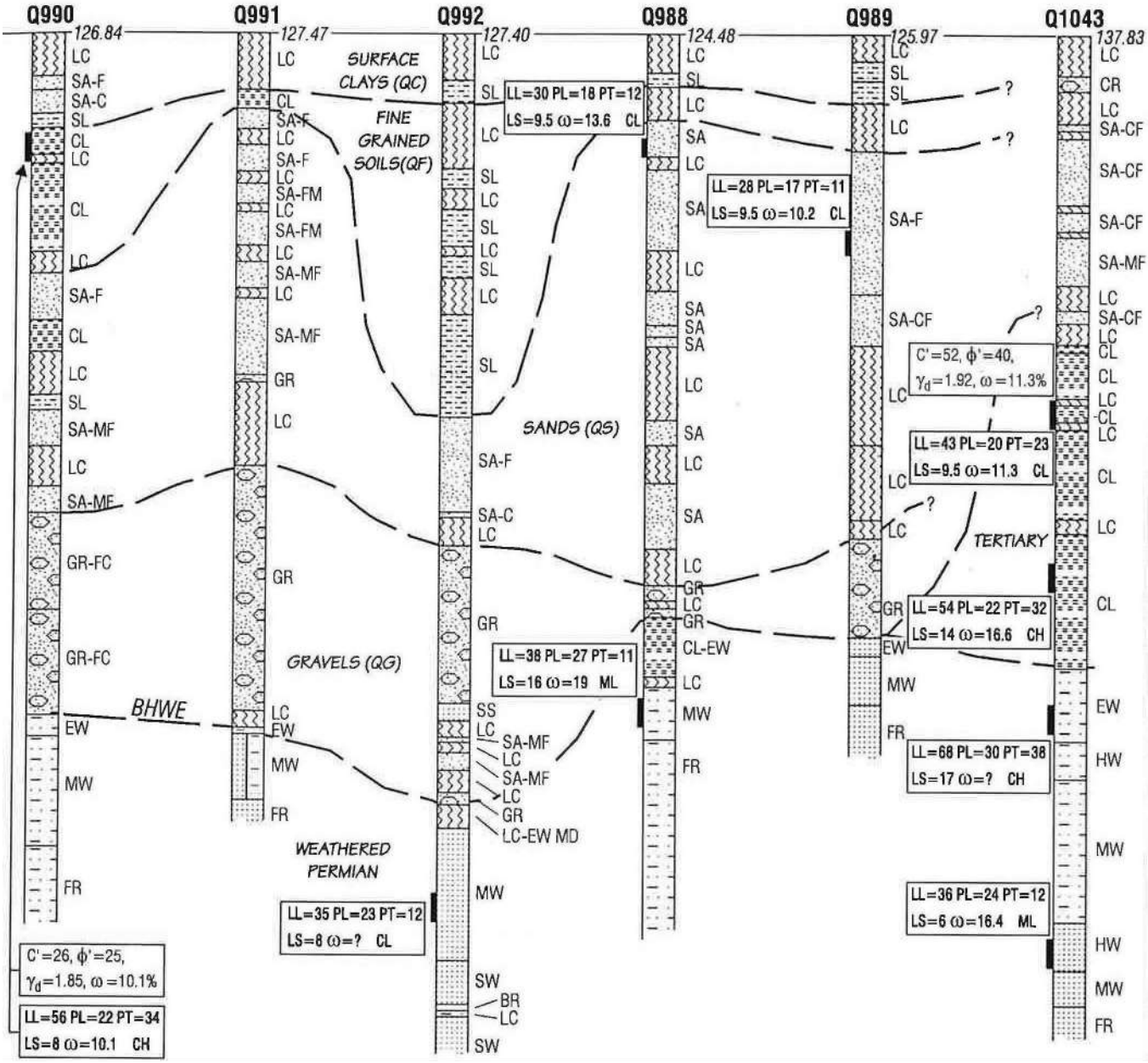
Generalised Geological Section



Douglas Partners Geotechnics / Environment / Groundwater	**GENERALISED GEOLOGICAL SECTION AFTER MG (1998A)** S Pit Groundwater Study Review Curragh Coal Mine, Blackwater, Central Queensland	PROJECT No: 80724.00 DRAWING No: C.1 REVISION: A
	CLIENT: Wesfarmers Curragh Pty Ltd	DATE: Oct 2014

A

A'



LEGEND

SA	SAND	EW	EXTREMELY WEATHERED
SL	SILTSTONE	MW	MODERATELY WEATHERED
SS	SANDSTONE	SW	SLIGHTLY WEATHERED
CL	CLAY	FR	FRESH
LC	LIGNITIC CLAY	BR	BRECCIA
GR	GRAVEL		
MS	MUDSTONE		

SCALE
1:200(V) N.T.S.(H)

Douglas Partners
Geotechnics / Environment / Groundwater

ALLUVIUM DETAIL CROSS SECTION AFTER MG (1998A)

S Pit Groundwater Study Review
Curragh Coal Mine, Blackwater,
Central Queensland

CLIENT: Wesfarmers Curragh Pty Ltd

PROJECT No: 80724.00

DRAWING No: C.2

REVISION: A

DATE: Oct 2014

Appendix D

Groundwater Sampling Results

Table D1: Summary table of groundwater sampling results 1999 to 2014.

Analyte	*Unit*	*Value Type*	*Bore 1308MB*	*Bore 1309MB*	*Bore 1312MB*	*Bore 1322MB*	*Bore 1323MB*	*Bore BH1*	*Bore BH2*	*Bore BH3*	*Bore BH4*	*Bore BH5*	*Bore BH6*	*Bore BH8*	*Bore BH8A*	*Bore MB1A*	*Bore MB1B*	*Bore MB2*	*Bore MB4A*	*Bore MB4B*	*ALL BORES*
pH	pH	MIN	7.7	7.2	7.1	7.1	7.0	6.6	6.7	6.7	6.6	6.5	6.9	6.8	6.6	7.3	7.0	7.6	7.4	7.1	6.5
		MAX	8.0	7.8	7.8	7.4	7.5	7.7	7.8	7.8	7.5	7.7	7.8	7.8	7.9	7.6	7.7	7.6	7.6	12	11.5
		AVG (Ex. LOR)[1]	7.9	7.5	7.5	7.3	7.2	7.1	7.1	7.1	7.0	7.2	7.3	7.2	7.1	7.4	7.3	7.6	7.5	8.1	7.2
TDS	mg/L	MIN	7,670	1,680	1,700	7,990	5,240	8,580	8,920	4,100	1,940	10,900	7,480	14,000	12,700	5,780	6,940	6,000	6,100	7,500	1,680
		MAX	7,850	2,040	2,500	8,340	6,870	9,930	9,340	4,560	3,900	12,300	7,700	15,700	18,000	9,120	9,260	6,000	7,010	18,100	18,100
		AVG (Ex. LOR) [1]	7,760	1,877	1,970	8,165	6,323	9,268	9,188	4,357	2,388	11,633	7,627	14,700	16,000	6,948	8,382	6,000	6,530	14,260	8,151
EC	µS/cm	MIN	12,000	2,700	2,600	14,000	8,100	11,000	11,000	6,200	3,000	14,000	12,000	22,000	19,000	10,000	11,000	9,800	10,000	12,000	2,600
		MAX	12,000	3,100	3,800	14,000	11,000	15,000	18,000	11,000	8,400	20,000	15,000	31,000	42,000	14,000	15,000	9,800	11,000	27,000	42,000
		AVG (Ex. LOR) [1]	12,000	2,967	3,033	14,000	10,033	13,632	15,354	7,737	5,699	17,687	13,250	26,714	33,714	11,333	13,667	9,800	10,600	22,000	13,484
Calcium	mg/L	MIN	82	150	160	110	210	122	5	5	6	9	96	240	170	140	150	45	150	250	5
		MAX	82	150	170	120	260	220	170	83	270	300	130	420	810	230	240	45	190	430	810
		AVG (Ex. LOR) [1]	82	150	165	115	235	166	137	66	124	196	111	366	622	182	210	45	165	355	178
Sulphate	mg/L	MIN	930	77	330	550	290	570	<1	480	<1	<1	450	620	630	870	540	860	1,000	780	<1
		MAX	930	390	420	710	610	1,390	1,300	840	620	26	820	930	1,100	1,200	1,100	860	1,100	1,100	1,390
		AVG (Ex. LOR) [1]	930	272	370	637	427	981	154	617	286	6	569	757	756	1,078	770	860	1,080	982	624
Nitrate	mg/L	MIN	0.24	0.07	0.14	0.02	0.14	0.07	0.01	0.02	0.02	0.02	0.02	0.92	0.99	0.02	0.01	0.05	0.03	0.03	0.01
		MAX	0.45	0.11	0.24	0.10	0.14	0.44	0.04	0.07	0.08	0.06	0.30	1.30	1.50	1.20	0.78	0.05	0.41	1.10	1.50
		AVG (Ex. LOR) [1]	0.35	0.09	0.21	0.06	0.14	0.23	0.02	0.05	0.04	0.03	0.13	1.07	1.23	0.37	0.33	0.05	0.22	0.48	0.30
Iron	µg/L	MIN	<5	<5	3,800	<5	40	<5	<5	32	<5	<5	220	<50	<50	<50	<50	<500	<50	140	<5
		MAX	3,300	12,000	4,600	850	5,100	3,400	3,000	4,200	2,500	20,000	1,700	3,900	7,100	16,000	2,000	<500	1,400	3,900	20,000
		AVG (Ex. LOR) [1]	1,970	6,850	4,200	780	2,047	1,168	1,550	913	876	15,030	733	2,717	3,713	5,840	1,463	-	1,210	2,485	3,202
Aluminium	µg/L	MIN	<50	<5	<5	<5	<5	<2	<2	<50	<2	<2	<50	<50	<50	<5	<5	<50	17	<50	<2
		MAX	2,500	2,700	230	82	220	67	35	1,300	37	120	130	2,700	260	9,600	170	<50	1,300	110	9,600
		AVG (Ex. LOR) [1]	2,500	2,700	230	82	220	67	35	1,300	37	120	130	2,700	260	3,228	90	-	659	99	989
Arsenic	µg/L	MIN	<10	<1	1	2	1	<1	<1	<10	<1	<1	<10	<10	<10	<1	<1	<10	<1	2	<1
		MAX	21	12	8	15	4	22	<10	20	55	55	20	41	35	15	13	<10	12	32	55
		AVG (Ex. LOR) [1]	21	12	5	9	3	22	-	20	-	27	20	41	35	9	13	-	12	17	16
Mercury	mg/L	MIN	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
		MAX	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0009	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
		AVG (Ex. LOR) [1]	-	-	-	-	-	-	-	-	0.0009	-	-	-	-	-	-	-	-	-	0.0009
TRH (C6-C9)	µg/L	MIN	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
		MAX	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
		AVG (Ex. LOR) [1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TRH (C10-C14)	µg/L	MIN	<50	<50	<50	<50	<50	85	110	<50	73.00	53	<50	<50	<50	<50	<50	<50	<50	<50	<50
		MAX	<50	<50	<50	<50	<50	180	290	51	750	53	93	<50	<50	<50	<50	<50	<50	<50	750
		AVG (Ex. LOR) [1]	-	-	-	-	-	120	200	51	253	53	93	-	-	-	-	-	-	-	164
TRH (C15-C28)	µg/L	MIN	<200	<200	<200	<200	<200	<100	<100	<100	<100	<100	<100	<100	<100	<100	<200	<200	<200	<100	<100
		MAX	<200	<200	<200	<200	<200	410	550	<200	510	<100	<100	<100	<100	<100	<200	<200	<200	<100	550
		AVG (Ex. LOR) [1]	-	-	-	-	-	227	430	-	495	-	-	-	-	-	-	-	-	-	361
TRH (C29-C36)	µg/L	MIN	<200	<200	<200	<200	<50	<10	<10	<50	<10	<10	<50	<50	<50	<200	<200	<200	<200	<200	<50
		MAX	<200	<200	<200	<200	<50	50	50	<200	50	<10	<50	<50	300	<200	<200	<200	<200	<200	300
		AVG (Ex. LOR) [1]	-	-	-	-	-	50	50	-	50	-	-	-	300	-	-	-	-	-	113

Notes:

1. Average calculation excludes sampling results that fall below the Limit of Reporting (LOR).
2. BORE COMPLETED IN THE QUATERNARY