Australasian Groundwater and Environmental Consultants Pty Ltd (AGE)

Report on

Drayton South Coal Project EIS

Groundwater Impact Assessment

Prepared for
Hansen Bailey

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Australasian Groundwater and Environmental Consultants Pty Ltd

AGE Head Office
Level 2 / 15 Mallon Street,
Bowen Hills, QLD 4006, Australia
T. +61 7 3257 2055
F. +61 7 3257 2088
brisbane@ageconsultants.com.au

AGE Newcastle Office
4 Hudson Street,
Hamilton, NSW 2303, Australia
T. +61 2 4962 2091
F. +61 2 4962 2096
newcastle@ageconsultants.com.au

Executive summary

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) has been engaged to complete a groundwater impact assessment for the Drayton South Coal Project (the Project). The Project allows for continued operation of the Drayton Mine infrastructure, equipment, and workforce by developing open cut mining within the Project area.

The Project application addresses the reasons provided by the NSW Planning Assessment Commission (PAC) for the refusal of the previous application. The mine plan and Project Boundary is defined by ridgelines nominated in the 'Drayton South Coal Project PAC Review Report' issued by the PAC in December 2013.

This report describes the amendment of the groundwater model, the calibration of hydraulic parameters, the predictive simulations undertaken, and the results of the simulations. Major findings of the investigation include:

Seepage rates

Groundwater modelling has produced two seepage rate results; one for total seepage rates, and the other for pumpable seepage rates. The total seepage rates are "gross", as the effect of evaporation has not been applied to them. The pumpable seepage rates are "net", as they have been adjusted for losses to evaporation. The pumpable rates represent the flow of water that will report to pit sumps and contribute to the mines water balance. The predicted pumpable seepage rates (coal measures and spoil), after evaporation, peak at about 381 ML/year. This volume will be managed within the sites water circuit.

The predicted total seepage rate from the Permian coal measures peaks at about 175 ML/year. Anglo American have committed to acquire a water allocation licence for the predicted take of groundwater from the Permian coal measures.

Extent of groundwater drawdown – during mining

Drawdown (represented by the 1 m contour) is predicted to not extend into the Hunter River alluvium.

The zone of drawdown influence is predicted to extend into the Saddlers Creek alluvium. The groundwater level within the Saddlers Creek alluvium is predicted to be cumulatively lowered by 1 m to 2 m along a 4 km creek section, located between the Project and the adjacent Mt Arthur mining areas.

Impacts to landholder bores – during mining

Two registered supply bores/wells are located within the end of mining and post mining zone of drawdown. Both bores are owned by Anglo American and will be removed by mining. No private bores will be impacted.

Reduction of bedrock leakage

The rate of upward leakage from the Permian coal measures into the Saddlers Creek alluvium is predicted to reduce by a maximum of 134 ML/year, occurring about 30 years after the completion of mining. The rate of upward leakage into the Saddlers Creek alluvium is predicted to progressively recover to a rate about 5 ML/year lower than pre-mining conditions.

The rate of upward leakage from the bedrock into the Hunter River alluvium is predicted to be reduced by a maximum of 8 ML/year, occurring about 245 years after mining. The rate of upward leakage into the Hunter River alluvium is predicted to progressively recover to a rate about 2 ML/year lower than pre-mining conditions.

Reduction of baseflow to rivers/creeks

Baseflow within Saddlers Creek is predicted to reduce by up to 130 ML/year about 50 years post mining. The baseflow within Saddlers Creek is predicted to progressively recover to a rate about 5 ML/year lower than pre-mining conditions.

Baseflow to the Hunter River is predicted to be progressively reduced by up to 10 ML/year about 300 years post mining. The baseflow within the Hunter River is predicted to progressively recover to a rate about 3 ML/year lower than pre-mining conditions. This will have negligible impact on the daily river flow.

Blakefield mining area – spoil water budget and quality

The Blakefield mining area will be completely backfilled and rehabilitated. The final landform will not contain a void area. Therefore, water level recovery within the spoil will not be influenced by evaporative processes that are associated with void areas.

The gross groundwater flow into the Blakefield spoil is predicted to decrease from 67 ML/year to 1 ML/year, over 245 years post mining. The gross flow of spoil water into the surrounding geology is predicted to increase over time as the water level within the spoil recovers. The gross groundwater flow from the Blakefield spoil is predicted to increase from 1 ML/year up to 39 ML/year.

In the long-term, a hydraulic gradient will be established towards Saddlers Creek, away from the Blakefield mining area.

The TDS concentration of water within the spoil of the Blakefield mining area was predicted to initially be 2881 mg/L, which then decreases to 2162 mg/L over time.

Whynot mining area – spoil water budget and quality

After mining ceases, the final landform of the Whynot mining area will consist of re-worked spoil across the entire disturbance area. The spoil will be shaped in a manner that promotes free drainage away from the northern and western mining areas. Drainage from the eastern and central areas will be directed towards a central void area.

The gross groundwater flow into the Whynot spoil is predicted to decrease from 142 ML/year to 31 ML/year, over 800 years post mining. The gross groundwater flow from the Whynot spoil is predicted to increase from 0 ML/year up to 6 ML/year.

In the long-term, the hydraulic gradient adjacent to the Whynot mining area will be maintained away from Saddlers Creek. Spoil water is predicted to predominantly migrate towards the south.

The TDS concentration of water within the spoil of the Whynot mining area was predicted to be initially 2542 mg/L, decreasing to 2262 mg/L over time.

The hydraulic gradients in the very long-term will result in a "flow through" system within the Whynot spoil and void. The gradients will enable gross flow of water from the void into the spoil of about 100 ML/year. Salts that have accumulated in the void through evaporative processes will be transported into the spoil as a result of the water migration.

Whynot mining area – void water budget

Saturation of the Whynot spoil is predicted to take ~245 years before a permanent lake surface develops within the final void area. This is due to the backfilling of the spoil in the final landform and the need for the groundwater level to re-saturate the spoil before it is high enough to daylight into the void. Prior to this, any water that is captured in the void is expected to either infiltrate into the spoil or be removed through evaporation.

The initial head in the void will be ~115 mAHD, and is predicted to increase to an elevation of about 128 mAHD at equilibrium. The spill elevation for the void is 145 mAHD. Therefore, the void is unlikely to overtop because of a predicted 17 m freeboard.

The rate of evapotranspiration is predicted to increase to a maximum of 401 ML/year. Recharge to the void from direct rainfall and runoff was predicted to be about 214 ML/year. Net water movement from the spoil into the void increases from 0 ML/day to a maximum of 188 ML/year to replace surface water in the void that is lost to evaporation.

Final void water quality

The TDS concentration of the water stored within the Whynot void is predicted to progressively increase to an equilibrium level of about 6773 mg/L. This assumes that the void derived salts pervasively mix through the spoil in the Whynot mining area, resulting in the spoil attaining a TDS concentration comparable with the void. This assumption is considered highly conservative.

Groundwater quality

The existing beneficial use of the Saddlers Creek alluvial groundwater will not be impacted during mining. The Saddlers Creek alluvium will most likely remain too saline for primary industries in the long-term. Post mining migration of lower TDS spoil water from the Blakefield mining area into the Saddlers Creek alluvium may reduce the salinity of water in the alluvium over the long-term.

The existing beneficial use of the Hunter River alluvial groundwater will not be impacted during mining. The beneficial use will remain classified as primary industry with the main use being for stock watering, and limited irrigation where better water quality water is present.

The beneficial use of the Permian coal measures will not be impacted post mining for at least 350 years post mining. The generally low yield and poor quality of the groundwater in the coal seams limits its beneficial use and it will remain suitable for primary industry with the main potential use being for stock watering.

After 350 years, the Permian coal measures immediately down-gradient of the Whynot mining area may be progressively impacted by an increasing TDS concentration caused by seepage from the mining area.

Predicted impact on the Hunter River water quality

The TDS concentration of the Hunter River is predicted to not be increased by more than 1 %, which is below the NSW Aquifer Interference Policy (AIP) trigger guideline.

AIP minimal impact considerations

No minimal impact considerations, other than the removal of two registered bores (which are owned by Anglo American), have been identified in this assessment. Based on the findings of the groundwater assessment, the Project meets the Level 1 Minimal Impact Considerations of the AIP.

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Drayton South Coal Project EIS Groundwater Impact Assessment

1. Introduction

Drayton Mine is located approximately 13 km south of Muswellbrook in the Upper Hunter Valley of New South Wales (NSW). Drayton Mine has been operating for over 30 years and the coal reserves will be exhausted in 2015. Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) was commissioned by Hansen Bailey on behalf of Anglo American Coal (Anglo American) to complete a groundwater impact assessment as part of the Environmental Impact Statement (EIS) for the Drayton South Coal Project (the Project).

The Project will allow for the continuation of the existing Drayton Mine for up to 15 years, by developing an open cut mining area within exploration licence (EL) 5460. The Project will extract up to 6.4 Mtpa in any one year, of export quality thermal coal by utilising existing Drayton Mine assets and infrastructure.

2. Project description

2.1 Overview

The Drayton South Coal Project (the Project) addresses the reasons provided by the NSW Planning Assessment Commission (PAC) for the refusal of the previous application. The mine plan and Project Boundary is defined by ridgelines nominated in the 'Drayton South Coal Project PAC Review Report' issued by the PAC in December 2013. The Project will remain behind the ridgelines nominated by the PAC. Significantly, this at least doubles the buffer setback distance from the Coolmore and Woodlands thoroughbred horse studs and is at least two kilometres (km) from the horse stud operational areas.

The Project generally includes:

- Continuation of operations at Drayton Mine as currently approved with minor additional mining within the existing East, North and South Mining Areas for a period of 15 years;
- Development of a new open cut mining area with EL 5460 mining up to 6.4 Mtpa Run-Of-Mine (ROM) coal;
- Ongoing employment of a workforce of up to 500 full time equivalent employees;
- Utilisation of the existing Drayton Mine equipment fleet;
- Storage of water, and emplacement of tailings and rejects generated by the Project in existing Drayton Mine voids;
- Utilisation of the existing Drayton Mine infrastructure including the CHPP, rail loop and associated infrastructure, workshops, bath houses and administration offices;
- Construction of a transport corridor to the new mining area;
- Continued utilisation of the Antiene Rail Spur off the Main Northern Railway Line to transport product coal to the Port of Newcastle for export;

- Realigning and upgrading a section of Edderton Road;
- Continuation of mutually beneficial arrangements with neighbours Macquarie Generation and Mt Arthur Coal Mine;
- Installation of further water management and power reticulation infrastructure to support the new mining areas; and
- Progressive rehabilitation of disturbed areas as mining operations are completed.

2.2 Proposed mine development

Mining will extract coal from numerous coal seams including the Whybrow, Redbank Creek, Wambo, Whynot, and Blakefield coal seams (in descending stratigraphic order). The upper four seams will be mined in the Whynot mining area and only the lowermost seam will be mined in the Blakefield mining area. The mining areas will range in depth from 40 m in the north, to about 120 m in the southern extremity of the Whynot mining area. Operations in the early years will be above, or close to, the prevailing water table. Active mining would then progress southward below the water table with gradual deepening in the down-dip direction. Interburden waste rock (spoil) will be emplaced behind the active mining area as the operation advances.

After mining ceases, the final landform will consist of re-worked spoil across the entire disturbance area. The spoil will be shaped in a manner that promotes free drainage away from the northern and western mining areas. Drainage from the eastern and central areas will be directed towards a central void area.

Mine development below the water table will result in depressurisation of the coal measures. Such depressurisation will induce change to groundwater flow directions within the coal measures and may induce leakage from the surface drainage systems. The water table within the spoil will recover after mining has ceased. However, the water level will be dissimilar to the pre-mining water table. Long-term groundwater quality in the mined areas will also change due to the fragmentation and leaching of salts from emplaced spoil.

3. Objectives and scope of work

The objective of the groundwater impact assessment is to address the requirements provided by various NSW government departments and the federal government. Sections below outline requirements for the groundwater study presented by each government department, and where these have been addressed within this report.

3.1 Secretary's Environmental Assessment Requirements

The Department of Planning and Environment (DP&E) collated the requirements from all NSW government departments and provided these to Anglo American. These are known as the Secretary's Environmental Assessment Requirements (SEARs). Sections below tabulate the requirements that relate to groundwater.

3.1.1 NSW Department of Planning and Environment

Requirements	Addressed in section
An assessment of the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources, having regard to the EPA's and NOW's requirements.	Section 12.5 and 13.8
An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users.	Section 12 and 13

3.1.2 NSW Environmental Protection Agency

Recommendation	Addressed in section
The EIS should include:	
7.2.4. Describe existing surface and groundwater quality. An assessment needs to be undertaken for any water resource likely to be affected by the proposal.	Section 9.1.1.4, 9.1.2.4, and 9.1.5.4
7.2.5. State the Water Quality Objectives for the receiving waters relevant to the proposal. These refer to the community's agreed environmental values and human uses endorsed by the NSW Government as goals for ambient waters. Where groundwater may be impacted the assessment should identify appropriate groundwater environmental values.	Section 9.1.1.4, 9.1.2.4, and 9.1.5.4
7.2.6. State the indicators and associated trigger values or criteria for the identified environmental values. This information should be sourced from the ANZECC (2000) Guidelines for Fresh and Marine Water Quality.	Section 9.1.1.4
7.2.12. Assess impacts on groundwater and groundwater dependent ecosystems (GDEs).	See ecology study for GDE assessment
7.2.17. Describe how predicted impacts will be monitored and assessed over time. Including a Trigger Action Response Plan, or similar response management plan, that will be implemented in response to any adverse impacts identified from the activity. This plan is to identify appropriate trigger values for the site and provide appropriate response actions to be implemented if adverse impacts are identified through the monitoring program.	Section 19
7.2.19. Describe in detail, including maps or plans of all water quality monitoring locations, water quality parameters, and proposed monitoring frequencies.	Section 8

3.1.3 NSW Division of Resources and Energy, NSW Trade and Investment

Recommendation	Addressed in section
The EIS should state the interaction between the existing mining operations, the proposed mining activities, and the existing environment and so include a comprehensive description of the following activities and their impacts:	
• Surface and groundwater usage and management.	Section 9.1.1, 9.1.2, 9.1.3, 9.1.4, and 9.1.5

Recommendation	Addressed in section
Where a void is proposed to remain as part of the final landform, the assessment is to provide details in regards to the following:	
• Outcomes of the surface and groundwater assessments in relation to the likely final water level in the void. This should include as assessment of the potential for fill and spill along with measures required be implemented to minimise associated impacts to the environment and downstream users.	Section 13.1, 13.2, 13.5, 13.7, and 13.8
The EIS must address surface water flow and flooding regimes and how these will be impacted and mitigated by the project both during and after mining has ceased. This is to include an evaluation of potential impacts from the final void on both surface and groundwater quality and flow regimes.	Section 13.1, 13.2, 13.5, 13.7, and 13.8

3.1.4 NSW Office of Environment and Heritage

Recommendation	Addressed in section
6. The EIS must map groundwater.	Appendix C, Section 12.2 and 13.3
7. The EIS must describe background conditions for any water resource likely to be affected by the development, including:	
• Existing surface and groundwater.	Section 9
• Water Quality Objectives (as endorsed by the NSW Government) including groundwater as appropriate that represent the community's uses and values for the receiving waters.	Section 9.1.1.4, 9.1.2.4, and 9.1.5.4
• Indicators and trigger values/criteria for the environmental values in accordance with the ANZECC (2000) guidelines for Fresh and Marine Water Quality and/or local objectives, criteria, or targets endorsed by the NSW Government.	Section 9.1.1.4
8. The EIS must address the impacts of the development on water quality, including:	
• The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved.	Section 12.5 and 13.8
• Identification of proposed monitoring of water quality.	Section 19
E. The description of existing water quality/hydrology in the EIS must be based on suitable data and must include:	
• Water chemistry.	Section 9
• A description of any impacts from existing industry or activities on water quality.	Section 9
• An outline of baseline groundwater information, including, for example, depth to water table, flow direction and gradient, groundwater quality, reliance on groundwater by surrounding users and by the environment.	Section 9

Recommendation	Addressed in section
F. The proposed monitoring of water quality must be undertaken in accordance with the Approved Methods for the Sampling and Analysis of Water Pollutants in NSW 2004. The EIS must include a water quality and aquatic ecosystem monitoring program that includes:	
• Adequate data for evaluating maintenance, or progress towards achieving, the relevant Water Quality Objectives.	Section 19
• Measurement of pollutants identified or expected to be present.	Section 19

3.1.5 NSW Office of Water

Recommendation	Addressed in section
General requirements	
It is recommended that the EIS be required to include:	
• Details of water proposed to be taken (including through inflow and seepage) from each surface and groundwater source as defined by the relevant water sharing plan.	Section 17
• Assessment of any volumetric water licensing requirements (including those for ongoing water take following completion of the project).	Section 17
• A detailed assessment against the NSW Aquifer Interference Policy (2012) using the NSW Office of Water's assessment framework.	Section 18
• Assessment of impacts on surface and ground water sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, wetlands, and groundwater dependent ecosystems, and measures proposed to reduce and mitigate these impacts.	Section 12 and 13
• Full technical details and data of all surface and groundwater modelling, and an independent peer review.	Appendix C Section 11
• Proposed surface and groundwater monitoring activities and methodologies.	Section 19
• Assessment of any potential cumulative impacts on water resources, and any proposed options to manage the cumulative impacts.	Section 15
• Assessment of whether the activity may have a significant impact on water resources, with reference to the Commonwealth Department of Environment Significant Impact Guidelines.	Section 12, 13, and 18
• If the activity may have a significant impact on water resources, then provision of information in accordance with the Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals, including completion of the information requirements checklist.	Not applicable
Water sharing plans	
The proposal is located within the area covered by the Water Sharing Plan (WSP) for the Hunter Unregulated and Alluvial Water Sources 2009 and the WSP for the Hunter Regulated River Water Source 2003. The EIS is required to:	

Recommendation	Addressed in section
• Demonstrate how the proposal is consistent with the relevant rules of the Water Sharing Plan including rules for access licences, distance restrictions for water supply works and rules for the management of local impacts in respect of surface water and groundwater sources, ecosystem protection (including groundwater dependent ecosystems), water quality, and surface-groundwater connectivity.	Section 17
Licensing considerations	
The EIS is required to provide:	
• Identification of water requirements for the life of the project in terms of both volume and timing (including predictions of potential ongoing groundwater take following the cessation of operations at the site – such as evaporative loss from open voids or inflows).	Section 12.1 and 17
• Details of the water supply source(s) for the proposal including any proposed surface water and groundwater extraction from each water source as defined in the relevant Water Sharing Plan/s and all water supply works to take water.	Section 12.1 and 17
• Explanation of how the required water entitlements will be obtained (i.e. through a new or existing licence/s, trading on the water market, controlled allocations etc.).	Section 17
• Details on all bores and excavations for the purpose of investigation, extraction, dewatering, testing and monitoring. All predicted groundwater take must be accounted for through adequate licensing.	Section 8 and 19
Groundwater assessment	
To ensure the sustainable and integrated management of groundwater sources, the EIS needs to include adequate details to assess the impact of the project on all groundwater sources including:	
• Works likely to intercept, connect with or infiltrate the groundwater sources.	Section 2
• Any proposed groundwater extraction, including purpose, location and construction details of all proposed bores and expected annual extraction volumes.	Section 12.1
• Bore construction information is to be supplied to the Office of Water by submitting a "Form A" template. The Office of Water will supply "GW" registration numbers (and licence/approval numbers if required) which must be used as consistent and unique bore identifiers for all future reporting.	Not applicable
• A description of the water table and groundwater pressure configuration, flow directions and rates and physical and chemical characteristics of the groundwater source (including connectivity with other groundwater and surface water sources).	Section 9, 12, and 13
• Sufficient baseline monitoring for groundwater quantity and quality for all aquifers and GDEs to establish a baseline incorporating typical temporal and spatial variations.	Section 8
• The predicted impacts of any final landform on the groundwater regime.	Section 13
• The existing groundwater users within the area (including the environment), any potential impacts on these users and safeguard measures to mitigate impacts.	Section 12.3 and 13.4
• An assessment of groundwater quality, its beneficial use classification and prediction of any impacts on groundwater quality.	Section 12.5 and 13.8

Recommendation	Addressed in section
• An assessment of the potential for groundwater contamination (considering both the impacts of the proposal on groundwater contamination and the impacts of contamination on the proposal).	Section 12.5 and 13.8
• Measures proposed to protect groundwater quality, both in the short and long term.	Section 19
• Measures for preventing groundwater pollution so that remediation is not required.	Section 19
• Protective measures for any groundwater dependent ecosystems (GDEs).	Not applicable
• Proposed methods of the disposal of waste water and approval from the relevant authority.	Not applicable
• The results of any models or predictive tools used.	Section 12 and 13
Where potential impact/s are identified the assessment will need to identify limits to the level of impact and contingency measures that would remediate, reduce or manage potential impacts to the existing groundwater resource and any dependent groundwater environment or water users, including information on:	
• Any proposed monitoring programs, including water levels and quality data.	Section 19
• Reporting procedures for any monitoring program including mechanism for transfer of information.	Section 19.2.5
• An assessment of any groundwater source/aquifer that may be sterilised from future use as a water supply as a consequence of the proposal.	Not applicable
• Identification of any nominal thresholds as to the level of impact beyond which remedial measures or contingency plans would be initiated (this may entail water level triggers or a beneficial use category).	Section 19.2
• Description of the remedial measures or contingency plans proposed.	Section 19.3
• Any funding assurances covering the anticipated post development maintenance cost, for example on-going groundwater monitoring for the nominated period.	Section 19
Groundwater Dependent Ecosystems	refer to EIS ecology study

3.2 Federal government

3.2.1 Department of the Environment

Recommendation	Addressed in section
The EIS must include a description of the environment and management practices of the proposal site and the surrounding areas and other areas that are affected by the action. Include the relevant MNES protected by controlling provisions of Part 3 of the EPBC Act:	
a) A description of the important water resources within the site and in surrounding areas, which is consistent with the most recent version of the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Developments' *Information Guidelines for Proposals Relating to the Development of Coal Seam Gas and Large Coal Mines where there is significant impact on water resources.*	Section 9
b) The EIS should identify and address and cumulative impacts…	Section 15

3.3 Impact assessment methods

The methodology for this study was based on the requirements of the NSW and federal governments. In particular, AGE has:

- conducted a desktop review of available reports and literature review;
- established a baseline groundwater data set;
- compiled and analysed data from the Project and surrounding mines, including:
  - temporal groundwater level data from the Project monitoring network, published reports from surrounding mines, the NSW Office of Water (NOW) groundwater monitoring network and PINNEENA[1] database; and
  - temporal groundwater and surface water quality data from the monitoring network;
- merged digital terrain data sets to create a detailed terrain model within the Project and the wider region (site supplied detailed data merged with SRTM data[2] [Geoscience Australia, 2011]);
- reviewed the existing geological data supplied for the Project and extrapolated the data beyond the Project based on public domain reports from surrounding mines;
- conducted an initial census of selected privately owned bores within and surrounding the Project;
- developed a conceptual hydrogeological model of the groundwater regime for the purpose of defining any impact on highly productive aquifers;
- developed a numerical flow model of the groundwater system and calibrated this to available groundwater and surface water data to identify any potential for impact to the highly productive aquifers; and
- simulated the effect of the proposed mining on the groundwater regime using the calibrated model to:

[1] PINNEENA – NOW supplied database of registered groundwater bores in NSW.

[2] 1 arc second DEM-S (smoothed digital elevation model - 1 second SRTM derived) - © Commonwealth of Australia (Geoscience Australia) 2011.

- predict groundwater seepage rates into the Whynot and Blakefield mining areas during the mine life, as a function of mine position and timing;
- estimate the zone of depressurisation during (and post) mining to identify if any registered bores are predicted to be impacted by the Project;
- update the current model to include a new final landform;
- assess the leading practice final landform (void) design through predicted model water balance;
- predict the residual groundwater drawdown/recovery rates post mining;
- estimate the final landform lake level in the partially filled Whynot mining area;
- predict the seepage rate of void water into the surrounding geology, assuming the final void area becomes a 'flow-through' system; and
- predict the reduction of natural seepage from the Permian coal measures into the alluvial systems of the Hunter River and Saddlers Creek.

4. NSW water regulation

The Project will need to consider the requirements of the following NSW legislation, policy and guidelines for groundwater:

- *Water Act 1912* (Water Act);
- *Water Management Act 2000* (WM Act);
- Water Sharing Plan (WSP) for Hunter Unregulated and Alluvial Water Sources;
- WSP for the Hunter Regulated River Water Source;
- Aquifer Interference Policy (AIP);
- Groundwater Quality Protection Policy;
- Groundwater Dependent Ecosystems (GDE) Policy;
- Groundwater Quantity Management Policy; and
- Strategic Regional Landuse Policy and Plan (SRLUP).

Sections below summarise the intent of the above legislation, policy and guidelines and how they apply to the Project.

4.1 Water Act 1912

The Water Act regulates water sources including rivers, lakes and groundwater aquifers in NSW. It also manages the trade of water licences and allocations. However, relevant parts of the Water Act do not apply to any part of the State to which the equivalent parts of the WM Act applies (see sections 27A and 129A).

The WM Act is progressively replacing the Water Act in NSW. The WM Act has replaced the Water Act for alluvial water sources, but remains in place outside alluvial zones. Seepage of groundwater to the proposed mining areas requires an aquifer access licence under the Water Act.

4.2 Water Management Act 2000

The NSW WM Act provides for the "*protection, conservation and ecologically sustainable development of the water sources of the State*". The WM Act provides clear arrangements for controlling land based activities that affect the quality and quantity of the State's water resources. It provides for three primary types of approval in Part 3:

- water use approval – which authorise the use of water at a specified location for a particular purpose, for up to 10 years;
- water management work approval; and
- controlled activity approval which includes an aquifer interference activity approval – which authorises the holder to conduct activities that affect an aquifer such as approval for activities that intersect groundwater, other than water supply bores and may be issued for up to 10 years.

The water management principles (set out in Section 5 of the Act) state that:

a) the carrying out of controlled activities must avoid or minimise land degradation, including soil erosion, compaction, geomorphic instability, contamination, acidity, waterlogging, decline of native vegetation or, where appropriate, salinity and, where possible, land must be rehabilitated; and

b) the impacts of the carrying out of controlled activities on other water users must be avoided or minimised.

4.3 Water Sharing Plans

WSPs establish rules for sharing water between the environmental needs of the river or aquifer and water users, and between different types of water use such as town supply, rural domestic supply, stock watering, industry, and irrigation.

NOW are progressively developing WSPs for rivers and groundwater systems across NSW following the introduction of the WM Act. The plans are to protect the health of rivers and groundwater, while also providing water users with perpetual access licences, equitable conditions, and increased opportunities to trade water through separation of land and water.

Two WSPs apply to the aquifers affected by the Project, these being:

- Hunter Unregulated and Alluvial Water Sources WSP (HUAWSP); and
- Hunter Regulated River Water Source WSP (HRRWSP).

4.3.1 Hunter unregulated and alluvial water sources water sharing plan

The HUAWSP includes the Hunter unregulated rivers and creeks, the highly connected alluvial groundwater (which are above the tidal limit), and the tidal pool areas.

In total there are 39 water sources covered by the HUAWSP and nine of these are further sub-divided into management zones. The water source of Saddlers Creek and the alluvial aquifers associated with Saddlers Creek are contained within the Jerrys Management Zone of the Hunter Extraction Management Unit (EMU). The alluvial aquifers associated with the Hunter River are contained within the Up-stream Glennies Creek Management Zone (alluvial water source 1) of the Hunter Regulated River Alluvium EMU.

The total licensed water entitlement within the Jerrys Management Zone has a share component of 10,278 ML/year. The majority of this entitlement (76%) is currently categorised for industrial purposes with the remainder used for irrigation purposes. The total licensed groundwater entitlement within the Hunter Regulated River Alluvium EMU has a share component of 8,714 ML/year. The majority of this entitlement (36%) is currently categorised for irrigation purposes and 7% is used for industrial purposes.

4.3.2 Hunter Regulated River Water Source Water Sharing Plan

The Hunter Regulated River Water Source lies within the Hunter Water Management Area and comprises:

- the bed and banks of all rivers, from the upstream limit of Glenbawn Dam, downstream to the estuary of the Hunter River, and from the upstream limit of Glennies Creek Dam, downstream to the junction with the Hunter River; and
- the unconsolidated alluvial sediments underlying the waterfront of all rivers which have been declared by the Minister to be regulated rivers, except those unconsolidated alluvial sediments within one metre of works taking water pursuant to licences issued under Part V of the Water Act 1912 or their equivalent aquifer access licences issued under the WM Act.

The Hunter Regulated River Water Source is divided into three management zones (Zone 1, Zone 2, and Zone 3). The Project is located within the first Hunter River management zone listed, this being the Hunter River from Glenbawn Dam to its junction with Glennies Creek.

The Hunter River is the only regulated river included in the Hunter Regulated Water Source located within the near vicinity of the Project.

Table 1 shows the categories of access licences in the HRRWSP and their total share components at the commencement of the WSP. High security licences have a higher priority allocation of water than general security licences.

Table 1 Hunter regulated river water source share components

Access licence category	Total share component in the Hunter River
Major utility	36,000 megalitres per year
Local water utility	10,832 megalitres per year
Domestic and stock	1,738 megalitres per year
High security	22,159 unit shares
General security	128,163 unit shares
Supplementary water	49,000 unit shares

Source: *DIPNR, 2004*

Under very dry conditions where additional water is required in the water management system to supply operations, the Project will hold the necessary water allocation licences (WALs) to draw water from the Hunter River. Anglo American currently hold two general security WALs (WAL 491 and 1066) which provide an allocated share of 99 units each (198 units combined).

4.4 State groundwater policy

4.4.1 Aquifer interference policy considerations

4.4.1.1 Policy overview

The AIP has been developed by the NSW government as a component of the SRLUP. The AIP applies state-wide and details water licence and impact assessment requirements. The purpose of the AIP is to ensure equitable water sharing between various water users and proper licensing of water taken by aquifer interference activities, such that the take is accounted for in the water budget and water sharing arrangements.

4.4.1.2 Licensing requirements

The AIP requires all water taken by aquifer interference activities to be accounted for within the extraction limits set by a relevant WSP. A water licence is required, whether water is taken either incidentally or for consumptive use, where any act by a person carrying out an aquifer interference activity causes:

- the removal of water from a water source; or
- the movement of water from one part of an aquifer to another part of an aquifer; or
- the movement of water from one water source to another water source, such as:
    - from an aquifer to an adjacent aquifer; or
    - from an aquifer to a river/lake; or
    - from a river/lake to an aquifer.

The AIP also requires consideration of the continued take of water from groundwater or connected surface waters following cessation of an aquifer interference activity. For example, the post-closure seepage that occurs until a groundwater system reaches equilibrium following cessation of open cut mining is required to be considered.

4.4.1.3 Productive groundwater classification

In addition to licensing requirements, the WM Act includes the concept of ensuring "*no more than minimal harm*". In this regard, the AIP includes minimal impact considerations relating to water table and groundwater pressure drawdown and changes in groundwater and surface water quality.

The AIP establishes minimal impact considerations for groundwater categories of both "highly productive" and "less productive" groundwater. Highly productive groundwater is defined by the AIP as groundwater which has been declared in regulations and based on the following criteria:

a. has a total dissolved solids (TDS) concentration less than 1500 mg/L; and
b. contains water supply works that can yield water at a rate greater than 5 L/sec.

Highly productive groundwater sources are further grouped by geology into alluvial, coastal sands, porous rock, and fractured rock. "Less productive" groundwater includes aquifers that cannot be defined as "highly productive" according the yield and water quality criteria.

Figure 1 shows the mapped extent of highly productive groundwater sources in the vicinity of the Project (NOW, 2013). Adjacent to the Project, the alluvium of the Hunter River (south) and Saddlers Creek (north) is mapped as highly productive. Inside the Project, the Permian coal measures, that are the target of the Project, are mapped as less productive groundwater sources.

Baseline data presented in this report and salinity measurements indicate that the alluvial aquifer of Saddlers Creek may be a less productive aquifer than initially mapped. Section 9.2 includes a discussion regarding the groundwater regime and presents data supporting the above conclusion.

4.4.1.4 Minimal impact considerations

There are two levels of minimal impact considerations specified in AIP. If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable. The AIP describes the required process of evaluation if the predicted impacts are greater than Level 1.

The AIP specifies minimal impact considerations for both “highly productive” and “less productive” aquifers. The Level 1 minimal impact considerations for the Project are provided in Table 2 (Hunter River alluvium), Table 3 (Saddlers Creek alluvium), and Table 4 (Permian coal measures).

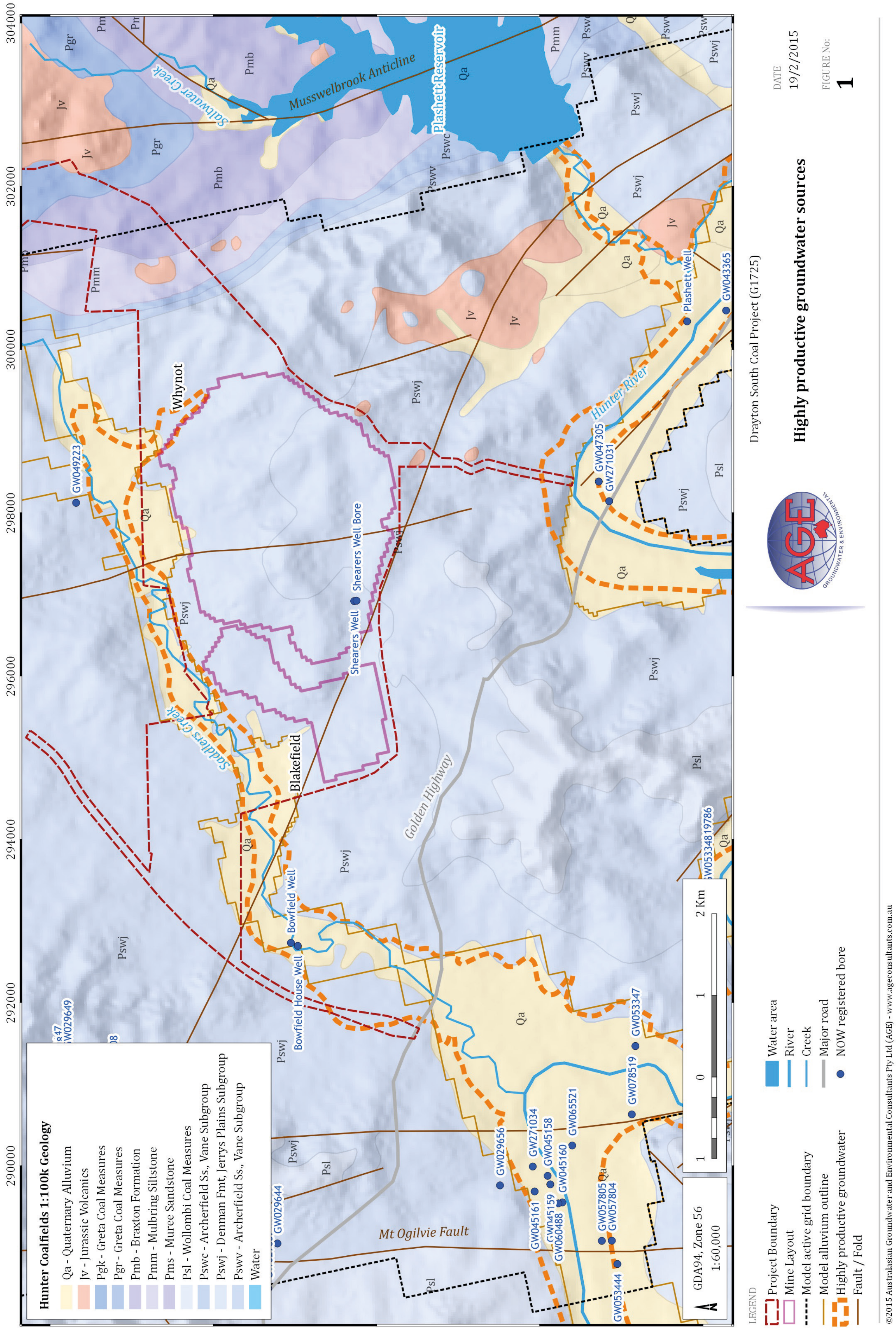

Drayton South Coal Project (G1725)
Highly productive groundwater sources
DATE
19/2/2015
FIGURE No:
1
GROUNDWATER & ENVIRONMENTAL
Hunter Coalfields 1:100k Geology
Qa - Quaternary Alluvium
Jv - Jurassic Volcanics
Pgk - Greta Coal Measures
Pgr - Greta Coal Measures
Pmb - Braxton Formation
Pmm - Mulbring Siltstone
Pms - Muree Sandstone
Psl - Wollombi Coal Measures
Pswc - Archerfield Ss., Vane Subgroup
Pswj - Denman Fmt, Jerrys Plains Subgroup
Pswv - Archerfield Ss., Vane Subgroup
Water
LEGEND
Project Boundary
Mine Layout
Model active grid boundary
Model alluvium outline
Highly productive groundwater
Fault / Fold
Water area
River
Creek
Major road
NOW registered bore
GDA94, Zone 56
1:60,000
0
1
2 Km
©2015 Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) - www.ageconsultants.com.au
Musswelbrook Anticline
Plashett Reservoir
Saltwater Creek
Saddlers Creek
Hunter River
Golden Highway
Mt Ogilvie Fault
Whynot
Blakefield
Shearers Well Bore
Shearers Well
Bowfield Well
Bowfield House Well
Plashett Well
GW049223
GW029649
GW029644
GW029656
GW271034
GW045158
GW045160
GW045161
GW045159
GW060488
GW065521
GW057805
GW057804
GW053444
GW078519
GW053347
GW047305
GW271031
GW043365
GW053348 19786
290000
292000
294000
296000
298000
300000
302000
304000
6406000
6408000
6410000
6412000
6414000

Table 2 Level 1 minimal impact considerations for aquifer interference policy – Hunter River alluvium

Aquifer: Hunter River alluvium		
Category: Highly productive water source		
Level: 1 minimal impact consideration		
Water table	**Water pressure**	**Water quality**
1. Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan; or A maximum of a 2 m decline cumulatively at any water supply work.	1. A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work.	1. (a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity; and (b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a "reliable water supply" is not an appropriate mitigation measure to meet considerations 1.(a) and 1.(b) above. (c) No mining activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100 m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply". (d) Not more than 10% cumulatively of the three dimensional extent of the alluvial material in this water source to be excavated by mining activities beyond 200 m laterally from the top of high bank and 100 m vertically beneath a highly connected surface water source that is defined as a "reliable water supply".

Table 3 Level 1 minimal impact considerations for aquifer interference policy – Saddlers Creek alluvium

Aquifer: Saddlers Creek alluvium		
Category: Less productive water source		
Level: 1 minimal impact consideration		
Water table	**Water pressure**	**Water quality**
1. Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan; or A maximum of a 2 m decline cumulatively at any water supply work.	1. A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work.	1. (a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity; and (b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a "reliable water supply" is not an appropriate mitigation measure to meet considerations 1.(a) and 1.(b) above. (c) No mining activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100 m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply". (d) Not more than 10% cumulatively of the three dimensional extent of the alluvial material in this water source to be excavated by mining activities beyond 200 m laterally from the top of high bank and 100 m vertically beneath a highly connected surface water source that is defined as a "reliable water supply".

Table 4 Level 1 minimal impact considerations for aquifer interference policy – Permian coal measures

Aquifer: Permian coal measures (porous or fractured rock)		
Category: Less productive water source		
Level: 1 minimal impact consideration		
Water table	**Water pressure**	**Water quality**
Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan. A maximum of a 2 m decline cumulatively at any water supply work.	A cumulative pressure head decline of not more than a 2 m decline, at any water supply work.	Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.

4.4.2 Groundwater quality protection

The *NSW Groundwater Quality Protection Policy* (1998), states that the objectives of the policy will be achieved by applying the management principles listed below:

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

4.4.3 Groundwater dependent ecosystems

The NSW GDE Policy is specifically designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored for the benefit of present and future generations. The policy defines GDEs as "*communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater*".

Five management principles establish a framework by which groundwater is managed in ways that ensure, whenever possible, that ecological processes in dependent ecosystems are maintained or restored. A summary of the principles follows:

- GDEs can have important values. Threats should be identified and action taken to protect them;
- groundwater extractions should be managed within the sustainable yield of aquifers;
- priority should be given to GDEs, such that sufficient groundwater is available at all times to meet their needs;
- where scientific knowledge is lacking, the precautionary principle should be applied to protect GDEs; and
- planning, approval and management of developments should aim to minimise adverse effects on groundwater by maintaining natural patterns, not polluting or causing changes to groundwater quality and rehabilitating degraded groundwater ecosystems where necessary.

4.4.4 Groundwater quantity protection

The objectives of managing groundwater quantity in NSW are to (NOW, 2012a):

- "*achieve the efficient, equitable and sustainable use of the State's groundwater;*
- *prevent, halt and reverse degradation of the State's groundwater and their dependent ecosystems;*
- *provide opportunities for development which generate the most cultural, social and economic benefits to the community, region, state and nation, within the context of environmental sustainability; and*
- *involve the community in the management of groundwater resources*."

4.4.5 Strategic Regional Landuse Policy and Plan – Upper Hunter

The NSW government has released the SRLUP for the Upper Hunter region of the state. The SRLUP maps have used the extent of the Hunter River alluvium to designate the Biophysical Strategic Agricultural Land (BSAL) located nearest to the Project. The maps within the plan indicate that there is no BSAL located with the Project Boundary.

Further field survey assessment was undertaken in accordance with process provided in *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007* and verified that approximately 78.8 ha of land within the Project Boundary meets the assessment criteria for BSAL. This assessment is provided in full as Appendix B of the Drayton South Gateway Certificate Application Report and described in the main volume of the EIS. .

The maps within the SRLUP indicate that there is no critical industry clusters (CICs) located with the Project Boundary. As such the EIS is not required to address the gateway criteria for CICs.

5. Previous hydrogeological studies

Groundwater and surface water management studies were first conducted over the Project area by Mackie Environmental Research (MER, 1998). This early study provided preliminary measurements of hydraulic parameters and identified potential water management issues for a conceptual open cut and underground mine plan. The 1998 study included regional data gathering, installation of eight piezometers into coal measures, core inspections and laboratory testing, formation hydraulic testing, and monitoring of groundwater levels. The study identified moderately saline, low permeability aquifers within coal measures, and alluvial/colluvial aquifers along Saddlers Creek and the Hunter River.

Computer based groundwater flow modelling conducted by MER in 1998, was also undertaken to simulate the underground and open cut mining scenarios. Based on the mine plans at the time, the groundwater model predicted that open cut mining would not induce leakage from the Hunter River, but the underground mine plan had the potential to induce leakage from the river to the longwall operations. The report concluded that the impact to the surrounding groundwater system by the proposed mine was low, and suggested the viticultural activities within the Arrowfield Winery Estate would not be affected by open cut mining operations.

MER (2000) was commissioned to undertake a review of water management aspects of the Drayton South Project based on alternative mine plans. These plans contained simultaneous open cut and shallow underground operations. Pre-feasibility studies assessed the likely groundwater seepage rates to the open cut and underground operations. Findings indicated that open cut operations would not induce significant rates of seepage.

In 2001, MER was again commissioned to consolidate hydrogeological data arising from the 2001 exploration drilling program targeting the deeper Woodlands Hill, Arrowfield, Bowfield, and Warkworth coal seams. During this program, hydrogeological information continued to be gathered in order to more fully appreciate the regional hydrogeology and the potential impacts of groundwater seepage on future open cut or underground mine operations. In particular, airlift yield measurements were obtained from exploration bores, water sampling was undertaken to further characterise groundwater quality, three more piezometers were installed, and monitoring of the existing monitoring bore network continued.

In 2012, AGE used a numerical groundwater flow (MODFLOW) model to assess the impact of the Drayton South Project on the groundwater regime for an Environmental Assessment (EA). The model provided a range of predictions for the rate of groundwater seepage to the mined voids, the area of depressurisation, and post-mining impacts.

AGE subsequently updated the groundwater model in 2014 with a retracted mine plan to re-simulate groundwater inflow into the mining areas, and predicted the associated impacts on the surrounding groundwater regime.

AGE have also undertaken impact assessment studies involving finite element modelling in obtaining approvals for nearby mines; Mt Arthur North (MAN) (AGE, 2006; AGE, 2007, and AGE, 2009), the Drayton Mine Extension (AGE, 2006), and the Bengalla Mine Wantana Extension (AGE, 2007).

Data from all of the above studies have been used in undertaking the current assessment.

6. Regional setting

6.1 Location

The Project is located wholly within EL 5460, in the Upper Hunter Valley of NSW. The closest regional centre is Jerrys Plains, located approximately 10 km south-east of the Project. The larger township of Muswellbrook is located approximately 13 km north of the Project.

6.2 Landuse

The major industries surrounding the Project are agriculture, equine industries, viticulture, power generation, and mining. The land to the north of the study area is associated with coal mines including Mt Arthur Coal Mine and Drayton Mine. Dellworth (EL 6812) adjoins the study area to the immediate north-east and east, and Spur Hill (EL 7429) adjoins the study area to the west. Bayswater and Liddell Power Stations (both operated by Macquarie Generation) are located approximately 5 km and 7.5 km to the north-east of the Project, respectively.

The land surface within the Project boundary is primarily cleared, open paddock grazing land, with limited native remnant vegetation.

6.3 Climate

The climate of the region is temperate and characterised by hot summers and mild dry winters. Two long standing Bureau of Meteorology (BoM) rainfall gauges are located in proximity to the Project, one in the township of Jerrys Plains (Station No. 061086), and a second at Scone (Station No. 061089) located about 40 km north.

Mean monthly temperatures and rainfall are available from the Jerrys Plains Station for the period 1884 to 2011. The average annual rainfall at Jerrys Plains is 644.7 millimetres (mm), of which the majority falls in the warmer months of the year (November to February), with January being the wettest month (77 mm).

Jerrys Plains has mean maximum temperatures ranging from 31.7°C in January to 17.4°C in July. Mean minimum temperatures range from 17.1°C in January and February to 3.8°C in July. Heat waves can occur between October and March, and frosts between May and August.

The closest weather station to the Project recording evaporation is located at the Scone BoM Station. Mean daily pan evaporation in the summer season reaches 7.1 mm in December and January, and 1.6 mm in June. Average daily evaporation of 4.4 mm/day (1606 mm/year) exceeds mean rainfall throughout the year, the highest moisture deficit occurring during summer.

In order to place recent rainfall years into an historical context, the Cumulative Rainfall Departure (CRD) was calculated. This is a summation of the monthly departures of rainfall from the long-term average monthly rainfall. A positive slope in the CRD plot indicates periods of above average rainfall, whilst a negative slope indicates periods when rainfall is below average. Figure 2 shows the calculated CRD for the Jerrys Plains BoM Station.

The CRD indicates that the area experienced above average rainfall from 2006 up to about March 2012, and has since been below average.

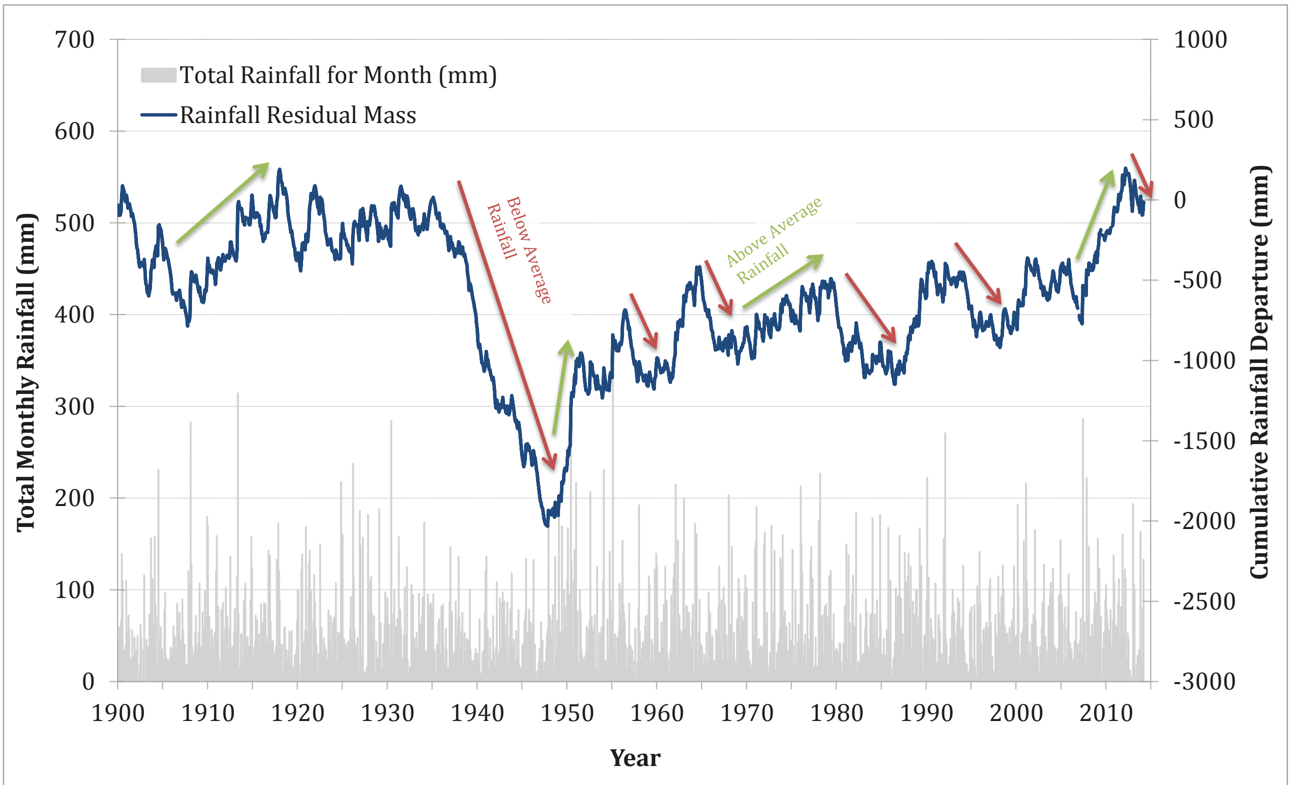


Figure 2 Cumulative rainfall departure – Jerrys Plains (Station No. 061086)

6.4 Topography and drainage

The outcrop of the coal measures forms the undulating hills on which the Project is situated. Flat alluvial flood plains flank the Hunter River and to a lesser degree along Saddlers Creek.

The undulating topography within the Project boundary creates numerous small gullies which drain into Saddlers Creek. The gullies are predominantly dry, flowing only for a short periods after rainfall. The ephemeral nature of the gullies suggests they do not receive a significant amount groundwater discharge from the fractured bedrock.

The headwaters of Saddlers Creek are located towards the north-east, near the existing Drayton Mine. Saddlers Creek is ephemeral and only flows after significant rainfall. Saddlers Creek is known to have periods of low flow driven by groundwater discharge of poor quality (MineCraft, 2006).

Saddlers Creek flows in a south-westerly direction and discharges into the Hunter River near the south-western corner of EL 5460. The ground immediately adjacent to Saddlers Creek is flat. However, away from the creek, the land is undulating to hilly with slopes between 20% and 30%.

The topographic elevation is approximately 150 m to 200 m above the Australian Height Datum (AHD) along the northern boundary of the Project, decreasing to 110 mAHD where Saddlers Creek bisects the western portion of the Project boundary. The proposed mining operation will not intersect any part of Saddlers Creek or the associated alluvium.

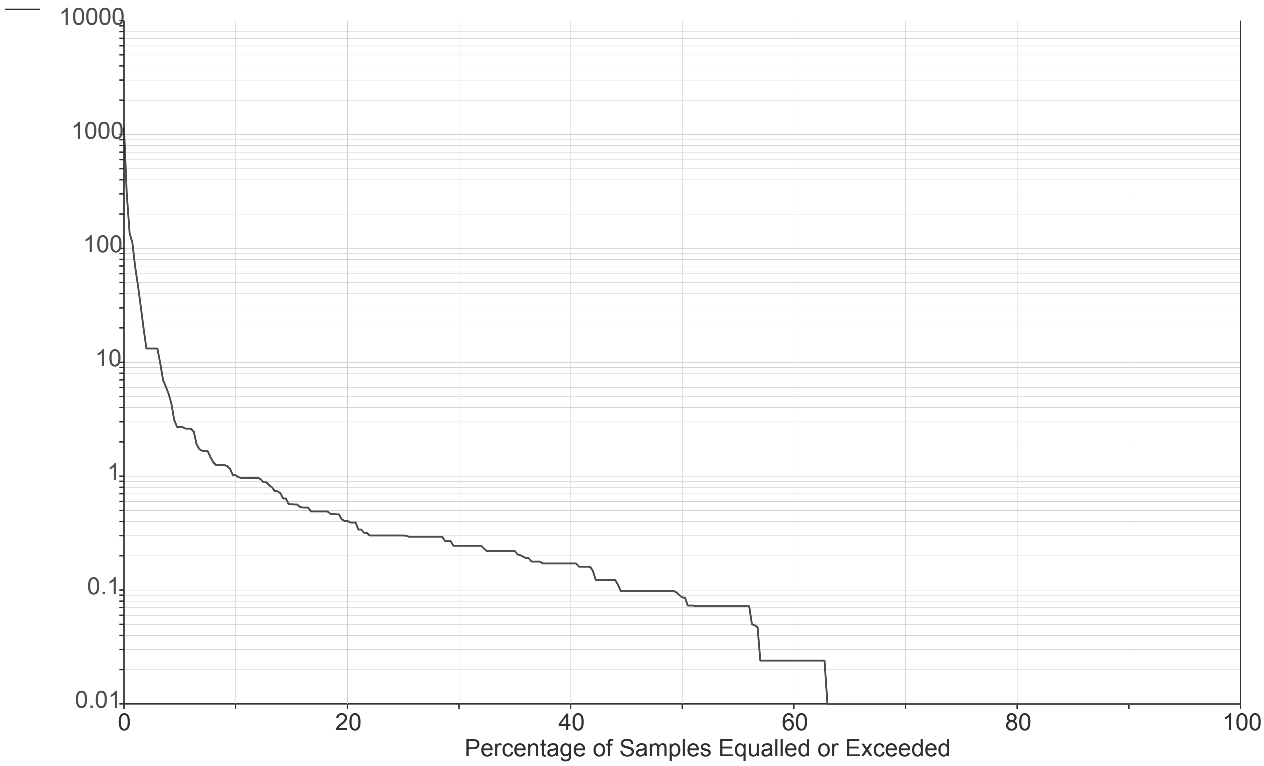
The Hunter River is located about 2.2 km south of the proposed mining areas and meanders from the north-west to the south-east. The Hunter River is constantly flowing (i.e. perennial), has a large catchment and an elevation of about 75 mAHD near the Project.

Plashett Dam was built to provide a secure water supply for the nearby Bayswater Power Station. The dam is situated on Saltwater Creek which only flows during times of dam discharge into the Hunter River.

6.5 River and stream flows

6.5.1 Saddlers Creek

Flow records exist for Saddlers Creek for the period from 1956 to 1981 from a gauge located on the Bowfield property. Figure 3 shows the flow-duration relationship for the recorded flows at the Bowfield Gauge (GS 210043). While no flow occurred for 35% of the recording period, flow rates less than 1 megalitre per day (ML/day) were noted across the majority of the recording period. Flow exceeded 1 ML/day for 10% of the recording period and flows above 100 ML/day occurred for 1% of the time with a single event above 1,000 ML/day appearing in the records. Extended periods of baseflow are evident indicating that the system is fed by groundwater flow. The median flow is 0.09 ML/day and the highest recorded daily flow over the period of record is 1,137 ML/day. However, there is likely to be a high level of uncertainty associated with the data for Saddlers Creek. An accurate relationship between water level and stream flow is not available because very few stream gauge measurements greater than 10 ML/day have been recorded (WRM, 2012).

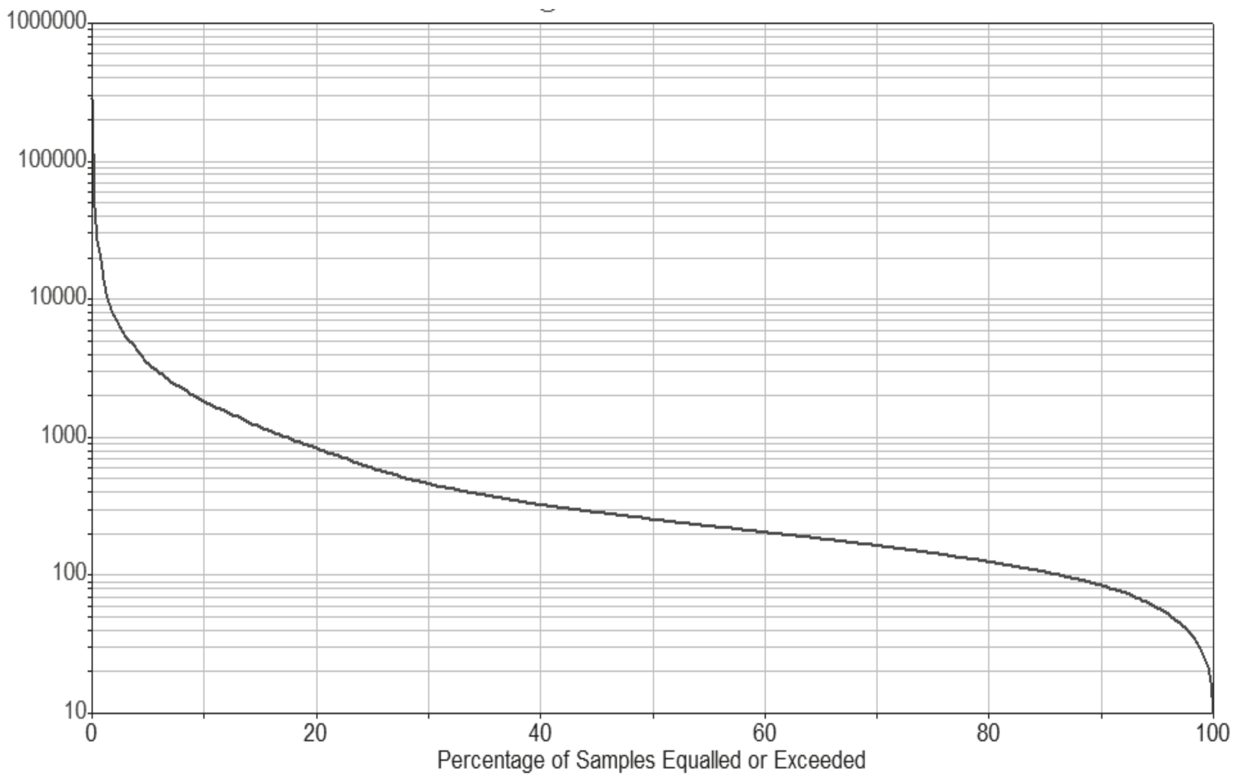


Source: NOW, 2014

Figure 3 Derived flow-duration relationship for Saddlers Creek at Bowfield (1956-1981)

6.5.2 Hunter River

Figure 4 shows the flow-duration relationship for the recorded Hunter River flows at the Liddell gauge (GS 210083). The Liddell gauge is closest to the Project, located approximately 9 km downstream of the Project with an upstream catchment of 13,400km². Data has been collected at Liddell since 1969. The flow-duration relationship indicates that flow is non-zero all of the time, which is characteristic of regulated river systems. The median flow is about 270 ML/day and flows exceed 1,000 ML/day about 8% of the time. The volumetric runoff coefficient (rainfall to runoff relationship) of the Hunter River flows to Liddell is approximately 4% (WRM, 2012).



Source: http://realtimedata.water.nsw.gov.au/water.stm

Figure 4 Recorded flow-duration relationship for the Hunter River at Liddell (1969-2015)

7. Geology

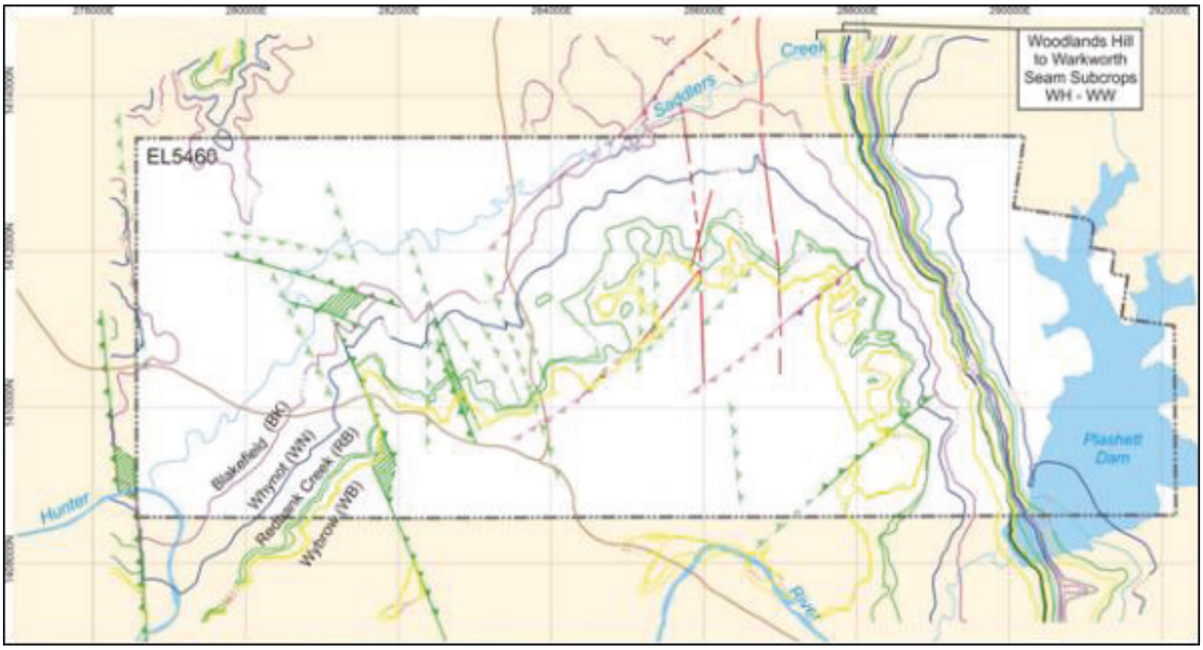
7.1 Lithology and stratigraphy

The underlying geology of the Project comprises:

- Quaternary alluvial deposits; and
- Permian coal measures.

The Permian coal measures are described as the Singleton Supergroup (formerly known as the Singleton Coal Measures). The Singleton Supergroup incorporates several geological subgroups including the Newcastle Coal Measures, Tomago Coal Measures, Watts Sandstone and the Wittingham Coal Measures.

The Project is located on the western side of the Muswellbrook Anticline within the Jerrys Plains Subgroup of the Late Permian Wittingham Coal Measures. These coal measures outcrop in the north of EL 5460 and along the strike of the Muswellbrook Anticline as shown on Figure 5.



Source: MineCraft, 2006

Figure 5 Coal seam subcrop within EL 5460

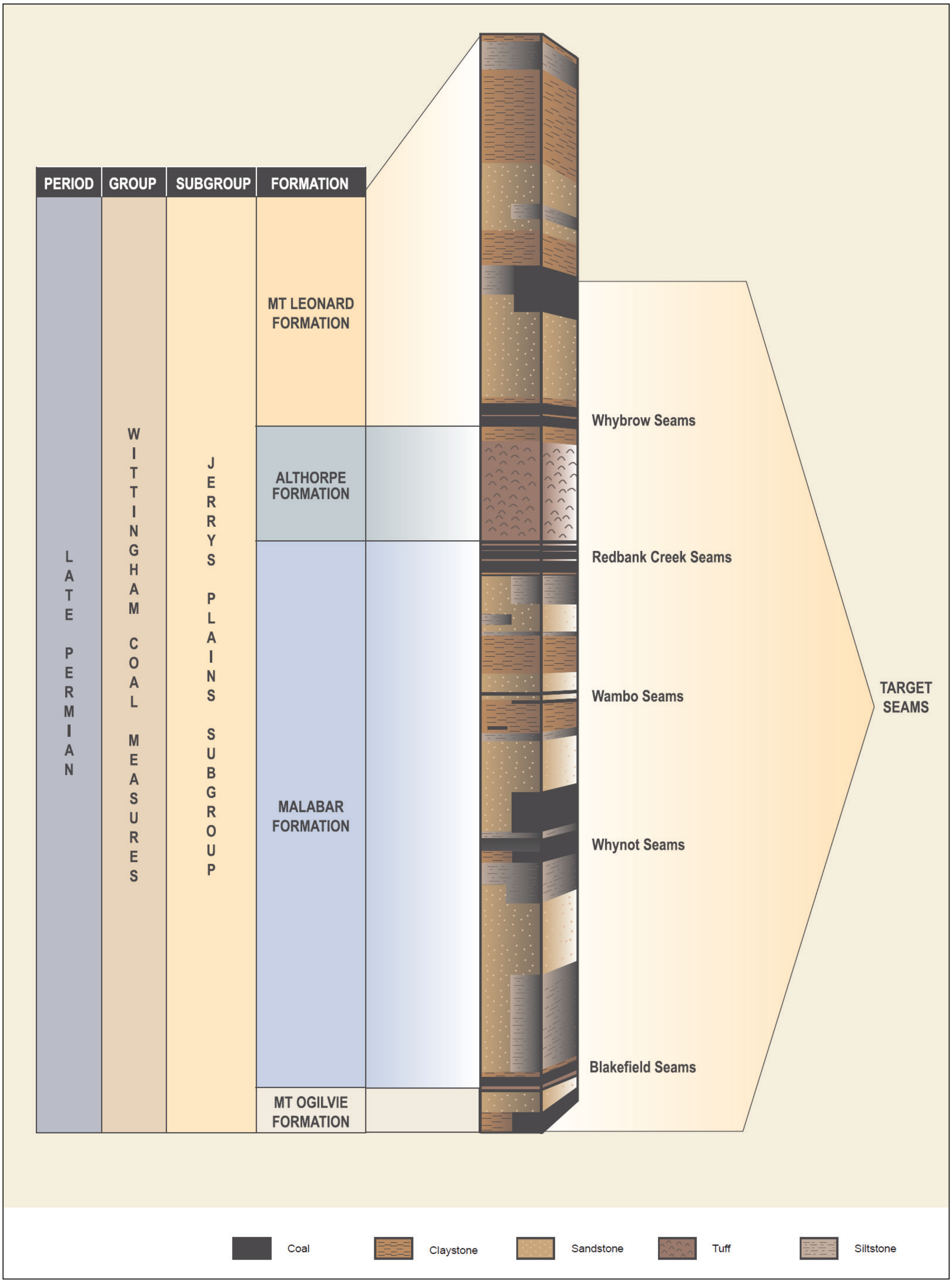
Five coal seams are proposed to be mined by the Project, these are (in descending stratigraphic order):

1. Whybrow Seam;
2. Redbank Creek Seam;
3. Wambo Seam;
4. Whynot Seam; and
5. Blakefield Seam.

The coal seams generally dip gently to the south-west and are separated by interburden comprising siltstone, sandstone, claystone, and tuff. A stratigraphic summary is given in Table 5 and a typical stratigraphic column of the Jerrys Plains Subgroup is shown in Figure 6.

Table 5 Summary of stratigraphic sequence

Age	Group	Sub-group	Coal seams	Lithology
Quaternary	-	-	-	Residual soils and colluvium units including all blanketing sandy, loamy and clay soils
Permian	Wittingham Coal Measures	Jerrys Plains Subgroup	Whybrow	Coal seams, claystone, tuff, siltstone, sandstone and conglomerate
			Redbank Creek	
			Wambo	
			Whynot	
			Blakefield	



Source: Anglo American, 2011

Figure 6 Stratigraphic column of Jerrys Plains Subgroup

The Permian coal measures within the study area are overlain by thin unconsolidated Quaternary age deposits along the alignments of Saddlers Creek and the Hunter River. The Quaternary deposits consist of silts, sand, and minor fine gravels of mixed colluvial-alluvial origin. There is limited public domain data available for the Quaternary unit associated with Saddlers Creek. However, recent drilling has confirmed that this unit is thin, averaging less than 10 m thickness.

Data held by NOW suggests that the alluvial deposits of the Hunter River to the immediate south of the Project are up to 20 m thick with basal gravel varying between 2.5 m and 4 m in thickness. The material overlying the basal gravel consists predominantly of silt with minor clay.

7.2 Structural geology

The geology within the region of the Project has a moderate level of structural complexity. Notably, the axis of the south-southeast plunging Muswellbrook Anticline is located to the east of the Project. Here, the strata dip steeply (from approximately 20° to > 40°) to the west-southwest from the seam outcrop along the anticline's western limb. Dip of the strata across the remainder of the study area flattens and is gentle at 3° to 5°, towards the south-west. Figure 7 shows a section from the geological model indicating the nature of the folding.

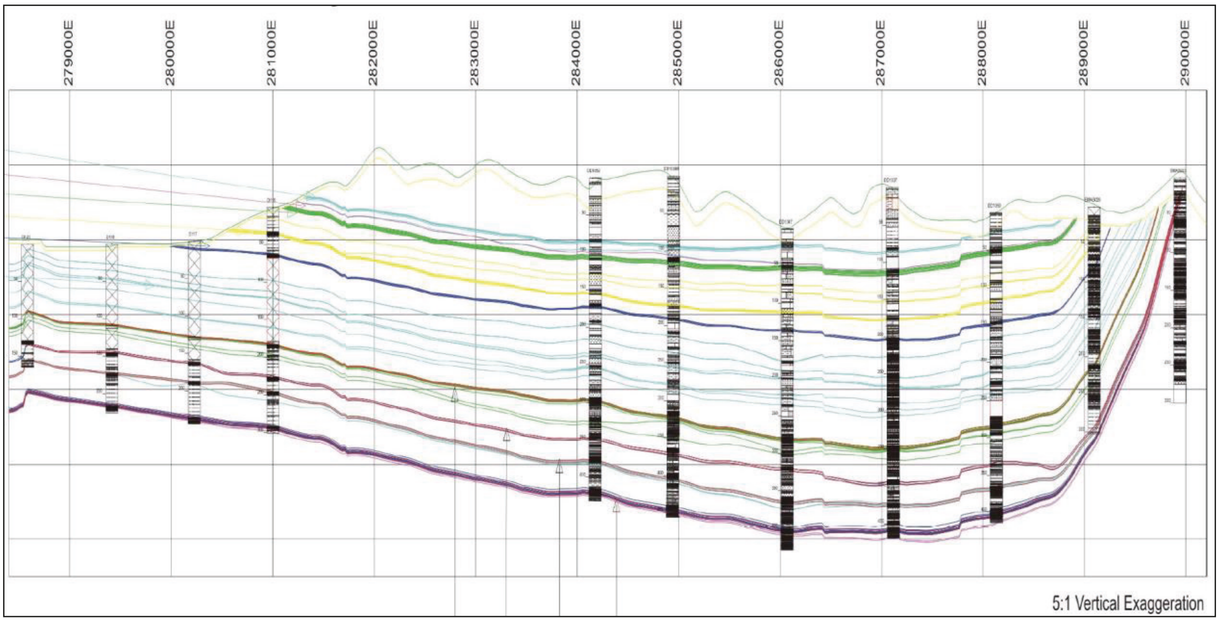
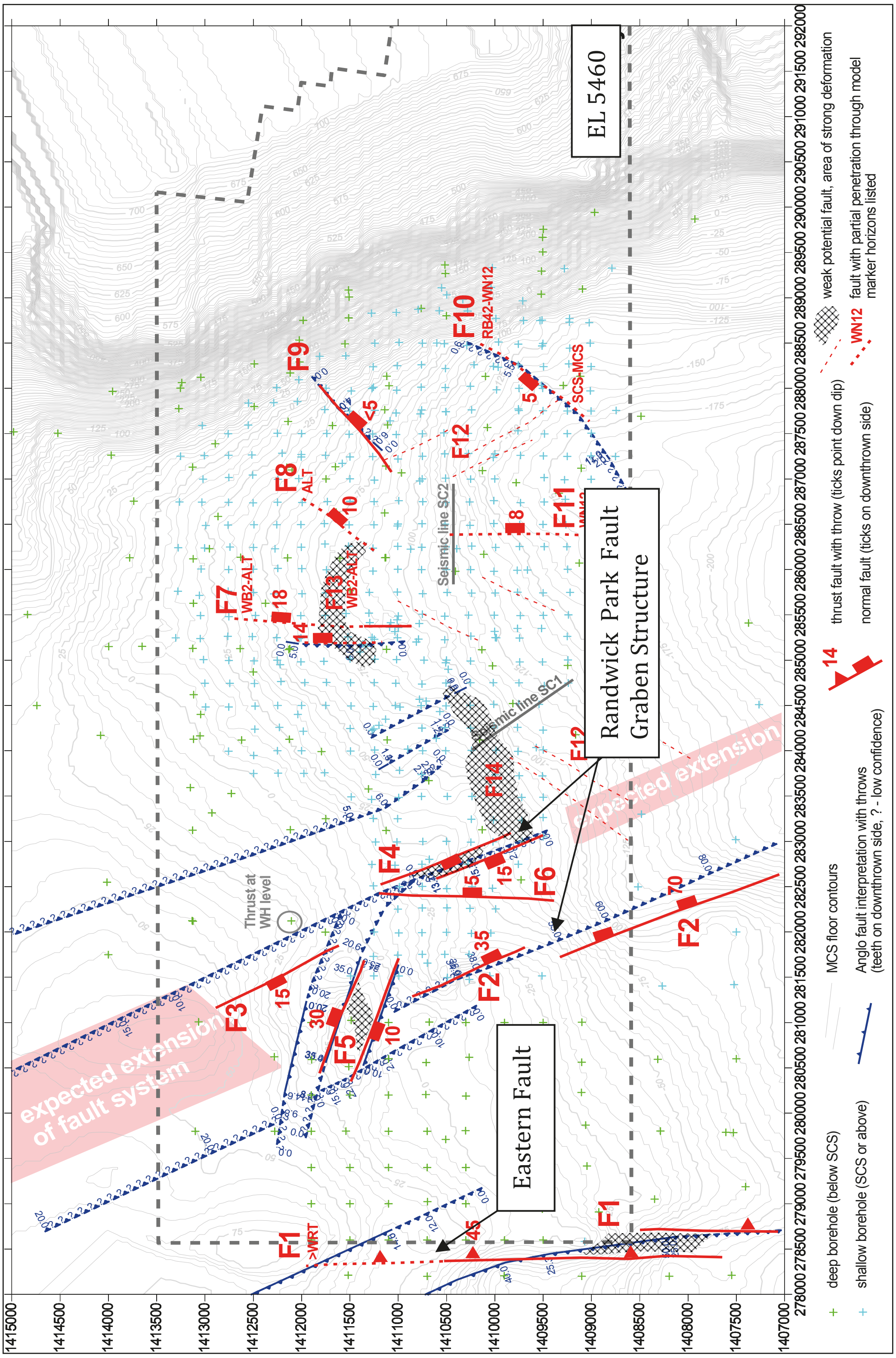


Figure 7   Section showing folding within coal measures

7.3 Faulting

Major faulting within the study area is uncommon. However, several faults have been identified within the vicinity, including the:

- north trending Mount Ogilvie Fault that forms a structural boundary about 2 km west of the Project. The regional displacement (down-throw to the west) is greater than 150 m;
- Eastern Fault, located proximal to the western boundary of EL 5460 (Figure 8) that has a down-throw to the west of greater than 50 m; and a
- north-northwest trending graben structure (Randwick Park Fault) is located to the immediate west of the Project. The structure varies in width from 1.1 km to 1.3 km and has variable down throws to 60 m. The northern and southern extents of the graben block are not well defined. The graben fault system contains short overlapping fault segments connected by more structurally complex zones (CSIRO, 2003).



Source: CSIRO, 2003

Figure 8 Locations of interpreted faults

8. Groundwater monitoring network

8.1 Drayton Mine

The Drayton Mine currently undertakes groundwater monitoring in accordance with its Environmental Approval. This monitoring program will continue and will be augmented by the groundwater monitoring program for the Project. Therefore, a common groundwater monitoring program will be undertaken for the entire Drayton Mine complex.

The Drayton Mine has had a groundwater monitoring network in place for the life of the mine. As mining has progressed, a number of bores have been destroyed over time. The groundwater monitoring network covering the Drayton Mine currently consists of 15 bores. Long-term data is available from all of these bores, with some bores providing data in excess of thirty years. Table 6 provides a summary of the bore coordinates, depth, and monitoring period. Seven bores were installed in 1982, two were installed in 2000, and six were installed in 2005. All of the monitoring bores located at the Drayton Mine target the Permian coal measures.

Table 6 Monitoring bore construction summary – Drayton Mine

Bore name	Easting (MGA94, z56)	Northing (MGA94, z56)	Ground level (mAHD)	Total depth (mbgl)	Data range
F1024	305761	6419755	236.70	236	1982 – ongoing
F1162	304256	6420755	228.20	274	1982 – ongoing
F1163	301045	6415695	194.70	384	1982 – ongoing
F1164	304223	6420406	220.80	191	1982 – ongoing
F1167	305124	6421790	230.50	314	1982 – ongoing
F1168	305235	6420774	212.90	189	1982 – ongoing
R4171A	304821	6419129	229.62	138	2000 – ongoing
R4171B	304821	6419128	229.62	138	2000 – ongoing
R4214	304606	6416180	257.89	136	2005 – ongoing
R4220	304968	6416196	228.42	119	2005 – ongoing
R4224	305473	6416199	202.98	133	2005 – ongoing
R4241	305853	6416205	195.98	150	2005 – ongoing
R4243	304231	6416180	290.41	142	2005 – ongoing
R4258	304364	6420217	225.10	176	2005 – ongoing
W1102	300984	6416044	186.70	23	1982 – ongoing

Note: *mbgl = metres below ground level*

8.2 Drayton South

The Project area has had a groundwater monitoring network in place since 1998. The monitoring network has progressively been expanded and now comprises 23 monitoring bores and seven vibrating wire piezometers (VWPs) including:

- six monitoring bores installed in 1998;
- eight bores installed between 2000 and 2003;
- two VWPs installed in 2010; and
- nine monitoring bores and five VWPs installed in 2011.

Table 7 and Table 8 provide a summary of the network coordinates, depth, and monitoring period. Figure 9 shows the location of the monitoring bores and VWPs. The monitoring bores installed in the 1990s and early 2000s targeted the Permian coal measures, with the majority of these bores located within the footprint of the proposed mining areas. These bores will be removed progressively by mining.

The early network was augmented in 2011 by the addition of four sites (which have clustered bores) along the alignments of Saddlers Creek and the Hunter River. The recently installed monitoring bores will remain (during and post mining) to allow regional monitoring. All of the VWPs target the coal measures, and all but one of them are located between the coal deposit and the Hunter River.

The early network of monitoring bores (i.e. 1982 to 2003) were installed in exploration holes drilled into the coal measures. Geological logs are available for the exploration drill holes. However, no records of monitoring bore construction or screen intervals are available. Appendix A contains construction logs for the monitoring bores installed in 2011.

Table 7 Monitoring bore construction summary – Drayton South

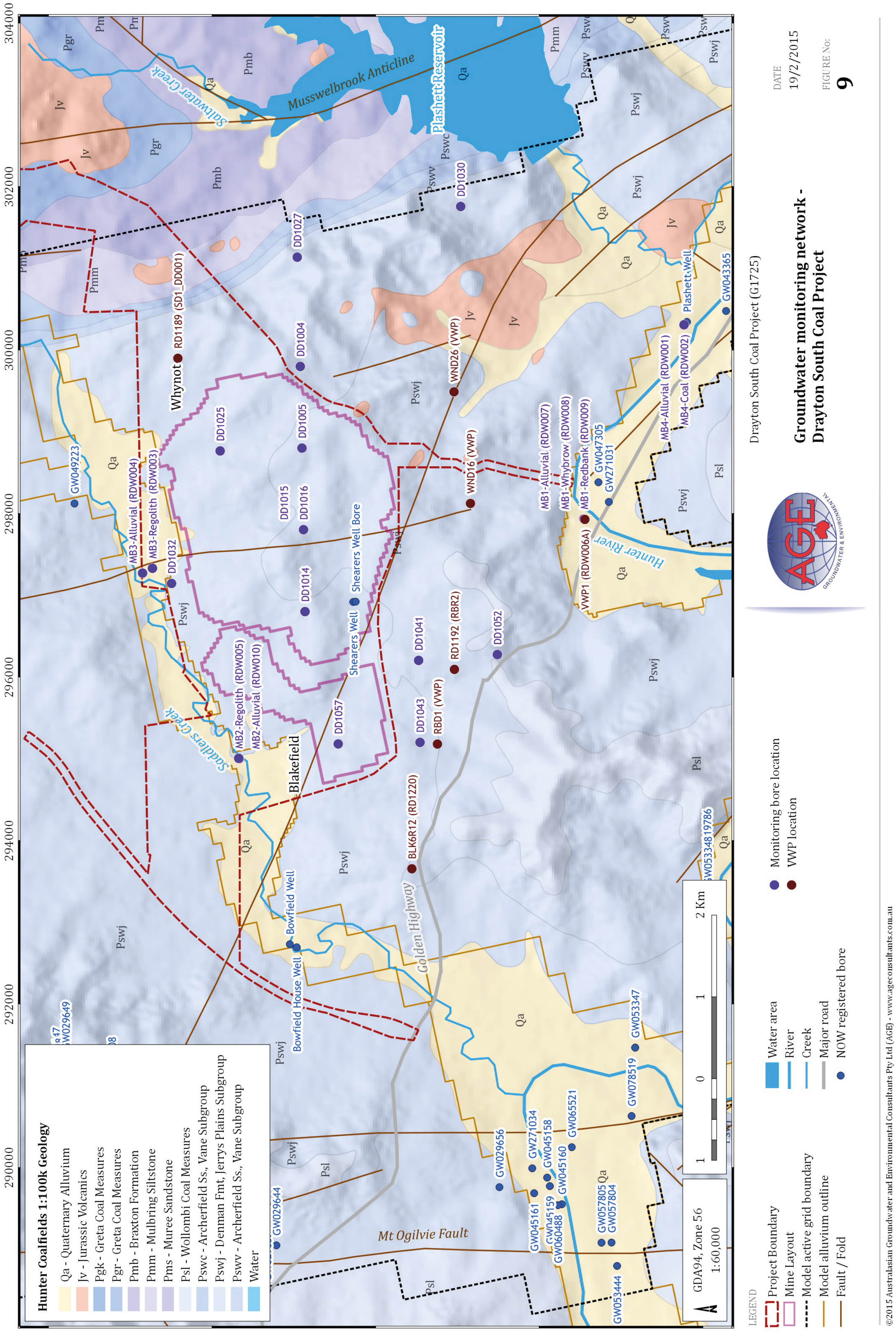
Bore name	Easting (MGA94, z56)	Northing (MGA94, z56)	Ground level (mAHD)	Total depth (mbgl)	Monitoring bore screen interval (mbgl)	Data range
DD1004	299798	6410922	217.38	105.74	-	Oct 1998 – ongoing
DD1005	298799	6410901	225.02	138.55	-	Oct 1998 – ongoing
DD1014	296799	6410864	183.40	90.48	-	Sep 1998 – ongoing
DD1015	298815	6409900	212.65	162.5	-	Oct 1998 – ongoing
DD1016	297801	6410882	201.15	126.4	-	Oct 1998 – ongoing
DD1025	298764	6411901	169.81	44.62	-	Aug 1998 – ongoing
DD1027	301133	6410960	235.82	252.75	-	July 2000 – ongoing
DD1030	301754	6408961	160.08	282.48	-	July 2000 – ongoing
DD1032	297143	6412495	140.25	276.46	-	July 2001 – ongoing
DD1041 – Deep	296202	6409476	187.32	387.32	-	July 2001 – ongoing
DD1041 – Shallow				-		
DD1043	295200	6409458	173.78	203	182 – 203	Apr 2003 – ongoing
DD1052	296274	6408513	183.12	127	105 – 127	Apr 2003 – ongoing
DD1057	295181	6410458	146.93	188	164 – 188	Apr 2003 – ongoing

Bore name	Easting (MGA94, z56)	Northing (MGA94, z56)	Ground level (mAHD)	Total depth (mbgl)	Monitoring bore screen interval (mbgl)	Data range
MB1-Alluvial	297933	6407459	81.01	11	8 - 11	Aug 2011 - ongoing
MB1-Whybrow	297928	6407448	80.84	30	25 - 28	Aug 2011 - ongoing
MB1-Redbank	297930	6407453	80.89	60	51 - 57	Aug 2011 - ongoing
MB2-Alluvial	294998	6411669	115.34	7	5 - 7	Aug 2011 - ongoing
MB2-Regolith	295004	6411675	115.43	30	20 - 29	Aug 2011 - ongoing
MB3-Alluvial	297269	6412850	132.72	16	8.5 - 14.5	Aug 2011 - ongoing
MB3-Regolith	297328	6412729	137.34	30	27 - 30	Aug 2011 - ongoing
MB4-Alluvial	300302	6406234	81.43	20	10 - 18	Aug 2011 - ongoing
MB4-Coal	300307	6406231	81.34	60	42 - 47	Aug 2011 - ongoing

Table 8 VWP construction summary – Drayton South

VWP name	Easting (MGA94, z56) (m)	Northing (MGA94, z56) (m)	Ground RL (mAHD)	Total depth (mbgl)	Sensor positions (mbgl)	Date installed
RD1189 (SD1_DD001)	299896.4	6412419	208.63	322	Woodlands Hill Seam – 78.9 mbgl ZZBF Seam – 145.5 mbgl Warkworth Seam – 186.2 mbgl Mt Arthur Seam – 230 mbgl Piercefield Seam – 255.5 mbgl Bayswater Seam – 315 mbgl Wynn Seam – 322 mbgl	2010
RD1192 (RBR2)	296091.8	6409038	177.06	148.5	Wambo Seam – 61.2 mbgl Redbank Seam – 80 mbgl Blakefield Seam – 148.5 mbgl	2010
BLK6R12 (RD1220)	293653.1	6409558	186.25	135	Whybrow Seam – 25 mbgl Redbank Seam – 40.5 mbgl Whynot Seam – 86.5 mbgl Blakefield Seam – 113.7 mbgl	August 2011
VWP1 (RD1221) (RDW006A)	297925.7	6407444	80.96	155	Interburden – 21 mbgl Interburden – 40 mbgl Interburden – 73 mbgl Whybrow Seam – 87 mbgl Whynot Seam – 109.2 mbgl Blakefield Seam – 138 mbgl	August 2011

VWP name	Easting (MGA94, z56) (m)	Northing (MGA94, z56) (m)	Ground RL (mAHD)	Total depth (mbgl)	Sensor positions (mbgl)	Date installed
RBD1 (VWP) (DD1170)	295178.4	6409246	169.55	111.29	Whybrow Seam – 24.65 mbgl Redbank Seam – 33.55 mbgl Whynot Seam – 79.5 mbgl Blakefield Seam – 103.3 mbgl	April 2011
WND16 (VWP) (DD1188)	298121.5	6408842	130.58	126.16	Wambo Seam – 33.75 mbgl Whynot Seam – 59.25 mbgl Blakefield Seam – 90.15 mbgl Blakefield Seam – 110.5 mbgl	May 2011
WND26 (VWP) (DD1187)	299486.6	6409044	163.71	152	Whybrow Seam – 77.3 mbgl Redbank Seam – 84.6 mbgl Wambo Seam – 123.45 mbgl Whynot Seam – 144.25 mbgl	May 2011


Groundwater monitoring network - Drayton South Coal Project
Drayton South Coal Project (G1725)
DATE 19/2/2015
FIGURE No: 9
Hunter Coalfields 1:100k Geology
Qa - Quaternary Alluvium
Jv - Jurassic Volcanics
Pgk - Greta Coal Measures
Pgr - Greta Coal Measures
Pmb - Braxton Formation
Pmm - Mulbring Siltstone
Pms - Muree Sandstone
Psl - Wollombi Coal Measures
Pswc - Archerfield Ss., Vane Subgroup
Pswj - Denman Fmt, Jerrys Plains Subgroup
Pswv - Archerfield Ss., Vane Subgroup
Water
LEGEND
Project Boundary
Mine Layout
Model active grid boundary
Model alluvium outline
Fault / Fold
Water area
River
Creek
Major road
NOW registered bore
Monitoring bore location
VWP location
GDA94, Zone 56
1:60,000
2 Km
Musswelbrook Anticline
Saltwater Creek
Plashett Reservoir
Saddlers Creek
Hunter River
Golden Highway
Mt Ogilvie Fault
Whynot
Blakefield
Shearers Well Bore
Shearers Well
Bowfield Well
Bowfield House Well
Plashett Well
RD1189 (SD1_DD001)
DD1027
DD1030
DD1004
DD1025
DD1005
DD1015
DD1016
DD1014
DD1032
DD1041
DD1043
DD1052
DD1057
WND26 (VWP)
WND16 (VWP)
RD1192 (RBR2)
RBD1 (VWP)
BLK6R12 (RD1220)
VWP1 (RDW006A)
MB3-Alluvial (RDW004)
MB3-Regolith (RDW003)
MB2-Regolith (RDW005)
MB2-Alluvial (RDW010)
MB1-Alluvial (RDW007)
MB1-Whybrow (RDW008)
MB1-Redbank (RDW009)
MB4-Alluvial (RDW001)
MB4-Coal (RDW002)
GW049223
GW047305
GW271031
GW043365
GW029644
GW029649
GW029656
GW271034
GW045158
GW045160
GW045161
GW045159
GW060488
GW065521
GW057805
GW057804
GW078519
GW053347
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9. Hydrogeological regime

9.1 Hydrostratigraphic units

The groundwater regime in the Project area consists of four hydrostratigraphic units, including:

- alluvium associated with the Hunter River;
- alluvium associated with Saddlers Creek;
- shallow weathered bedrock (regolith); and
- coal seams and interburden of the Permian Wittingham Coal Measures.

The sections below detail the properties of the hydrostratigraphic units.

9.1.1 Hunter River alluvium

9.1.1.1 Distribution

Alluvial deposits along the Hunter River are known to be highly productive aquifers. Data held by the NOW indicate the Hunter River alluvium is up to 20 m thick with sand and gravel deposits that fill paleo-channels. The material overlying the basal gravel is less permeable and consists predominantly of silt with minor clay.

9.1.1.2 Yield and use

Groundwater yield from the Hunter River alluvium is often sufficient to warrant exploitation for stock and domestic supplies by bores and wells. Data provided by NOW for stock and irrigation bores located immediately south and south west of the Project, indicates bore yields vary from 0 L/s to 21 L/s. The NOW 2009 Report Card for the Jerrys Plains Water Source does not report any groundwater entitlements.

9.1.1.3 Hydraulic parameters

A hydraulic conductivity value of 2×10^{-1} m/day was calculated from a falling head test performed at MB1-Alluvial. Elsewhere in the Hunter Valley, the alluvium is known to have a highly variable hydraulic conductivity that is dependent on the grain size of the sediments. This can potentially lead to more productive sands and gravels having a hydraulic conductivity of between 1 m/day and 1×10^{2} m/day.

9.1.1.4 Groundwater quality and environmental value/beneficial use

The salinity of the water samples can be categorised based on Total Dissolved Solids (TDS) concentrations as follows:

- Fresh water <500 mg/L
- Slightly Brackish 500 to 1000 mg/L
- Brackish 1000 to 3000 mg/L
- Moderately saline 3000 to 7000 mg/L
- Saline 7000 to 14000 mg/L
- Highly saline 14000 to 35000 mg/L
- Brine >35000 mg/L

Water quality within the Hunter River alluvial aquifer is known to be variable from fresh to moderately saline, with TDS concentrations ranging from about 400 mg/L to about 4000 mg/L (AGE, 2012). Discharge of saline water under pressure from the coal measures to the alluvium can result in pockets of variably saline quality water. The pH ranges from 6.9 to about 8.4, that is, from slightly acidic to slightly alkaline.

The Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) have prepared a guideline for water quality management for use throughout Australia and New Zealand based on the philosophy of ecologically sustainable development (ESD). The guideline is called the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) and is often referred to as the 'ANZECC guideline'.

The NSW Department of Environment and Conservation (now the NSW Office of Environment and Heritage) has prepared a booklet Using the ANZECC Guidelines and Water Quality Objectives in NSW (DEC, 2006) to assist with applying the ANZECC guidelines in NSW.

The NSW guideline defines the 'Environmental values' of receiving waters as those values or uses of water that the community believes are important for a healthy ecosystem. The environmental values of the receiving waters of the Hunter River are regarded as:

- aquatic ecosystem;
- irrigation water supply;
- livestock water supply;
- primary and secondary contact recreation; and
- visual amenity.

Groundwater within the Hunter River alluvium exhibits a higher quality compared with groundwater sourced from the underlying coal measures. However, the alluvial groundwater is typically not suitable for human consumption as it commonly has a TDS concentration above 500 mg/L.

The environmental value/beneficial use can be classified as primary industry with the main potential use being for stock watering, and limited irrigation where better water quality water is present.

9.1.1.5 Groundwater levels and recharge

Appendix B presents a series of hydrographs of groundwater levels from the Project monitoring bores. The hydrogeological regime indicates elevated groundwater levels and pressures within the coal measures which dissipate regionally through upward leakage into the alluvial systems along the Hunter River and Saddlers Creek.

The potentiometric surface grades from approximately 160 mAHD in the north-east, to 70 mAHD in the south near the Hunter River. The Hunter River provides a regional sink for both surface and groundwater drainage. Aquifer pressures within the coal measures adjacent to, or immediately beneath the river, exhibit higher levels than the river elevation thereby indicating a very slow upward leakage to the river and adjacent alluvial lands. This process is identified in the coal seam bores and VWPs located near the Hunter River. This process can result in pockets of variably saline water quality in the alluvium.

Recharge to the Hunter River alluvium occurs predominantly through infiltrating rainfall and runoff from adjacent bedrock areas. However, during very dry periods when groundwater levels are low, the Hunter River alluvium is recharged from regulated flow in the Hunter River. The regular flow in the Hunter River is maintained through the release of water from Glenbawn Dam upstream. Conversely, the alluvial aquifers provide water to the Hunter River as baseflow during periods of above average rainfall when groundwater levels are higher.

No field based studies of groundwater recharge into the Hunter River alluvium have been undertaken within the vicinity of the Project. Despite the lack of site data, recharge for the Hunter River alluvium is expected to fall between 5% and 15% of annual rainfall based on other investigations in the Hunter Valley area (MER, 2000; MER, 2007, and Mackie, 2009).

9.1.2 Saddlers Creek alluvium

9.1.2.1 Distribution

Deposits of mixed colluvial-alluvial origin occur in the valley of Saddlers Creek adjacent to the Project. The deposits are dominated by clay and silt, interspersed with thin lenses of sandy material. Bore logs indicate that these lenses are typically only a few metres thick.

The Saddlers Creek alluvium is thin and of limited areal extent due to a steep bed grade that prevents alluvial sediment being deposited. Often the distinction between alluvial-colluvial materials and the underlying regolith proves difficult to identify. Groundwater within the Saddlers Creek alluvium is limited and is restricted to thin sandy lenses.

9.1.2.2 Yield and use

The finer grained sediments of the Saddlers Creek alluvium and its thickness means it transmits much less water than the Hunter River alluvial deposits. Saddlers Creek has a poor capacity to store and transmit water and does not form a single, well-connected aquifer. Rather, the Saddlers Creek alluvium consists of poorly connected and isolated sandy lenses where rainfall infiltrates and accumulates following periods of heavy rainfall.

The Saddlers Creek alluvium is not commonly targeted for water supply. Only two privately owned bores (Bowfield House Well and Bowfield Well) are located within the alluvium.

9.1.2.3 Hydraulic parameters

Hydraulic conductivity values of 4.6×10^{-1} m/day and 8×10^{-2} m/day were calculated from falling head tests performed in MB2-Alluvial and MB3-Alluvial, respectively (AGE, 2012).

9.1.2.4 Groundwater quality and environmental value/beneficial use

Groundwater quality from the Saddlers Creek alluvium is typically moderately saline, with TDS concentrations ranging from 5700 mg/L to 6100 mg/L (AGE, 2012). Saddlers Creek alluvium is too saline for use in primary industries.

9.1.2.5 Groundwater levels and recharge

The upper reach of Saddlers Creek (near Drayton Mine) is above the regional groundwater table and receives no groundwater discharge. The upper reach therefore acts as a surface drainage feature rather than a sink for groundwater flow. This process is typical for ephemeral watercourses.

Further downstream, Saddlers Creek receives minor groundwater seepage via upward leakage from the underlying Permian coal measures.

Similar to the Hunter River, recharge to the Saddlers Creek alluvium occurs predominantly through infiltrating rainfall and runoff from adjacent bedrock areas.

9.1.3 Other creek systems

The remaining creeks located adjacent to the Drayton Mine (i.e. Ramrod Creek, Saltwater Creek, and Bayswater Creek) contain colluvial sediments. These colluvial deposits are thin, of limited areal extent, and do not have capacity to store useful volumes of groundwater. Recharge to this colluvium likely occurs following heavy rainfall. Water within the colluvium rapidly discharges into the creeks and gullies. However, discharge to the creeks is short lived. The fact that these creeks are ephemeral suggests they are not receiving a significant amount groundwater discharge from the fractured bedrock aquifer.

9.1.4 Weathered (regolith) bedrock

The weathered Permian bedrock (regolith) directly below the ground surface may have a higher hydraulic conductivity compared to the underlying fresh coal measures due to the effects of weathering. The depth of weathering varies, but generally extends to a depth of about 30 mbgl.

The regolith is likely to act as a temporary water storage during sustained wet periods and provides a source of recharge to the underlying coal measures. However, the volume of recharge to the underlying coal measures is limited given the very low hydraulic conductivity of deeper strata. This contrasting permeability between the regolith and underlying fresh coal measures can sometimes result in the presence of very minor springs or artesian conditions near changes of ground slope.

The yield from the regolith is not well documented within the NOW registered bore database, reflecting the limited storage and use of groundwater within the unit.

9.1.5 Permian coal measures

9.1.5.1 Distribution

The fresh unweathered Permian strata may be categorised into the following hydrogeological units:

- hydrogeologically "tight" and hence very low yielding to essentially dry sandstone and lesser siltstone that comprise the majority of the Permian interburden/spoil; and
- low to moderately permeable coal seams, typically ranging in thickness from 1 m to 5 m, which are the prime water bearing strata within the Permian coal measures.

Occurrence and flow of groundwater is governed by the presence of micro faults, joints, fractures, and bedding planes, which are often locally discontinuous. Areas devoid of secondary structural features tend to have low transmissivity. Areas with enhanced jointing, such as near the sub-crop or the steeply dipping strata near the Muswellbrook Anticline, are likely to provide localised conduits for flow and potential for more active recharge or discharge.

Some coal seams subcrop in, or close to, the Project area but all are progressively confined in areas to the south where they dip beneath the Hunter River. This increasing 'wedge' of rock restricts hydraulic connection between individual coal seams at depth.

9.1.5.2 Yield and use

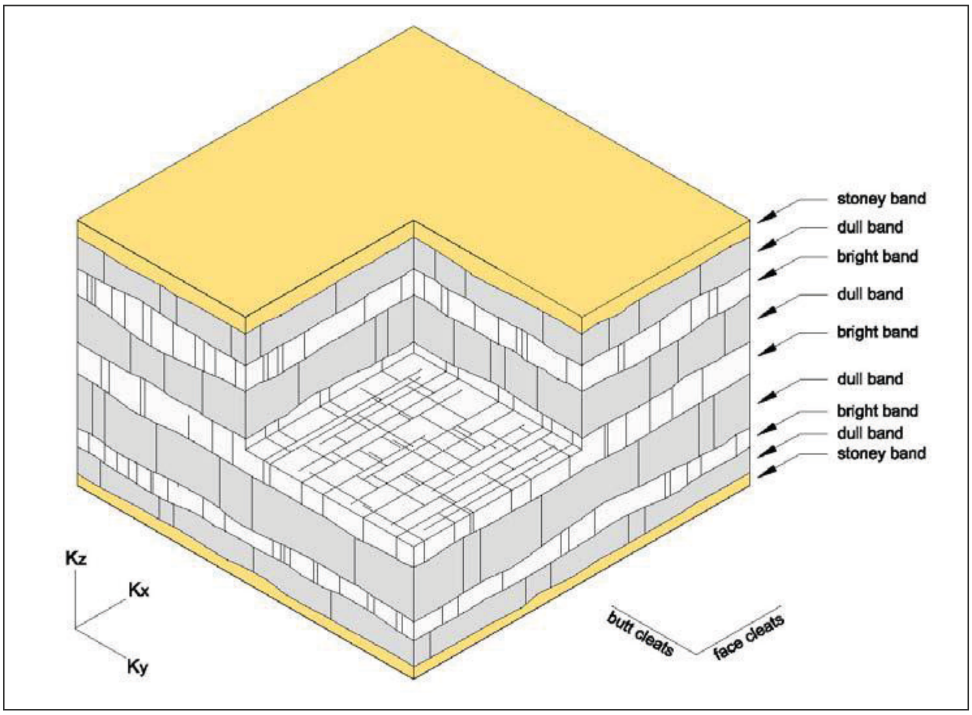
The closest registered water bore located outside of the study area and not on land owned by Anglo American is GW049223. This bore is screened within the Permian coal measures and is located approximately 1.1 km north of the Project. Yield information is not available but it is anticipated to be low based on yields measured during nearby exploration drilling. All other registered bores are located more than 4 km from the Project. The yield of these other bores is anticipated to be low based on results of nearby exploration drilling.

Groundwater has been noted to seep into the open cut at Drayton Mine (and other neighbouring mines). This groundwater seepage is often difficult to observe on the mine pit walls due to the low seepage rates and high evaporative losses. Seepage is more obvious in shallower high wall areas following extended rain periods when vertical infiltration through regolith generates weeps.

9.1.5.3 Hydraulic parameters

The primary permeability of the interburden and overburden is known to be extremely low and typically does not yield significant quantities of water. Coal seam hydraulic conductivity within the Hunter Valley coal deposits ranges across several orders of magnitude. The permeability values are influenced by the depth of burial of the seam and degree of jointing and cleat density (Mackie, 2009). The geometry of cleating in coals is illustrated Figure 10.

Areas devoid of secondary structural features tend to have poor groundwater transmission characteristics and confinement within different strata. Areas with enhanced jointing, such as near the sub-crop or the steeply dipping strata near the Muswellbrook Anticline, are likely to provide localised conduits for flow and the potential for more active recharge or discharge.



Source: Mackie, 2009

Figure 10 Geometry of cleating in banded coals

A number of hydraulic tests have previously been undertaken within the Project area. Aquifer testing provides a means of estimating the hydraulic conductivity and storage characteristics of a geological formation. Various procedures can be employed depending upon the saturated aquifer thickness, regional extent, yields, and bore completeness. MER (1998 and 2003) undertook a number of tests using various assessment methods, including:

- airlift yield tests of coal measures;
- injection (falling head) tests of coal measures; and
- laboratory core tests of interburden (i.e. sandstone/siltstone).

The relationship between hydraulic conductivity determined from the tests undertaken by MER (1998 and 2003) and depth below ground level is illustrated in Figure 11. An exponential relationship is observed within the hydraulic conductivity of the coal measures decreasing with depth below ground surface. The decline of coal seam hydraulic conductivity with depth has previously been documented for the Jerrys Plains Subgroup for sites located within the Hunter Valley by AGC (1984). The data obtained by MER (1998 and 2003) has a good correlation with the values obtained by AGC (1984).

Figure 11 indicates a general decline in coal seam permeability with increasing depth of about two orders of magnitude. The hydraulic conductivity near the surface is about 2 x 10^{-1} m/day and decreases down to about 1 x 10^{-3} m/day at a depth of approximately 300 m. The median hydraulic conductivity for the coal seams lies between 1 x 10^{-3} m/day and 1 x 10^{-2} m/day.

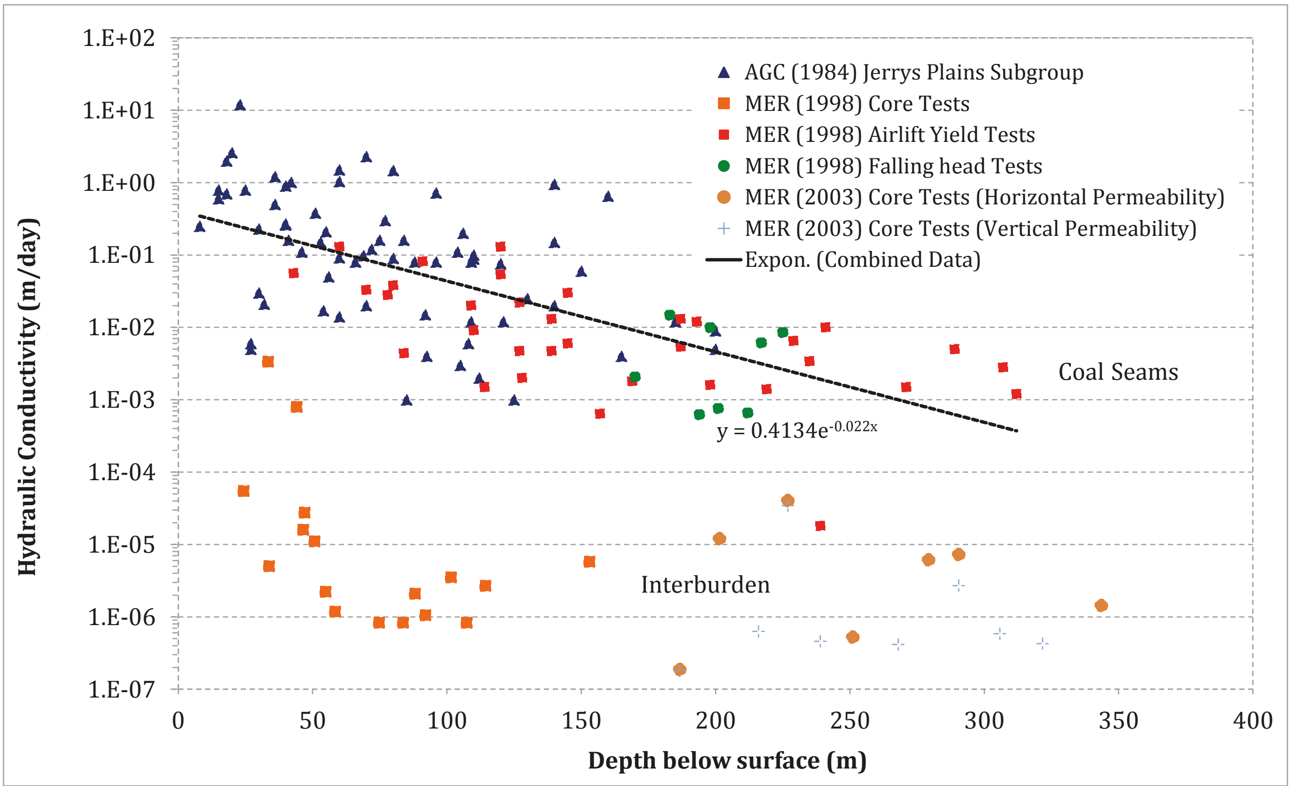


Figure 11 Hydraulic conductivity versus depth for Jerrys Plains Subgroup

9.1.5.4 Groundwater quality and environmental value/beneficial use

Groundwater within the Permian coal measures is known to be moderately saline with a mean TDS concentration of about 3500 mg/L (AGE, 2012). The salinity of this groundwater is typical of coal seam aquifers. The low yield and poor quality of the groundwater in the coal seams limits the beneficial use to primary industry with the main potential use being for (salt tolerant) stock watering. The Permian coal measures groundwater typically has a TDS concentration too high for irrigation.

9.1.5.5 Groundwater levels and recharge

Appendix B presents hydrographs for the VWPs located within the Project area. Continuous pressure/water level monitoring exhibits low frequency movements relating to seasonal change, and higher frequency movement attributed to atmospheric pressure change. It is considered that these water level oscillations indicate low storativity in the coal measures.

A vibrating wire piezometer was installed near the monitoring bore MB1. The pressure sensors within VWP1 were installed within the following units:

- Interburden located immediately beneath the Hunter River alluvium (~28 mbgl);
- Interburden located between the Whybrow and Redbank Creek coal seams (~56 mbgl);
- Interburden located beneath the Redbank Seam (~73 mbgl);
- The Wambo Seam (~86 mbgl);
- The Whynot Seam (~116. mbgl); and
- The Blakefield Seam (~143 mbgl).

The hydrograph of VWP1 is shown in Figure 12. The hydrograph illustrates that the shallow interburden at a depth of about 28 and 56 mbgl (i.e. beneath the Hunter River) has a pore pressure similar to the water level measured in the alluvium of 73mAHD. The deeper units show a higher pore pressure and therefore confirm an upward hydraulic gradient exists between the alluvium and the underlying units.

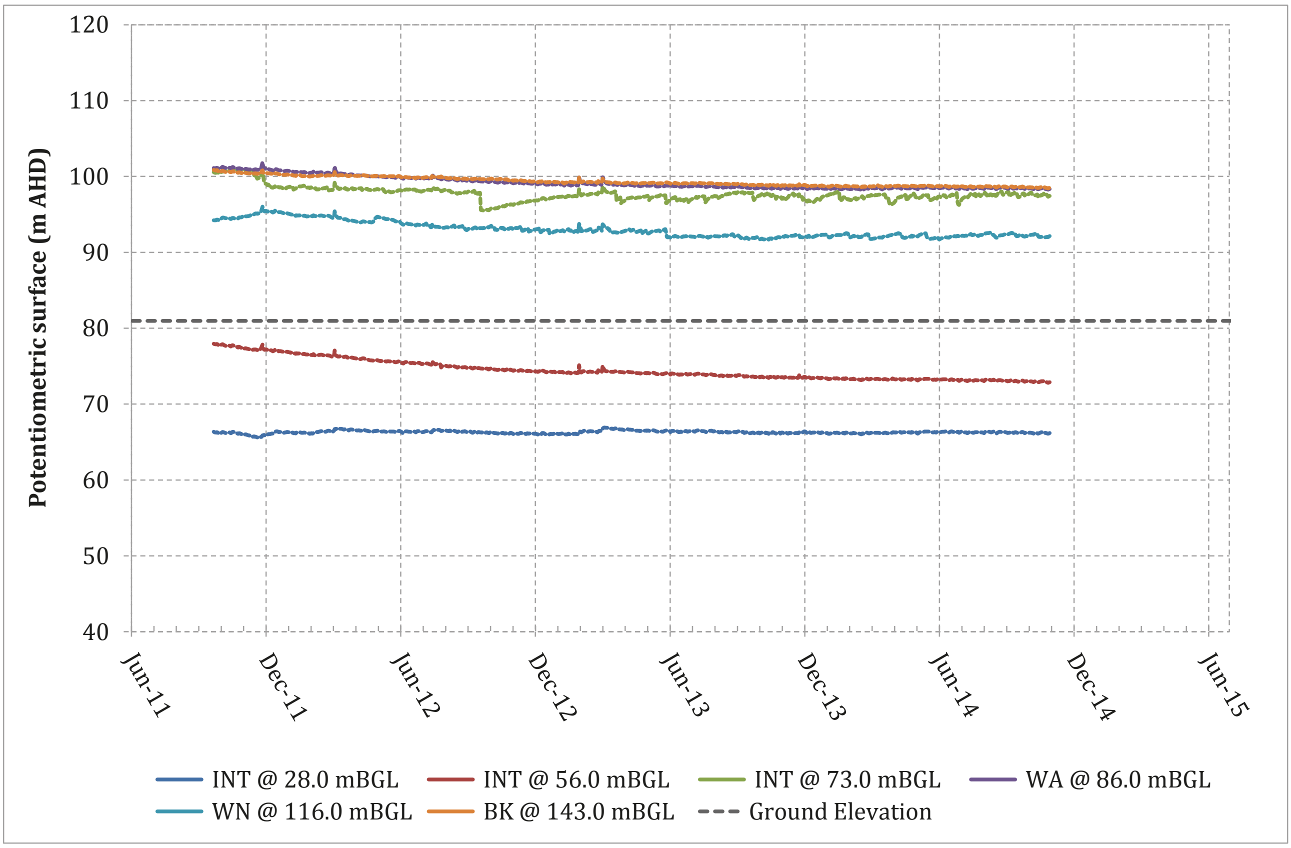


Figure 12 Hydrographs for VWP1 (RD1221)

9.2 Highly productive groundwater

Mapping of highly productive and less productive groundwater systems is available as a GIS database from NOW (NOW 2013). Figure 1 shows the available mapping of the aquifers for the area surrounding the Project. There is currently no meta-data available for this supplied mapping, although comparison to published geological maps suggests that more detailed Quaternary alluvium mapping has been used than is available in the public domain. The defined area of alluvium for Saddlers Creek appears to represent the local quaternary environment better than the published geology images (Hunter Coalfield Regional 1:100,000 Geology Map).

As previously described, the AIP establishes minimal impact considerations for “highly productive” and “less productive” groundwater systems. Highly productive groundwater is defined by the AIP as groundwater which has been declared in Regulations and based on the following criteria:

a. has a TDS concentration less than 1500 mg/L; and
b. contains water supply works that can yield water at a rate greater than 5 L/sec.

The average alluvial groundwater TDS records for Saddlers Creek (Section 9.1.2.4) is significantly greater than the 1,500 mg/L limit within the AIP. Based on TDS data alone, the Saddlers Creek alluvial system should be reclassified as a “less productive” groundwater source.

The AIP also defines highly productive aquifers as having a yield of greater than 5 L/s. No yield information is available for bores/wells located in the Saddlers Creek alluvium. However, results from the bore census suggest the long-term yield from the two bores/wells in the Saddlers Creek alluvium is less than 5 L/s. This assumption is supported by the observation that groundwater is extracted by shallow large diameter wells where storage within the well would overcome the low aquifer yield for short supply periods.

The Hunter River alluvium meets the criteria of the “highly productive” category.

9.3 Reliable surface water

The AIP also refers to a surface water source that is defined as a “reliable water supply”. It is noted the definition of a “reliable water supply” is provided in the current SRLUP for the Upper Hunter. The definition of a reliable water supply is as follows:

“reliable water of suitable quality, characterised by having rainfall of 350 mm or more per annum (9 out of 10 years); or properties within 150 m of a regulated river, or unregulated rivers where there are flows for at least 95 % of the time (i.e. the 95th percentile flow of each month of the year is greater than zero) or 5th order and higher rivers; or groundwater aquifers (excluding miscellaneous alluvial aquifers, also known as small storage aquifers) which have a yield rate greater than 5 L/s and total dissolved solids of less than 1500 mg/L”.

Saddlers Creek does not meet the “reliable water supply” criteria because it is ephemeral, with flow recorded about 63% of the time and is dry 37% of the time (WRM, 2012). In addition, Saddlers Creek is less than a 5th order stream, and typically has a TDS concentration above 1500 mg/L.

The Hunter River meets the criteria for “reliable surface water”. Therefore, assessment of predicted changes in surface water quality is only required by the AIP for the Hunter River.

9.4 Groundwater dependent ecosystems

9.4.1 Flora

The Hunter River Unregulated and Alluvial Water Sources Water Sharing Plan does not define any high priority GDE or high priority culturally significant sites within the Project area or surrounds. Cumberland Ecology (2015) undertook an ecology impact assessment to determine the potential for GDEs to exist near the Project area. Tree species such as Eucalyptus camaldulensis (River Red Gum) and Casuarina cunninghamiana (River Oak) were used as indicators of potential GDEs. These species are likely to have some root access to deep water tables and thus comprise a GDE.

The majority of the native vegetation that once covered the study area has been cleared primarily for grazing. However, a number of areas of remnant vegetation still occur. Cumberland Ecology (2015) noted:

"*One individual Eucalyptus camaldulensis (River Red Gum) was recorded along Saddlers Creek to the west of Edderton Road; occasional occurrences of Casuarina cunninghamiana (River Oak) were also found along the length of Saddlers Creek in this community. On the basis of the latter two occurrences, this community is considered to be a GDE. The community is restricted to the creek banks and is rarely found on the alluvial flats*".

Cumberland Ecology (2015) also stated:

"*It is difficult to ascertain the degree of dependence of terrestrial ecosystems on groundwater. In the Hunter region where watercourses are typically ephemeral and historically have been degraded due to surrounding land use and water extraction, it is likely that communities characterised by Eucalyptus camaldulensis (River Red Gum) and Casuarina cunninghamiana (River Oak) trees have a moderate reliance, but not a complete dependence, on groundwater*".

9.4.2 Fauna

Eco Logical (2015) completed a stygofauna impact assessment to determine the potential for stygofauna to exist nearby the Project area. This assessment included sampling within the alluvial units associated with Saddlers Creek and the Hunter River. Two rounds of stygofauna sampling were undertaken from a several monitoring bores. Only two occurrences of stygofauna taxa were recorded in Saddlers Creek. Eco Logical (2015) reported:

"*Two taxa collected from the Saddlers Creek alluvial aquifer are unlikely to be endemic to the aquifer; however, their presence here indicates that there may be a larger stygofauna community present*".

Although no stygofauna taxa were collected from the Hunter River alluvium near the Project during the sampling program, other studies undertaken throughout the region have identified stygofauna colonies within this alluvial system.

Eco Logical (2015) also confirmed that:

"*Due to the depth of the water table, the low hydraulic conductivity and the isolation of the deeper Permian aquifers, these areas were considered as having a very low chance of being suitable for stygofauna habitat. Sampling in September 2011 found no stygofauna in Permian bores, and further sampling of these bores is unlikely to yield any fauna*".

10. Conceptual model

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

Extensive information on the natural system is typically required to develop an equivalent and simplified conceptual groundwater model representative of the system. Development of the conceptual groundwater model is a crucial step in groundwater modelling. Care has to be taken during the development of such models since errors in the conceptual model cannot be corrected during the model calibration, or at any later stage of the modelling study, without major revisions. Formulation of the conceptual model often highlights gaps in data or deficiencies in the understanding of the groundwater system.

Zheng and Bennett (1995) note that:

"*A conceptual model contains numerous qualitative and subjective interpretations. The appropriateness of the conceptual model cannot be tested until a numerical model is built and comparisons between field observations and model simulation results are made*".

MDBC (2000) define a conceptual model as an:

"*… idealised summary of the current understanding of catchment conditions, and the key aspects of how the flow system works…subject to some simplifying assumptions.*"

The conceptual model of the region has the following hydrogeological boundaries:

- The Mount Ogilvie Fault to the west;
- The outcrop of the Saltwater Creek Formation, that is the base of the Wittingham Coal Measures in the east;
- The watershed north of the Mt Arthur Coal Mine which is a groundwater divide; and
- The Hunter River located south of the Project.

The groundwater regime in the Project area consists of four hydrostratigraphic units, including:

- alluvium associated with the Hunter River;
- alluvium associated with Saddlers Creek;
- shallow weathered bedrock (regolith); and
- coal seams and interburden of the Permian Wittingham Coal Measures.

Table 9 summarises the dominant lithology and aquifer category for each hydrostratigraphic unit.

The Hunter River alluvium is the main aquifer near the Project area, commonly providing good quality water for agricultural use. In contrast, the alluvium associated with Saddlers Creek is not a significant aquifer, producing low yields and high TDS groundwater.

The Permian coal measures are also not a significant aquifer. While some coal seams may have elevated hydraulic conductivity, the dominant interburden typically has very low hydraulic conductivity. The interburden restricts hydraulic connection between individual coal seams at depth. Only the weathered component of the interburden (regolith) may have a somewhat higher hydraulic conductivity compared to fresh interburden.

Table 9 Hydrostratigraphic summary

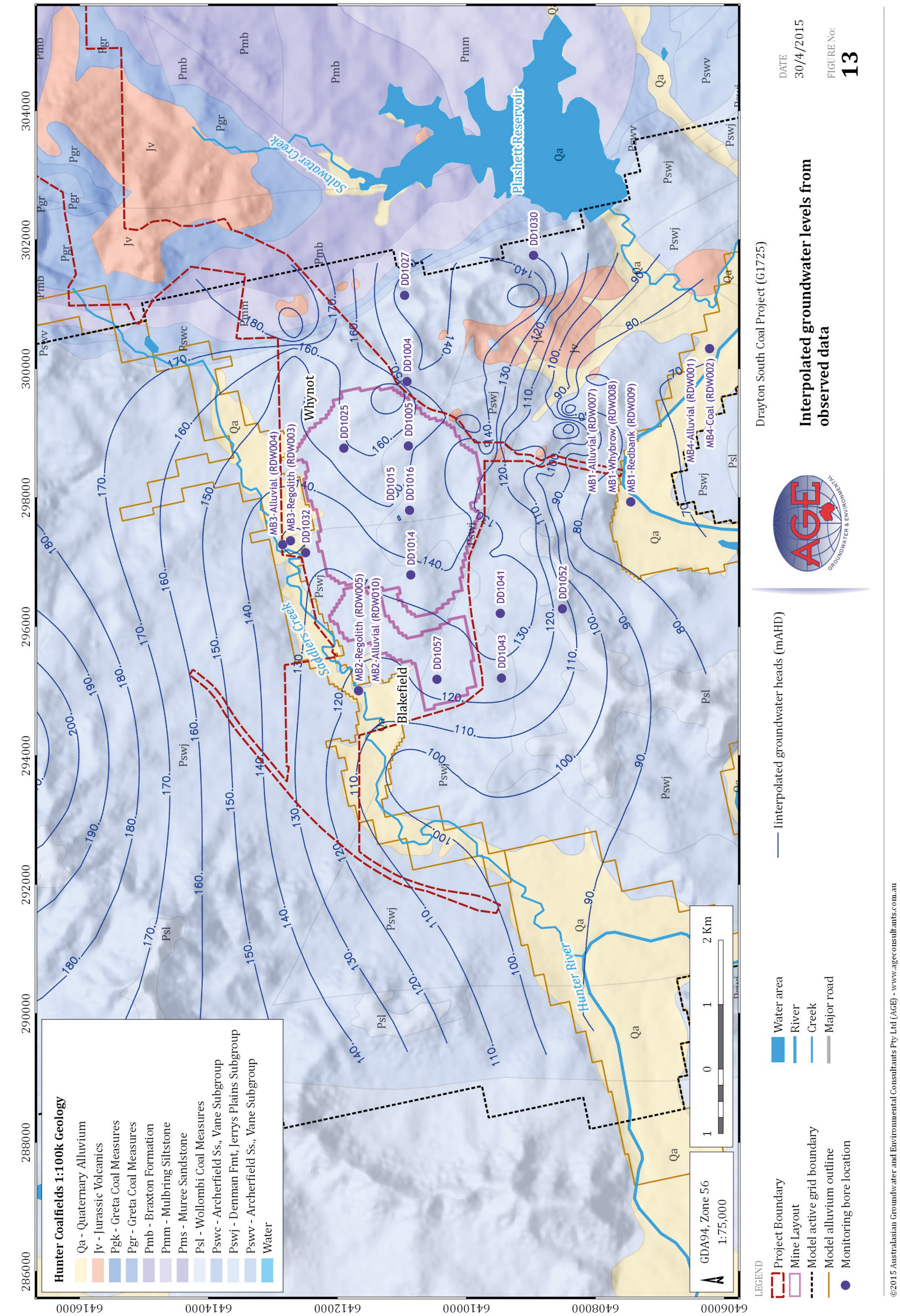
Formation	Dominant lithology	Aquifer type/category
Quaternary alluvium – Hunter River	sands and gravels	high yield aquifer
Quaternary alluvium – Saddlers Creek	clays with sand lenses	poor yield aquifer to aquitard
Regolith (weathered Permian coal measures)	sandstone/siltstone	poor yield aquifer
Permian coal measures – interburden	sandstone/siltstone	poor yield aquifer to aquitard
Permian coal measures – coal seams	coal	Low to moderate yield aquifer

Due to the higher permeability and storage of the alluvial sediments, a larger volume of groundwater recharge occurs to the alluvium compared to the Permian coal measures and other consolidated and weathered formations. The groundwater balance is dominated by recharge to the Hunter River alluvium. Groundwater seepage occurs to the alluvial deposits from the underlying Permian coal measures, causing moderate salinity levels found in the alluvium. During events of high water flows in Saddlers Creek and the Hunter River, the surface water systems can provide recharge to the alluvium.

The majority of groundwater recharge to the Permian coal measures occurs through deep percolation of rainfall where coal seams crop out near the ground surface. Recharge to the Permian coal measures is significantly lower than the alluvial aquifers. Recharged groundwater migrates down dip within the coal seams. The lower permeability interburden retards migration of recharge through the vertical profile where thick interburden sequences are present above the coal seams.

Although groundwater levels are sustained by recharge, they are controlled largely by surface topography, surface water levels, and aquifer hydraulic conductivity. Groundwater mounds occur beneath elevated areas located within the Project area and a hydraulic gradient exists towards the lower lying alluvial lands.

Groundwater flow occurs from these elevated areas, with discharge to the Hunter River in areas where the potentiometric surface is above the river level. Evaporation and/or evapotranspiration through vegetation are other discharge mechanisms, and take place where the water table is within a few metres of ground surface. Groundwater contours generated from observation data show the general groundwater flow directions across the site and are presented in Figure 13.


Drayton South Coal Project (G1725)
Interpolated groundwater levels from observed data
DATE
30/4/2015
FIGURE No:
13
LEGEND
Project Boundary
Mine Layout
Model active grid boundary
Model alluvium outline
Monitoring bore location
Iinterpolated groundwater heads (mAHD)
Water area
River
Creek
Major road
Hunter Coalfields 1:100k Geology
Qa - Quaternary Alluvium
Jv - Jurassic Volcanics
Pgk - Greta Coal Measures
Pgr - Greta Coal Measures
Pmb - Braxton Formation
Pmm - Mulbring Siltstone
Pms - Muree Sandstone
Psl - Wollombi Coal Measures
Pswc - Archerfield Ss., Vane Subgroup
Pswj - Denman Fmt, Jerrys Plains Subgroup
Pswv - Archerfield Ss., Vane Subgroup
Water
GDA94, Zone 56
1:75,000
2 Km
Plashett Reservoir
Saltwater Creek
Saddlers Creek
Hunter River
Whynot
Blakefield
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On a regional scale, irrigation, and stock/domestic bores remove a significant amount of water from the Hunter River alluvium. However, relatively minimal extraction of groundwater from the Hunter River alluvium occurs within the immediate vicinity of the Project.

In places where mining is proposed, groundwater discharge to the mine workings is expected to be via the mined coal seam and to a lesser extent from the strata above and below at a rate related to the hydraulic conductivity of the strata and the hydraulic gradient in the surrounding aquifer. Figure 14 shows a schematic section showing the hydraulic processes that are anticipated to occur during mining.

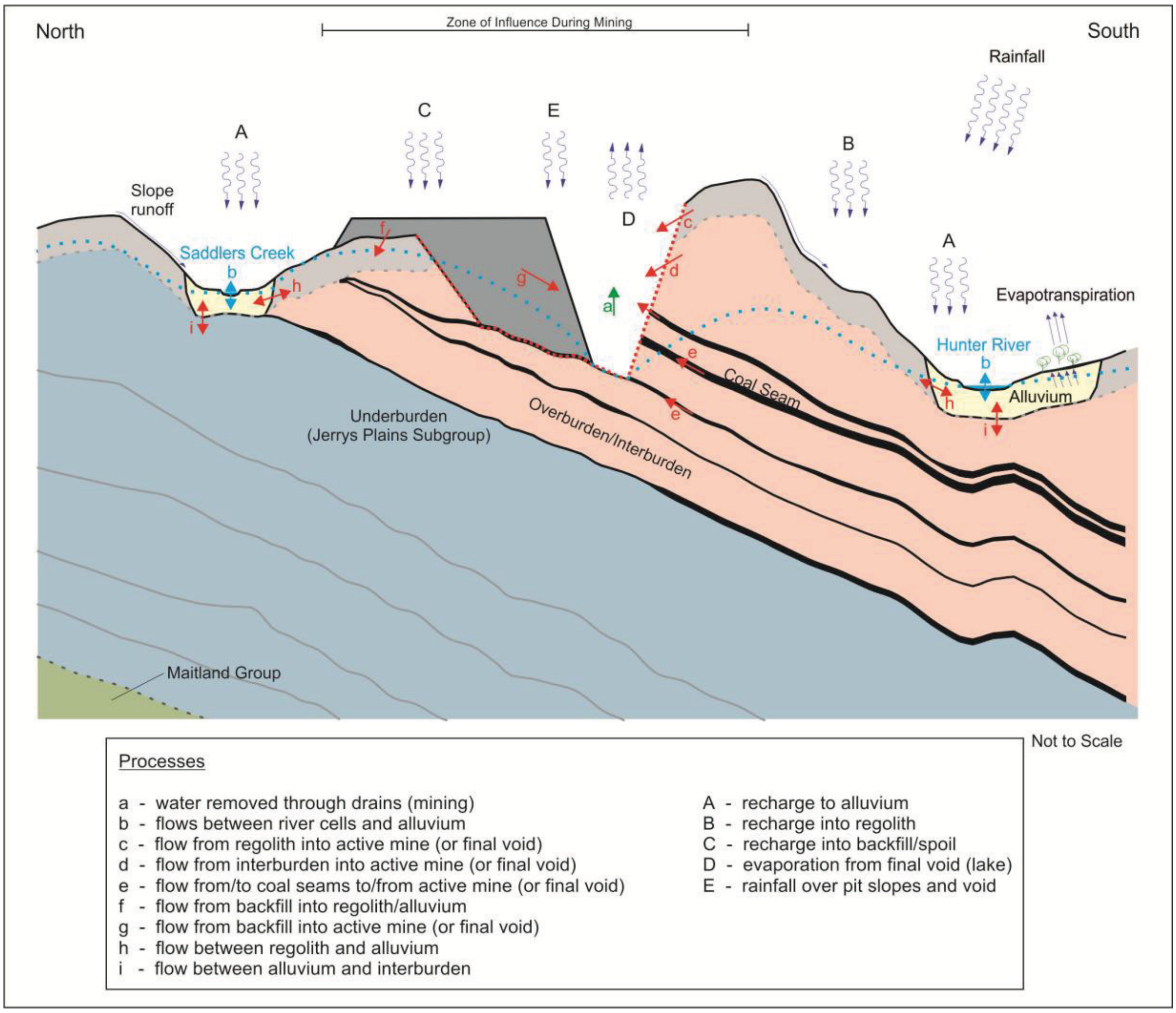


Figure 14 Schematic section showing conceptual hydrogeology – during mining

Groundwater will seep into the open pits from the mined coal seams, adding to the water that will accumulate in the pit from rainfall runoff and seepage from spoil. The rate at which groundwater seeps from the coal face and the spoil is governed by the hydraulic conductivity of the units, the hydraulic gradient, and the storage potential of the units. The coal seams typically have varying thickness and hydraulic conductivity. Consequently, some coal seams will yield greater and more persistent seepage over time to the pit void.

During the life of the Project, the rate of groundwater extraction from the mine workings will exceed the rate that the aquifers can recharge. This process will lead to depressurisation of the groundwater potentiometric surface surrounding the Project.

11. Groundwater model generation and calibration

11.1 Overview of groundwater modelling

The objective of the groundwater modelling was to produce a model that suitably represented the current understanding of the groundwater environment and can predict changes in groundwater conditions due to future activities within the model domain, including but not limited to the development of the Project.

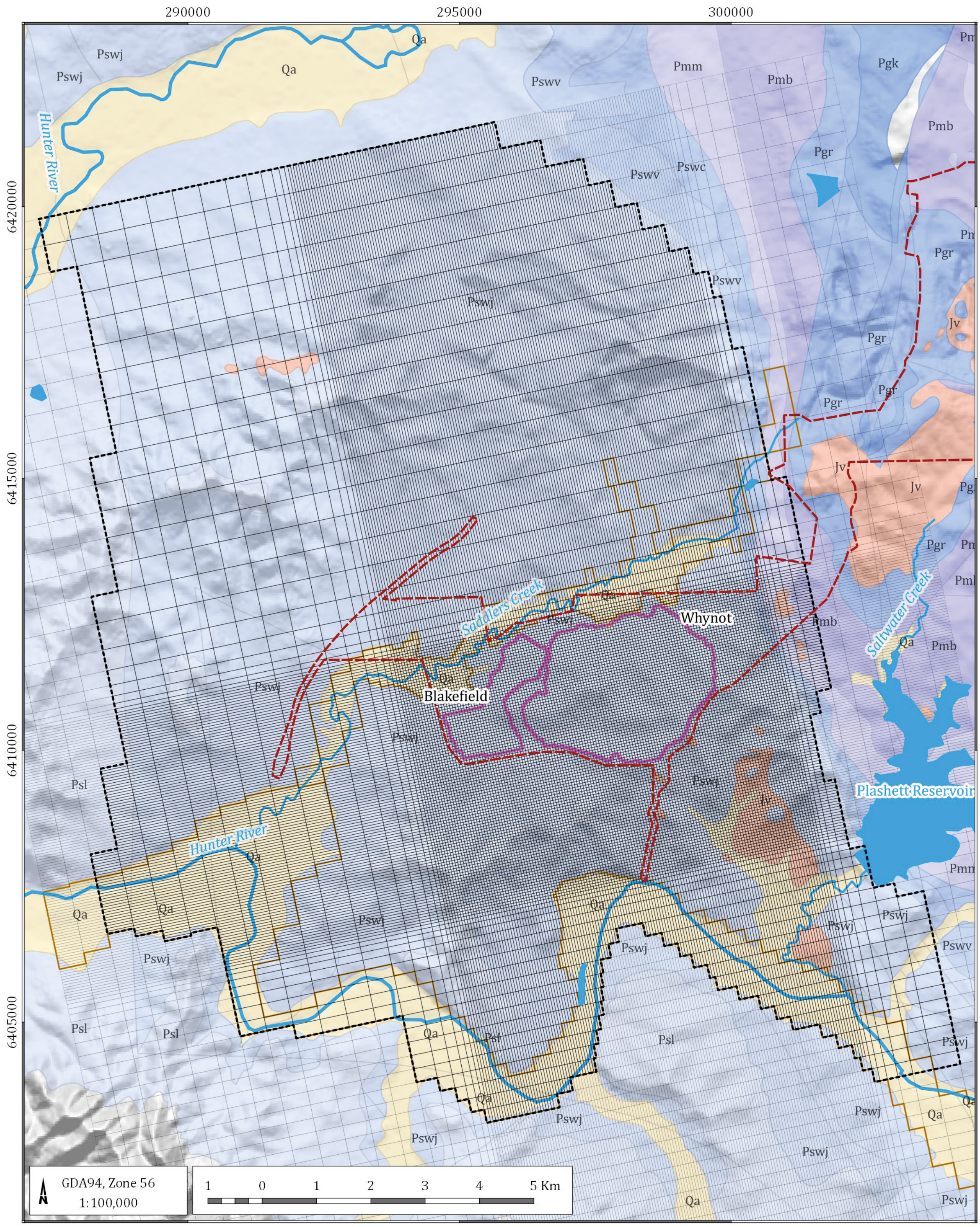
The design, construction and calibration of the model were all tailored to meet these objectives as well as providing a framework for future iterations of the model following the addition of new data. Appendix C details the model design, objectives, calibration and predictive modelling approach. It is assessed that the model objectives have been addressed and it is considered fit for purpose. The objectives of the modelling, based on Australian modelling guidelines, were to:

- replicate measured groundwater levels at each observation bore;
- simulate groundwater drawdown during the mining phase and then groundwater recovery post mining.
- produce water budgets with a numerical error of less than 1% at each time step and on a cumulative basis;
- estimate groundwater seepages to the open-cut mining areas over the Project life;
- predict the zone of depressurisation in Quaternary alluvium and Permian coal measures from mining activities and the level and rate of drawdown at specific locations;
- predict any changes to surface flows and other groundwater users due to Project operations; and
- identify areas of potential risk where groundwater impact mitigation/control measures may be necessary.

A three-dimensional numerical groundwater flow model was developed for the Project using MODFLOW-SURFACT. The model comprised 18-layers with a model extent of 17 km x 22 km. The model was built around the conceptual groundwater model (Section 10). The model was calibrated to a steady state condition, using water level observation data from the Project site, and from neighbouring bores, to achieve a suitable fit in accordance with modelling guidelines. Comparison of observed and steady state modelled groundwater heads are provided in Appendix D. The model was then calibrated to a transient condition to replicate the seasonal fluctuations observed in groundwater levels. Comparison of transient observed and modelled groundwater heads are provided in Appendix E.

There was no separate simulation of evapotranspiration in the model, rather the net effect of this is encapsulated in the calibrated recharge rate. For the purposes of simulating groundwater recovery into the final void, evaporation was applied separately to allow the model to determine the equilibrium level in the void.

The model grid and the mine plan are presented in Figure 15.



LEGEND

- Mine Layout
- Project Boundary
- Model active grid boundary
- Model active grid
- Model alluvium outline
- Water area
- River
- Creek

Hunter Coalfields 1:100k Geology

- Qa - Quaternary Alluvium
- Jv - Jurassic Volcanics
- Pgk - Greta Coal Measures
- Pgr - Greta Coal Measures
- Pmb - Braxton Formation
- Pmm - Mulbring Siltstone
- Pms - Muree Sandstone
- Psl - Wollombi Coal Measures
- Pswc - Archerfield Ss., Vane Subgroup
- Pswj - Denman Fmt, Jerrys Plains Subgroup
- Pswv - Archerfield Ss., Vane Subgroup
- Water

Drayton South Coal Project (G1725)

Model grid and proposed mine pits

DATE 18/3/2015

FIGURE No: **15**

11.2 Model calibration summary

The steady state calibration is summarised in the scatter diagram presented in Figure 16.

The calibrated model provides a good match between the observed and modelled/simulated heads within the alluvial aquifer zone. However, the model generally over-predicts heads in the Permian coal measures. Comparison of observed and modelled groundwater heads are provided in Appendix D.

The root mean square (RMS) error, which is a statistic similar to standard deviation, is a measure of the variability in the observed versus simulated water level records. The steady state model has a RMS error of 13.2 m. The ratio of RMS to the total head change across the calibration points (174.9 m) produces a Scaled RMS of 7.55%.

The 2012 Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012) warn against prescriptive performance targets but note that targets less than 10% SRMS may provide useful guides. SRMS varies between models and is typically lowest in models dominated by porous media such as sands and gravels (i.e. uniform and homogeneous). However, achieving a low SRMS within models dominated by fractured rock systems, such as the Permian coal measures, is not always possible owing to the non-uniformity and heterogeneity of the aquifers.

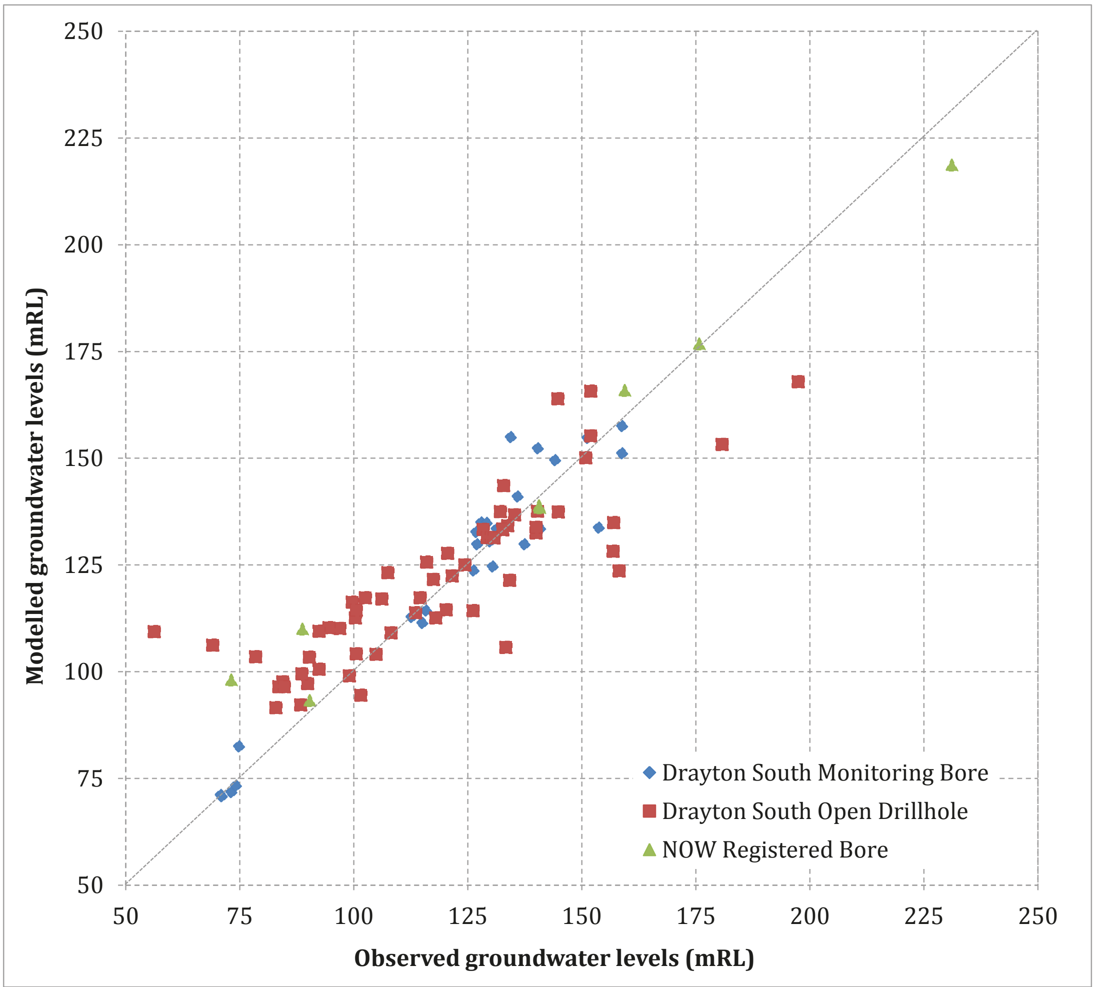


Figure 16 Steady state scatter diagram

Appendix E presents 76 hydrographs that compare simulated water levels against observed transient data. The transient calibration hydrographs generally illustrate a good match to the observed water level measurements from monitoring bores. Reproducing the VWP pressure heads was less successful.

The observed VWP pressure head trends often conflict with the trends observed within neighbouring monitoring bores (Appendix E). For this reason, less weight was given to attaining a simulated match against the observed VWP data. The reason for the discrepancy between the trends observed by the VWPs and monitoring bores is not readily apparent.

Comparison of observed groundwater levels against model simulated groundwater levels are presented in Figure 17. The scattergram of observed versus modelled groundwater levels should ideally fall along a straight line with a slope of one. The R^2 value of the data is 0.36, which represents an acceptable result considering the challenge of reproducing the VWP dataset.

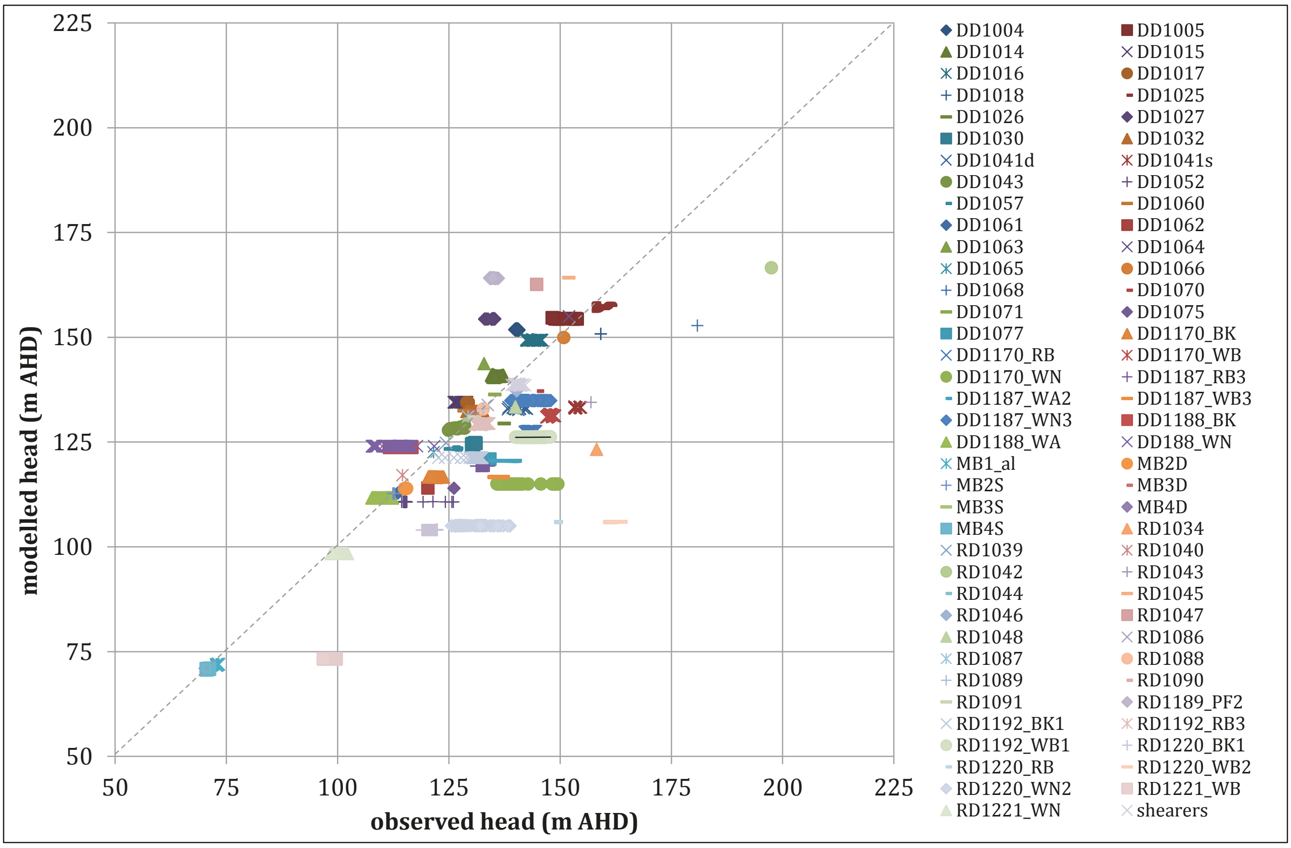


Figure 17 Transient scatter diagram

The transient calibrated model has a RMS error of 18.08 m. The ratio of RMS to the total head change across the calibration points (127.2 m) produces a Scaled RMS 14.2%. As stated earlier, achieving a successful calibration against the observed VWP dataset was challenging due to their conflicting trends compared to neighbouring monitoring bores. If calibration had been only undertaken using the monitoring bore dataset, the SRMS would have been 5.8%.

The average mass balance error, for each time step throughout the transient calibration period fluctuated between -0.02% and 0.02% (average error of 0.001%), which indicates good accuracy of the numerical solution and overall stability of the model.

Table 10 summarises the steady state model water budget. The steady state budget shows water enters the model domain at a rate of 1142 ML/year from diffuse rainfall recharge and 19810 ML/year from surface water leakage, predominantly from the Hunter River into the alluvium.

The breakdown of the simulated total losses to Saddlers Creek and the Hunter River is shown in Table 11. The Hunter River is the main sink for groundwater within the Project area, followed by Saddlers Creek. Steady state groundwater net losses to the Hunter River are simulated to be about 799 ML/year and about 245 ML/year to Saddlers Creek.

Table 10 Overall steady state water budget

Parameter	Input	Output
Rainfall recharge	1142 ML/year (5.5%)	-
Recharge to alluvial aquifers from river/creek (losing streams)	19810 ML/year (94.5%)	-
Recharge to creeks/river from alluvial aquifers (gaining streams)	-	20949 ML/year (100%)
TOTAL	20952 ML/year	20949 ML/year

Table 11 Steady state surface drainage water budgets

Creek/River (receiving recharge from alluvium)	Net Discharge (baseflow)
Hunter River	799 ML/year
Saddlers Creek	245 ML/year
Secondary Creeks and Drainages	95 ML/year
TOTAL	1139 ML/year

Table 12 summarises the transient model water budget for the calibration period.

Table 12 Transient calibration water budget

Parameter	Input (ML/year)			Output (ML/year)		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Rainfall recharge	33	1369	6851	-	-	-
Recharge to alluvial aquifers from river/creek (losing streams)	2364	20221	173330	-	-	-
Recharge to creeks/river from alluvial aquifers (gaining streams)	-	-	-	872	21491	138861
TOTALS	2396	21590	180181	872	21491	138861

11.3 Prediction approach

Once calibrated, the model was used to predict the groundwater level behaviour of the systems, in response to simulated mining. The model simulated mining over a 15-year period, consistent with the mine plan. The model also simulated groundwater level recovery post mining over a 1,000 year period.

The model allows groundwater levels, seepage, and fluxes to be predicted within the model extent, and this model output is presented in the following sections on impact assessment. Detail in the regional model domain was applied to those areas considered to have the greatest influence in the impact assessment (the mine area). The model mesh was generated in accordance with the Australian guidelines. No faults have been represented in the model domain to ensure a conservative approach that maximises the predicted impacts.

12. Predicted impacts during mining

12.1 Seepage to mine pits

12.1.1 Total seepage (pre-evaporation)

The predicted total groundwater seepage rate for each mine pit is presented in Table 13. These rates represent the total seepage into the pits from the Permian coal measures and the backfilled spoil, without the reducing effect of evaporation.

Predicted total seepage rates (Permian and spoil) peaks at 427 ML/year in Year 8, as shown by Figure 18. The seepage rate over the life of the mine averages 288 ML/year.

The predicted seepage from the Permian coal measures contributes about 55% of the total seepage rate, as shown by Figure 19. The predicted total seepage rate from the Permian coal measures peaks at 175 ML/year in Year 9.

The predicted seepage rates vary throughout the mining period. This variability in seepage is directly related to the proposed mine plan, the depth/thickness of saturated coal being mined, and hydraulic gradients induced by the depressurisation of the coal seam.

The peaks in the predicted seepage are partially due to the yearly steps used to represent mining in the model, and in reality, the seepage rate would not be expected to peak as predicted by the model simulation.

Table 13 Total seepage per pit – baseline prediction

Year	Seepage (ML/year)						
	Whynot mining area		Blakefield mining area		Total		Total Seepage
	Permian	Spoil	Permian	Spoil	Permian	Spoil	
1	43	-	-	-	43	-	43
2	77	32	21	-	98	32	130
3	83	82	30	22	113	104	217
4	85	131	38	66	123	196	319

Year	Seepage (ML/year)						
	Whynot mining area		Blakefield mining area		Total		Total Seepage
	Permian	Spoil	Permian	Spoil	Permian	Spoil	
5	79	160	55	64	134	224	359
6	88	175	34	49	121	223	345
7	102	183	46	59	149	242	391
8	109	210	54	55	163	264	427
9	115	186	60	58	175	244	419
10	113	187	-	-	113	187	300
11	114	189	-	-	114	189	303
12	123	179	-	-	123	179	302
13	128	141	-	-	128	141	269
14	129	128	-	-	129	128	257
15	115	128	-	-	115	128	243

Figure 18 Predicted seepage – total (baseline prediction)

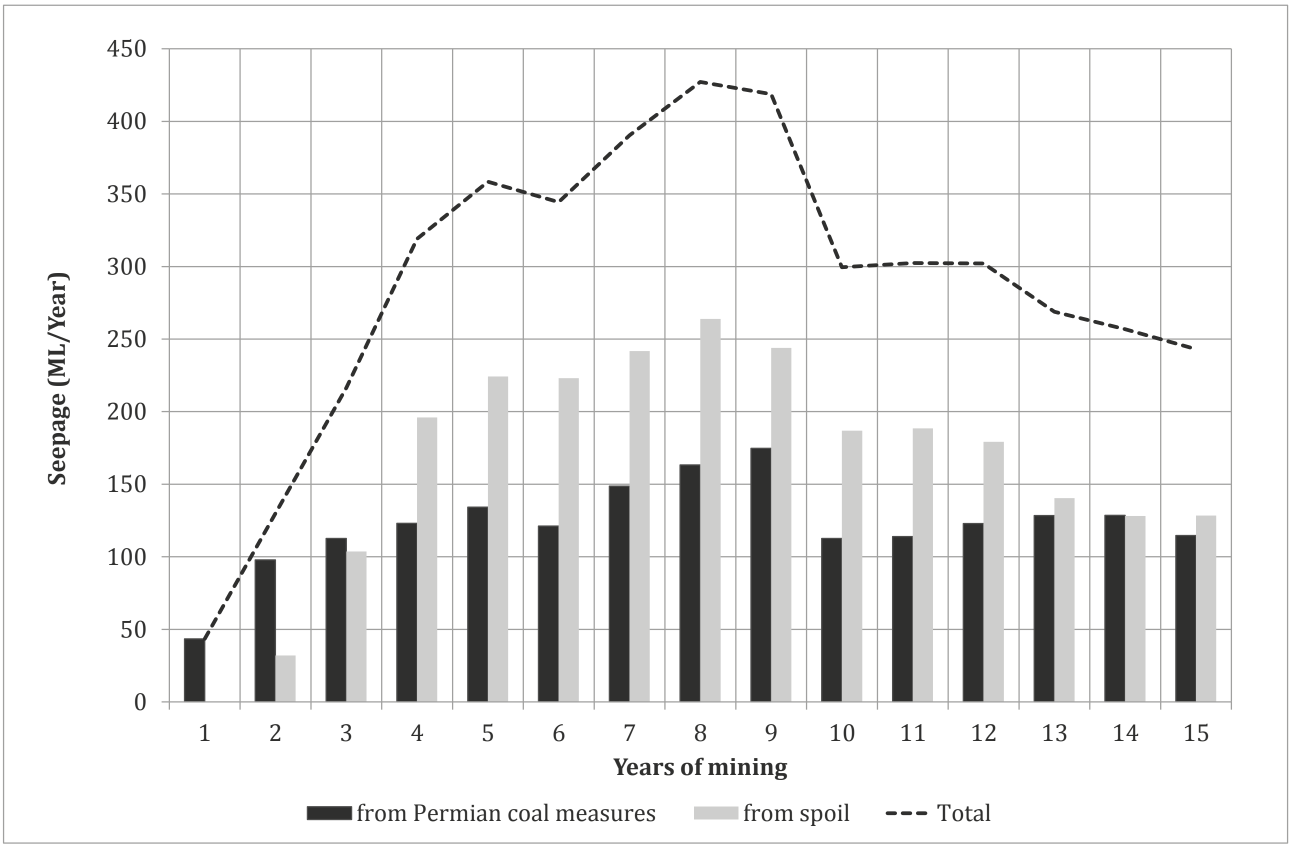


Figure 19 Spoil and Permian Coal Seams – total seepage (baseline prediction)

12.1.2 Pumpable seepage (post-evaporation)

Evaporation from the coal face exposed in the highwall and endwall will remove a proportion of the predicted total seepage rate, and not all of the predicted seepage will flow to pit sumps for removal by pumping.

The effect of evaporation was simulated by applying a pan evaporation rate of 4.4 mm/day to the surface area of coal seams exposed in each pit for each year. The predicted groundwater seepage rate that will flow to each pit sump after evaporation (i.e. the pumpable rate) is presented in Table 14.

Predicted pumpable seepage rates (coal measures and spoil) peak at about 381 ML/year in Year 8, as shown by Figure 20. The pumpable seepage rate over the life of the mine averages 248 ML/day.

Table 14 Pumpable seepage per pit – baseline prediction

Year	Pumpable seepage (ML/day)		Total (ML/year)
	Whynot mining area	Blakefield mining area	
1	17	-	17
2	80	4	84
3	135	34	169
4	177	83	260
5	201	86	287
6	225	67	292

Year	Pumpable seepage (ML/day)		Total (ML/year)
	Whynot mining area	Blakefield mining area	
7	252	92	344
8	286	95	381
9	270	103	373
10	270	-	270
11	275	-	275
12	274	-	274
13	243	-	243
14	233	-	233
15	220	-	220

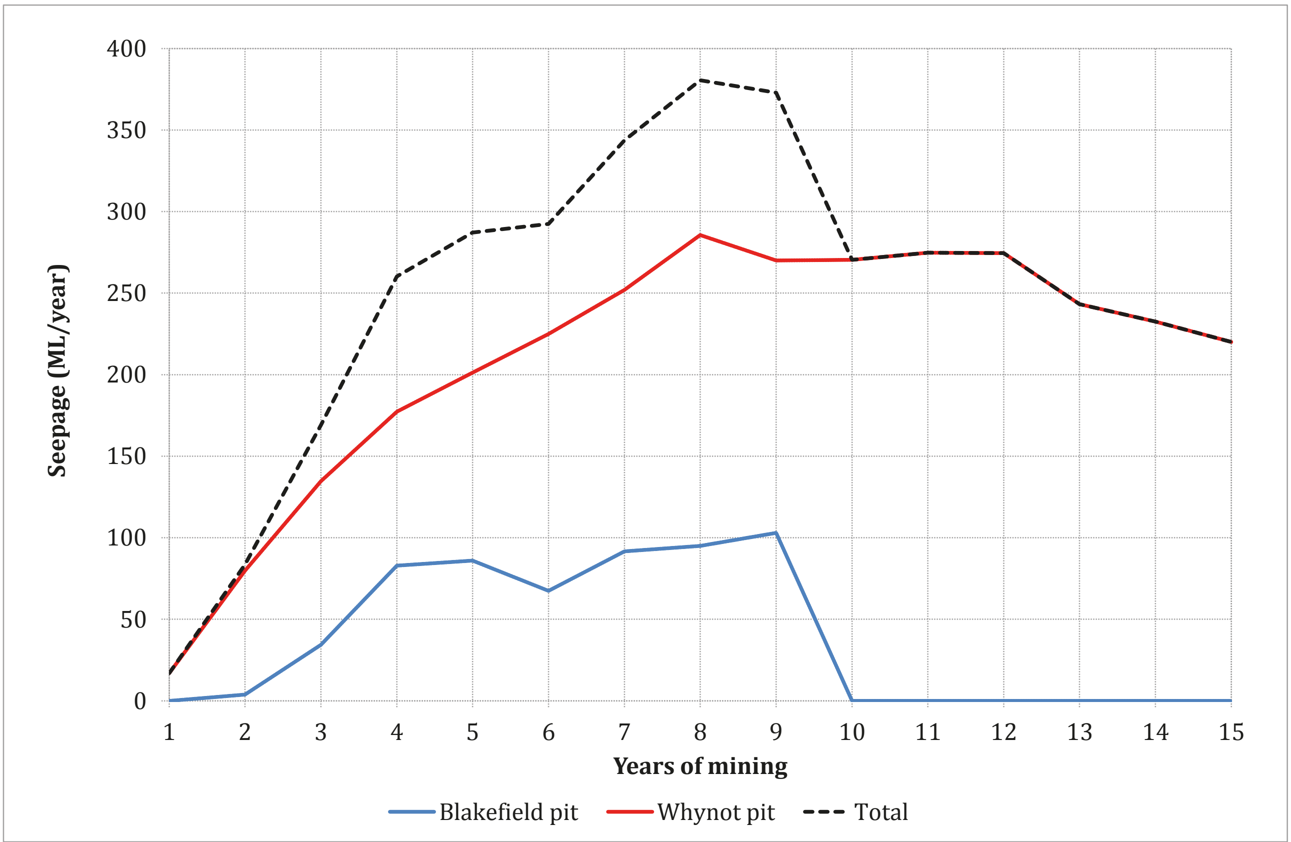


Figure 20 Predicted seepage – pumpable (baseline prediction)

12.2 Groundwater drawdown, heads and hydraulic gradients

During the life of the Project, the rate of groundwater extraction from the mine workings will exceed the rate that the aquifers can recharge. This process will lead to depressurisation of the groundwater potentiometric surface surrounding the Project.

The groundwater model was constructed with multiple layers to represent different geological units. The uppermost model layer represents the Quaternary alluvium of Saddlers Creek and the Hunter River, and the weathered (regolith) profile of the Permian coal measures. The vertical and horizontal connections between each of the geological units within Layer 1 were applied conservatively to create reasonable hydraulic connection between the units. For this reason, the contours from Layer 1 are discussed below to demonstrate the predicted impacts on the alluvial and regolith geological units.

The Permian coal measures are represented by Layers 2 to 18. The overburden/interburden and the coal seams have considerably lower vertical hydraulic connection compared to Layer 1. The contours from Layer 5 are discussed below to demonstrate the predicted impacts on the Redbank Creek coal seam. The largest area affected by depressurisation at the end of mining is predicted to occur within Layer 5.

The predicted extent of groundwater drawdown is shown as a series of contour maps for mining years 4, 6, 9, 12, and 15 (end of mining). The predicted drawdown for Layer 1 is shown on Figure 21 to Figure 25, and for Layer 5 on Figure 26 to Figure 30. Figure 31 and Figure 32 illustrate the predicted groundwater heads at the end of mining for model Layers 1 and 5, respectively.

Drawdown (represented by the 1 m contour) within the regolith is not predicted to extend to the Hunter River alluvium. However, drawdown is predicted to extend into the Saddlers Creek alluvium adjacent to the Project (Figure 25). The 1 m drawdown for Layer 5 is predicted to approach the Hunter River alluvium at the end of mining, but does not extend under the alluvium. Drawdown within the coal seams is predicted to extend under Saddlers Creek alluvium as shown on Figure 30.

12.3 Predicted impact on groundwater users

The minimal impact considerations in the AIP require the cumulative water table and pressure head decline by no more than 2 m at any water supply work. A total of two registered bores/wells are encompassed within the zone of influence (excluding monitoring bores) at the end of mining. These registered bores are known as Shearers Well (regolith) and Shearers Well Bore (Permian coal measures). The locations of the registered bores within the zone of depressurisation at the end of mining are shown in Figure 25 (Layer 1) and Figure 30 (Layer 5).

Both of these bores are located on land owned by Anglo American, and will be removed by mining. No other registered bores are located within the predicted zone of influence at the end of mining.