APPENDIX **N**
GROUNDWATER IMPACT ASSESSMENT

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Australasian Groundwater & Environmental Consultants Pty Ltd

REPORT on

MT ARTHUR COAL CONSOLIDATION PROJECT

GROUNDWATER IMPACT ASSESSMENT

prepared for
HANSEN BAILEY PTY LTD

Project No. G1446
June 2009

ABN:64 080 238 642

Australasian
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EXECUTIVE SUMMARY

Mt Arthur Coal Pty Limited is seeking approval to consolidate the existing approvals for its open cut operations at the Mt Arthur Coal Mine Complex (Mt Arthur Coal), south-west of Muswellbrook in the Upper Hunter Region of New South Wales. The Project continues all aspects of Mt Arthur Coal's current activities and specifically, seeks approval for the following:

- Consolidation of all of Mt Arthur Coal's open cut planning approvals into one contemporary Project Approval;
- Extension of the mine footprint to uncover additional coal reserves within the current Mining Leases (MLs);
- Increasing the Mt Arthur Coal approved production levels by 8 Mtpa up to 36 Mtpa ROM coal. This will be achieved by;
    - Increasing open cut coal production by up to 8 Mtpa; and
    - Having the flexibility to increase either open cut or underground production by an additional 4 Mtpa if the maximum production from either underground or open cut methods is not being met (total not to exceed 36 Mtpa).
- Relocating a section of Edderton Road in approximately 2019;
- Upgrading the existing Mt Arthur CHPP to process up to 36 Mtpa of ROM coal and allow the inclusion of an ultra-fine coal circuit to re-process fines which will facilitate increased resource recovery and reduce water demand;
- Increasing the approved rail haulage capacity (in line with the increased coal production from 19 Mtpa to 27 Mtpa), with the construction of a second rail loading facility and associated conveyor system;
- Modifications to existing infrastructure (such as workshop and bath house), construction of additional ROM coal hoppers and the extension of ROM and product coal stockpiles; and
- A total workforce of approximately 2,600 at peak production, which represents an increase of approximately 1,610 from current staffing levels and an estimated additional 720 positions directly attributable to the Project.

No changes to the mining method or hours of operation are proposed, although a gradual increase in the mobile equipment fleet will be required.

This groundwater impact assessment was prepared for the Environmental Assessment report to support the application for Project Approval under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The groundwater impact assessment includes a review of previous studies undertaken for Mt Arthur Coal and surrounding mines, conceptualization of the groundwater regime, development of a finite element groundwater model and simulation of the impact of the Project on the groundwater regime.

Previous Studies

A number of previous groundwater studies have been undertaken at Mt Arthur Coal and surrounding mines. Studies undertaken by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) and for which approvals were obtained include the Mt Arthur Coal South Pit Extension, Bengalla Mine; Wantana Extension and the Drayton Mine Extension. These projects involved development of finite element groundwater flow models and impact simulation.

The most recent study was undertaken by Mackie Environmental Research for the Mt Arthur Underground Project, for which a finite element model was also developed for impact simulation.

Aquifer Systems

A review of existing data and reports indicates that the hydrogeological regime of the EA Boundary and surrounds consists of:

- an extensive Quaternary alluvial aquifer system associated with the Hunter River and tributary creeks and a smaller alluvial system associated with Saddlers Creek and minor tributaries;
- a thin veneer of weathered bedrock (regolith); and
- the coal seams of the Permian Wittingham Coal Measures.

The Hunter River alluvium is up to 13m thick and contains a basal gravel layer that is exploited for irrigation and stock supplies. The upper section of the alluvium is predominantly silt with minor portions of clay, while all of the Saddlers Creek alluvium, which is relatively thin, is of similar composition. The groundwater quality of the alluvial aquifers is variable with the poorest quality water in the basal sections due to discharge from the underlying coal seam aquifers.

The regolith comprising superficial soils and weathered bedrock is approximately 10m thick and is a temporary groundwater store during sustained wet periods providing recharge to the underlying coal measures.

The Permian strata and coal seam aquifers outcrop in the elevated areas and subcrop beneath the alluvium. They are generally low yielding and contain poor quality water. The water table / piezometric surface of the Permian aquifers form a subdued reflection of the topography with groundwater flow and discharge to the alluvial areas.

Hydraulic Properties

Numerous testing consisting of packer tests, falling head tests and pump-out tests have been undertaken during past studies within the EA Boundary to assess the hydraulic properties of the aquifers, overburden and interburden. This data has indicated a hydraulic conductivity range of 5-40m/day for the Hunter River alluvium with a median value of 8.2m/day. Similarly, hydraulic conductivity values for the coal seams range from about 0.01 - 0.7m/day and of the interburden from 5.2×10^{-3} to 8.6×10^{-5} m/day, which means that the coal seams exhibit hydraulic conductivities several orders of magnitude higher than the interburden.

Numerical Model

A finite element numerical model was developed from the conceptualisation of the groundwater regime using the FEFLOW software package. The model was adapted from the model developed for the Mt Arthur Coal South Pit Extension Project and incorporated data from the Mt Arthur Underground model. The model included Bengalla Mine in order to assess cumulative impact, but did not include the Bayswater No. 2 Pit or Drayton Mine, both of which mine seams from the stratigraphically deeper Greta Coal Measures, and which are structurally and hydraulically isolated. The model consists of nine layers, the upper layer representing the alluvium and weathered bedrock and the bottom (base of the model layer), representing the Saltwater Creek Formation. The intermediate layers represent the Permian coal measures, the hydraulic conductivity of each layer being the weighted sum of the interburden and coal seam permeabilities. The hydraulic conductivity was reduced continuously with depth to account for the effect of increasing confining stress and the model was calibrated by adjusting hydraulic conductivity.

Predictive Simulations

Model predictions indicates that the cumulative impacts of existing and proposed operations (Mt Arthur Coal open cut and underground operations, along with surrounding mines operations) will result in cumulative depressurisation of the Permian aquifers. The maximum drawdown will be 290m at the Mt Arthur North Pit in 2022 with the cone of depression (depressurisation), of the aquifers extending up to 0.5km north of the EA boundary beneath the Hunter River, and up to 1.6km south of the EA boundary. Depressurisation will not extend outside the eastern and western boundaries primarily due to the subcrop in the east and the Mount Ogilvie Fault in the west.

Groundwater inflow to the open cut pits will progressively increase from about 0.85 Megalitres (ML)/day in 2009 reaching a peak of 2.45ML/day in 2016 and decreasing slightly to 2.39ML/day at the end of open cut mining in 2022.

The impact on the Hunter River alluvium is predicted to reverse - from a discharge from the coal seams to the alluvium of 0.2ML/day in 2009, to leakage from the alluvial area to the coal seams mined in the MAN Pit of 0.48ML/day in 2016, increasing to approximately 0.74ML/day at the end of mining in 2022. The predicted volume of leakage is considered to be a worst case scenario as the model does not account for a potentially weathered, clay rich zone at the base of alluvium that inhibits leakage.

Mining will initially reduce the rate of groundwater discharge from the Permian aquifers to the alluvium of Saddlers Creek, however by 2011 the groundwater flow will be reversed, with seepage from the alluvium to the pits stabilising at a rate of about 0.09ML/day.

Existing bores and wells lying within the footprint of depressurisation of the Permian aquifer may be impacted, with water levels declining or the bores drying up. However, the two bores identified to occur within the footprint of depressurisation and potentially impacted, are within land owned by Mt Arthur Coal.

There are no identified groundwater dependent ecosystems within the area likely to be impacted by depressurisation of the Permian aquifers.

Recovery simulations of the final voids were undertaken for the Environmental Assessment as part of the Surface Water Impact Assessment and are reported separately. Steady state groundwater inflows to the final voids were provided for various pit water elevations for input to the simulation of the Surface Water Impact Assessment.

Mitigation Options

In areas where open cut mining may intersect alluvial deposits, such as those associated with Whites and Fairford Creeks and a tributary of Saddlers Creek, potentially resulting in seepage from the alluvium of the Hunter River and Saddlers Creek, further investigation of the extent of the alluvium in each tributary will be undertaken. If necessary this will be followed by the design and construction of a low permeability slurry or engineered / compacted clay cut-off trench across the relatively narrow and thin alluvial bodies to provide an impermeable barrier that will hydraulically separate the tributary creek alluvium from the saturated alluvial sediments of the Hunter River and Saddlers Creek, while mitigating the need to alter the configuration for the proposed open cut mine.

Where water levels in existing landholder bores decline as a result of the Project, leading to an adverse impact on water supply from the bore, the supply will be re-instated by Mt Arthur Coal in consultation with the landholder in a manner agreed by both parties, which may include options such as deepening the bore, construction of a new bore or surface water dam, or piping water from an external source.

Groundwater Monitoring Program

A groundwater monitoring network has previously been established by Mt Arthur Coal within the EA Boundary and surrounding areas, comprising both paired and discrete bores located at 79 sites. A number of these sites are regularly monitored by Mt Arthur Coal for water levels, pH and electrical conductivity.

An expanded groundwater monitoring network consisting of paired bores, one in the alluvium and the second in the underlying Permian strata are recommended for the alluvial areas of the Hunter River and Saddlers Creek that may be impacted. The purpose of the bores is to monitor depressurisation and groundwater quality with the objective of quantifying leakage from the alluvial aquifer. In addition it is recommended that fracture mapping of the highwall and endwall adjacent to the Hunter River be undertaken on a regular basis and any increase in groundwater flows be recorded, the objective being to provide early detection of potential connection with the alluvial aquifer. Containment or mitigation strategies may include compacted clay trenches, slurry walls or grout injection.

TABLE OF CONTENTS

Page No.

TABLE OF CONTENTS
(continued)

Page No.

Attachments:

EHB/UWS:ae (Mt Arthur)
Project No. G1446
June 2009

REPORT ON

MT ARTHUR COAL CONSOLIDATION PROJECT GROUNDWATER IMPACT ASSESSMENT

1.0 INTRODUCTION

Mt Arthur Coal Pty Limited, a wholly owned subsidiary of BHP Billiton Hunter Valley Energy Coal (HVEC) operates the Mt Arthur Coal Mine Complex (Mt Arthur Coal) in the Upper Hunter Valley of New South Wales. The currently approved Mt Arthur Coal Complex consists of the following approved mining areas:

- Bayswater No. 2 open cut pit (extraction completed);
- Bayswater No. 3 open cut pit (operated since 1995);
- Mount Arthur North (MAN) open cut pit (operated since 2001);
- South Pit extension open cut pit (approved in 2008 – extends the MAN South Pit 2.5km south);
- Exploration Adit (commenced operations in 2007); and
- Mt Arthur Underground Project (MAU) approved in 2008.

Mt Arthur Coal currently has approval to produce up to 28 Million tonnes per annum (Mtpa) of Run of Mine (ROM) coal from the combined complex, of which 8 Mtpa is from underground mining methods.

Coal production from the MAN mining area has been the focus of Mt Arthur Coal's operations since 2002. Open cut coal mining is conducted via truck, shovel and excavator. In 2008, coal was mined from the Glen Munro seam to the Ramrod Creek seam within the Wittingham coal measures. Open cut mining methods at Mt Arthur Coal allow the full recovery of all coal down to the Ramrod Creek coal seam.

Mt Arthur Coal is applying to the Minister for Planning for a new Project Approval under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to gain a single, contemporary planning approval for its open cut operations and the mining of additional areas within its current Mining Leases (ML) (the Project). The Project Application Boundary (EA Boundary) is shown on Drawing No. 1 and is consistent with the Project Approval area for the MAU.

Hansen Bailey Pty Ltd (Hansen Bailey) has been commissioned by Mt Arthur Coal to prepare an Environmental Assessment (EA) in support of the Project Application. This groundwater impact assessment has been completed by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) at the request of Hansen Bailey, on behalf of their client Mt Arthur Coal.

This report, which forms part of the EA, assesses the potential impact of the Project on the groundwater regime, in particular on the Hunter River and Saddlers Creek alluvial areas and associated dependent ecosystems and groundwater users. A further objective is to assess future inflows into the pit and groundwater recovery post mining.

The report describes the hydrogeological regime of the local area, identifies potential risks and constraints, and where necessary, mitigation and/or containment strategies are developed. The assessment is based on a three-dimensional transient, groundwater flow model of the area that was developed to provide predictive simulations of the impact of the Project, including the MAU Project on the groundwater regime.

Most data necessary for the assessment of the groundwater regime and required for construction of the groundwater model was sourced from existing reports (including the MER 2007 MAU model), the Mt Arthur Coal databases and from information obtained from previous studies undertaken by AGE at Mt Arthur Coal and surrounding mines. A groundwater specific field investigation was undertaken of the alluvial deposits of White and Fairford Creeks, tributaries of the Hunter River and a small tributary of Saddlers Creek.

2.0 PROJECT OVERVIEW

The Project continues all aspects of Mt Arthur Coal's current activities and specifically, seeks approval for the following:

- Consolidation of all of Mt Arthur Coal's open cut mining related planning approvals into one contemporary Project Approval;
- Extension of the mine footprint to uncover additional coal reserves within the current MLs;
- Increase the Mt Arthur Coal complex approved production levels by 8 Mtpa up to 36 Mtpa ROM coal. This will be achieved by;
  - Increasing open cut coal production by up to 8 Mtpa; and
  - Having the flexibility to increase either open cut or underground production by an additional 4 Mtpa if the maximum production from either underground or open cut methods is not being met (total to not exceed 36 Mtpa).
- Relocation of a section of Edderton Road in approximately 2019;
- Upgrading of the existing Mt Arthur Coal CHPP to wash up to 36 Mtpa of ROM coal and allow the inclusion of an ultra-fine coal circuit to re-process fines which will facilitate increased resource recovery and reduce water demand;
- Increasing the approved rail haulage capacity (in line with the increased coal production from 19 Mtpa to 27 Mtpa), with the construction of a second rail loading facility and associated conveyor system;
- Modifications to existing infrastructure (such as workshop and bath house), construction of additional ROM coal hoppers and the extension of ROM and product coal stockpiles; and
- A total workforce of approximately 2,600 at peak production, which represents an increase of approximately 1,610 from current staffing levels and an estimated additional 720 positions directly attributable to the Project.

No changes to the mining method or hours of operation are proposed, although a gradual increase in the mobile equipment fleet will be required.

3.0 SCOPE OF WORK

The scope of work for the groundwater impact assessment as outlined in the Preliminary Environmental Assessment of March 2009 is as follows[1]:

- *An assessment of the potential for mine groundwater impacts, including impacts on alluvial aquifers and neighbouring landowners boreholes utilising a minimum of two years baseline data, via predictive numerical modelling in the finite-element simulation package FEFLOW (Diersch, 2005);*
- *Estimation of mine groundwater inflow rates suitable for input into the water balance for the Project;*
- *An assessment of any groundwater impacts of infrastructure;*
- *An assessment of cumulative groundwater impacts incorporating surrounding mining and other activities;*
- *An assessment of post-mine groundwater impacts; and*
- *Identification of any groundwater impact mitigation measures for the Project.*

Previously conducted core test results and in-situ boreholes will be utilised to determine seam and interburden permeability's in conjunction with past studies. Exploration and survey data will be used to assign geographic and geological parameters like seam depths, special geological anomalies and river bed heights etc. Coal seam geometry, other smaller drainages, alluvial lands and adjacent mining operations will also be considered in the model.

The Director General's Requirements for the Project dated 21 April 2009 state that, with respect to key issues Soil and Water, the following must be undertaken:

– *a detailed assessment of the potential impacts of the project, using quantitative modelling on:*

  - *the quantity and quality of both surface and groundwater resources;*
  - *water users both in the vicinity and downstream of the project.*

4.0 LEGISLATION, POLICY AND GUIDELINES

The following section outlines New South Wales State Government legislation, policy and guidelines with respect to groundwater that have been addressed for the Project.

4.1 Water Management Act 2000

The objective of the *Water Management Act 2000* (WM Act) is the sustainable and integrated management of the State's water for the benefit of both present and future generations. 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 four types of approval:

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[1] Hansen Bailey, (Jan. 2009), *"Mt Arthur Coal Open Cut Consolidation Project, Preliminary Environmental Assessment",* prepared for Hunter Valley Energy Coal Pty Ltd.

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

For controlled activities and aquifer interference activities, the WM Act requires that the activities avoid or minimise their impact on the water resource and land degradation, and where possible the land must be rehabilitated.

4.2 Hunter Unregulated and Alluvial Water Sources -– Water Sharing Plan

The Water Sharing Plan is currently a “draft” but is planned for implementation in late 2009.

Water Sharing Plans for unregulated rivers and groundwater systems are now being completed using a “macro” or broader scale river catchment or aquifer system approach. Unregulated rivers are those which rely only on natural flow and are not regulated by releases from upstream dams.

Macro water sharing plans for streams and aquifers are developed under the WM Act. The plans set rules for sharing water between the environment and water users and clearly defines shares in available water for licence holders, enabling better water trading opportunities. Water sharing plans support the long-term health of rivers and aquifers by making water available specifically for the environment. With respect to groundwater, macro water sharing plans for unregulated rivers may include rules that recognise that some alluvial aquifers are highly connected to their parent streams and in these circumstances, the goal of water sharing rules is to manage the surface water and highly connected groundwater as one resource.

A long-term average annual extraction limit referred to as the Extraction Management Unit (EMU) will apply across an entire catchment area to which a plan applies. The limit is a longer-term management tool against which total extraction will be monitored and managed over the 10-year life of the plan. The rules in the plan that determine when licence holders can and cannot pump on a daily basis are more specific. Basic landholder rights (i.e. example extraction of a “reasonable use” volume of surface or groundwater for stock or domestic supply) do not require a water access licence, however, water access licences are required for mining activities where these activities intercept an unregulated river or connected aquifer water.

4.3 State Groundwater Policy

The NSW State Groundwater Policy (Framework Document) was adopted in 1997 and aims to manage the State’s groundwater resources to sustain the environmental, social and economic uses. The policy has three components parts:

- the NSW Groundwater Quality Protection Policy, adopted in December 1998;
- the NSW State Groundwater Dependent Ecosystems Policy, adopted in 2002; and
- the NSW Groundwater Quantity Management Policy (Draft).

4.3.1 Groundwater Quality Protection

The NSW Groundwater Quality Protection Policy (1998), states that the objectives of the policy will be achieved by applying the management principals 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. *Groundwater dependent ecosystems 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*

4.3.2 Groundwater Dependent Ecosystems

The NSW Groundwater Dependent Ecosystems 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 Groundwater Dependent Ecosystems 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:

- groundwater dependent ecosystem (GDE) 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 ensure that sufficient groundwater is available at all times to identified GDEs;

- where scientific knowledge is lacking, the precautionary principle should be applied to protect GDE; and
- planning, approval and management of developments should aim to minimise adverse affects on groundwater by maintaining natural patterns, not polluting or causing changes to groundwater quality and rehabilitating degraded groundwater ecosystems.

4.3.3 Groundwater Quantity Protection

The objectives of managing groundwater quantity in NSW are:

- *to achieve the efficient, equitable and sustainable use of the State's groundwater;*
- *to prevent, halt and reverse degradation of the State's groundwater and their dependent ecosystems;*
- *to 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*
- *to involve the community in the management of groundwater resources.*

4.4 Aquifer Risk

The "Aquifer Risk Assessment Report" of 1998[2] used a number of criteria in classifying the Hunter Valley Alluvium as a "high risk aquifer" on a state wide basis for regulated river reaches, and the Hunter Miscellaneous Tributaries Alluvium as "medium risk aquifers".

4.5 Guideline Requirements for Buffer Zone

Guidelines were prepared for the Hunter Region by the Department of Infrastructure, Planning and Natural Resources now Department of Water and Energy (DWE) in April 2005[3], to assist the coal mining industry in managing risks when mining close to streams using either longwall or open cut mining methods. The guidelines relate to the classification of the stream that may be impacted by mining and indicates that DWE is adopting a precautionary approach to mining in the vicinity of Schedule 3 streams, such as the Hunter River, and associated alluvial groundwater. With respect to open cut mining next to a Schedule 3 stream the guideline requires a buffer of 150m between the mining area and the stream and its related alluvium as shown on Figure 1. The guideline states that *"the buffer provides a front line protection for surface and groundwater quality and managing connectivity"*.

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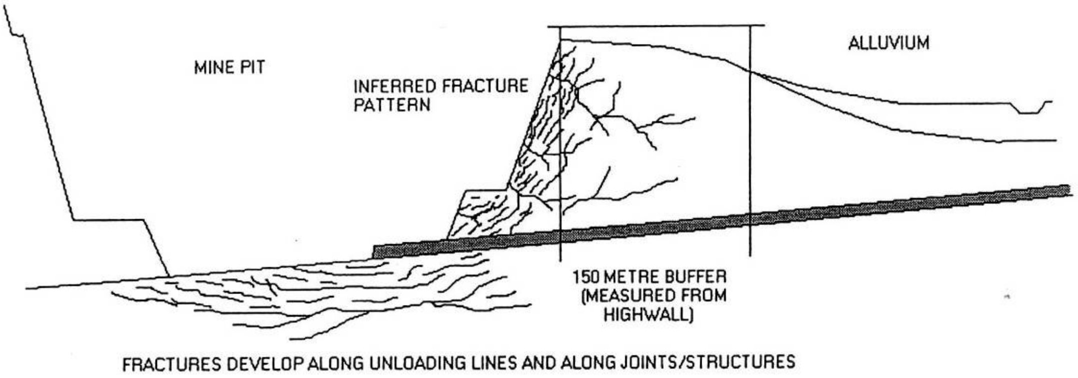
[2] NSW Department of Land and Water Conservation, (April 1998), *"Aquifer Risk Assessment Report"*, HO/16/98.

[3] Department of Infrastructure, Planning and Natural Resources, (April 2005), *"Management of Stream/Aquifer Systems in Coal Mining Developments, Hunter Region"*. Guidelines Ver. 1.



Source: DIPNR Hunter Region (April 2005)

Figure 1: Buffer zone requirement for open cut mining operation next to river / alluvium

5.0 REGIONAL SETTING

5.1 Location

The Project is located approximately 5km south-west of the township of Muswellbrook in the Upper Hunter Valley of NSW. The EA Boundary adjoins Denman Road which parallels the southern edge of the Hunter River alluvial flats. Edderton Road, a sealed rural road bisects the EA Boundary from north to south.

The EA Boundary covers an area of over 130km^2, and consists of the following mining tenements:

• ML1487 and ML1548:	MAN open cut pit;
• ML1358, ML1593, EL5965 and A437:	Bayswater No. 3 open cut pits; and
• CCL744, CL396, MPL 263 and A171:	Bayswater No. 2 open cut pit.

The existing open cut mines and associated infrastructure located within the EA Boundary are:

- Bayswater No. 2 open cut mine which commenced in the early 1960's and ceased mining in 1998, this former mining area now being used for reject and spoil emplacement and on-going rehabilitation;
- Bayswater No. 3 open cut mine which commenced in 1995 and consists of three Pits (Saddlers, Belmont and MacDonald);
- The MAN open cut pit which obtained development consent in May 2001 and commenced mining in late 2001;
- Mt Arthur Coal CHPP; and
- The South Pit Extension for which approval was obtained in January 2008.

Surrounding mines include the Drayton open cut mine operated by Anglo Coal which adjoins the eastern perimeter of the EA Boundary and the Bengalla open cut mine which is approximately 3km to the north across the Hunter River.

The features of the EA Boundary are shown on Drawing No. 1, Figure 2 and Figure 3.

5.2 Topography and Drainage

The topography of the EA Boundary is generally gently undulating; however the landform steepens with some rugged terrain associated with the slopes and foothills of Mount Ogilvie (RL468m) in the south-west sector, and Mount Arthur (RL483m) in the central east (Drawing No. 1). An east-west orientated ridge is associated with these two dominant topographic features and is a major drainage divide; broadly subdividing the area within the lease into two catchments. The northern catchment contains three main creeks; Quarry, Fairford and Whites Creeks, which discharge to the Hunter River alluvial land and the river. The dominant creek of the southern catchment is Saddlers Creek which flows in a south-easterly direction eventually discharging into the Hunter River about 6km further downstream. The topographic elevation is approximately RL140-150m along the northern Denman Road boundary, and approximately RL130m where Saddlers Creek crosses the southern boundary.

Due to the steep to gently undulating topography, there are numerous small creeks which drain the area and feed into the larger creeks. All of the creeks are ephemeral and only run for short periods after rainfall.

The topography of the EA Boundary has been heavily altered by the existing mining operations, of Bayswater No. 3, Bayswater No. 2, MAN and South Pit Extension Pits.

5.3 Land Uses

The predominant land use surrounding the EA Boundary is agriculture with the main activity being relatively low intensity cattle grazing. Roxburgh Vineyard is located on the northern boundary of EL5965. The rich alluvial plain of the Hunter River, north of the EA Boundary, supports a variety of intensive agricultural land uses including dairy and beef cattle grazing on improved pastures, fodder cropping, horse breeding and training.

A small area of remnant woodland is associated with Crown Land around the summit of Mount Arthur.

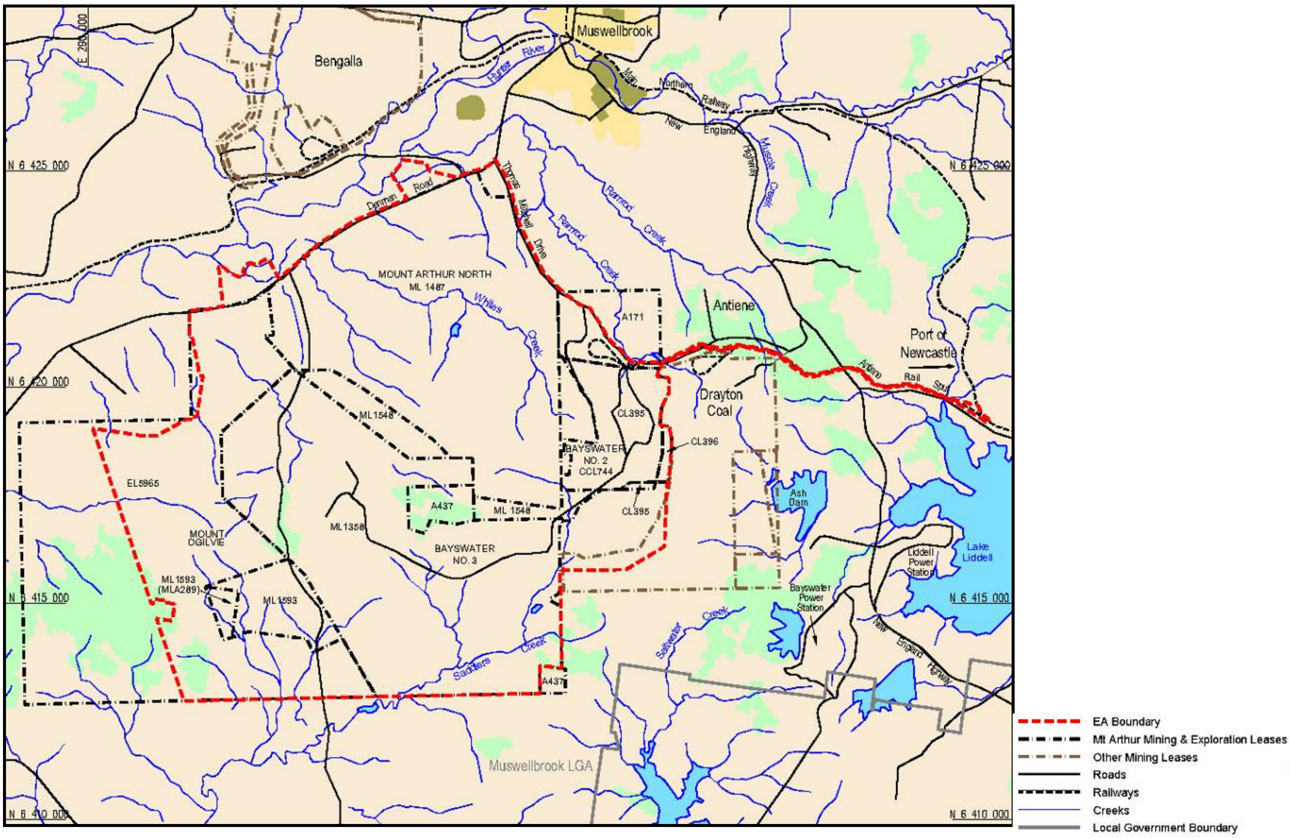


Figure 2: Locality Plan (after Hansen Bailey 2009)

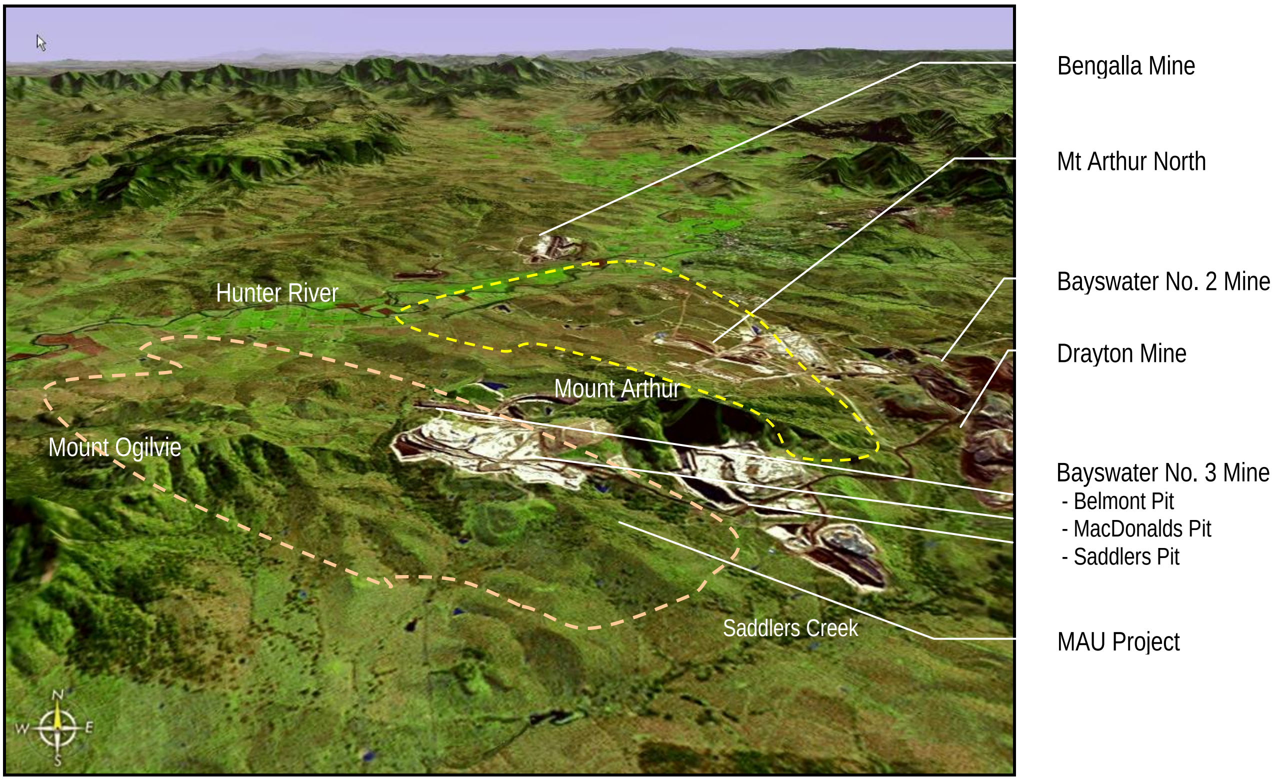


Figure 3: Three Dimensional View of Mt Arthur Coal (Google Earth satellite imagery)

5.4 Climate

The climate in the EA Boundary is typical of temperate areas and is characterised by hot summers dominated by thunderstorms and mild dry winters.

Climate monitoring data collected by the Bureau of Meteorology (BoM) was obtained for Muswellbrook High School (5km north-east of the EA Boundary), Jerry's Plains (13km to the south-east) and Scone (around 30km north-east of the EA Boundary) stations. Statistical data of mean monthly temperatures are available from Jerry's Plains Station and of rainfall from Muswellbrook High School Station. However, evaporation has only been recorded at the distant Scone Station. The mean maximum temperature during winter varies in the range of 17.4°C to 19.4°C and in summer, the mean maximum daily temperature reaches 31.7°C (January). The average annual rainfall is 616mm, with January being the wettest month (79mm). Evaporation of 1,570mm/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) which is a summation of the monthly departures of rainfall from the long-term average monthly rainfall was calculated as follows:

$$CRD_n = CRD_{n-1} + (R_n - R_{av})$$

Where: CRD_n = CRD for a given month

CRD_{n-1} = CRD for a preceding month

R_{av} = long-term average rainfall for a given month

R_n = actual rainfall for given month

The average monthly rainfall used to produce the CRD graph was obtained from the BoM, Jerry's Plains Station (061086), which has a continuous record for the period 1884-2009. A positive slope in the CRD plot indicates periods of above average rainfall, whilst a negative slope indicates periods when rainfall is below average. The CRD from 1994-2009 shown on Figure 4 indicates that the area experienced a long period of generally below average rainfall from March 2001 until end of May 2007 but has experienced above average rainfall from then until the present.

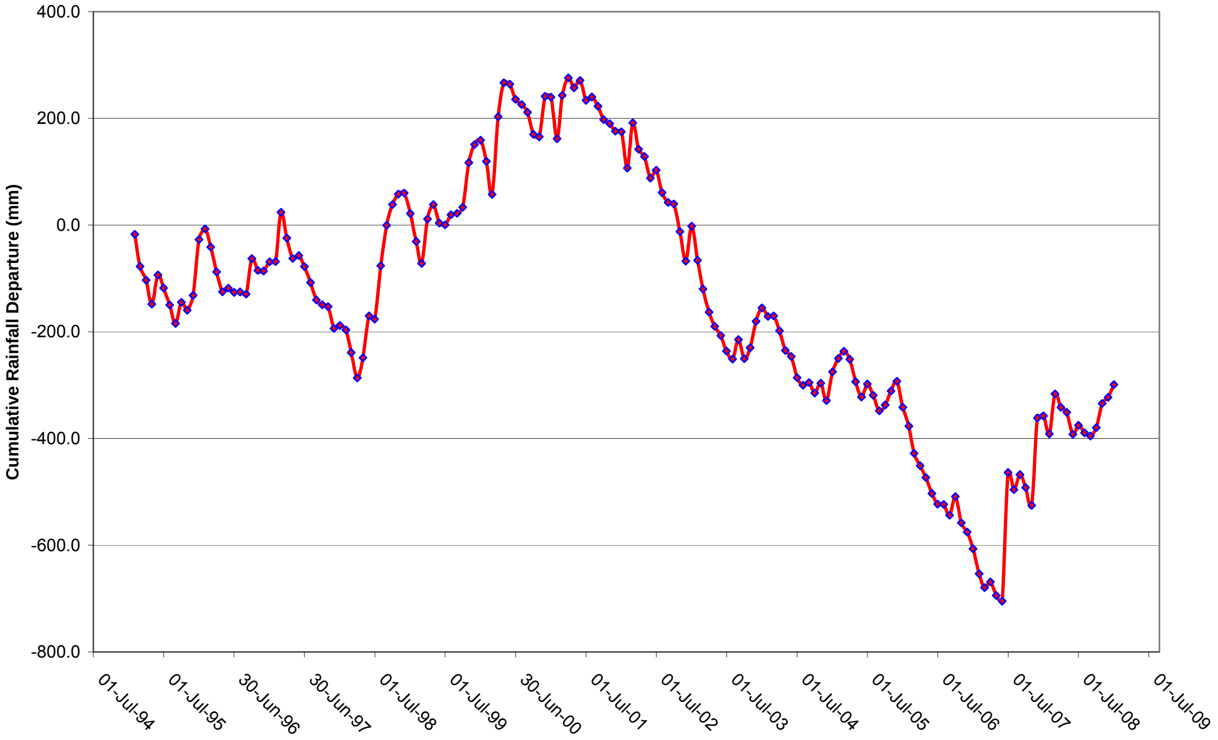


Figure 4: Cumulative Rainfall Departure Graph – Jerrys Plains Station (061086)

6.0 PREVIOUS GROUNDWATER STUDIES

A number of previous groundwater studies have been undertaken within the EA Boundary and immediate surrounds.

The earliest study cited was undertaken by Australian Groundwater Consultants Pty Ltd (AGC) in 1979[4] for the Electricity Commission of NSW. The investigation included:

- “packer” permeability tests at 10.54m intervals to 216m depth on a deep borehole;
- three falling head tests to obtain comparative permeability data; and
- two airlift/recovery type hydraulic tests.

The overall objective was to obtain data on the hydraulic characteristics of the stratigraphic profile in order to provide an assessment of groundwater inflow to a 2km shallow strip mining operation at MAN. The seams of interest were the Vaux, Bayswater, Edinglassie and Ramrod Creek.

In August 1980[5] AGC revised and extended the prediction of groundwater inflow to take into consideration changes to the proposed mining areas, including a shallow pit north of Whites Creek and a deep pit north of Mount Arthur. An assessment was also undertaken of dewatering using

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[4] Australian Groundwater Consultants Pty Ltd, (June 1979), *“Mt Arthur North Coal Project Groundwater Studies – Preliminary Report”,* Job No. 533/1.

[5] Australian Groundwater Consultants Pty Ltd, (Aug 1980), *“Mt. Arthur North Coal Project, Groundwater Yields”,* Report 628.

deep boreholes and the potential impact of dewatering on the Hunter River alluvium. The Hunter River alluvium was also broadly considered as a water supply source.

AGC also undertook a groundwater investigation for the Mt Arthur South Coal Project in 1981[6] and the data obtained from this report is summarised by Sinclair Knight and Partners (SKP) in 1981[7]. The AGC (1981)[6] report assessed inflow to the pits and the potential to obtain a groundwater supply for coal processing.

Laurie Montgomerie and Petit Pty Ltd (LM&P) undertook a groundwater investigation for the Mt Arthur North Coal Project in 1982[8]. The report summarises the results of a long-term pumping test and describes numerical modelling of the coal seam aquifer in Whites Creek and Ramrod Creek Pits using assumed borefield dewatering networks.

A groundwater study for the MAN Coal Project and surrounding areas was undertaken by Mackie Environmental Research (MER) in March 2000[9] as part of an Environmental Impact Statement (EIS) prepared by URS (2000)[10]. The study included review of existing information, field investigations, groundwater monitoring, sampling and analysis. Additional monitoring piezometers were constructed as part of the studies and a composite piezometric surface developed for the region. Historical and more recent hydraulic properties and hydrochemistry of groundwaters were summarised and a mathematical groundwater model of the aquifer systems developed to assess the impact of open cut mining on the groundwater regime.

AGE (2003)[11] completed a preliminary assessment of potential risks and constraints associated with groundwater for a proposed multi-seam underground mining operations within the EA Boundary. Inflow assessments were based on hydraulic properties reported from previous investigations and the proposed mine plan. It was assessed that inflow could range from 1.5ML/day (17L/s) from the shallow Glen Munro Seam to 0.14ML/day (1.7L/s) for the deep Edinglassie Seam, with cumulative inflow to the Edinglassie Seam from all overlying seams, assuming a top-down mining sequence of the seams, and goaf interconnections of the mined seams, of 3.6ML/day (42L/s). The maximum radius of influence of seam depressurisation was predicted to be 3.25km from the perimeter of the mined area.

In March 2006[12] AGE completed an internal groundwater impact assessment for Mt Arthur Coal on the MAN Pit's impact on the groundwater regime, particularly the Hunter River and Saddlers Creek alluvium and to assess future inflows to the pits. A three-dimensional, transient, finite element model was developed with predictive modelling indicating a peak inflow rate of 2.9ML/day at year 7, declining and stabilising at 1.5ML/day at year 10. The model indicated an impact of about

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[6] Australian Groundwater Consultants Pty Ltd, (Feb 1981), *"Mt. Arthur South Coal Project – Groundwater Studies",* Report 590.

[7] Sinclair Knight and Partners Pty Ltd, (April 1981), *"Mount Arthur South Coal Project – Water Management Study".*

[8] Laurie, Montgomerie and Petit Pty Ltd, (Nov 1982), *"Mt. Arthur North Coal Project, Water Management-Groundwater Hydrology Investigation Final Report."*

[9] Mackie Environmental Research, (March 2000), *"Mt. Arthur North Groundwater Management Studies".*

[10] URS, (April 2000), *"Mt Arthur North Coal Project – Environmental Impact Statement".*

[11] Australasian Groundwater and Environmental Consultants Pty Ltd, (Dec 2003), *"Report on Mt Ogilvie Underground Project, Concept Study – Hydrogeological Assessment",* Project No. G1206.

[12] Australasian Groundwater and Environmental Consultants Pty Ltd, (March 2006), *"Report on Mt Arthur North Open Cut Coal Mine – Groundwater Impact Assessment",* Project No. G1301/A.

3.2km^2 of Hunter River alluvium after 21 years with flow rates from the alluvium to the pits of 0.47ML/day (5.4L/s), comparable to the annual rainfall recharge rate on that area of alluvium. Similarly the model indicated a reduced recharge to Saddlers Creek of 0.04ML/day to 0.07ML/day.

In July 2006[13] AGE undertook a groundwater impact assessment of the proposed South Pit Extension using a regional finite element model. The study which was undertaken to obtain project approval found that the impact of the South Pit Extension will be overprinted during most of the mine life by dewatering of the adjacent MAN Pit. Simulated groundwater inflow to the Pit is of the order of 0.3ML/day after 21 years of mining and the radius of depressurisation from the pit crest was predicted to be 1 to 1.5km.

The most recent study at Mt Arthur Coal was undertaken by MER (2007)[14] for the groundwater impact assessment of multi-seam, longwall extraction, to obtain approval for the proposed MAU Project. A regional finite element groundwater model comprising 13 layers was developed incorporating each target seam and including the Hunter River and Saddlers Creek alluvium. Total groundwater seepage to the underground operations is predicted to steadily increase over the period of mining from 0.5ML/day during entry and development of the Woodlands Hill Seam, to a maximum 6ML/day at completion of mining in the deeper Piercefield Seam. Vertical leakage from the Hunter River alluvium due to depressurisation of the coal seam was predicted to remain unchanged whereas vertical leakage from the Saddlers Creek alluvium may be affected with a reduction in upward leakage from the coal seams of 0.08ML/day. Recovery of groundwater levels post mining was predicted to take 50 years.

AGE have also undertaken impact assessment studies involving finite element modelling in obtaining approvals for nearby mines; the Drayton Mine Extension (AGE, 2006[15]) and the Bengalla Mine Wantana Extension (AGE, 2007[16]).

All of the above studies have been used in undertaking the current assessment.

7.0 METHODOLOGY

The scope of work and methodology were staged as follows:

Stage 1 – Data Review

A request for all existing data of relevance to the groundwater regime of the EA Boundary, including monitoring of drawdown and inflows due to current mining operations was reviewed. Discussions were also held with mine site personnel to ensure that the Project and the geology of the area, particularly the structural geology, was fully understood.

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[13] Australasian Groundwater and Environmental Consultants Pty Ltd, (July 2006), *"Report on Groundwater Impact Assessment, Mt Arthur Coal South Pit Extension Project",* Project No. G1329.

[14] Mackie Environmental Research Pty Ltd, (Sept. 2007), *"Mt Arthur Underground Project Environmental Assessment, Groundwater Management Studies".*

[15] Australasian Groundwater and Environmental Consultants Pty Ltd, (October 2006), *"Report on Drayton Mine Extension – Groundwater Impact Assessment",* Project No. G1341.

[16] Australasian Groundwater and Environmental Consultants Pty Ltd, (April 2007), *"Report on Bengalla Mine Wantana Extension – Groundwater Impact Assessment",* Project No. G1372.

Stage 2 – Field Investigation

A field investigation was undertaken to determine the lithology, aerial extent, thickness and degree of saturation of the alluvium of Whites and Fairford Creeks which are tributaries of the Hunter River that will be mined through and removed as part of the extension of MAN Pit. The alluvium of a small tributary of Saddlers Creek that it is proposed will be mined through and removed by the extension of Saddlers Pit was also investigated.

Stage 3 – Conceptual Groundwater Model Development

A conceptual groundwater model of the Project was developed based on the previous work AGE has undertaken within the EA Boundary and the additional and more recent data provided in relation to the current Project.

Stage 4 – Numerical Modelling

A three-dimensional numerical model was developed using the regional finite element models developed by AGE (2006)[13] for the South Pit Extension, the regional finite element model developed for the MAU Project which was provided by Mr Colin Mackie of MER, and the more recent data on coal seams floor elevations and geological structure. The model was developed to include the cumulative impact of the Project and Bengalla Mine to the immediate north of the Hunter River but not of the nearby Drayton Mine which is structurally and hydrogeologically separated from the Project.

The model was used for predictive simulations of the impact of the Project on the groundwater regime with emphasis on:

- the impact on the Hunter River and Saddlers Creek alluvium;
- prediction of inflow to the mine; and
- assessment of post mine groundwater impacts including predictive final void water levels.

Stage 5 – Recommendations

Recommendations for mitigation or containment strategies were made where adverse impacts are likely, for monitoring and management of the groundwater resource, and of groundwater contributions to the operations water balance, based on the results of the numerical modelling.

8.0 FIELD INVESTIGATIONS OF ALLUVIUM

The Project proposes to extend the footprint of the open cut mine to uncover additional coal reserves. This will require mining through and removing the remaining portion of Whites and Fairford Creeks and associated alluvium which drain into the Hunter River. A small tributary and associated alluvium of Saddlers Creek will also be removed by mining in the south.

In order to assess the potential impact of the Project on the groundwater regime, the extent (both laterally and vertically) of the alluvium in these tributary creeks, the lithology, groundwater bearing potential and degree of hydraulic connection to the main aquifers of the Hunter River and Saddlers Creek alluvium was investigated through test pitting and drilling. The following sections describe these investigations and the findings.

8.1 Whites and Fairford Creeks

Nine test pits (DTP1 to DTP9) were excavated and six boreholes (DBH1 to DBH6) were drilled on the southern side of Denman Road in the area of Whites and Fairford Creeks, the locations of which are shown on Drawing No. A1 in Appendix 1. Soil logs for the test pits and boreholes are also provided in Appendix 1. Conclusions reached from the data obtained are that:

- the test pits excavated and visual inspection of the Whites Creek and Fairford Creek drainage alignments have shown that the extent of the alluvial sediments appears to be similar to that identified for the 2007 Mt Arthur Underground study by MER[14].
- drilling at selected locations has identified the presence of sand or gravel sediments at the base of the alluvium in which groundwater was also intersected. These sediments appear relatively narrow and occur within two discreet areas, one at DBH2 within the central portion of the Whites Creek alignment roughly midway and downslope of a water storage dam embankment, and the other at DBH4 within the Fairford Creek alluvium. Both creeks drain north-west towards the Hunter River.
- comparison between the alluvial sediments intersected in bores DBH2 and DBH4 south-east of Denman Road and those intersected in nearby monitoring bores MGW3 (GW16) and MGW4 (GW17) drilled within the Hunter River alluvial floodplain north-west of Denman Road as part of the MAN EIS, shows that generally similar stratigraphic sedimentary sequences were intersected in the holes, but at slightly more elevated levels south-east of Denman Road. This suggests the likelihood for hydraulic interconnection within the sandy gravel sediments occurring between these two areas, and an overall groundwater gradient to the north-west towards the Hunter River.

In summary the borehole test pitting and drilling has shown that there is a narrow band of alluvium extending between 200m and 350m to the south-east along Whites and Fairford Creeks respectively, and that in the down gradient end of the creeks, the alluvium is saturated and in hydraulic connection with the Hunter River alluvium. The sediments in the upper part of the creeks however consist predominantly of silty to sandy clays which typically form an aquitard and hence do not readily transmit groundwater. The extent of these alluvial sediments along the Whites Creek and Fairford Creek drainage alignments is similar to that shown by MER, 2007[14].

Cross-sections showing the relationship between the alluvial sediments intersected at DBH2 and DBH4, and those intersected in monitoring bores MGW3 (GW16), and MGW4 (GW17), drilled in the Hunter River floodplain as part of the MAN EIS are shown in Figure 5 and Figure 6.

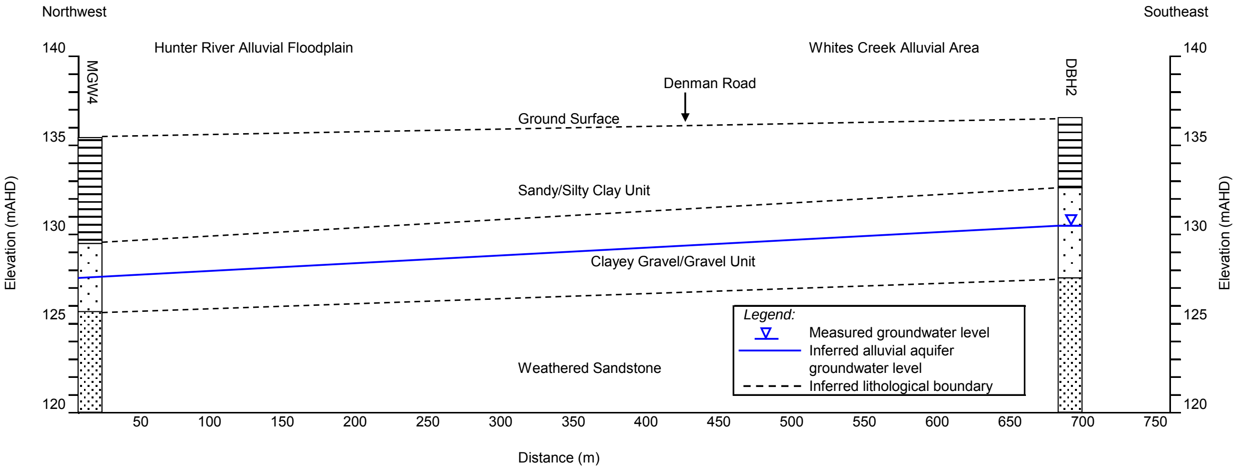


Figure 5: Northwest-Southeast Cross Section across the Whites Creek Alluvial Area and Hunter River Floodplain

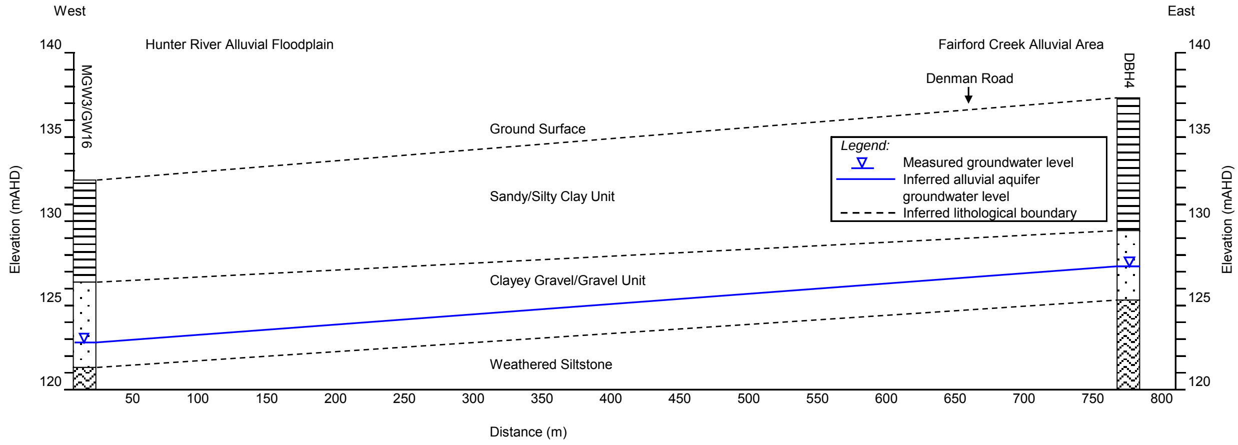


Figure 6: West-East Cross Section across Fairford Creek Alluvial Area and Hunter River Floodplain

8.2 Tributary of Saddlers Creek

The proposed continuation of mining in Saddlers Pit will mine through and remove alluvial sediments in the upper part of a small tributary that drains into Saddlers Creek. In order to assess the potential impact of this proposal and potential mitigation options, the extent of the alluvium was mapped and two test pits were excavated in the alluvium. The test pit locations are shown on Drawing A2 in Appendix 1. The data obtained indicates that:

- the extent of the alluvium is similar to that identified from previous mapping as shown on Drawing No. 1;
- the alluvium consists of clayey sand and gravels, sandy clays and medium plasticity clay. The test pit logs and photographs are given in Appendix 1;
- groundwater was intersected in one test pit (STP1), at 1.5m depth and is associated with sandy or gravely alluvial sediments; and

- the second test pit (STP2), downstream of STP1 which extended to 2.5m depth in a clayey sand, did not intersect groundwater.

Based on the data obtained, it is concluded that the alluvium is relatively thin, and that groundwater occurrence is sporadic, being associated with lenses of more permeable sand and gravely sand.

9.0 GEOLOGICAL SETTING

9.1 Stratigraphy

The stratigraphic sequence across the EA Boundary comprises two distinct units, namely a Permian coal seam sequence with an overburden and interburden consisting of lithic sandstone, interbedded with siltstone, tuffaceous claystone and mudstone. The Permian sediments are unconformably overlain by thin Quaternary alluvial deposits. The Quaternary alluvial deposits consist of sand and gravel along the creek valleys within the EA Boundary, and in the alluvial floodplain of the Hunter River to the north of the Project.

The Permian rocks form a regular layered sedimentary sequence consisting of two main units:

- the Wollombi Coal Measures that, within the EA Boundary, contain uneconomic coal seams and are confined to isolated portions of elevated sections of the Mount Ogilvie area. These measures are typically above the groundwater table; and

- the Wittingham Coal Measures that contain economic coal seams and underlie the whole of the EA Boundary to a depth of about 500m.

The Wittingham Coal Measures which include the basal Saltwater Creek Formation are underlain by a thick, non coal bearing sequence of siltstone, sandstone and mudstone known as the Maitland Group which in turn overlies the Greta Coal Measures. Both the Wittingham Coal Measures and the Maitland Group outcrop in the eastern part of ML1487 and ML1358. The Greta Coal Measures outcrop at Bayswater No. 2 where they were mined and at Drayton Mine where they are currently being mined.

A general stratigraphic section for the mine area is given on Figure 7.

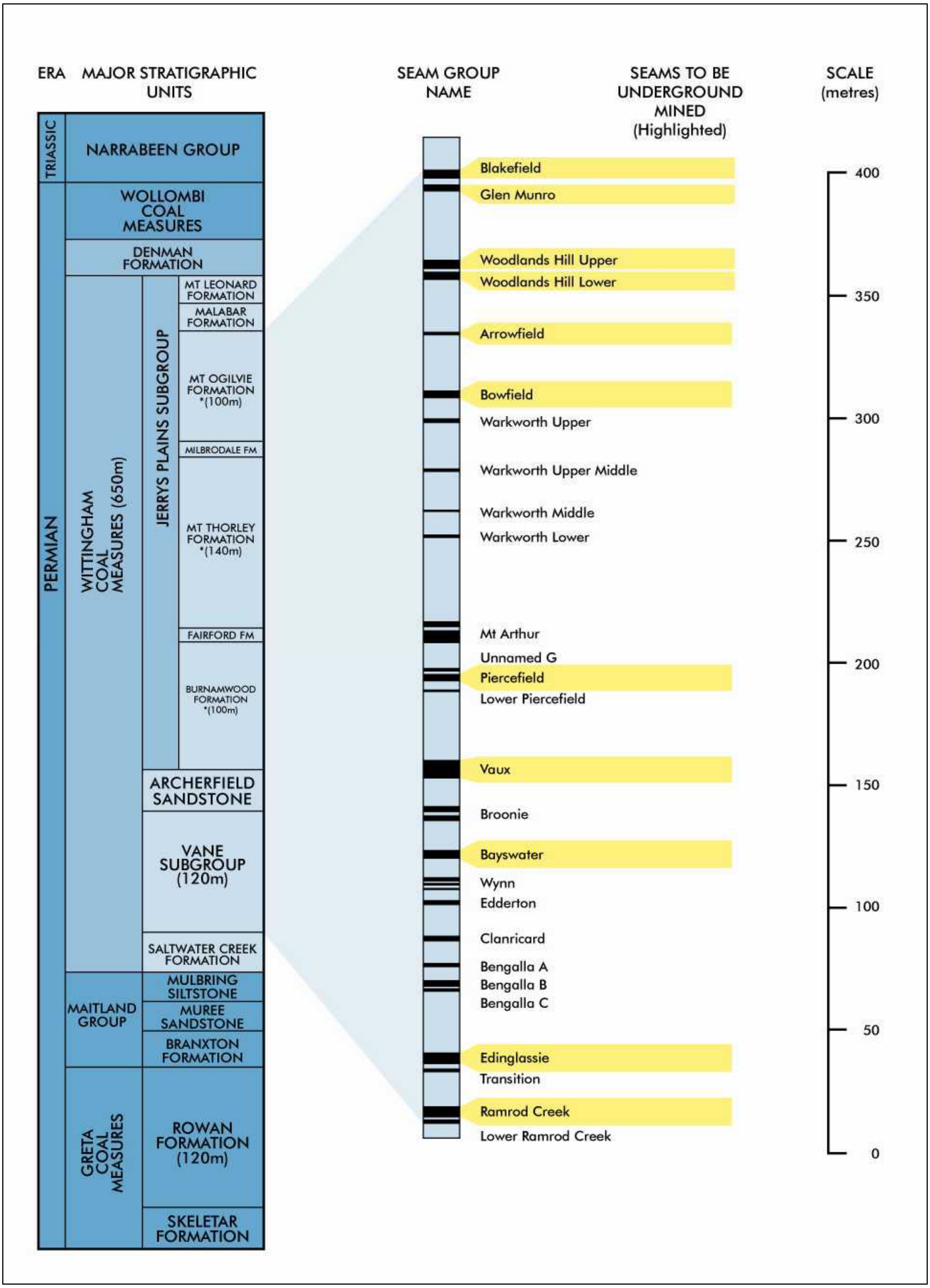


Figure 7: Stratigraphic Column (supplied by Mt Arthur Coal)

The coal seams within the Jerrys Plains and Vane Subgroups of the Wittingham Coal Measures will be mined by the Project. A summary of the seams and interburden and their average thicknesses are presented in Table 1 below. The data referring to the thickness of the seams and interburden are based on the already cited AGE (2003)[11] report on the Ogilvie Underground Mine and on information received from Mt Arthur Coal. The total thickness of the coal measures is 200m to 220m.

Table 1: SEAMS BEING MINED BY THE PROJECT

Seam Name	**Thickness (m)**		**Interburden to Underlying Seam (m)**
	Range	*Average*	*Average*
Blakefield	0.2-5.6	3.8	54
Glen Munro	0.2-5.6	2.7	34
Woodlands Hill	0.2-7.5	3.6	66
Arrowfield	0.1-3.7	2.3	20
Bowfield	0.4-4.7	2.5	117
Mt Arthur		4.5	5
Unnamed 1		< 1	10
Piercefield	0.4-5.4[2]	2.3	26[2]
Vaux	0.5-4.5[2]	4	20[2]
Broonie	1-1.5	1.3	13[2]
Bayswater	0.5-4.8	2.8	10
Wynn		<1	5
Unnamed 2		1	5
Edderton		2	10
Clanricard	1.5-2.0	1.8	10
Bengalla	<3.5	2.5	10
Edinglassie	3.0-4.8[2]	3.9[2]	30
Ramrod Creek	<8.5	6.5	-

Note: [2] Information received from Mt Arthur Coal.

Igneous intrusions within the EA Boundary occur mainly as dolerite dykes generally 0.5m to 1.0m in width which selectively intrude the coal seams in localised areas. Occurrences of igneous sills, recorded at Mt Arthur South and in the upper seams of the MAU, are not expected to be significant in the EA Boundary (EIS, 2000)[10].

9.2 Structure

The Project is located to the west of the Muswellbrook Anticline where the seams sub-crop as shown on Figure 8. The coal seam sub-crop area continues to the north of the Project beneath the Quaternary deposits of the Hunter River. From the sub-crop the Wittingham Coal Measures dip to the west-south-west towards the Calool Syncline.

The regional geological structure is dominated by a north-south trending monocline and open cut mining has generally been located to the north-east and east of the monocline but will extend to the west as part of the Project.

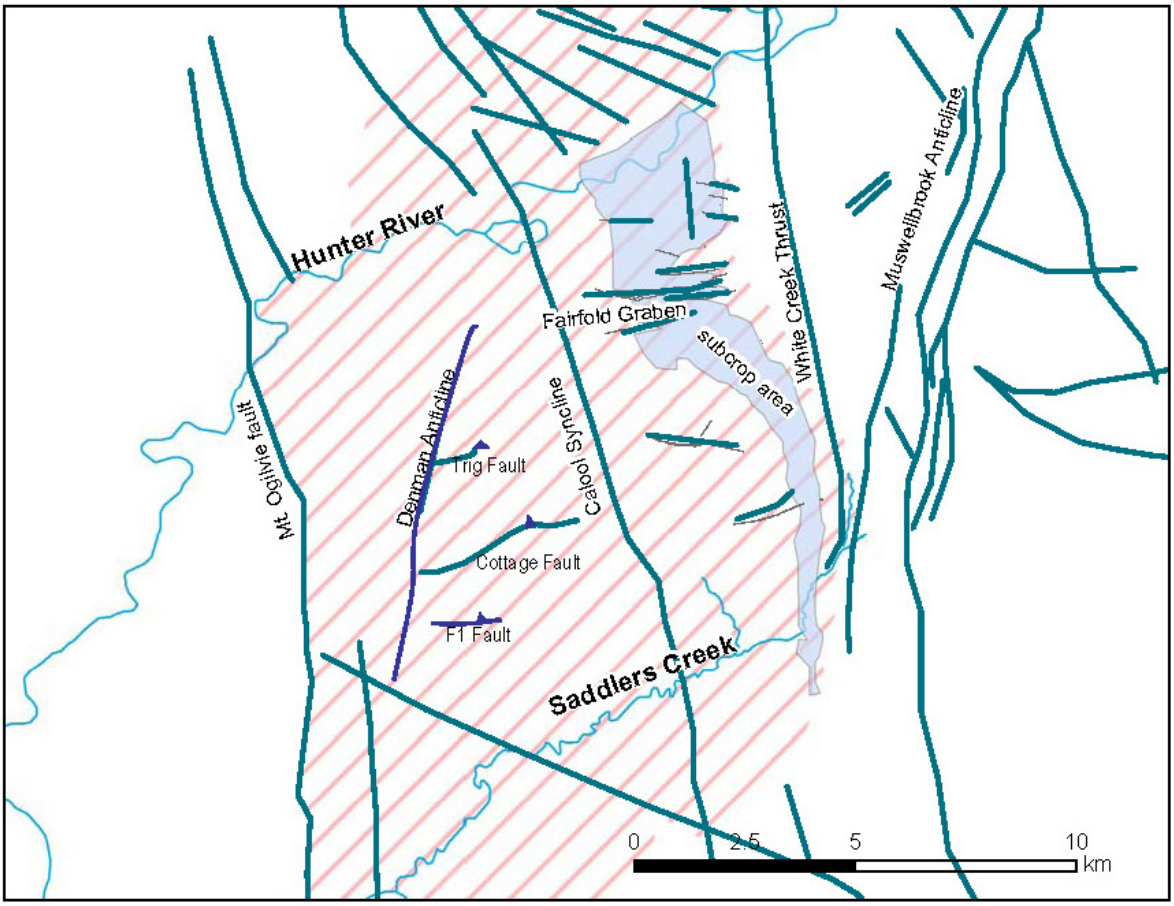
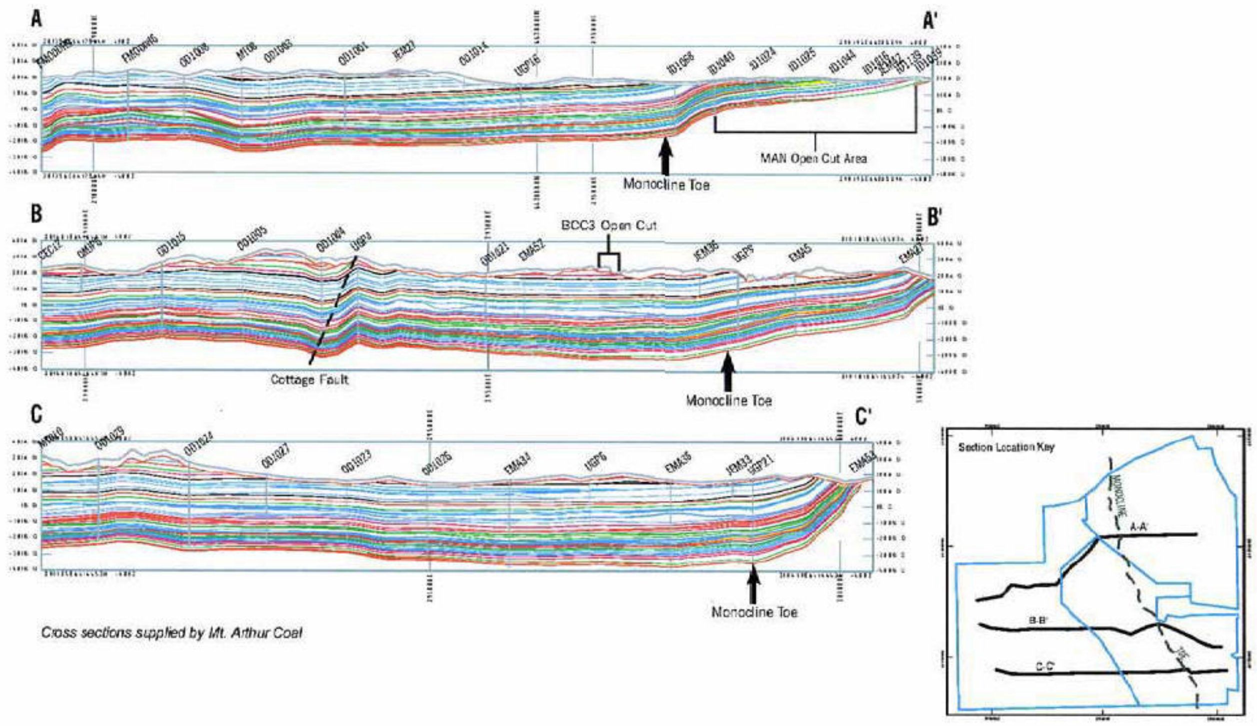


Figure 8: Overview of Main Faults and Folds within EA Boundary and Surrounds (hatched)

Major faulting within the area is infrequent however several fault directions have been identified from the studies undertaken. These include, as shown on Figure 8:

- an east-west trending graben structure, the Fairford Graben located in the central part of MAN Pit which varies in width from 750 – 1,000m and which displaces coal seams by up to 110m. North of the graben the dip of the seams varies between 2º and 10º with an average of about 8º and to the south the dip varies between 2º to 20º;
- the northerly trending Mount Ogilvie Fault Zone in the west of the area, which is significant in that it exhibits a regional displacement (down-throw to the west) of 200m. The Mount Ogilvie Fault forms a structural boundary to the west of the EA Boundary;
- north-easterly trending faults including:
  - Trigg Fault which has a displacement varying from 0m to about 40m, east to west;
  - Cottage Fault which has a displacement varying from 0m at the eastern (MacDonald’s Pit) end up to 120m at the western end; and
  - F1 Fault which has a displacement of 20m to 45m, east to west.

East-west geological cross sections are shown on Figure 9.



Cross sections supplied by Mt. Arthur Coal

Figure 9: Geological Cross Sections

10.0 CONCEPTUAL MODEL - HYDROGEOLOGICAL REGIME

10.1 Conceptualisation

Based on the review of existing data, a conceptual model of the hydrogeological regime has been developed. This section of the report discusses the conceptualisation and the data used to develop the model.

The conceptual groundwater model of the Project, illustrated in Figure 10, was developed based on geological and topographical maps of the area, geological information provided by Mt Arthur Coal, and on the results of previous studies.

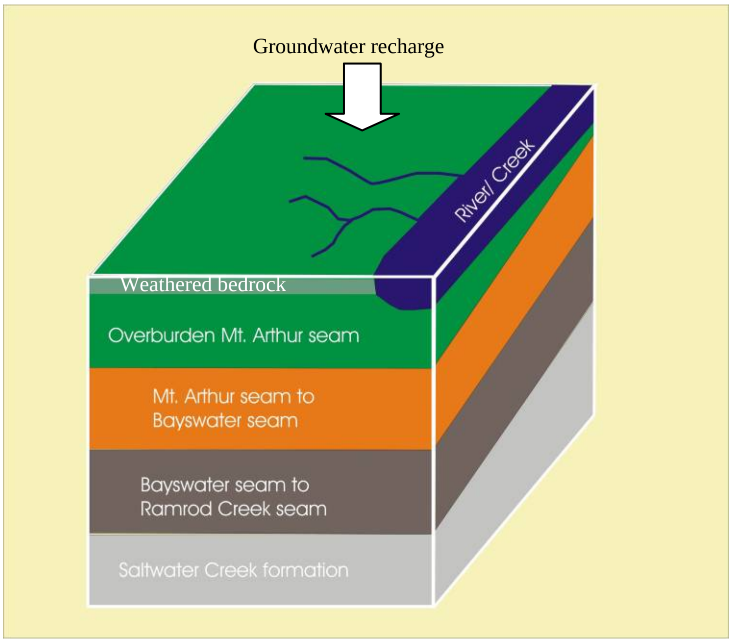


Figure 10: Conceptual Model - Mt Arthur Coal

The conceptual model of the region encompasses the area shown on Drawing No. 2, that is, the area between:

- the watershed north of Bengalla Mine which is a groundwater divide,
- the outcrop of the Saltwater Creek formation, that is the base of the coal seams in the east,
- the watershed (groundwater divide) to the south of Saddlers Creek valley; and
- the Mount Ogilvie fault zone to the west.

Alluvial deposits within the model domain are present along the Hunter River and also along Saddlers Creek. The Permian Wittingham Coal Measures are not considered to be a significant aquifer. While some coal seams may show an elevated hydraulic conductivity, the dominant interburden sections are of very low hydraulic conductivity. Only the weathered bedrock (regolith) directly below the ground surface may have a somewhat higher hydraulic conductivity due to weathering. Therefore, from a conceptual groundwater model perspective, the groundwater system in the EA Boundary is considered to consist of three aquifer systems, *viz*:

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

Recharge to the aquifers is assumed to occur over the entire model area. The rate of recharge over the alluvial deposits and areas of coal seam sub-crops is considered to be higher than over the areas covered by the overburden and interburden.

The following sections characterise the different aquifer systems and discuss the underlying data.

10.2 Alluvial Aquifers

10.2.1 Distribution

Deposits of unconsolidated silts, sand and minor fine gravels of mixed colluvial-alluvial origin occur in the valleys of the creeks and gullies within the EA Boundary. These deposits are thin and of limited extent, and hence do not have significant groundwater storage capacity. They may contain groundwater which has infiltrated from surface runoff following periods of heavy rainfall and discharge of this groundwater from the alluvium maintains a baseflow in the creeks and gullies following rainfall. The alluvium however drains quickly and discharge/baseflow to the creeks is short lived.

Farm dams have been constructed on many of the creeks within the EA Boundary indicating that the alluvium is both of very low permeability and is thin, as otherwise the dams would leak and not retain water. Field investigations have shown that the upper part of the Saddlers Creek valley is infilled with the less permeable unconsolidated silts.

In contrast, the alluvial deposits of the Hunter River to the immediate north of the EA Boundary are a significant source of groundwater. MER (2000)[9] reviewed available data from existing stock and irrigation bores in the Hunter River alluvium and constructed five monitoring bores MGW1-5, subsequently renamed by Mt Arthur Coal as GW16, 17, 21, 24 and 25. The location of these bores is shown on Drawing No. 3. The data indicated that "*groundwater within the alluvial lands of the Hunter River occurs within the basal gravel sequence and overlying sands*".

The Hunter River alluvium is up to 13m thick and contains basal gravel varying between about 2.5m and 4m in thickness. The material overlying the basal gravel consists predominantly of silt with minor clay. Water bearing sand lenses occur within the silt.

The saturated thickness of the alluvium in bores GW16, 17, 21, 24 and 25 ranged from 2m to 6m (MER, 2000)[9].

10.2.2 Yield

Due to the thin saturated thickness of the alluvium bore yields are generally quite low; the higher yielding bores being those with the greatest saturated thickness. MER (2000)[9] undertook pump out tests on the five monitoring bores (GW16, 17, 21, 24 and 25) at rates of around 0.25L/s, with the drawdown in individual bores varying between 0.01m and 0.97m.

Data provided by the DWE for stock and irrigation bores indicates that bore yields vary from 1L/s to 80L/s, with the higher yielding bores being close to the river. The stock and irrigation bore locations are shown on Drawing No. 3.

10.2.3 Hydraulic Parameters

Pumping tests on bores GW16, 17, 21, 24 and 25 by MER (2000)[9] indicates that the basal gravel of the Hunter River alluvium has a moderate to high hydraulic conductivity in the range 5-40m/day, with a median value of 8.2m/day. Values determined at other locations in the area range from 2m/day to more than 60m/day.

The data suggests a highly variable and anisotropic hydraulic conductivity distribution in the alluvium.

10.2.4 Recharge and Groundwater Flow

Recharge to the alluvium occurs from direct infiltration of rainfall, and runoff from elevated bedrock sub-crop areas. The groundwater that occurs in the thin, limited alluvial deposits within the EA Boundary is perched above the main water table and is short lived, draining relatively rapidly into the creeks and gullies.

Apart from infiltration of rainfall and runoff from higher areas the alluvium along the Hunter River is recharged during very dry periods from flow in the Hunter River. The flow in the Hunter River is maintained by release of water from Glenbawn Dam upstream. Upward leakage from the underlying coal measures also adds to recharge of the Hunter River alluvium and to the Saddlers Creek baseflow.

MER (2000)[9] state that measurements of groundwater levels in the alluvium indicate a shallow hydraulic gradient towards the Hunter River, consistent with the regional hydraulic gradient. That is the hydraulic gradient from the edge of the alluvium appears to be consistent with that of the coal seams and with the overall gradient in the EA Boundary. There is also an alluvial water table hydraulic gradient following the alluvium and the Hunter River down stream.

10.3 Shallow Bedrock (Regolith) Aquifer

The regolith or shallow bedrock aquifer comprises surficial soils and weathered bedrock. The depth of the aquifer is variable and depends on such factors as:

- depth of weathering; and
- extent and frequency of fracturing.

Interpretation of available data indicates that there are perched aquifers at the interface between soils and bedrock, and zones of locally increased permeabilities caused by weathering of the bedrock. MER (2000)[9] states that the transition of the mixed colluvial-alluvial type deposits to underlying weathered coal measures is often difficult to define in areas where coarse clastics occur and the depth of weathering is significant.

MER (2007)[9] states the rainfall recharge to other shallow groundwater systems situated in elevated areas including the weathered rock zone or regolith, is often variable. The coal measures in these areas tend to weather to a relatively thin regolith (5m to 10m thick) comprising mixed sandy, silty-clayey sediments. The silty-clayey zones have poor transmission characteristics but the sandy areas offer increased potential for groundwater recharge.

The regolith acts as a temporary water store during sustained wet periods and provides a source for recharge to the underlying coal measures. However, recharge to the underlying coal measures is inferred to be limited given the very low hydraulic conductivities of deeper strata and observed minimal change in water levels in deep monitoring bores throughout the region. This differentiation in properties between the regolith and underlying coal measures can sometimes result in the presence of shallow springs although few are noted within the EA Boundary.

The shallow bedrock aquifer is implemented in the conceptual groundwater model as a zone of enhanced hydraulic conductivity, compared to the sediments in the creeks and Permian sediments.

10.4 Permian Aquifers

The 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 / overburden; and
- low to moderately permeable coal seams which are the prime water bearing strata within the Permian sequence.

10.4.1 Distribution

As discussed the Permian deposits occur across the whole of the EA Boundary as a regular layered sedimentary sequence.

10.4.2 Yield

A number of hydraulic tests have been undertaken on various coal seams within the EA Boundary in the past. A long-term (28 days) pumping test undertaken in bore P3(R) located in the Ramrod Creek seam was reported by LM&P (1982)[8] to provide a continuous yield of about 1.7L/s. The seam at the site of P3(R) is 178m below ground level. Other bores were also installed and tested in the Edinglassie Seam and Ramrod Creek Seam. The test results are summarised in Table 2 below. The location of P1(R) and P3(R) now referred to as GW11 and GW9 respectively, are shown on Drawing No. 3.

Table 2: SUMMARY OF PUMPING TESTS

Site	Pump Well	Seam	Approximate Depth to Seam (m)	Yield (L/sec)	Comments
1	P1(R) [GW11]	Ramrod Ck	105	3.3	Constant rate test – 2 days
2	P3(R) [GW9]	Ramrod Ck	178	1.7	Constant rate test – 28 days
3	P4(E)	Edinglassie	147	1.0	Constant rate test – 3 days

The tests indicate that yields from individual bores within the coal seams are in the range 1.0L/s - 3.3L/s, which is considered to be relatively high given the depth of the tested sections of the seam.

10.4.3 Hydraulic Parameters

Various tests including pump-out, variable head and packer tests have been undertaken in the past. A summary of the hydraulic parameters obtained from these tests is given in Table 3.

All tests were undertaken in the MAN approved mining area. The tests indicate a relatively large variation in hydraulic conductivity of the coal seams in the sub-crop area; the prime difference being related to whether the results were obtained from pumping tests or from packer tests. LP&M (1982)[8] state that *“it is considered that the results of the pump tests are closer to true permeability values and that the results of the packer testing are low*”. If this is correct then the pumping test results gave unusually high hydraulic conductivity values for the coal seams in the range 2 – 20m/day, which is more characteristic of a fine to coarse sand.

Table 3: SUMMARY OF HYDRAULIC PARAMETERS

Bore	Seam	Depth Tested (m)	T (m^2/day)	K (m/day)	S	Test Method	Reference
WT1	Vaux	25-35	1	0.12	-	Packer	AGC (1979)[4]
	Bayswater	50-60	1	0.11	-		
	Wynn	65-75	0.1	0.04	-		
	Clanricard	85-95	0.01	0.01	-		
	Bengalla	98-108	0.05	0.02	-		
	Edinglassie	130-140	0.5	0.05	-		
	U. Ramrod Ck	156-166	0.6	0.12	-		
	L. Ramrod Ck	168-178	0.3	0.15	-		
	Interburden	various	<0.01	<0.01	-		
T13 (BH403)	Piercefield	-	-	0.69	-	Packer	LPM(1982)[8]
	Vaux	-	-	0.52	-		
	Bayswater	-	-	0.35	-		
	Wynn	-	-	0.35	-		
	Clanricard	-	-	0.26	-		
	Bengalla	-	-	0.15	-		
	Edinglassie	-	-	0.16	-		
	Ramrod Ck	-	-	0.06	-		
	Interburden	-	-	-	-		
T16 (BH401)	Piercefield	-	-	0.60	-	Packer	LPM(1982)[8]
	Vaux	-	-	0.52	-		
	Bayswater	-	-	0.26	-		
	Wynn	-	-	0.17	-		
	Clanricard	-	-	0.35	-		
	Bengalla	-	-	0.60	-		
	Edinglassie	-	-	0.26	-		
	Ramrod Ck			0.1			
	Interburden	-	-	5.2 x 10^{-3} to 8.6 x 10^{-5}	-		
P1(R)-1	Ramrod Creek	177	39.5	6.0	8 x 10^{-4}	Constant Rate – 1L/s	LPM(1982)[8]
P1(R)-3	Ramrod Creek	177	39.1	6.0	2 x 10^{-3}	Constant Rate – 2.1L/s	
P1(R)-5	Ramrod Creek	105	71.9	11.2	7 x 10^{-5}	Constant Rate – 3.2L/s	
P3(R)-1	Ramrod Creek	105	21.1	3.4	3 x 10^{-4}	Constant Rate – 1.5L/s	LPM(1982)[8]
P3(R)-3	Ramrod Creek	105	16.2	2.6	9 x 10^{-5}	Constant Rate – 2L/s	
P4(E)-4	Edinglassie	147	39.2	9.5	2 x 10^{-5}	Constant Rate – 1.0L/s	LPM(1982)[8]
WT3	Ramrod Creek	22	50	9.5	3 x 10^{-4}	Constant Rate	LPM(1982)[8]
WT4	Ramrod Creek	54	35	7.8	2 x 10^{-4}	Constant Rate	LPM(1982)[8]
WT6	Ramrod Creek	68	100	19.9	4 x 10^{-4}	Constant Rate	LPM(1982)[8]

Notes: i) T = transmissivity ii) K = hydraulic conductivity
iii) S = storage coefficient

A reduction in the hydraulic conductivity of the coal seam aquifers with depth is observed in many coal mines. AGC (1984)[17] developed an equation based on the interpretation of depth-dependent hydraulic conductivities of 17 seams in the Upper Hunter Valley as shown below:

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[17] Australian Groundwater Consultants Pty Ltd, (June 1984), *"Effects of Coal Mining on Groundwater Resources in the Upper Hunter Valley"*, Volume 1.

$$k = k_o * e^{(-cz)}$$

with

k = hydraulic conductivity [m/day]
k_o = reference hydraulic conductivity = 5 [m/day]
c = slope of trendline (0.046 for Hunter Valley coal seams)
z = depth [m]
e = base of the natural logarithm (approximately 2.71828182846)

Therefore even if very high hydraulic conductivities are indicated by the pumping tests within the sub-crop area, much lower values can be expected at greater depths.

URS (2000)[10] states that laboratory permeability tests on core samples yielded a vertical hydraulic conductivity range of the interburden between 1.8 x 10^{-4}m/day and 1 x 10^{-7}m/day.

Applying the above equation allows prediction of the value of hydraulic conductivity of the interburden for different depths. As Figure 11 below shows, the computed values match quite well with the laboratory results. During calculations the reference hydraulic conductivity has been set at 4 x 10^{-3}m/day. This value is very close to the reported maximum hydraulic conductivity of the interburden.

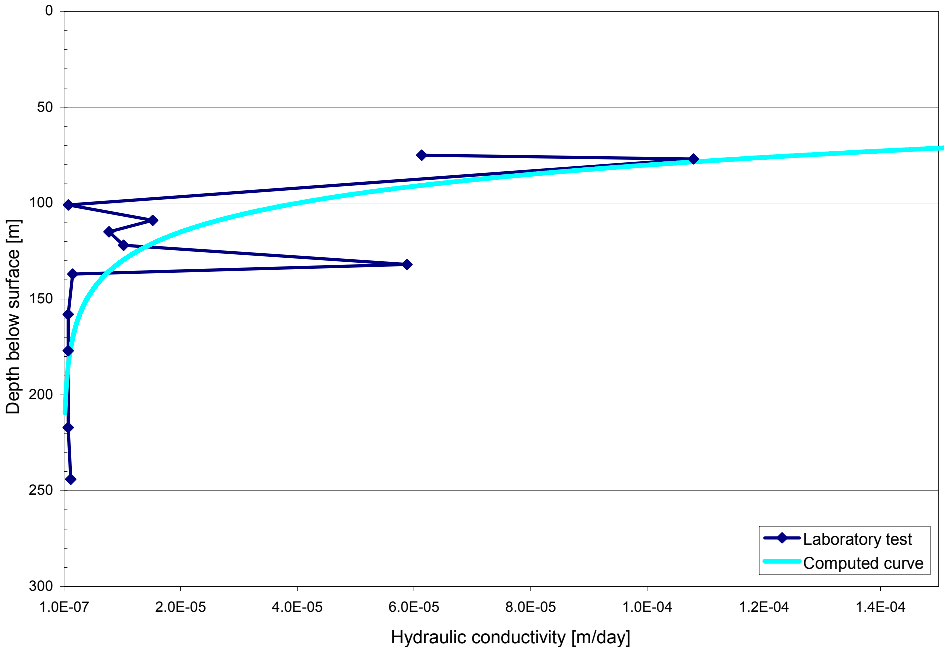

Figure 11: Laboratory results and trend curve for hydraulic conductivity of interburden

However, it should be noted that the laboratory results cannot take into account the impact of fracturing of the interburden and thus does not show the rock mass hydraulic conductivity but only the hydraulic conductivity of an undisturbed sample. Based on experience with similar geologic settings and with respect to the results of the packer tests that indicate a range of hydraulic conductivity values between 5 x 10^{-3}m/day and 8.6 x 10^{-5}m/day, it is further assumed that the horizontal hydraulic conductivity is 10 times higher than the vertical hydraulic conductivity.

10.4.4 Recharge and Groundwater Flow

A groundwater level (potentiometric) surface contour plan has been developed from water levels measured by Mt Arthur Coal in open exploration holes as well as in dedicated monitoring bores. The contours shown on Drawing No. 4 indicate that the potentiometric surface is a subdued reflection of the topography, with a groundwater mound beneath the topographically elevated areas of the ridgeline between Mount Arthur and Mount Ogilvie, and a hydraulic gradient towards the Hunter River valley to the north, and Saddlers Creek to the south.

Groundwater recharge is by rainfall infiltration via the regolith, and groundwater flow is towards the lower lying areas where discharge occurs into the alluvial valleys and creeks / rivers.

10.5 Summary of Conceptual Model

Based on suggestions made by Mt Arthur Coal personnel for development of the model by AGE (2006)[13] for the South Pit Extension approval, the Wittingham Coal measures have similarly been divided into three groups, which are treated as different aquifers in the model. From a conceptual groundwater model perspective, the groundwater system in the EA Boundary is therefore considered to consist of the following aquifer systems:

- alluvium along Hunter River and Saddlers Creek and an upper weathered bedrock zone;
- an upper Permian aquifer section of the Jerrys Plain Subgroup;
- an mid Permian aquifer section of the Jerrys Plain Subgroup (Burnamwood Formation); and
- a lower Permian aquifer section of the Vane Subgroup including the Archerfield Sandstone.

11.0 GROUNDWATER USE, QUALITY AND ENVIRONMENTAL VALUE

11.1 Groundwater Use – DWE Database

A search of the DWE database of registered bores and wells within a radius of 5km of the EA Boundary was undertaken. The data indicates that there are 32 registered bores within this radius as shown on Drawing No.3 and in Appendix 2. The registered bores include six (6) bores licensed for domestic, stock and irrigation supply, six (6) for stock and domestic only and eighteen (18) for stock supplies only. There are two (2) unlicensed bores as shown in Appendix 2.

Twenty (20) of the bores are located in sandstone, conglomerate, siltstone or coal of the Permian coal measures, and the remaining twelve (12) bores are reported to be in the alluvium of the Hunter River. Two (2) bores within the alluvium and eleven (11) of the bores within the Permian sequence are on land owned by Mt Arthur Coal, as shown on Drawing No. 3 and Appendix 2.

While it is recognised that not all existing bores are registered, the database gives an indication of groundwater usage in the area. The data suggests that groundwater from the Permian aquifers in the area is used primarily for stock use whereas those bores in the alluvial flats are used for a combination of irrigation, stock and domestic supply.

There are no registered bores in the alluvium of Saddlers Creek.

11.2 Groundwater Quality and Environmental Value

11.2.1 Terminology

An assessment was made of the groundwater quality in terms of Australia New Zealand Environment Conservation Council (ANZECC) criteria and environmental value. The ANZECC (2000)[18] guideline refers to "environmental value" rather than "beneficial use" which is often used, and state that the term beneficial use has lost favour because of its exploitative connotations. For this reason the term "environmental value" has been adopted by the National Water Quality Management Strategy (NWQMS). The following environmental values are recognised in the NWQMS Guidelines:

- aquatic ecosystems;
- primary industries (irrigation and general water uses, stock drinking water, aquaculture and human consumption of aquatic foods);
- recreation and aesthetics;
- drinking water;
- industrial water; and
- cultural and spiritual values.

The guidelines state that *"where two or more agreed environmental values are defined for a water body, the more conservative of the associated guidelines should prevail and become the water quality objective".* The assessment of "environmental value" given in this report is based on this guideline.

11.2.2 Alluvial Aquifer

Groundwater quality of the Hunter River alluvium has been monitored by Mt Arthur Coal in bores GW16, 17, 21, 24 and 25 since their installation in January 1999.

The data indicates that the water quality, as reflected by the Electrical Conductivity (EC), is quite variable, in the range 1,500µS/cm – 9,370µS/cm. The EC range within individual bores is similarly quite large and probably reflects the dominant recharge source at the time, that is, recharge from the underlying coal measures resulting in very poor quality water, or recharge from rainfall or the river itself, resulting in slightly improved quality water.

The pH ranges from 6.7 to about 7.6, that is, from slightly acid to slightly alkaline.

As observed during the site visit in December 2005 and confirmed by the monitoring data, the surface water in Saddlers Creek is brackish, indicating recharge from the underlying coal measures.

A summary of laboratory analysis of samples collected from alluvial bores is presented in Table 4 below. The table shows indicative values prior to commencement of mining at MAN and more recent, 2008 results.

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[18] Australian and New Zealand Environment and Conservation Council, (2000), *"Australia and New Zealand Guidelines for Fresh and Marine Water Quality".*

Table 4: PRE-MINING GROUNDWATER QUALITY – ALLUVIAL AQUIFERS										
Location	**Hunter River**								**Saddlers Ck**	
Bore	**GW16**		**GW17***	**GW21**		**GW24****	**GW25**		**GW2^**	**GW3^**
Date	Mar.99	Dec.08	Mar.99	Mar.99	Dec.08	Mar.99	Mar.99	Dec.08	Dec.08	Dec.08
Total Dissolved Salts	2,280	2,710	1,620	1,640	992	2,380	3,340	3,590	2,150	2,350
Sodium	440		295	390		440	840			
Magnesium	140		92	86		110	160			
Potassium	1.8		5.0	3.7		2.5	2.5			
Calcium	145		130	110		195	145			
Chloride	690		500	470		690	1,130			
Bicarbonate	400		400	680		510	560			
Iron	0.02	<0.05	0.36	0.05	10.7	0.02	0.03	<0.05	<0.05	<0.05
Manganese	-		0.49	0.11		0.16	-			
Phosphorus	0.2		0.1	0.1		1.1	0.2			

Note: all results expressed in mg/L

** Site decommissioned in 2004*

*** Site decommissioned since 2002.*

^ Sites established after 1999, therefore no comparison results available.

The data are compared to ANZECC (2000)[13] guidelines for "livestock" and for "potable" (human consumption) use. Given that groundwater in the alluvial aquifer is unsuitable for human consumption in most locations due to salinity in that it exceeds 500mg/L total dissolved salts (TDS) and has localised, relatively high iron concentrations, the environmental value has been classified as "primary industry", with the main use being for irrigation and stock watering. The environmental value of localised areas, such as swamps or more deeply incised channels (if any), across the floodplain with permanent water holes, could be classified as "aquatic ecosystems".

11.2.3 Coal Seams and Bedrock Aquifers

Table 5 provides pre-mining water quality data from boreholes intersecting coal seams and from samples collected from a sump within a box cut. The table indicates that the TDS content ranges from about 1750mg/L to 7760mg/L and that the pH is generally alkaline at about 8. The data shows that groundwater in the Permian is of poor quality and is typical of coal seam water quality.

The general low yield and poor quality of the groundwater in the coal seams indicates that the environmental value can be classified as "primary industry" with the main potential use being for stock watering.

Table 5: PRE-MINING GROUNDWATER QUALITY – PERMIAN AQUIFERS						
Location	**Bore K15**	**Bore WB1**	**ID1014A (GW8)**	**ID1049 (GW12)**	**ID1030 (GW19)**	**Box Cut West**
Date	12/1980	01/1981	02/1999	02/1999	02/1999	02/1999
pH (unit)	8.6	8.1	-	-	-	-
Electrical Conductivity (µS/cm)	8,950	7,005	-	-	-	-
Total Dissolved Salts	6,560	5,370	3,340	6,500	1,750	7,760
Hardness as Ca CO_3	235	1,000	-	-	-	180
Sodium	2,440	1,640	860	1,500	350	2,100
Potassium	9	15	20	13.5	13	18.5
Calcium	39	95	72	155	36	17.5
Magnesium	32	190	245	380	38	460

Table 5: PRE-MINING GROUNDWATER QUALITY – PERMIAN AQUIFERS

Location	Bore K15	Bore WB1	ID1014A (GW8)	ID1049 (GW12)	ID1030 (GW19)	Box Cut West
Chloride	3,174	2,045	1,100	2,500	450	3,460
Bicarbonate	826	1,390	1,250	730	650	620
Sulfate	250	590	-	-	-	-
Iron	<0.01	<0.01	-	-	1.04	-
Manganese	<0.01	0.63	0.02	0.28	0.28	-
Nitrate	0.4	0.53	-	-	-	-
Phosphorus	-	-	0.2	0.3	0.2	0.2
Reference	SKM (1981)[7]		MER (2000)[9]			

Note: Bore name in brackets e.g. (GW8) is new monitoring bore name adopted by Mt Arthur Coal.
All concentration in mg/L unless otherwise stated.

12.0 POTENTIAL IMPACT FROM EXISTING MINES

The available data show that the current mining within MAN Pit has impacted on the groundwater regime with results from the numerical model (AGE 2006[12]) indicating groundwater inflows ranging from 1.5ML/day (17L/s) from the shallow Glen Munro Seam to 0.14ML/day (1.7L/s) for the deep Edinglassie Seam, with a maximum cumulative inflow all seams of 3.6ML/day (42L/s). The maximum radius of influence of seam depressurisation was predicted to be 3.25km from the perimeter of the mined area. In addition other existing mines in the area have impacted on the surrounding aquifer system. These mines and potential impacts are as follows.

- The Bengalla Mine to the north of the Hunter River which has been operating since 1998 is mining the stratum above the Edderton Seam of the Wittingham Coal Measures. Predictive modelling by AGE 2007[16] indicated that the radius of cone of depression created by the Bengalla Mine will remain separated from that of MAN and that the mine will capture a maximum inflow of 0.7ML/day in 2012 of which about 0.15ML/day is seepage from the Hunter River alluvium.

- The Bayswater No. 3 Mine to the south-west of the MAN Pit, which has operated since 1995, is much shallower than the planned mining depth within the MAN Pit and therefore does not have a significant impact on the surrounding groundwater table. However re-activation of Saddlers Pit as part of the Project (located just to the north of Saddlers Creek targeting the Glen Munro Seam and Woodlands Hill Seam) is expected to influence groundwater levels in the Saddlers Creek alluvium. The disturbance of Saddlers Creek alluvium and associated impacts as part of the progression of Saddlers Pit was approved as part of the Bayswater No. 3 Development Consent (DA 201/93) in 1993.

- The Bayswater No. 2 Mine, as well as the Drayton Mine to the east of the MAN Pit do not influence the aquifer systems of the Project since they are structurally isolated and their mining activities are confined to Greta Coal Measures that are stratigraphically lower than the Wittigham Coal Measures. Bayswater No. 2 closed in 1998.

- The MAU Project is expected to contribute significantly to the cumulative impact on the groundwater system with time. For the first years, mining associated with the MAU will take place above the coal seams mined within the MAN Pit, however during later phases, mining of lower coal seams is planned. The regional finite element groundwater model of MER (2007)[14] predicted groundwater seepage to the underground operations steadily increasing over the period of mining from 0.5ML/day during entry and development of the

Woodlands Hill Seam, to a maximum 6ML/day at completion of mining in the deeper Piercefield Seam. Vertical leakage from the Hunter River alluvium due to depressurisation of the coal seam was predicted to remain unchanged whereas vertical leakage from the Saddlers Creek alluvium may be affected with a reduction in the rate of upward leakage from the coal seams of 0.08ML/day.

13.0 MINE DEVELOPMENT

Mine plans for the Project were developed for the open cut mining operations at Mt Arthur Coal for years 2011, 2016 and 2022 as shown on Drawing No. 5. These years were modelled as part of this assessment.

The main contributor to the coal production will be MAN including the South Pit Extension. Mining will proceed to the north into the Macleans Hill area and to the west following the dip of the coal seams and impacting on Edderton Road. The base of the open cut pit coincides with the floor of the Ramrod Creek Seam.

Coal extraction will continue in the Belmont Pit to the west of Edderton Road to allow access to the Glen Munro Seam, and in the Saddlers Pit area in the southern half of the operation where the Glen Munro and Woodlands Hill Seams will be mined.

The Project seeks approval to mine until 2022 in accordance with the existing approved Mt Arthur North Development Consent. Conceptually, there will be two final Pit voids remaining at completion of open cut mining, one in the MAN Pit and the second the final void of Saddlers Pit.

14.0 NUMERICAL GROUNDWATER MODEL

The finite-element simulation package FEFLOW (Diersch, 2008)[19], was used to simulate the impact of the mining operations on the groundwater regime. FEFLOW is a high-end groundwater flow package, capable of simulating two and three-dimensional density-coupled groundwater flow, mass and heat transport in saturated and unsaturated media. Since its creation in 1979, FEFLOW has been continuously improved. The FEFLOW source code is written in ANSI C/C++ and contains more than 1,300,000 lines. FEFLOW is used worldwide as a high-end groundwater modelling tool at universities, research institutes, government offices and engineering companies. It is applied worldwide for groundwater-related tasks within the mining sector.

FEFLOW was also used by AGE (2006)[12] for the simulation of the MAN Pit, simulation of the South Pit Extension (2006)[13] and by MER (2007)[14] for simulation of the MAU Project. The current model has been developed from these models.

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[19] H.-J. G. Diersch (2008), *“FEFLOW – Finite Element Subsurface Flow & Transport Simulation System, Reference Manual”*.

14.1 Model Geometry

The lateral extent of the groundwater flow model conforms with the hydrological boundaries described for the conceptual model. The mesh density varies laterally with the highest discretisation at the different mine sites. Figure 12 below shows the three-dimensional model mesh with the initial hydraulic head distribution.

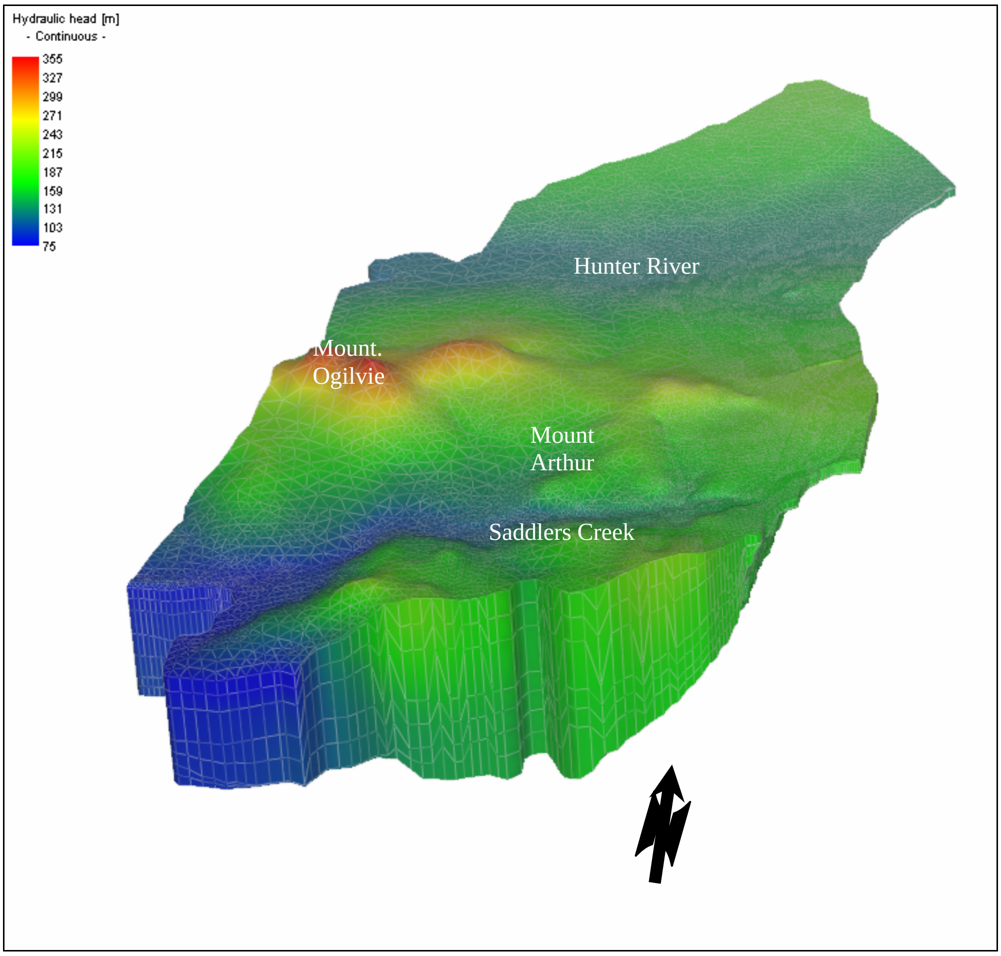


Figure 12: Three-Dimensional Model Mesh

The groundwater model consists of four layers with different geo-hydraulic properties. Figure 13 provides an overview of the layer geometry.

Layer 1
The top layer represents the alluvium along the Hunter River and Saddlers Creek as well as the weathered regolith zone directly beneath the ground surface. The layer has a saturated thickness of 5m to 10m. Its top is defined by the topographic surface of the EA Boundary.

Layer 2
Between the top layer (base of alluvium or weathered zone) and the top of the Mt Arthur Seam (Drawing No. 6).

Layer 3
The third layer represents the upper unit of the section of the Wittingham Coal Measures between the top of the Mt Arthur Seam and the floor of the Bayswater Seam. Its thickness is derived from

isocontour maps of the seam geometry of Mt Arthur and Bayswater seam as provided by Mt Arthur Coal. The thickness of this layer is up to 100m within the lease area. The unit sub-crops in the eastern part of the lease area (Drawing No. 7).

Layer 4

The fourth layer represents the lower unit of the mined section of the Wittingham Coal measures. Its base is defined by the top of the Saltwater Creek formation. This layer has a thickness of up to 120m within the EA Boundary (Drawing No. 8).

The top or base of the layers has been defined from structure contours provided by Mt Arthur Coal with extrapolation to the model perimeter where the structure contours did not extend to the model boundaries.

The four hydro-stratigraphic layers described above have been further subdivided into eight layers, however without changing the geo-hydraulic properties of the original layers. This subdivision allows for a better vertical discretisation of the model.

A ninth layer, the base of the model, has been added representing the relatively impermeable Saltwater Creek formation in order to prevent dry-out of finite elements during the dewatering of the Ramrod Creek Seam. Therefore the final model consists of nine layers and around 292,000 finite elements. The model area and mesh is shown on Drawing No. 9.

It should be noted that, due to model restrictions each layer has to extend over the whole model domain even where the represented aquifers have sub-cropped. However where the layer lies above the groundwater table, it is not of concern for the modelling task.

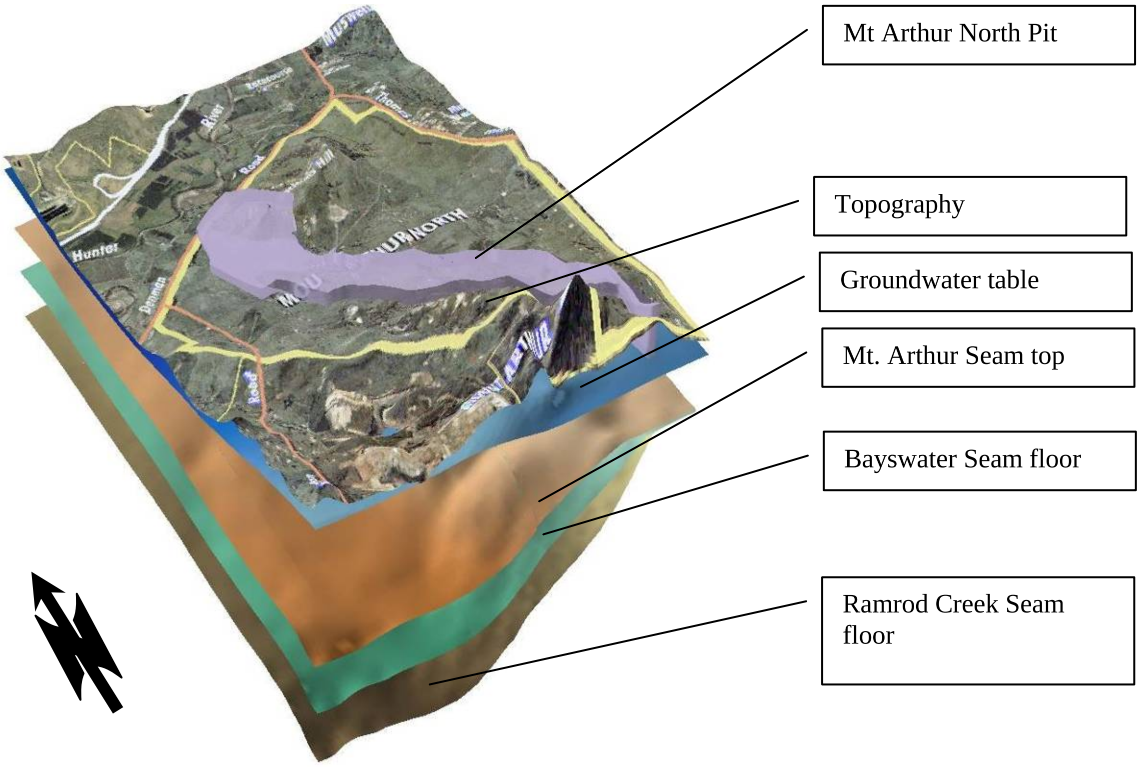


Figure 13: Model Geometry – 3D detail view MAN mining area

During simulation the top slice is adjusted automatically to the elevation of the groundwater table. All other slices are distributed along the top and bottom of the saturated model layers, preserving the original material distribution. This so-called Best-Adaptation-to-Stratigraphic-Data (BASD) technique is also useful if applying drainage boundary conditions for the mine dewatering. The node, on which such a boundary condition is set, automatically moves to the corresponding elevation in the model.

14.2 Model Boundary Conditions

In agreement with the conceptual model the numerical groundwater model is surrounded by “no flow” boundaries (Drawing No. 9). While the northern and southern borders run along topographic watersheds which correspond to groundwater divides, which by definition are “no flow” boundaries, the western border was set along the Mount Ogilvie Fault, which with a displacement of 200m is assumed to be a barrier to groundwater flow. The eastern boundary is formed by the outcrop of the impermeable Saltwater Creek formation.

The Hunter River to the north of the EA Boundary is simulated as a fixed hydraulic head boundary. This boundary condition allows infiltration of surface water into the aquifer or drainage of the aquifer system, depending on the hydraulic gradient between the river and the surrounding groundwater body.

The creeks within the EA Boundary are assumed to drain the thin alluvial deposits associated with the creeks and surface flow in the creeks is not considered a recharge source. Therefore drainage boundary conditions have been assigned in the model along the creek beds which do not allow infiltration of surface water into the alluvial deposits.

14.3 Recharge and Evapotranspiration

Only rainfall sourced recharge was used as an external input to the model domain. The dense natural drainage network in the EA Boundary suggests most of the rainfall discharges as surface run-off. There is only a relatively low rate of recharge to the groundwater system on the relatively high to moderate hill slopes of the EA Boundary due to this high percentage of surface run-off, whereas on the floodplains the rate of recharge is significantly higher.

Areas of known coal seam sub-crop are believed to receive more recharge than remaining areas and it became apparent during calibration of the model that coal seam sub-crop areas may receive as much as 2.4% or 15mm/year of the average annual rainfall as recharge, even in the areas of steeper slopes.

The highest recharge is expected over the permeable alluvium of the Hunter River. It was assumed in the model that the recharge over these alluvial areas is 10% of the average annual rainfall, that is, a recharge rate of 60mm/year. The rate of recharge in the model to the remaining areas was assumed to be:

- areas with gradient < 5%, recharge is 1% or 6mm/year of the annual average rainfall; and
- hilly regions with gradient >5%, recharge is 0.4% or 2.4mm/year of the annual average rainfall.

The distribution of recharge used in development of the model is shown on Drawing No. 10.

14.4 Model Hydraulic Parameters

The top layer (model Layer 1) represents the alluvium along the Hunter River, the creeks and the zone of weathered bedrock. A hydraulic conductivity of 8m/day was assigned to the alluvium associated with the Hunter River consistent with data presented in MER (2000)[9]. MER (2007)[14] states that for the MAU model *the alluvium is assumed to exhibit homogeneity and isotropy even though data suggests stratification of unconsolidated sands, silts and clays. Adoption of a uniform conductivity is considered to represent a conservative approach in determining potential leakage from the alluvium.* However in the current model, the vertical hydraulic conductivity within the alluvium has been reduced from 8m/day to 0.2m/day to take account of the silt and clay layers. This vertical hydraulic conductivity is still significantly higher than the hydraulic conductivity of the underlying bedrock aquifers and is considered conservative in that the model does not account for the likely occurrence of a weathered, clay rich transition zone at the base of alluvium that inhibits leakage.

The weathered bedrock (regolith) is assumed to have a hydraulic conductivity at least one order of magnitude higher than the underlying Permian aquifers. The alluvium of Saddlers Creek which consists of the fine grained material was assigned hydraulic properties similar to those of the weathered bedrock.

As discussed, based on suggestions made by Mt Arthur Coal personnel for development of the predictive model for the South Pit Extension, the Wittingham Coal Measures have been divided into three groups with each group treated as a separate aquifer layer within the model.

While most of the numerical model settings of the MAU Project (MER 2007)[14] and the current model agree quite well, discrepancies occurred for the coal seam elevations within the area of the underground mine. Therefore updated geometries provided by Mt Arthur Coal were imported into the groundwater flow model for a better agreement with the MER model.

The upper group (model Layer 2) represents the overburden of the Mt Arthur Seam that is from the base of the alluvium or regolith to the top of the Mt Arthur Seam. This group consists of very low conductivity siltstones and sandstones and thin Warkworth coal seams of the Mt Thorley formation (Drawing No. 6).

The middle group (model Layer 3) represents the coal seams and interburden between and including the Mt Arthur Seam and the Bayswater Seam (Drawing No. 7).

The lowest group (model Layer 4) represents the section of the Wittingham Coal Measures from the base of the Bayswater Seam to the floor of the basal Ramrod Creek Seam (Drawing No. 8).

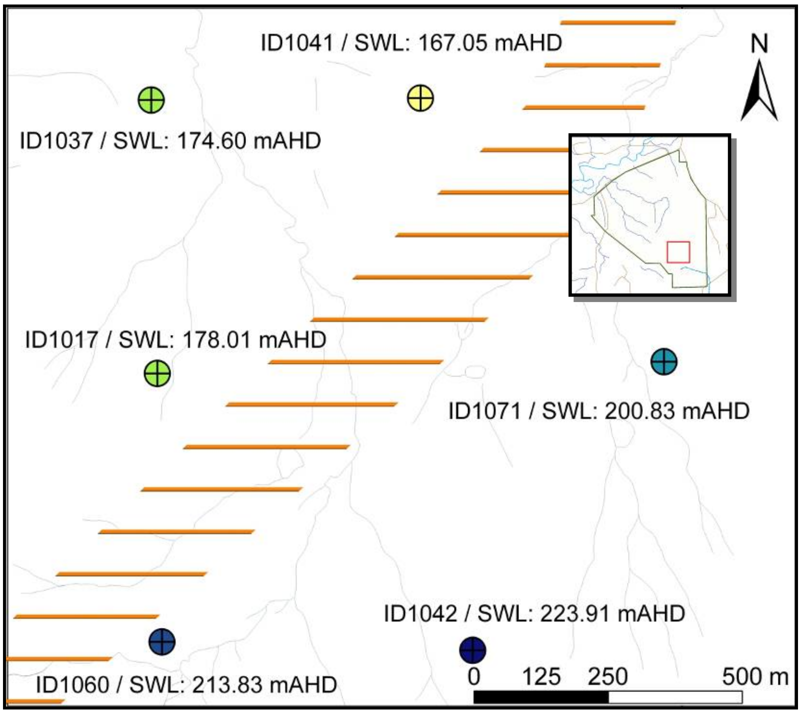
The underlying Saltwater Creek formation represents the base of the groundwater flow model since this formation is considered to be essentially impermeable. Nevertheless, this formation has been added to the model as a 100m thick “dummy layer” of very low hydraulic conductivity. This allowed for the simulation of dewatering of the Ramrod Creek Seam due to mining to the base of this seam. This also provided stabilisation of the model run.

The hydraulic conductivity of each model layer was calculated as the weighted sum of the interburden and coal seam permeabilities. The applied weighting factor was the thickness of the interburden and the coal seams within each model layer. The hydraulic conductivity was reduced continuously with depth by applying the formulas for the change of hydraulic conductivity with depth as discussed in Section 10.4.3. Only model Layer 5, representing the Saltwater Creek formation, was assigned a uniform hydraulic conductivity of 8.64×10^{-7}m/day. This is a very low hydraulic conductivity value representative of unfractured metamorphic and igneous rocks, shales or unweathered marine clays.

The fault area along the Fairford Graben was simulated in the model by assigning high conductivity zones of 0.6m/day along the fault lines. Another, probably tectonic structure was identified during data review and model calibration in the southern part of the MAN Pit where two groups of adjacent groundwater monitoring bores show differences in groundwater elevation of up to 57m, as shown on Figure 14. In order to simulate such a steep hydraulic gradient a north-east/south-west striking fracture with a reduced hydraulic conductivity of 8.6 x 10^{-4}m/day was assigned in the groundwater model. This fracture feature has no impact on the groundwater inflow into the Pits as it is excavated during the first years of operation of the currently approved MAN Pit.

A long section showing the hydraulic conductivity distribution with depth and along the Fairford Graben is shown on Drawing No. 11.

As discussed the model does not account for a potentially weathered, clay rich, low permeability transition zone between the base of alluvium and unweathered bedrock that would reduce leakage from the alluvium to the depressurised bedrock aquifers.



Note: low conductivity area is hatched

Figure 14: Assumed low conductivity zone with nearby monitoring bores

Aquifer storativity has been calculated based on the thickness of the coal seams and the interburden within each model layer and assuming a storativity of the coal seams and the interburden of 0.5% and 0.005% respectively. A uniform storage compressibility value of 5 x 10^{-6}/m was applied in the model.

A summary of the hydraulic parameters specified in the model is presented in Table 6**.**

Table 6: SUMMARY OF GROUNDWATER MODEL PARAMETERS

Model Layer	Layer Name	Feature/Parameter	Value
1	Alluvium and Weathered zone	distribution	Alluvium along Hunter River and Saddlers Creek, weathered zone over the entire model area
		Top	Interpolated from topographic data.
		Base	Weathered zone 5m thick, Hunter River alluvium 6m saturated thickness, Saddlers Creek deducted from topographic map
		horizontal hydraulic conductivity	8.2m/day Hunter River Alluvium, 0.4m/day Upper Saddlers Creek and weathered zone.
		vertical hydraulic conductivity	0.2m/day
		storativity	0.2 Hunter River alluvium, 0.01 elsewhere
		storage coefficient	$5 \times 10^{-6} m^{-1}$
		recharge	Hunter River alluvium 60mm/year (10% of average annual rainfall), remaining area 2.4mm/year to 15mm/year (0.4% to 2.4% of average annual rainfall), depending on slope of topography
2	Overburden Weathered zone to Mt Arthur Seam	distribution	Entire model area
		top	Base of Layer 1
		base	Top of Mt Arthur Seam
		horizontal hydraulic conductivity	0.01m/day to 0.6m/day (along Fairford Faults) in the area of MAN, 5.6×10^{-5}m/day to 0.2m/day elsewhere
		vertical hydraulic conductivity	20% of horizontal hydraulic conductivity
		storativity	10^{-4}
		storage coefficient	$5 \times 10^{-6} m^{-1}$
		thickness	Up to 180m at western border of lease area
3	Mt Arthur Seam to Bayswater Seam	distribution	Entire model area
		top	Top of Mt Arthur Seam
		base	Floor of Bayswater Seam
		horizontal hydraulic conductivity	1.6×10^{-4}m/day to 0.6m/day (along Fairford Faults)
		vertical hydraulic conductivity	20% of horizontal hydraulic conductivity
		storativity	10^{-4}
		storage coefficient	$5 \times 10^{-6} m^{-1}$
		thickness	Up to 100m at western border of lease area
4	Bayswater Seam to Ramrod Creek Seam	distribution	Entire model area
		top	Floor of Bayswater Seam
		base	Base of Ramrod Creek Seam
		horizontal hydraulic conductivity	1.8×10^{-4}m/day to 0.6m/day (along Fairford Faults)
		vertical hydraulic conductivity	20% of horizontal hydraulic conductivity
		storativity	10^{-4}
		storage coefficient	$5 \times 10^{-6} m^{-1}$
		thickness	Around 120m at western border of lease area
5	Saltwater Creek Formation	distribution	Entire model area
		top	Base of Ramrod Creek Seam
		base	100m below top
		horizontal hydraulic conductivity	8.6×10^{-7}m/day
		vertical hydraulic conductivity	10% of horizontal hydraulic conductivity
		storativity	10^{-4}
		storage coefficient	$5 \times 10^{-6} m^{-1}$
		thickness	100m (uniform)

15.0 MODEL CALIBRATION AND VALIDATION

15.1 Model Calibration

As stated in Anderson & Woessner, (1992)[20], *"calibration of a groundwater flow model refers to a demonstration that the model is capable of producing field measured heads and flows which are the calibration values. Calibration is accomplished by finding a set of parameters, boundary conditions and stresses that produce simulated heads and fluxes that match field measured values within an acceptable range of error"*.

The objective of model calibration was to reproduce the estimated steady state groundwater levels existing in the EA Boundary and allow simulation of the impact of the Project on the groundwater regime.

The accuracy of the model calibration depends on the quality of calibration parameters and the data defining the model domain such as aquifer geometry, boundaries, hydraulic properties and stresses imposed on the aquifer. It is considered that the horizontal and vertical extent of the model and model boundaries are sufficiently well defined to calibrate the groundwater model. Calibration was achieved from the rainfall recharge rate distribution shown on Drawing No.10 and adjusting hydraulic conductivity values.

For the steady state model calibration, groundwater measurements from the years 1999 to 2003 were available from groundwater monitoring bores within the EA Boundary. The most recent data prior to commencement of mining activities within the MAN Pit were selected as calibration targets. It was assumed that the water levels in the selected monitoring bores were representative of the long-term average (steady state) groundwater levels, as no impact from the mining operation was assumed to have occurred at that time.

The steady-state calibration is shown in Table 7 and Drawing No. 12 shows the resulting calibrated groundwater table for steady state conditions.

Table 7: MODEL CALIBRATION RESULTS

Bore ID	Simulated Water Level Elevation (mAHD)	Observed Water Level Elevation (mAHD, pre-mining)	Difference (m)
GW1	161.59	166.47	4.88
GW2	145.85	146.13	0.28
GW3	145.61	143.96	-1.65
GW4	175.48	170.63	-4.85
GW5	171.62	175.27	3.65
GW6	206.77	196.40	-10.37
GW7	173.68	173.43	-0.24
GW8	182.22	177.26	-4.96
GW9	182.67	179.66	-3.01
GW10	218.58	210.67	-7.91
GW12	147.80	146.79	-1.01
GW13	161.60	155.40	-6.20
GW15	140.61	141.94	1.33
GW16	122.69	122.67	-0.02

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[20] Anderson & Woessner, (1992), *"Applied Groundwater Modeling, Simulation of Flow and Advective Transport."*

Table 7: MODEL CALIBRATION RESULTS

Bore ID	Simulated Water Level Elevation (mAHD)	Observed Water Level Elevation (mAHD, pre-mining)	Difference (m)
GW17	124.49	126.83	2.34
GW19	137.29	131.51	-5.78
GW20	143.21	144.32	1.11
GW21	127.18	127.59	0.40
GW22	139.39	133.53	-5.86
GW23	139.45	133.37	-6.08
GW24	129.59	130.37	0.78

An objective method to evaluate the calibration of the model is to examine the statistical parameters associated with the calibration. One such method is by measurement of the error between the modelled and observed (measured) water levels. A root mean square (RMS) expressed as:

$$RMS = \left[\frac{1}{n} \sum_{i=1}^{n} \Sigma (h_o - h_m)^{\ 2} \right]^{0.5}$$

where: n = number of measurements
h_o = observed water level
h_m = simulated water level

is considered to be the best measure of error, if errors are normally distributed.

The RMS error calculated for the calibrated model is 4.5m. The maximum acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS error to the total head loss in the system is small, the errors are only a small part of the overall model response (Anderson and Woessner, 1992)[20]. The total head loss within the area of the model domain where the observation targets are distributed is 130m therefore the ratio of RMS to the total head loss is 3.5%.

This error is considered to be acceptably small and it is considered that calibration of the model is accomplished in that the simulated heads match field measured values within an acceptable range of error. This is supported by a mass balance error of 1.5%, that is the difference between calculated inflows and outflows to the model at the completion of the calibration run expressed as percent of discrepancy, as discussed in Section 15.3.

15.2 Model Validation

Calibration of the model was validated by using a second set of groundwater level measurements. The purpose of the validation is to confirm that that the steady-state calibrated model is representative of the real-world groundwater regime.

Groundwater measurements were provided for a larger number of bores for the years 1998 and 1999. This data set was used to create the isocontour plan of the interpreted groundwater table shown on Drawing No. 4, and as reference data for the validation of the model calibration.

For validation, only those water level measurements collected in years 1998 and 1999 across the whole of the area within the EA boundary were considered where the final depth of the monitoring bore was known. An additional condition was that at least one week must have passed between the completion of drilling of the bore and the water level measurement in order to allow a reasonable accuracy of the measurement. The summary of the validation results is presented in Appendix 3 and the bore locations are shown on Drawing No. 12.

Similar to model calibration the selected performance measure for testing the validity of the model is the RMS error. The error was 7.2m or 5.5% in respect to the total head loss of 130m for the observed model domain. It can therefore be concluded that the validation shows that the model responds sufficiently well to different sets of observed groundwater levels. The higher RMS value can be explained by the greater number of observations, the different year of observation and generally lower accuracy of water level measurements.

15.3 Pre-Mining Groundwater Balance

The steady state water balance of the calibrated model is shown in Table 8 and the breakdown of the simulated total losses to the different creeks and river is shown in Table 9.

Table 8: MODEL STEADY STATE WATER BUDGET

	Flow Rate (m^3/day)
River Leakage	-5,885
Recharge	5,974
Difference between Inflow and Outflow from the Model Domain (m^3/day)	89
Percent Discrepancy (%)	1.5%

Table 9: SIMULATED GROUNDWATER DISCHARGE TO THE CREEKS AND HUNTER RIVER

Creek/River	**Discharge (m^3/day)**
Hunter River	-3,580
Saddlers Creek	-1,080
Secondary Creeks	-1,225
Total	-5,885

Model simulation runs indicate steady state groundwater losses to the Hunter River of about 3,580m^3/day (3.58ML/day) and to Saddlers Creek of about 1,080m^3/day (1.08ML/day). The Hunter River is the main sink for groundwater within the EA Boundary, followed by Saddlers Creek.

16.0 PREDICTIVE SIMULATIONS

After the steady state model was calibrated to the available data, the model was then converted to transient flow conditions to undertake predictive scenarios of the impact of mining.

The whole of the Mt Arthur Coal operations and Bengalla Mine are simulated in the model as the Project will induce further change to the local groundwater environment to those that have and will continue to occur from the current mine approvals at Mt Arthur Coal. The changes or impacts arising from the Project relate to:

- aquifer depressurisation/drawdown;
- leakage of groundwater from alluvial lands;
- loss of groundwater yield at existing bore locations;
- change in groundwater quality;
- rising aquifer pressures post mining; and
- potential impacts on groundwater dependent ecosystems.

16.1 Modelling Strategy

The response of the groundwater system to the proposed mining schedule has been assessed by running the model for a period of 28 years from year 1995 to the end of year 2022. In order to take into account the existing mines, the simulation commences seven years prior to the start of operations within the MAN Pit. The first ten years of simulation time have been imported from the existing groundwater model developed by AGE (2006)[13] for the South Pit Extension. Simulated steady-state hydraulic heads from the model were used as initial conditions, during the predictive simulation.

Open Cut Mines: Active open cut areas were simulated using transfer boundary conditions. In general, transfer boundary conditions represent a reference hydraulic head outside the model domain, for instance the water level of a lake. Water exchange with the model is controlled by the hydraulic gradient between the boundary condition and the groundwater elevation and by a percolation layer between the groundwater body and the reference hydraulic head. The percolation layer is expressed as a constant factor and can be set so that it only allows water to be removed from the model domain, that is, by drainage, if the hydraulic head at a node is above a nominated water level. In the case of the current groundwater model the nominated drainage water levels were the elevations of the Pit floors with the deepest seam mined being the Ramrod Creek Seam. The drainage boundary conditions also covered areas of the mine, where only seams above the Ramrod Creek seam were mined. The elevation of drainage at each node varied in accordance with progress of the mine with time as shown on the mine plans for the Project.

Mt Arthur Underground Project: The underground mine was modelled using time-constant transfer boundary conditions. The boundary conditions describing the drainage elevations were exported from the existing MER (2007)[14] groundwater model and assigned manually at different time stages with the simulated progress of mining. The MER (2007)[14] model explicitly modelled the mined coal seams as five different layers, while the current model groups the coal seams and the interburden into three layers as described in Section 14.1. To take account of the different drainage levels, in the current model the drainage boundary conditions are distributed on numerical model slices. By applying the BASD technique (Section 14.1), the numerical slices are automatically mapped at the correct elevation during the simulation run.

In addition to the drainage elevations, the groundwater model takes account of the effects of subsidence and fracturing of the overburden caused by underground mining. The overburden sections of the mined areas are set simultaneously with the progress of mining with a relatively high vertical hydraulic conductivity of 8.6×10^{-3} m/day. This is also in agreement with the MER (2007)[14] model.

16.2 Aquifer Depressurisation/Drawdown – Regional Impact

Open cut mining together with underground mining will result in a cumulative depressurisation of the coal seams and water bearing layers in the interburden within the EA Boundary. Depressurisation, that is, the cone of depression (drawdown) in the piezometric surface/water table will migrate out from the highwall of the Pits as mining moves to the west and north and becomes progressively deeper. The development of the cone of depression from 2009 to 2022 is shown on Drawing No. 13.

The cone of depression south of Hunter River is, to a large part, the result of the dewatering in the northern and central parts of the MAN Pits and the MAU Project. The shallow Bayswater No. 3 Mine, the South Pit Extension and the Saddlers Creek Pit are of secondary importance.

Within the MAN Pit, the maximum drawdown is predicted to be 120m at the end of the year 2009 in the area of Fairford Graben. At this time the cone of depression of the MAN Pits, Bayswater No. 3 Mine and the MAU Project will have merged and discharge to both the alluvium of the Hunter River and Saddlers Creek are affected by this drawdown.

In 2016 the drawdown will reach a maximum of 200m and the cumulative cone of depression extends beneath the southern part of the Hunter River alluvium and sporadic drawdown is visible south of Saddlers Creek. The cumulative impact beneath the Hunter River alluvium reaches its peak with Bengalla Mine being active north of the river; however the cones of depression of the Bengalla Mine and Mt Arthur Coal operations are predicted not to meet beneath the Hunter River.

Drawdown in 2022 will be approximately 290m at the MAN Pit. By this time, the drawdown caused by the mines affects the whole south-eastern part of the model area to the south of Saddlers Creek. Conversely the impact of the Bengalla Mine north of Hunter River has been significantly reduced with the mine closure in 2017. It should be noted that even if Bengalla Mine extends its operations beyond 2017, the mining activities will probably move away from the Hunter River, following the dip of the coal seams and the hydraulic impact on the Hunter River alluvium from this operator will be reduced.

In summary, depressurisation of the coal seam aquifers as a result of open cut mining to 2022 will extend up to 0.5km north of the EA Boundary beneath the Hunter River alluvium and up to 1.6km south of the southern EA Boundary. Depressurisation will not extend outside the eastern and western boundaries primarily due to the sub-crop in the east and Mount Ogilvie Fault in the west, as shown on Drawing No. 13.

16.3 Pit Inflows

The main groundwater inflow is to the MAN Pit together with the South Pit Extension (see Table 10). The groundwater simulation indicates that from 2009 to 2016 the Pit inflow rates rise from 0.85ML/day to 2.45ML/day. From 2016 onwards, Pit inflows reduce, due to the growing impact of the underground mine and a general decline of the regional groundwater table. From the peak inflow in 2016, groundwater inflow rates stabilises in the latter part of mining at about 2.4ML/day in (see Figure 15). Groundwater inflows to Saddlers Pit are overprinted by dewatering within the MAN Pit, South Pit Extension and the MAU Project and stabilise after 2011 at a relatively constant rate of 0.15ML/day.

Table 10: PREDICTED AVERAGE INFLOW TO THE PITS (ML/day)				
Project Years	**MAN Pit**	**South Pit**	**Saddlers Pit**	**TOTAL**
June 2009	0.75	0.10	0	0.85
June 2011	1.05	0.12	0.15	1.16
June 2016	2.30	0.15	0.15	2.45
June 2019	2.14	0.15	0.15	2.29
June 2022	2.21	0.18	0.15	2.39

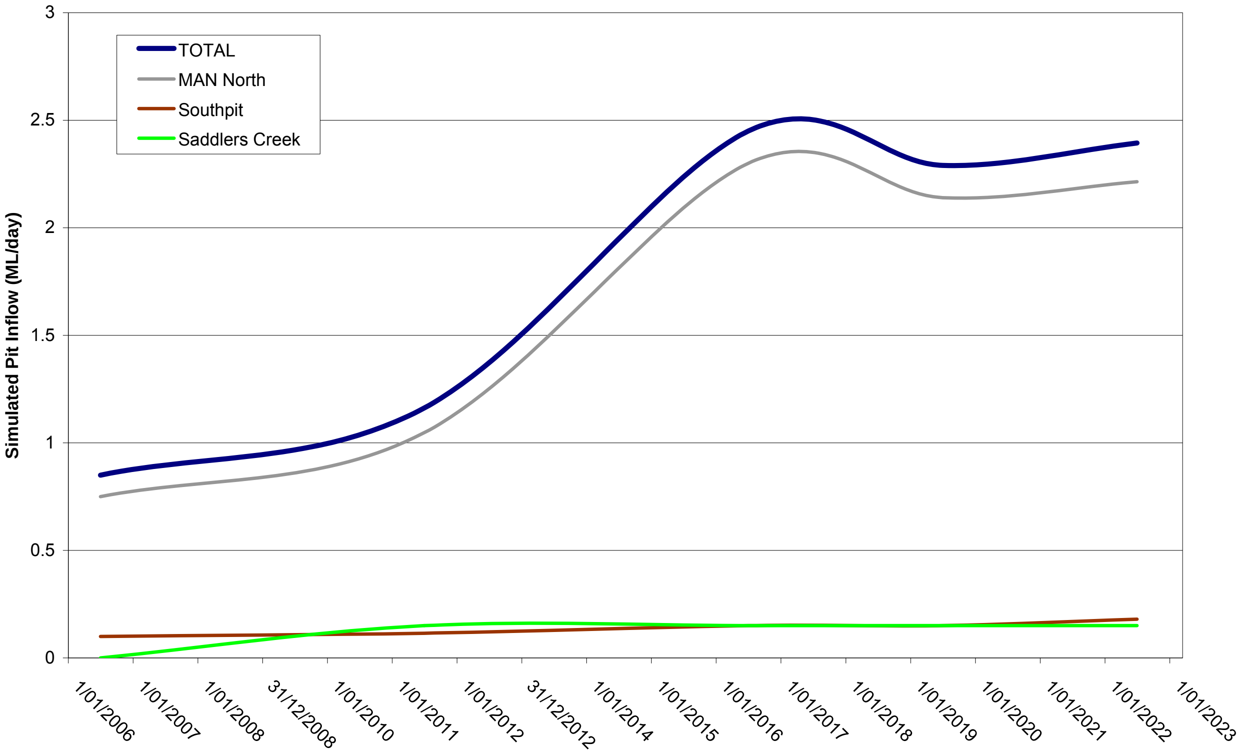

Figure 15: Prediction of Groundwater Inflow into the Pits

It should be noted that not all of this water will be available for the mine operation or will collect in sumps for disposal. The actual volume of water pumped from the mine may be less than the volumes predicted as some water will be removed as moisture with the coal and some will be lost by evaporation. At least 3% to 5% of this water will be exported with the product coal. Further water loss can be expected from evaporation from the Pit floor and coal face seepage with meteorological data indicating that the mean daily evaporation rate from the Pit floor can be as high as 3mm/day. This amounts to an average water loss of about 300L/day from each 100m^2 of exposed Pit floor and wall area.

Groundwater inflow to the Pits should be controlled by strategically located sumps and pumped to surface storages.

16.4 Leakage of Groundwater from Alluvial Aquifers

As discussed previously recharge of the alluvial aquifers occurs by rainfall infiltration and upward leakage from the Permian coal seam aquifers that sub-crop beneath the alluvium, the latter being responsible for the generally brackish to saline groundwaters at the base of the alluvium. Mining in the area will reduce the rate of the groundwater discharge from the Permian aquifers to the alluvial aquifer of the Hunter River and Saddlers Creek. The following sections describe the impact on groundwater flow to these two main water courses.

16.4.1 Hunter River Alluvium

Under natural conditions, groundwater flows from the northern part of the EA Boundary towards the Hunter River; however with mining at the MAN Pit and depressurisation of the Permian aquifers this groundwater flow will be reduced and with time, will be reversed of local magnitude.

Flow path analysis (Figure 16) shows that the main impact on the Hunter River alluvium will occur directly north of the MAN Pit and will affect the alluvium on the southern side of the river. In 2009 about 0.2ML/day (2.3L/s), flows from the Permian aquifers in the MAN Pit area towards the river and discharges to the base of the alluvium, but by mid 2011 the groundwater flow from the Permian and discharge to the alluvium has ceased, as shown on Figure 17. Subsequent to mid 2011 the direction of groundwater flow is reversed and flow is from the alluvial area to the MAN Pit.

By year 2016 the groundwater flow towards the MAN Pit reaches 0.48ML/day (5.6L/s), and at the end of mining activities in 2022 the flow rate towards the MAN northern Pit is about 0.74ML/day (8.6L/s) as shown on Figure 17.

The alluvial aquifer is affected over a length of approximately 6km, which corresponds to an alluvial area south of the Hunter River of 4.2km^2, or about 4% of the estimated 105km^2 area of Hunter River alluvium between Muswellbrook and the Saddlers Creek confluence. Approximately 0.176L/m^2/day (64mm/year) of groundwater is withdrawn from the alluvium, that is, at a rate that is comparable with the annual groundwater recharge from rainfall on the affected alluvium.

This volume of leakage is considered a worst case scenario as discussed in Section 14.4, as the model assumes direct hydraulic connection between the base of alluvium and bedrock, that is, the model does not account for the likely occurrence of a weathered, clay rich transition zone at the base of alluvium that inhibits leakage.

It should be noted that water quality at the base of the Hunter River alluvial aquifer is anticipated to improve in the area impacted by mining as groundwater discharge from the Permian aquifer declines.

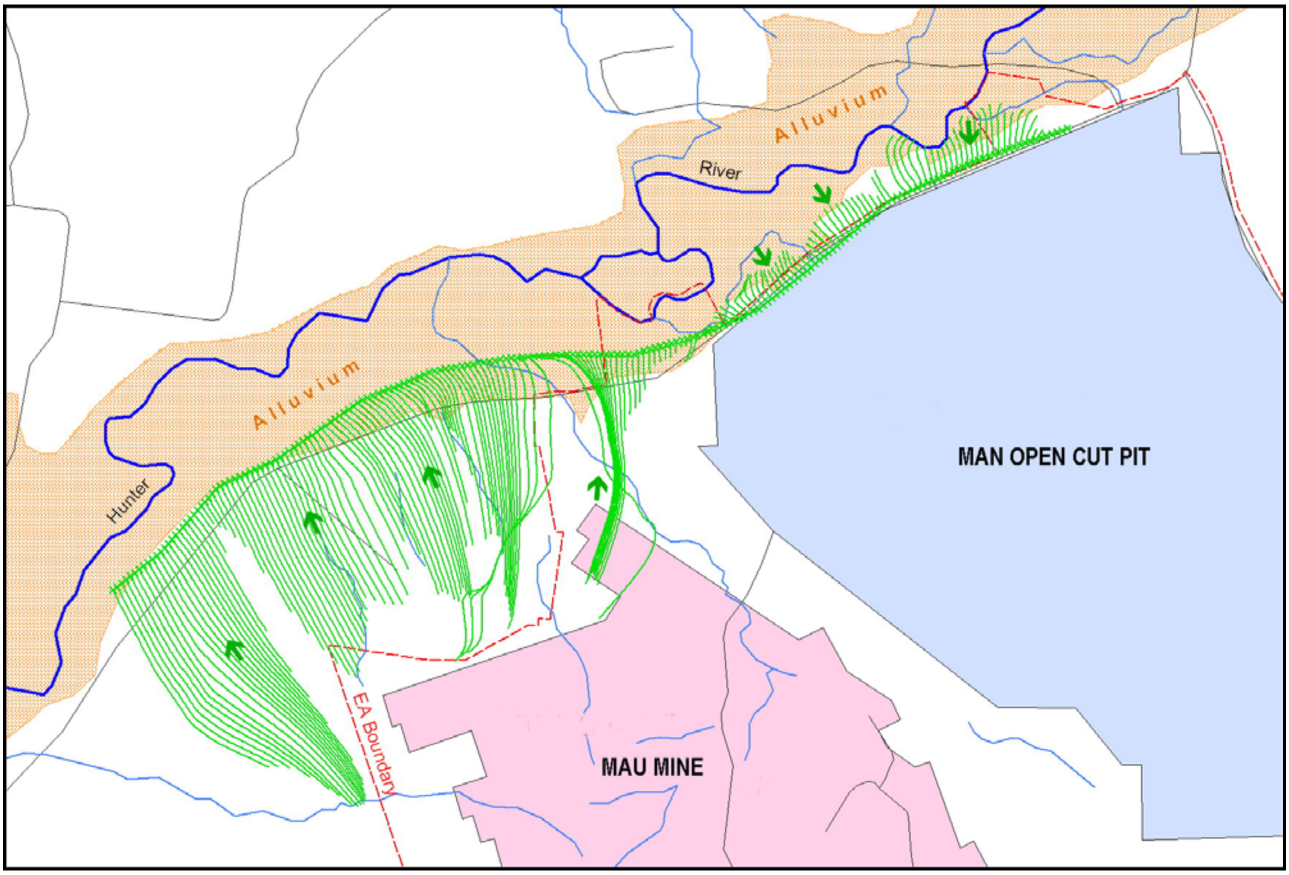

Figure 16: Flow Path Analysis from Hunter River Alluvium

During the recovery of the final voids the groundwater flow direction towards the mining area remains unchanged but the flow rates diminish slowly. Ten years after mining there will be about 0.5ML/day (5.8L/s) of groundwater flow towards the open void. Since the open voids recover to a level below the natural groundwater table, the inflow from Hunter River to the open void will continue post mining with the flow rate diminishing towards a steady-state value of 0.2ML/day (2.3L/s). The alluvial aquifer of Hunter River recovers much faster due to the higher permeability and storage characteristics of the alluvium, continuous inflow of surface water from the river itself and the higher direct groundwater recharge from rainfall.

16.4.2 Saddlers Creek Alluvium

Mining in the Saddlers Creek area will reduce the rate of the groundwater discharge from the Permian aquifers to the alluvial aquifer of Saddlers Creek. Simulation indicates that up to the year 2011 this reduction will be caused mainly by the advancing cone of depression developing around the MAN Pit and South Pit Extension, which will affect the Saddlers Creek alluvium over a length of around 3km. By 2011 the flow direction in the Permian aquifer is reversed with flow being from Saddlers Creek towards the South Pit Extension, stabilising on a rate of 0.09ML/day (1.04L/s) by about 2019. At this time the northern part of the Saddlers Creek alluvium will be hydraulically separated from the underlying Permian aquifer due to the ongoing groundwater drawdown. The creek alluvium however will still receive direct recharge from rainfall and surface runoff, and will retain some of its natural ephemeral surface flow.

By 2016 an additional minor impact on Saddlers Creek is caused by dewatering and depressurisation associated with mining of the Glen Munro and Woodlands Hill Seams in the southern part of Saddlers Pit, leading to a reversal of groundwater flow into the Pit. Predictive modelling indicates that the flow rate from Saddlers Creek towards the Pit never exceeds 0.02ML/day.

The simulation results indicate that the impact of the MAU Project may add to the reduction of flow and discharge towards Saddlers Creek along a 6km long section, directly downstream of the South Pit Extension. The simulated discharge rates to Saddlers Creek alluvium as a result of MAU are reduced from 0.1ML/day (1.16L/s) along this section to 0.01ML/day (0.12L/s), in 2022, however groundwater drawdown does not exceed 2m at the creek.

In the lower reaches, towards the Hunter River, the Saddlers Creek alluvium will continue to receive groundwater discharge from the coal seams even during peak mining activities within the MAN Pit, South Pit Extension and MAU. This is because the cone of depression around the Pits and underground mine is quite steep and limited to the immediate surrounds of the Pits and underground mine.

It should be noted that the reduction of groundwater discharge from the Permian aquifer to the Saddlers Creek alluvium may lead to improvement in the quality of groundwater along the affected section of the creek since the Permian groundwater is known to have a higher salt content.

With the end of the mining operation the flow rates do not recover significantly over a time range of 100 years. As long as a cone of depression around the open voids prevents groundwater to flow towards Saddlers Creek, the catchment area remains at a reduced size.

The change of discharge rates to/from the alluvial areas along the Hunter River and Saddlers Creek during mine operation is shown in Figure 17.

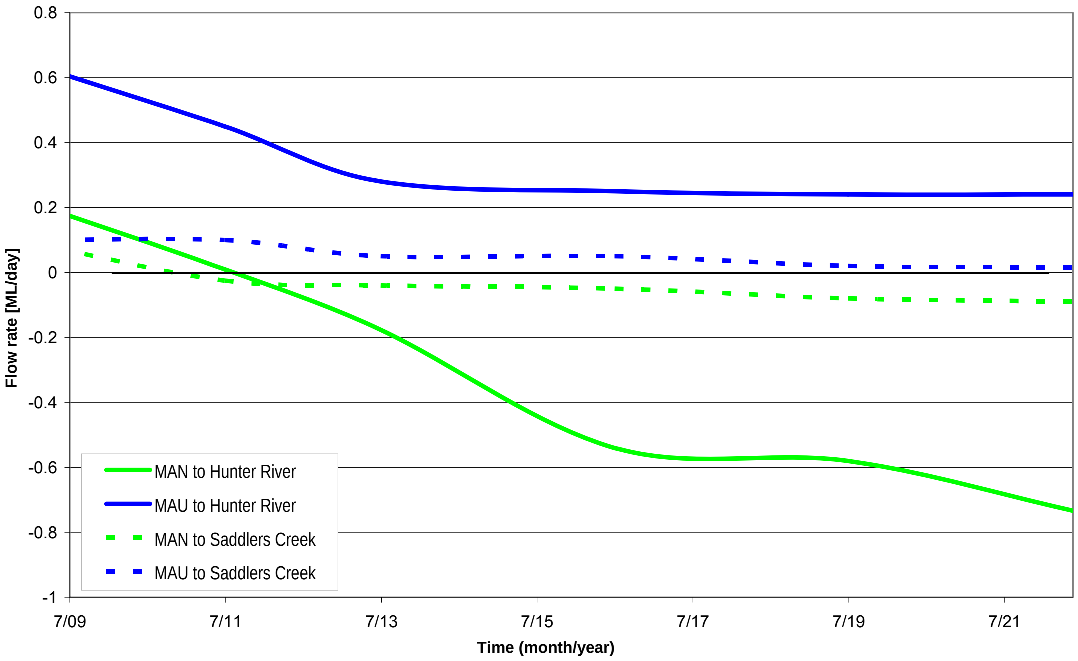

Figure 17: Groundwater Seepage Rates to/from Hunter River and Saddlers Creek Alluvium

16.5 Intersection and Removal of Tributary Creek Alluvium

16.5.1 Whites and Fairford Creeks

Apart from depressurisation of the coal seams resulting in a reversal of groundwater flow from, rather than to the alluvium, the MAN Pit will also mine through and remove alluvium associated with Whites and Fairford Creeks. Investigation of the alluvium of these tributaries was described in Section 8.1.

The investigation indicated that there is a narrow band of alluvium extending between 200m and 350m to the south-east along Whites and Fairford Creeks and that in the down gradient end of the creeks, the alluvium is saturated and in hydraulic connection with the Hunter River alluvium. The sediments in the upper part of the creeks however consist predominantly of silty to sandy clays which typically form an aquitard and hence do not readily transmit groundwater.

It is assessed that mining through the alluvium at the down-gradient end of the creeks may therefore provide hydraulic connection with the main Hunter River alluvial aquifer with resultant drainage of alluvial groundwater into the pit. Mitigation options to prevent this are discussed in Section 17.0 and a proposed monitoring plan is presented in Section 18.0.

16.5.2 Saddlers Creek Tributary

Apart from depressurisation of the coal seams resulting in a reversal of groundwater flow from, rather than to the alluvium, Saddlers Pit will also mine through and remove alluvium associated with a small tributary of Saddlers Creek, consistent with the Bayswater No. 3 Development Consent. The Bayswater No. 3 Development Consent (DA 201/93) provided approval for the disturbance of a part of Saddlers Creek to allow the western development of Saddlers Pit, as presented in the mine plans for the Project. Investigation of the alluvium of this tributary was described in Section 8.2 and Drawing No. A2 in Appendix 1 shows the extent of the alluvium that may be removed.

The investigation indicated that groundwater occurrence is sporadic and is associated with more permeable sand and gravel lenses in a predominantly sandy clay to clay rich sequence. Nevertheless, removal of the alluvium by mining will reduce the extent of alluvium of the Saddlers Creek system. It is assessed that the area of alluvium in the tributary creek that will be removed by Saddlers Pit is about 34ha or 3% of the total area of alluvium (about 10.1km^2), associated with Saddlers Creek.

This small percentage and the fact that much of the alluvial groundwater in the upper portion of the tributary would in any case be lost due to depressurisation of the coal seams, suggests that the overall impact on the Saddlers Creek alluvial aquifer system will be small. There is however a potential that exposure of the alluvium in the end-wall of Saddlers Pit will drain groundwater to the pit from a larger area of Saddlers Creek alluvium. Mitigation options to prevent this are discussed in Section 17.0 and a proposed monitoring plan is presented in Section 18.0.

16.6 Impact on Existing Groundwater Users

Drawdown of the piezometric surface of the coal seam aquifers and of the water table of the shallow alluvial and regolith aquifers will impact existing groundwater users, that is both human users from bores and GDE’s. The following sections discuss these impacts.

16.6.1 *Loss of Yield from Existing Bores*

Depressurisation and leakage as a result of mining may result in a lowering of water table/ piezometric levels in those existing bores that are used for irrigation, stock and domestic water supplies where these facilities lie within the radius of the cone of depression. As discussed, existing bores were identified from a search of the DWE database and are shown on Drawing No. 3. Many of the bores are located within the Hunter River alluvial floodplain, drawing water from the alluvial aquifers. However as stated by MER (2007)[14] *"these bores situated within the Hunter River alluvial lands are considered to be much less vulnerable than bores located within the coal measures since the former are generally situated in aquifer materials that offer high storage and recharge characteristics".*

As shown on Drawing No. 13 and discussed in Sections 16.2 and 16.4, approximately 4.2km^2 of Hunter River alluvial lands may lie within the cone of depression of mine dewatering and bores within this area may be impacted. This indicates that most bores within the alluvial lands will be unaffected since significant depressurisation is not predicted to extend sufficient distance that will affect the location of the bores. There are only two registered bores on the southern side of the river and within the cone of depression created by the MAN Pit; GW018298 and GW024700, shown on Drawing No. 3. Both of these registered bores within the cone of depression are located on Mt Arthur Coal owned land.

Depressurisation of the upper coal seam aquifers and regolith however has potential to impact existing bores located in these aquifers. Existing bores likely to be impacted are those exposed to a water table/piezometric drawdown of greater than 2m, which is considered to be within the natural range of fluctuation of groundwater levels. Drawing Nos. 2 and 13 indicate that the bores that are likely to be impacted are all located within land owned by Mt Arthur Coal.

A summary of the existing bores and the likely impact is given in Appendix 1.

16.6.2 *Groundwater Dependent Ecosystems*

There are no springs within the topographically elevated land, that is, the regolith and Permian subcrop areas supported by groundwater discharge, around which GDE's have developed. Similarly no GDE's have been identified in the alluvial areas and in any case if they do exist, it is unlikely that they will be impacted due to the fact that the alluvial areas are less vulnerable to depressurisation from the mine, as described. MER (2007)[14] states that Umwelt (Australia) Pty Ltd has undertaken ecosystem mapping throughout the EA Boundary and has not identified any GDE's likely to be affected within the groundwater depressurisation impact zone. This has been confirmed by Hansen Bailey for the Project.

16.7 Groundwater Recovery

Water level recovery in the final void following cessation of mining has been addressed by the surface water study for this Project and was simulated by the surface water model described in a separate report. Steady state groundwater inflow to the voids from the coal seams and spoil for various water level elevations within the Pits, were provided for input to the surface water model, which then took into account, rainfall, evaporation and surface runoff.

17.0 MITIGATION OPTIONS

In areas where open cut mining may intersect alluvial deposits, such as those associated with Whites and Fairford Creeks, potentially resulting in seepage from the Hunter River alluvium, Mt Arthur Coal will commit to further investigation of the extent of the alluvium in each tributary followed by the design and construction of a low permeability slurry or engineered/ compacted clay cut-off trench across the relatively narrow and thin alluvial bodies. The trench will be keyed into the top of the weathered coal measures underlying the creek alluvium. This will provide an impermeable barrier across the alluvium that will hydraulically separate the tributary creek alluvium from the saturated alluvial sediments of the Hunter River and Saddlers Creek, while mitigating the need to alter the configuration for the proposed open cut mine.

Similarly if leakage occurs via the regolith separating the pit and the Hunter River alluvium, mitigation measures such as a slurry trench or grout injection will be undertaken to prevent this inflow.

Where water levels in existing landholder bores decline as a result of the Project, leading to an adverse impact on water supply from the bore, the supply will be re-instated by Mt Arthur Coal in consultation with the landholder in a manner agreed by both parties, which may include options such as deepening the bore, construction of a new bore or surface water dam, or piping water from an external source.

18.0 GROUNDWATER MONITORING SYSTEM

This section of the report provides a recommended groundwater monitoring program that will provide both an on-going assessment of the impact of the Project and a proactive indicator of any adverse impacts on the groundwater regime, so that timely remedial action can be taken. The program will be implemented progressively and regularly reviewed to ensure impacts of the Project are monitored and responses to negative impacts implemented.

As discussed the prime areas of concern are:

- the leakage from the alluvium along the Hunter River and Saddlers Creek; and
- impact on domestic and/or farm bores and wells.

18.1 Installation of Monitoring Bores – Permeability Testing

A network of paired monitoring bores will need to be established in the alluvial aquifers associated with the Hunter River and Saddlers Creek and in underlying coal seams to monitor:

- depressurisation of the shallow coal measures strata and in particular the shallow coal seams and the potential impact on the overlying alluvial aquifers; and
- changes in groundwater quality as a result of depressurisation.

A similar monitoring strategy was recommended and accepted by DWE for monitoring the impact of open cut mining for the Bengalla Mine, Wantana Extension (AGE 2007)[21] on the immediate north side of the Hunter River to the Project.

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[21] Australasian Groundwater and Environmental Consultants Pty Ltd, (Aug. 2007), *“Report on Bengalla Mine – Wantana Extension, Groundwater Impact Assessment”,* Report No. G1372.

With respect to monitoring the potential impact of the Project on the alluvial aquifers, the following program is recommended:

18.1.1 Hunter River

Alluvium areas: At sites GW16, 17, 21, 24 and 25, a shallow monitoring bore has already been established in the alluvium but at two sites (GW17 and GW24) the bores have collapsed or there is no access). It is recommended that replacement bores be drilled at these two sites and that another bore be established in a shallow coal seam, up to 50m depth beneath the base of alluvium at all sites.

Regolith/Permian Strata: A monitoring bore has similarly been constructed in Permian strata at sites GW18, 19, 22 and 23, that is, in the buffer zone between the edge of the proposed Pit and the boundary of the alluvium. Of these, GW18 and GW19 have been destroyed. It is similarly recommended that they be replaced and that additional shallow bores be established in the regolith to a maximum depth of 30-40m at each site.

The bore locations are shown on Drawing No. 3.

18.1.2 Saddlers Creek

Saddlers Creek alluvium: It is recommended that paired monitoring bores be established at Site GW2 and at a second and third site 2km and 4km downstream of GW2 respectively. One monitoring bore should be installed to the base of alluvium and the second in the first coal seam, that is at least 10m below the base of alluvium.

18.1.3 Permeability Testing

It is recommended that permeability tests be undertaken when drilling the monitoring bores. This should consist of:

- Packer tests in the overburden between the base of alluvium and coal seams to provide an in-situ permeability profile of the overburden material.
- Collection of core samples of the overburden between the base of alluvium and coal seam for laboratory permeability testing.

It is considered that knowledge of the permeability of the overburden will be crucial in establishing with a higher degree of confidence the leakage rates from the alluvial aquifer as a result of depressurisation of the underlying coal seams due to open cut mining at Mt Arthur Coal.

A bore licence must be obtained from DWE prior to the installation of any new monitoring bores. All monitoring bores should be constructed according to the Australian guidelines[22] by an appropriately qualified water bore driller.

The recommended monitoring bores are summarised in Table 11 below.

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[22] Land and Water Biodiversity Committee (Sept. 2003) *"Minimum Construction Requirements for Water Bores in Australia"* Ed. 2.

Table 11: SUMMARY OF RECOMMENDED MONITORING BORES

Locality	**Co-ordinates**		**RL (mAHD)**	**Depth (m)**	**Aquifer**
	mE	**mN**			
Hunter River Alluvial Area					
GW16	294197.1	6422759.4	131.77	13	Alluvium
				max. 50	Coal seam
GW17	295003.0	6423569.8	134.63	10.8	Alluvium
				max. 50	Coal seam
GW21	296141.3	6424483.0	136.06	16	Alluvium
				max. 50	Coal seam
GW24	297386.0	6424914.0	137.10	13	Alluvium
				max. 50	Coal seam
GW25	298375.7	6425230.9	140.05	nr	Alluvium
				max. 50	Coal seam
MAN Northern Endwall					
GW18				max. 10	Alluvium
	295450.2	6422964.4	141.86	246.59	Coal seam
GW19				max. 30	Regolith
	295938.2	6423477.0	163.03	210.36	Coal seam
GW22				max. 30	Regolith
	296930.0	6423998.4	154.05	96.26	Coal seam
GW23	297919.4	6424514.9	181.40	max. 30	Regolith
				54.61	Coal seam
Saddlers Creek					
GW2				max. 10	Alluvium
	299044.8	6413510.6	153.74	115	Coal seam
New Site 2km downstream				max. 10	Alluvium
				max. 50	Coal seam
New Site 4km downstream				max. 10	Alluvium
				max. 50	Coal seam

Notes: i) 🟧 bores to be constructed ii) Co-ordinates MGA 94 Zone 56

18.2 Water Level Monitoring Plan

A decline in groundwater pressures in the coal measure aquifers indicates an increased potential for leakage from the alluvium. The hydraulic gradient between the alluvial water level and the underlying coal seam piezometric level can be used to provide an estimate of the leakage rate if the permeability of the base of alluvial or overburden of the coal seam is known or assumed.

A data logger should be installed in each of the paired monitoring bores and set to monitor water level fluctuations at six-hour intervals. This will enable water level fluctuations due to rainfall recharge and pumping to be distinguished from potential water level declines due to depressurisation of the underlying Permian strata as a result of open cut mining within the MAN Pit.

Apart from the above paired monitoring bores, all bores in the Mt Arthur Coal existing monitoring program should continue to be monitored on a quarterly basis. It is also recommended that regular monitoring be undertaken on existing farm/domestic bores located in the alluvial areas both upstream and downstream of the EA Boundary.

18.3 Water Quality Monitoring Plan

MER (2007)[14] recommended within the MAU groundwater impact assessment, that Mt Arthur Coal enhance their water quality monitoring program to consist of the following:

- Quarterly monitoring of basic water quality parameters of pH and EC in the paired monitoring bores and pumped mine water with the objective of providing an early indication of seepage and mixing of shallow alluvial groundwaters with the deeper and poorer quality groundwaters of the Permian strata;
- Bi-annual monitoring in the paired bores for TDS, major ions (Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4) and elements As, B, Br, F, Fe (soluble), Li, Mn, P, Se, Si, Sr, Zn. Speciation of the water samples, and in particular bromide, strontium and boron assist in identifying future mixing, if any, of groundwaters from the alluvial and Permian aquifers;
- Annual monitoring of groundwater quality using the same analytes described above, from all monitoring bores; and
- Graphical plotting of the water quality data, identification of trend lines and comparison of trends with rainfall and other identifiable processes that may influence such trends.

These recommendations were also included within the Statement of Commitments for the MAU EA. As such, no further water quality monitoring recommendations are required for the Project.

18.4 Mine Water Seepage Monitoring

It is recommended that monitoring of mine water seepage should be undertaken, particularly to identify seepage rates associated with potential leakage from the alluvium. Of particular interest are seepage rates from the northern highwall and endwall of MAN Pit, that is, the area of pit closest to the Hunter River alluvium. The monitoring program should include:

- regular geological and geotechnical mapping of fractures in the highwall and endwall;
- recording of the time, location and volume of any unexpected increased groundwater outflow from the highwall and endwall;
- recording of the location and cause of any highwall/endwall stability issues;
- measurement of all water pumped from the MAN Pit particularly at the northern end, using flow meters or other suitable gauging apparatus; and
- monitoring of coal moisture content.

18.5 Data Management and Reporting

MER (2007)[14] recommended that for the MAU groundwater impact assessment, impact verification should include:

- *Quarterly assessment of departures from identified monitoring data trends. The key data sets in this regard should be the mine water seepage rate calculated from the underground water balance, and the pressure monitoring data for buffer zone piezometers. If the average daily seepage rate exhibits an increase beyond the rate predicted (allowing for 0.5ML/day additional transient storage depletion), or if consecutive pressure monitoring data over a* *period of 6 months exhibit an increasing divergence in an adverse impact sense from the previous data or from the established or predicted trend, then such departures should initiate further actions. These may include a need to conduct more intensive monitoring (including installation of additional piezometers) or to invoke impacts re-assessment and/or mitigative measures.*

- *Formal review of depressurisation of coal measures and comparison of responses with aquifer model predictions biennially. Expert review should be undertaken by a suitably qualified hydrogeologist.*
- *Annual reporting (including all water level and water quality data) as part of the AEMR.*

These recommendations were also included within the Statement of Commitments for the MAU EA and should be adopted for the Project whether or not MAU proceeds. As such, no further data management and reporting recommendations are required for the Project, provided that the AEMR reports any newly constructed bores recommended for the Project.

19.0 MODEL LIMITATIONS

Development, calibration and the results of predictive simulations from any groundwater model is based on available data characterising the groundwater system under investigation. It is not possible to collect all the data characterising the whole aquifer system in detail and therefore various assumptions have to be made during development of the groundwater model. A number of assumptions were made during development of the groundwater model described in this report and these assumptions together with their impact on the simulation results are discussed below.

Since the simulated aquifers sub-crop along the eastern border of the groundwater model, it is assumed that they are hydraulically separated from the groundwater regime east of the Project. The impact of such an assumption on the simulation results is such that the cone of depression around the EA Boundary caused by the MAN Pit cannot be extended beyond the eastern boundary. It also implies that the Bayswater No. 2 and Drayton Mine have no impact within the EA Boundary.

The conceptual model assumes that the hydraulic properties of the numerous Permian coal seams present within the EA Boundary can be represented by three major layers. The hydraulic properties of a number of coal seams present within these layers were merged with the properties of the interburden. This simplification may lead to underestimation of the extent and the velocity of development of the cone depression. This is because the cone of depression in coal seams that have relatively higher hydraulic conductivity is likely to develop somewhat quicker than in the less permeable interburden.

However, the chosen approach is considered to be reasonable since the extent of the cone of depression is limited and the period of the simulated mine development is sufficiently long to compensate for any major difference between the development of the cone of depression in the coal seams and in the interburden.

With respect to the MAU Project, all information and data used in the current model has been extracted from the corresponding numerical groundwater flow model of the underground mine (MER 2007)[14]. Nonetheless, some discrepancies occur in the interpretation of the results regarding the hydraulic impact of the underground mine. This may be due to the different settings of the outer boundaries. Where the MER model extended the model domain beyond the Mount

Ogilvie Fault, the current model uses this structural feature as model boundary, reducing the available volume for dewatering. This leads to a prediction of a somewhat higher impact on the Saddlers Creek and Hunter River alluvium, even though the general assessment remains similar.

20.0 GLOSSARY

Alluvium - Sediment (gravel, sand, silt, clay) transported by water (i.e. deposits in a stream channel or floodplain).

Aquiclude - A low-permeability unit that forms either the upper or lower boundary of a ground-water flow system.

Aquifer - Rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Aquifer, confined - An aquifer that is overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer.

Aquifer, perched - A region in the unsaturated zone where the soil may be locally saturated because it overlies a low-permeability unit.

Aquifer, semi-confined - An aquifer confined by a low-permeability layer that permits water to slowly flow through it. During pumping of the aquifer, recharge to the aquifer can occur across the confining layer. Also known as a leaky artesian or leaky confined aquifer.

Aquifer, unconfined - An aquifer in which there are no confining beds between the zone of saturation and the surface. There will be a water table in an unconfined aquifer. Water table aquifer is a synonym.

Aquitard - A low-permeability unit than can store ground water and also transmit it slowly from one aquifer to another.

Colluvium - Sediment (gravel, sand, silt, clay) transported by gravity (i.e. deposits at the base of a slope).

Cone of Depression - The depression in the water table around a well or excavation defining the area of influence of the well. Also known as cone of influence.

Drawdown - A lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping of ground water from wells or excavations.

Hydraulic Conductivity - A measure of the rate at which water moves through a soil/rock mass. It is the volume of water that moves within a unit of time under a unit hydraulic gradient through a unit cross-sectional area that is perpendicular to the direction of flow.

Hydraulic gradient - The change in total head with a change in distance in a given direction. The direction is that which yields a maximum rate of decrease in head.

Infiltration - The flow of water downward from the land surface into and through the upper soil layers.

Model calibration - The process by which the independent variables of a digital computer model are varied in order to calibrate a dependent variable such as a head against a known value such as a water-table map.

Packer test - An aquifer test performed in an open borehole; the segment of the borehole to be tested is sealed off from the rest of the borehole by inflating seals, called packers, both above and below the segment.

Piezometer - A non-pumping well, generally of small diameter, that is used to measure the elevation of the water table or potentiometric surface. A piezometer generally has a short well screen through which water can enter.

Porosity - The ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment.

Potentiometric surface - A surface that represents the level to which water will rise in tightly cased wells. If the head varies significantly with depth in the aquifer, then there may be more than one potentiometric surface. The water table is a particular potentiometric surface for an unconfined aquifer.

Pumping Test - A test made by pumping a well for a period of time and observing the response/change in hydraulic head in the aquifer.

Slug Test - A test made by the instantaneous addition, or removal, of a known volume of water to or from a well. The subsequent well recovery is measured.

Specific yield - The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Gravity drainage may take many months to occur.

Storativity - The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer, per unit change in head.

Transmissivity - A measure of the rate at which water moves through an aquifer of unit width under a unit hydraulic gradient.

Unsaturated zone - The zone between the land surface and the water table. It includes the root zone, intermediate zone, and capillary fringe. The pore spaces contain water at less than atmospheric pressure, as well as air and other gases. Saturated bodies, such as perched ground water, may exist in the unsaturated zone. Also called zone of aeration and vadose zone.

Water budget - An evaluation of all the sources of supply and the corresponding discharges with respect to an aquifer or a drainage basin.

AUSTRALASIAN GROUNDWATER AND ENVIRONMENTAL CONSULTANTS PTY LTD

ULRICH SCHOTT
Groundwater Modeller

ERROL BRIESE
Principal Hydrogeologist / Managing Director

LIMITATIONS OF REPORT

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) has prepared this report for the use of Hansen Bailey Pty Ltd in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 16 July 2008.

The methodology adopted and sources of information used by AGE are outlined in this report. AGE has made no independent verification of this information beyond the agreed scope of works and AGE assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to AGE was false.

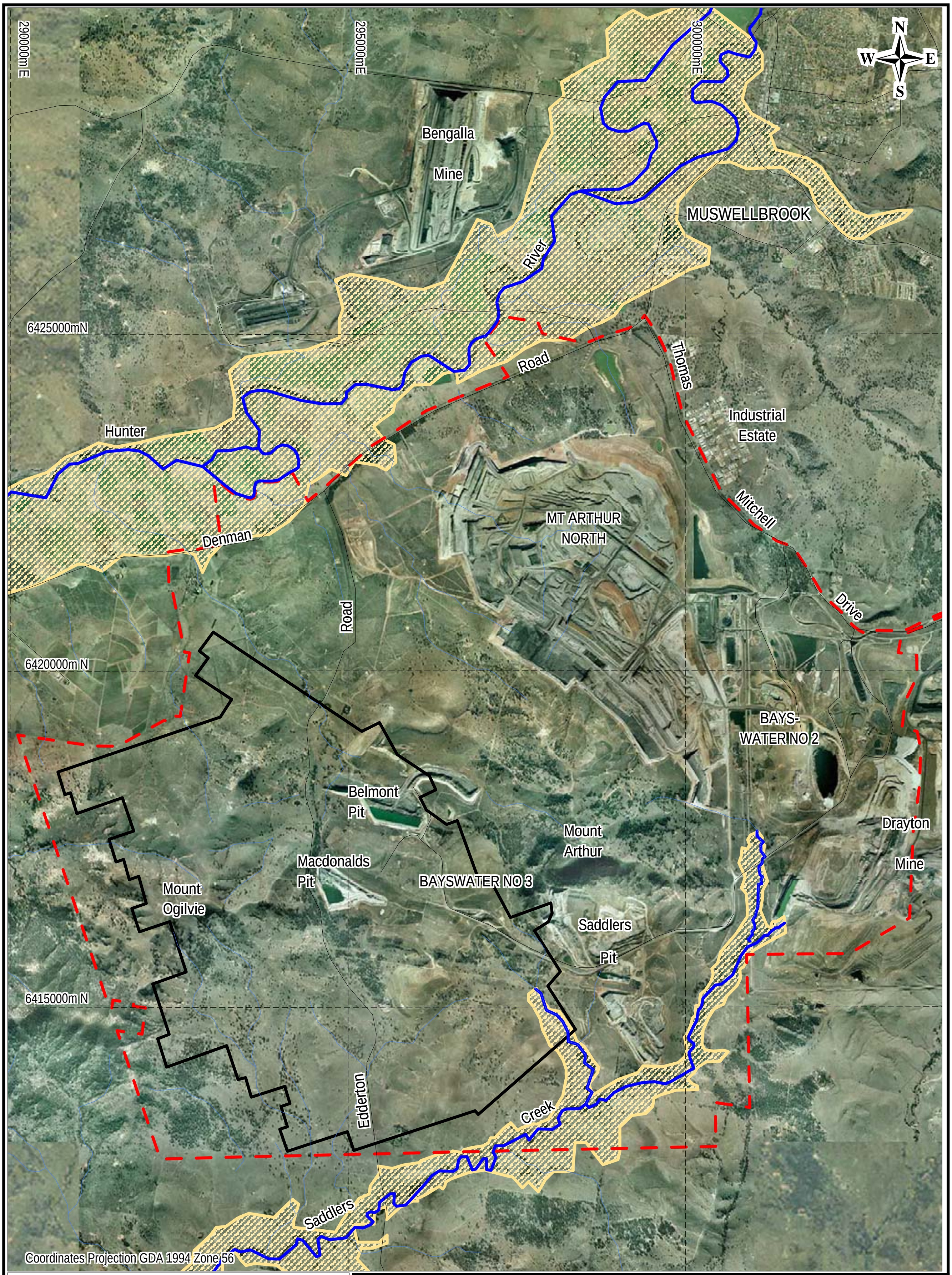
This study was undertaken between 3 October 2008 and 17 August 2009 and is based on the conditions encountered and the information available at the time of preparation of the report. AGE disclaims responsibility for any changes that may occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. It may not contain sufficient information for the purposes of other parties or other users. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

This report contains information obtained by inspection, sampling, testing and other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. Where borehole logs are provided they indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the frequency and method of sampling, and the uniformity of the site, as constrained by the project budget limitations. The behaviour of groundwater is complex. Our conclusions are based upon the analytical data presented in this report and our experience.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, AGE must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge, information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time. Therefore this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.



- LEGEND -

▭ Mt Arthur Underground

▭ EA boundary

― Major river/creek

▨ Alluvium

― Major road

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36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: MT ARTHUR COAL CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
EA BOUNDARY

CLIENT: Hansen Bailey Pty Ltd			**OFFICE:** Brisbane
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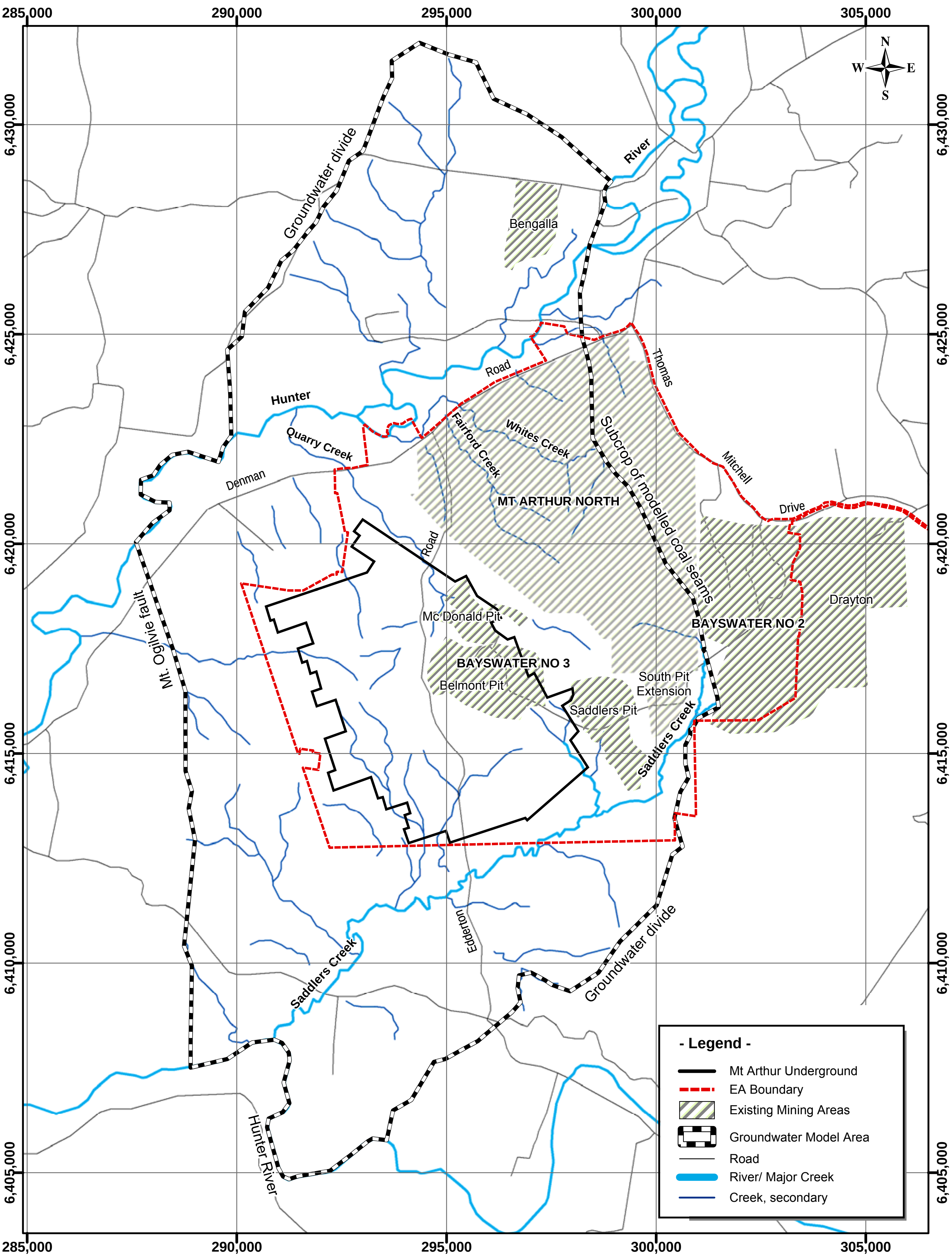
APPROVED BY:		**DATE:** April 2009	



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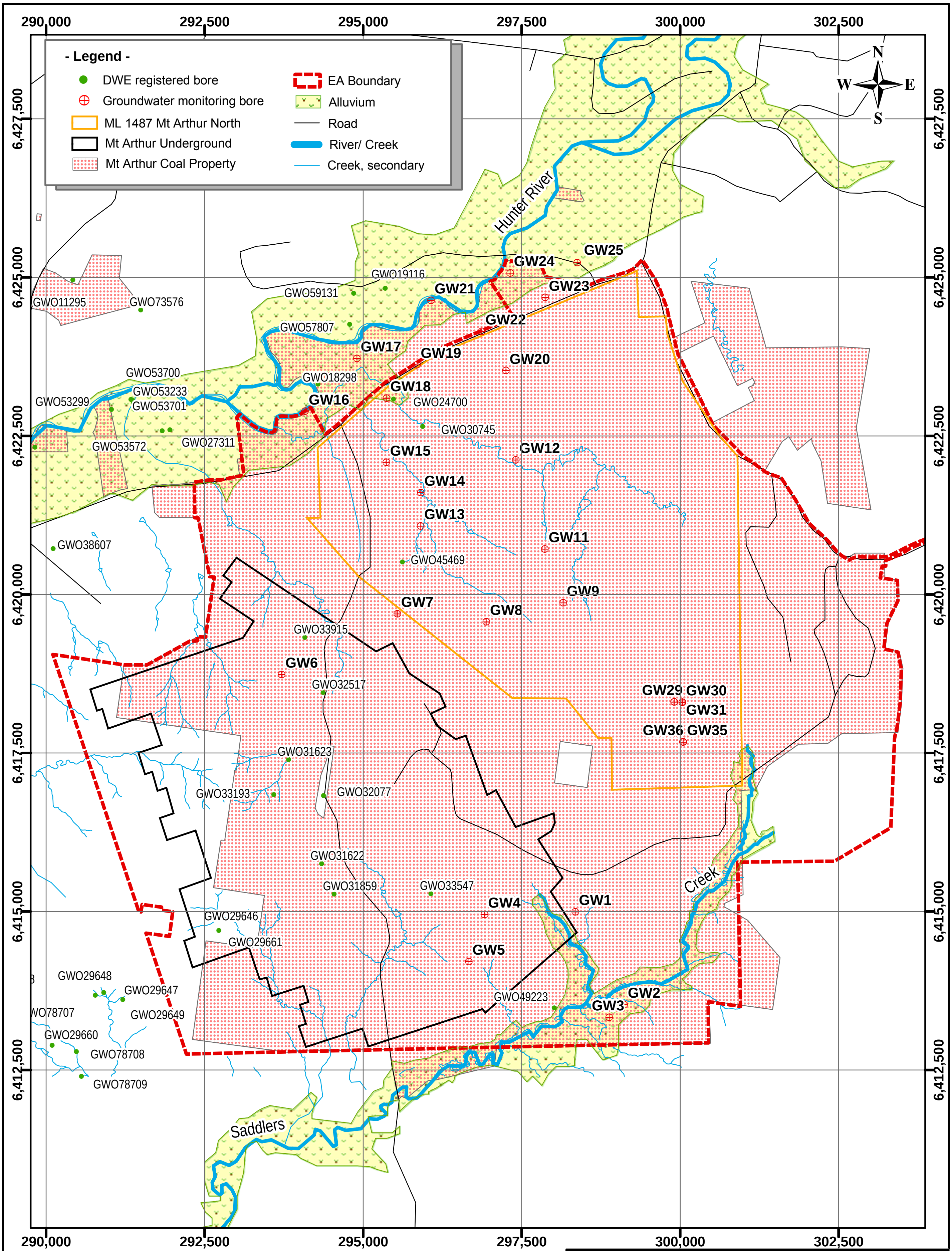
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: MT ARTHUR COAL CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
CONCEPTUAL MODEL AREA

CLIENT: Hansen Bailey Pty Ltd			**Office:** Brisbane
DRAWN BY: TMM	**SCALE:** 1:125,000 (A4)	**PROJECT No:** G1446	**DRAWING No:** 2
APPROVED BY:		**DATE:** April 2009	



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TITLE: MT ARTHUR COAL CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
DWE REGISTERED AND MONITORING BORES

CLIENT: Hansen Bailey Pty Ltd			**Office:** Brisbane
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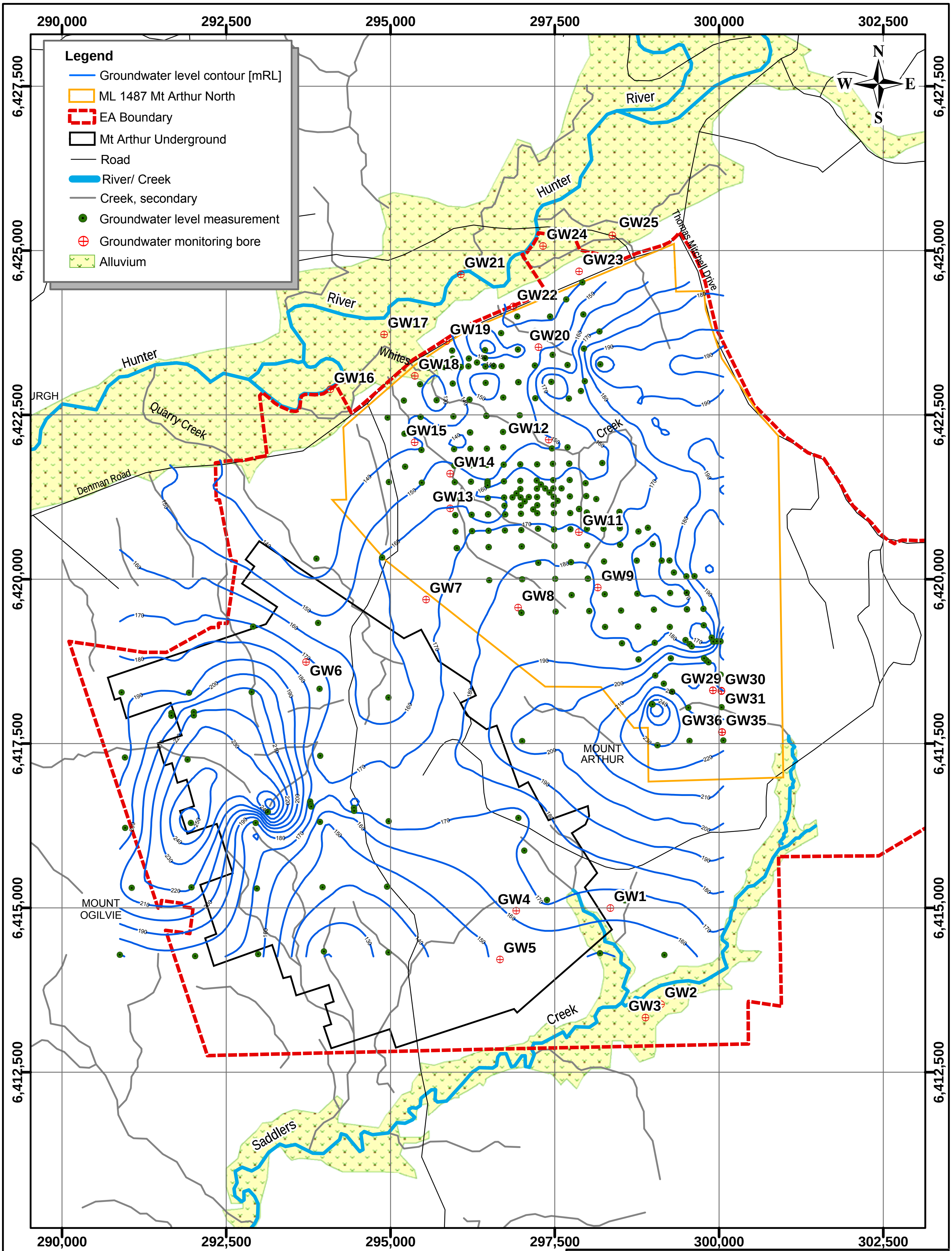
APPROVED BY:	**DATE:** April 2009		



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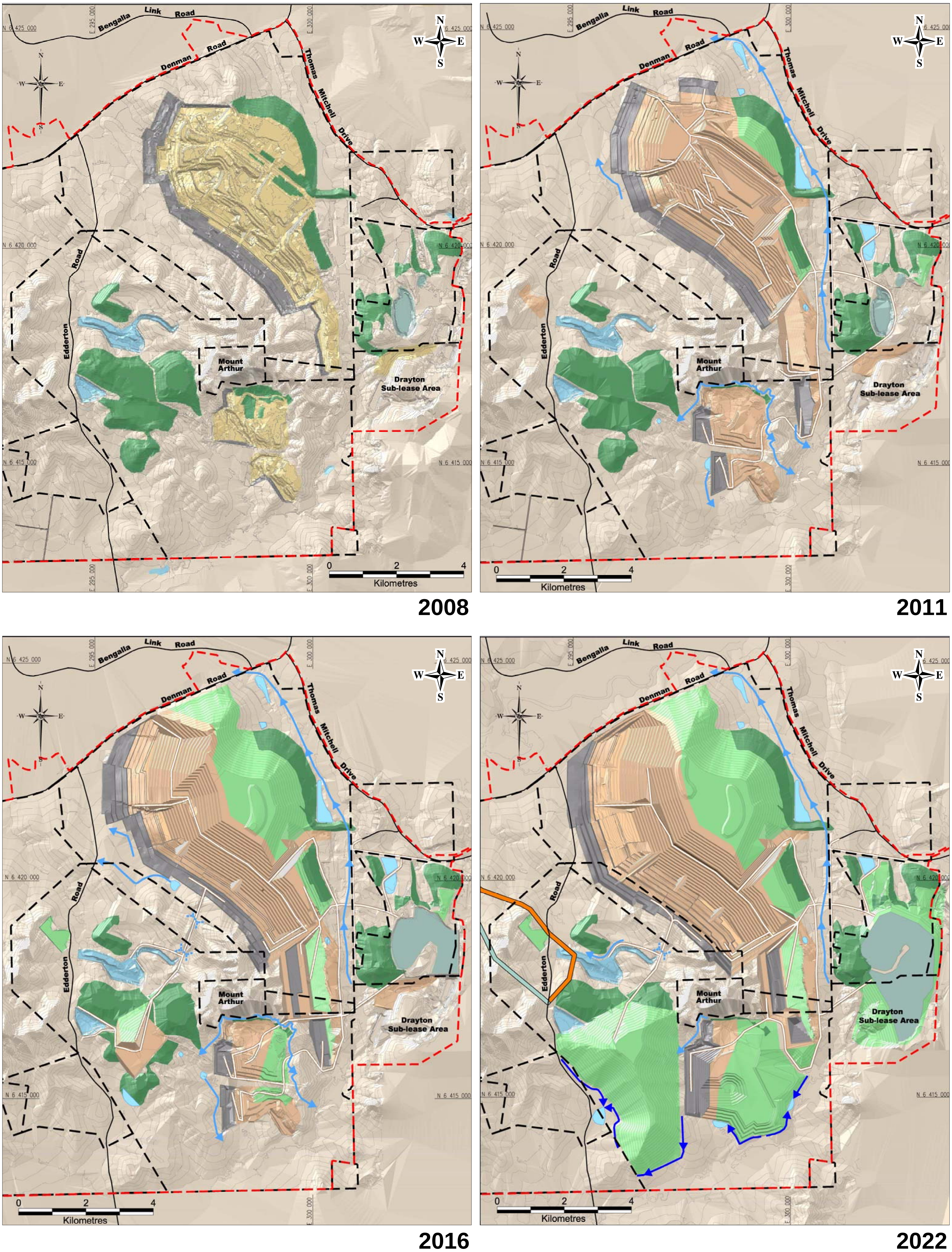
CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: MT ARTHUR COAL CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
INTERPRETED GROUNDWATER TABLE

CLIENT: Hansen Bailey Pty Ltd
Office: Brisbane
DRAWN BY: TMM
SCALE: 1:75,000 (A4)
PROJECT No: G1446
DRAWING No: 4
APPROVED BY:
DATE: April 2009



- LEGEND -

🟩 Existing Rehabilitation
🟩 Proposed Rehabilitation
🟦 Water Storage
→ Drainage

Mt Arthur Coal Mining & Exploration Leases
EA Boundary
▨ Edderton Road Realignment Option 1
🟧 Edderton Road Realignment Option 2
▨ Active Mining
▨ Spoil
▨ Tailings
Haul Roads
Culvert
→ Collection Drain

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TITLE: MT ARTHUR COAL CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
SHORT TERM - PLANNED MINING SEQUENCE

CLIENT: Hansen Bailey Pty Ltd
OFFICE: Brisbane
DRAWN BY: TMM
SCALE: as above
PROJECT No: G1446
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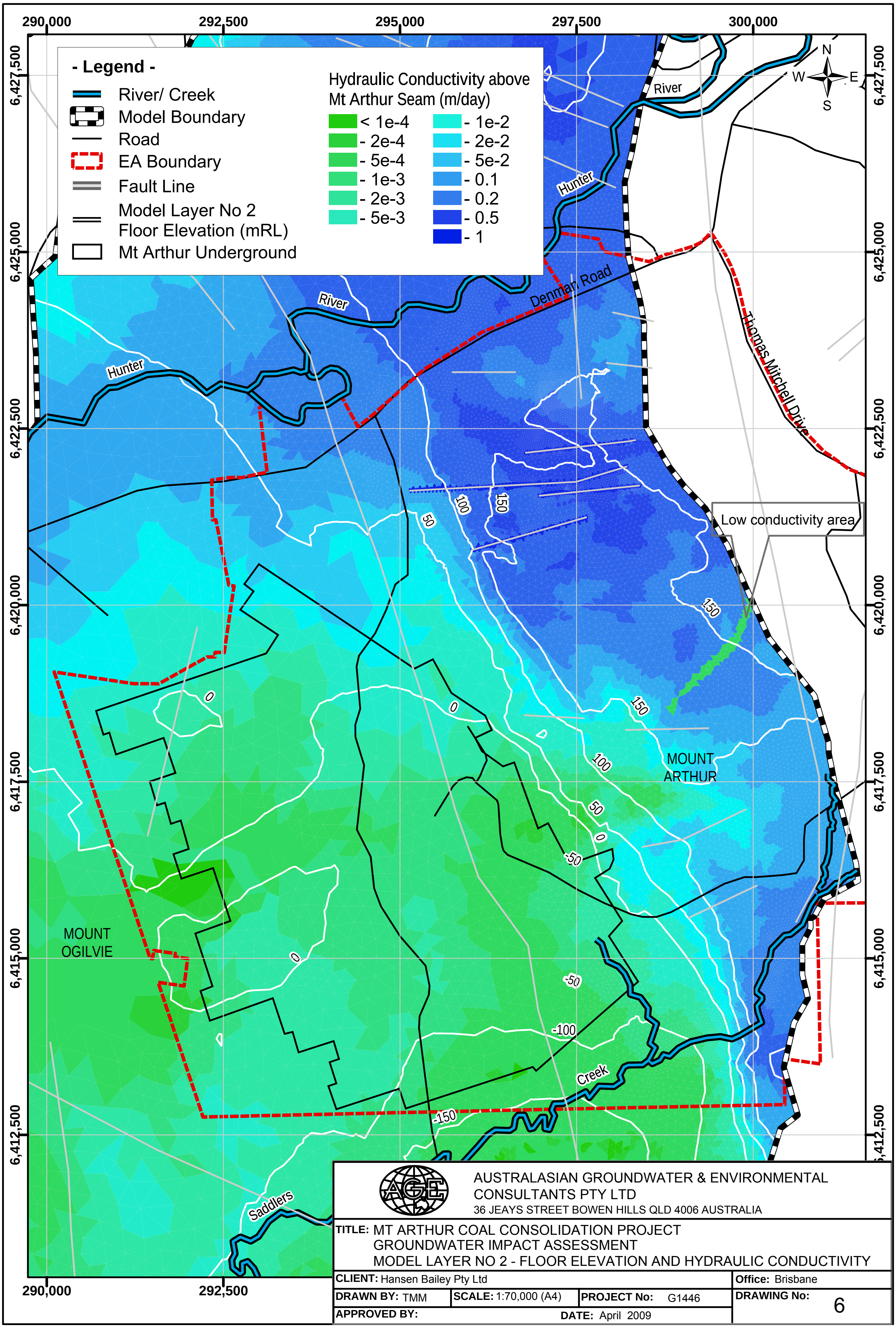
APPROVED BY:
DATE: April 2009



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TITLE: MT ARTHUR COAL CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
MODEL LAYER NO 2 - FLOOR ELEVATION AND HYDRAULIC CONDUCTIVITY

CLIENT: Hansen Bailey Pty Ltd
Office: Brisbane
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SCALE: 1:70,000 (A4)
PROJECT No: G1446
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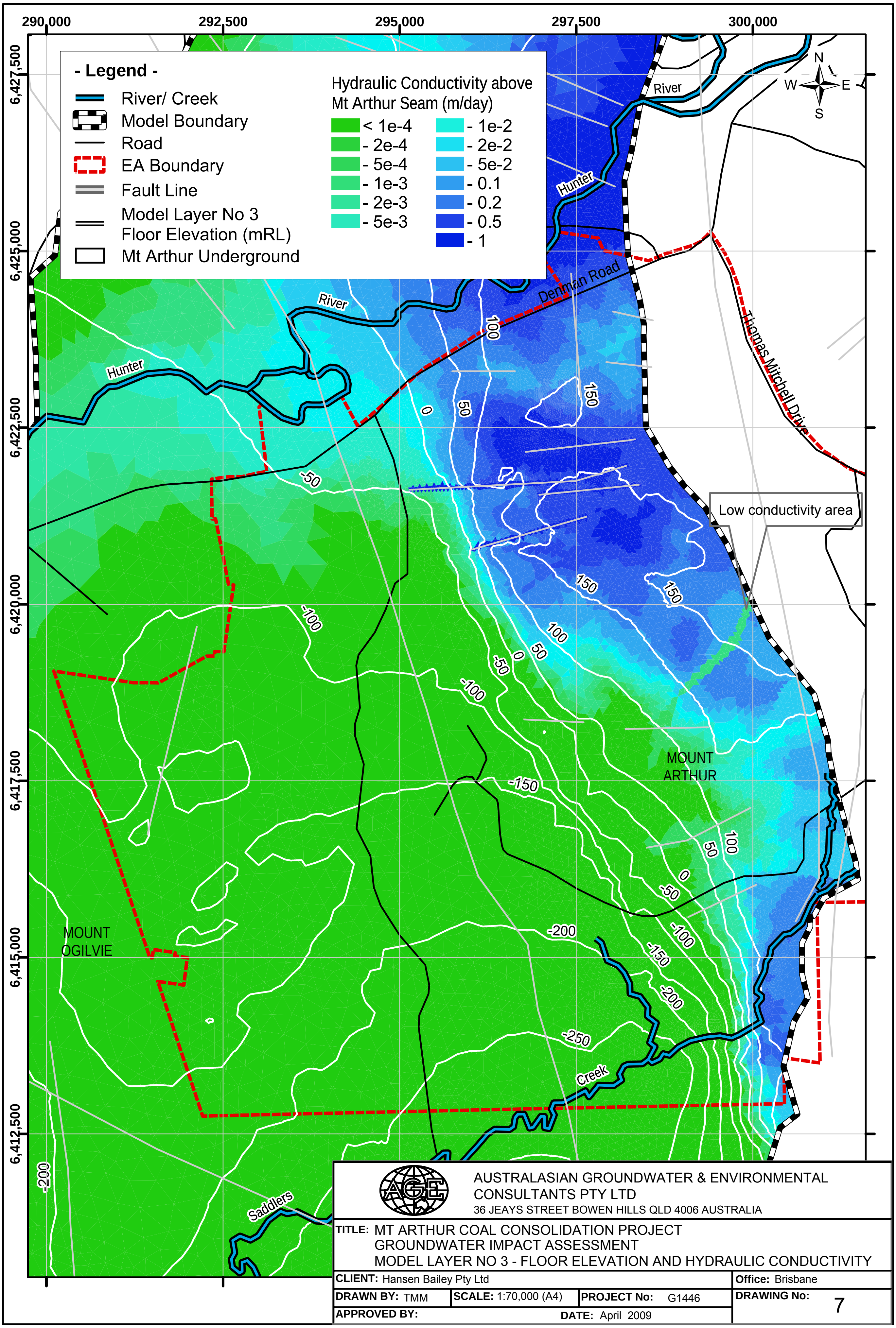
APPROVED BY:
DATE: April 2009



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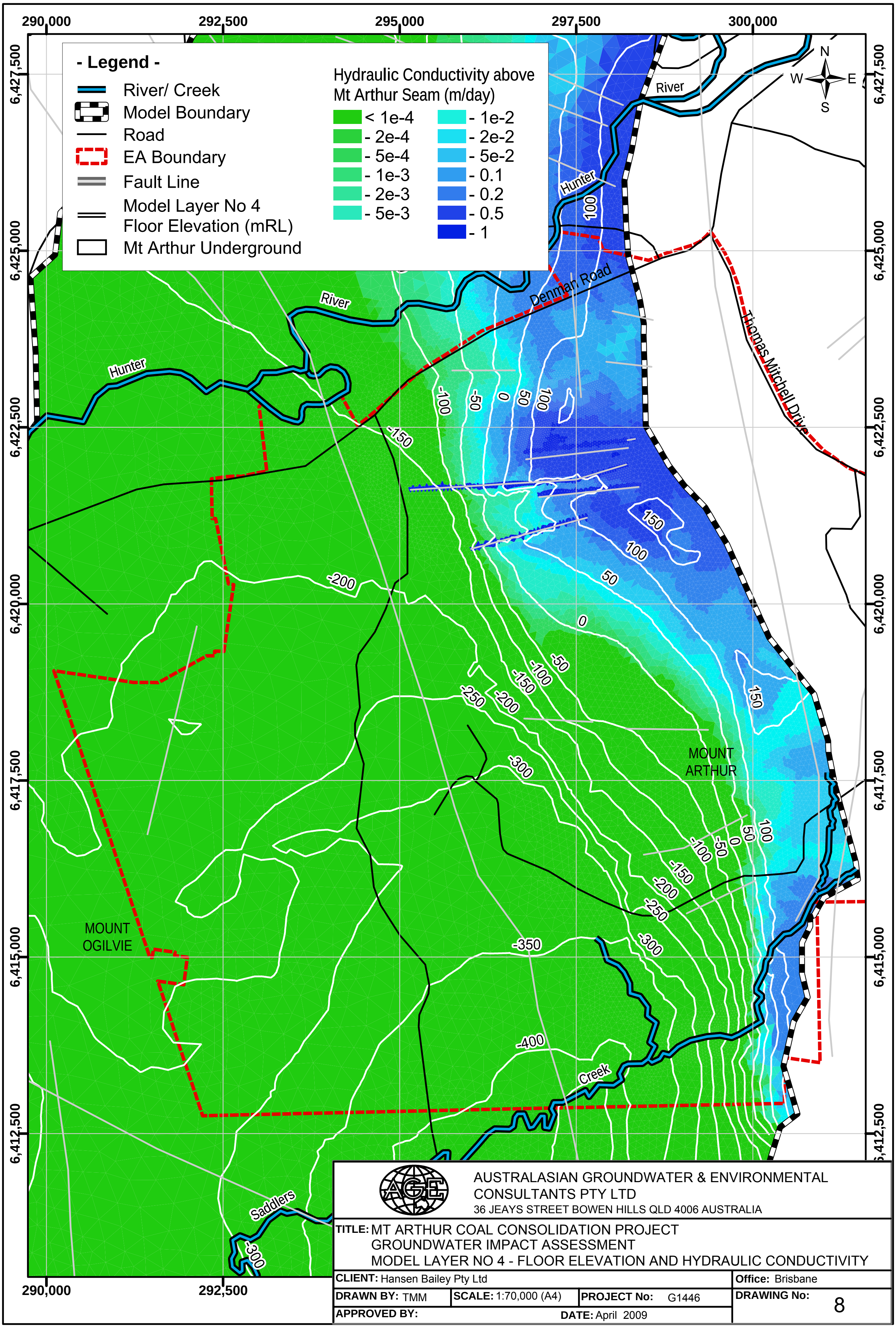
TITLE: MT ARTHUR COAL CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
MODEL LAYER NO 3 - FLOOR ELEVATION AND HYDRAULIC CONDUCTIVITY

CLIENT: Hansen Bailey Pty Ltd			**Office:** Brisbane
DRAWN BY: TMM	**SCALE:** 1:70,000 (A4)	**PROJECT No:** G1446	**DRAWING No:** 7
APPROVED BY:		**DATE:** April 2009	



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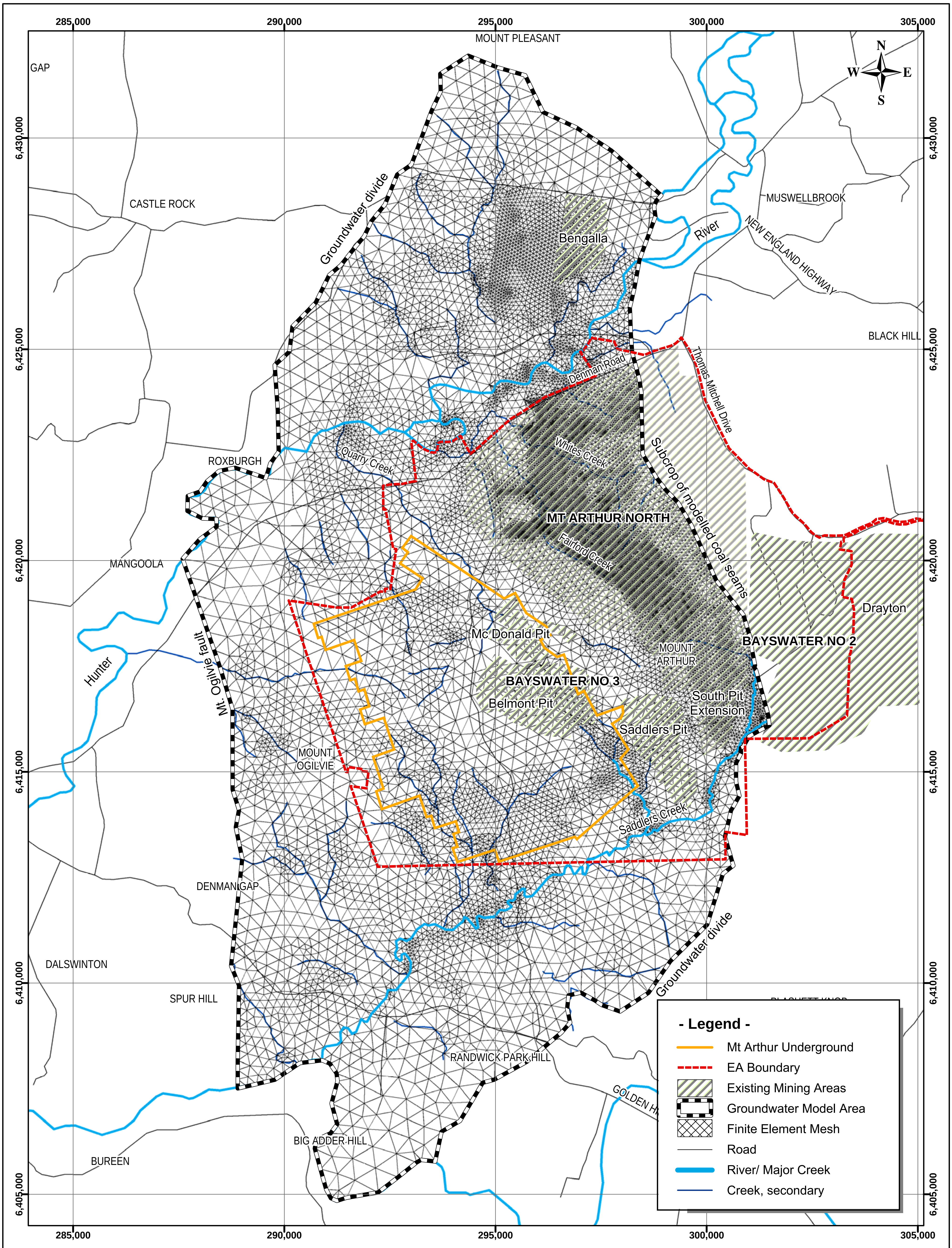
TITLE: MT ARTHUR COAL CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
MODEL LAYER NO 4 - FLOOR ELEVATION AND HYDRAULIC CONDUCTIVITY

CLIENT: Hansen Bailey Pty Ltd			**Office:** Brisbane
DRAWN BY: TMM	**SCALE:** 1:70,000 (A4)	**PROJECT No:** G1446	**DRAWING No:** 8
APPROVED BY:		**DATE:** April 2009	



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TITLE: MT ARTHUR COAL CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
MODEL AREA

CLIENT: Hansen Bailey Pty Ltd			**Office:** Brisbane
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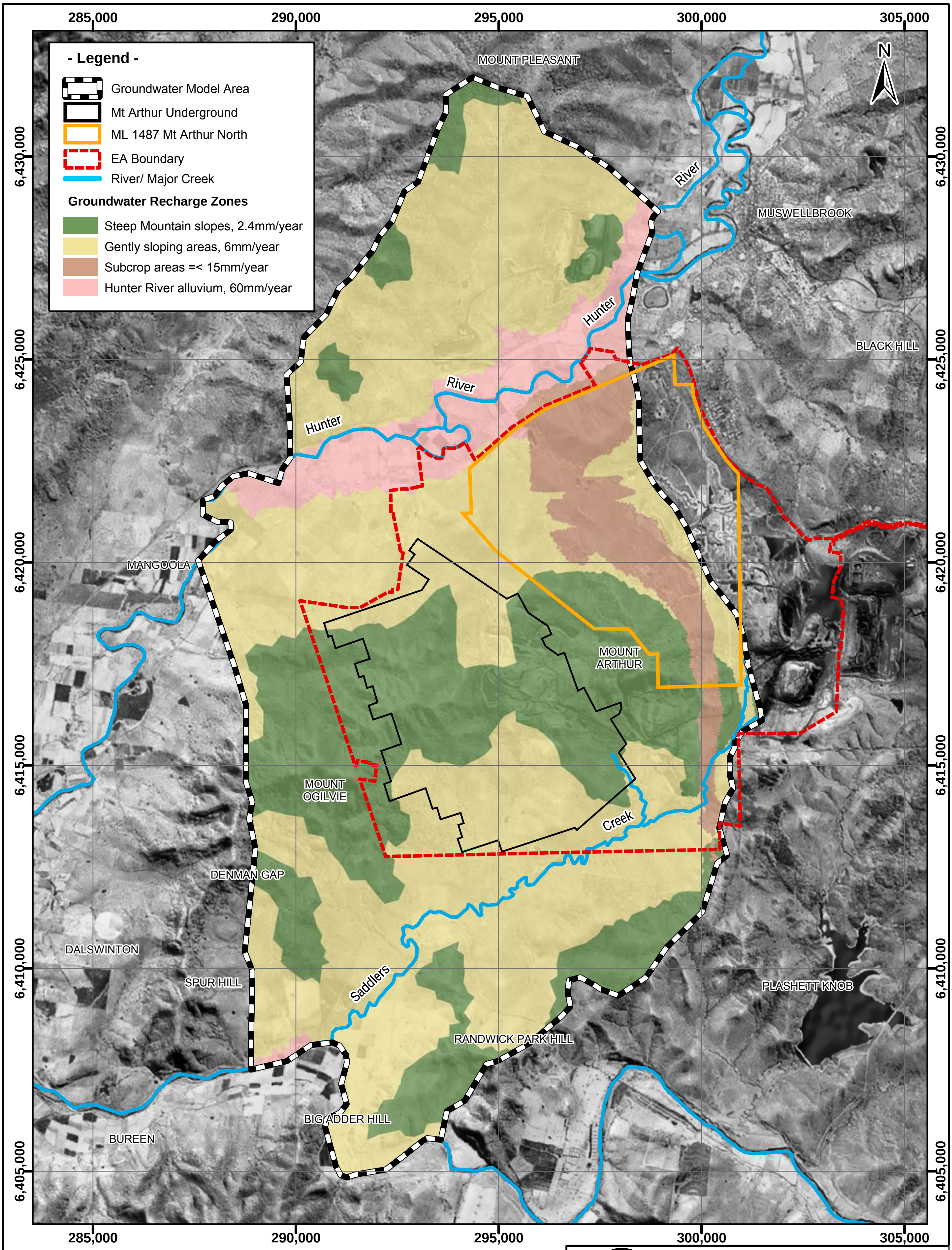
APPROVED BY:		**DATE:** April 2009	



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TITLE: MT ARTHUR COAL CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
GROUNDWATER MODEL BOUNDARIES AND RECHARGE DISTRIBUTION

CLIENT: Hansen Bailey Pty Ltd
Office: Brisbane
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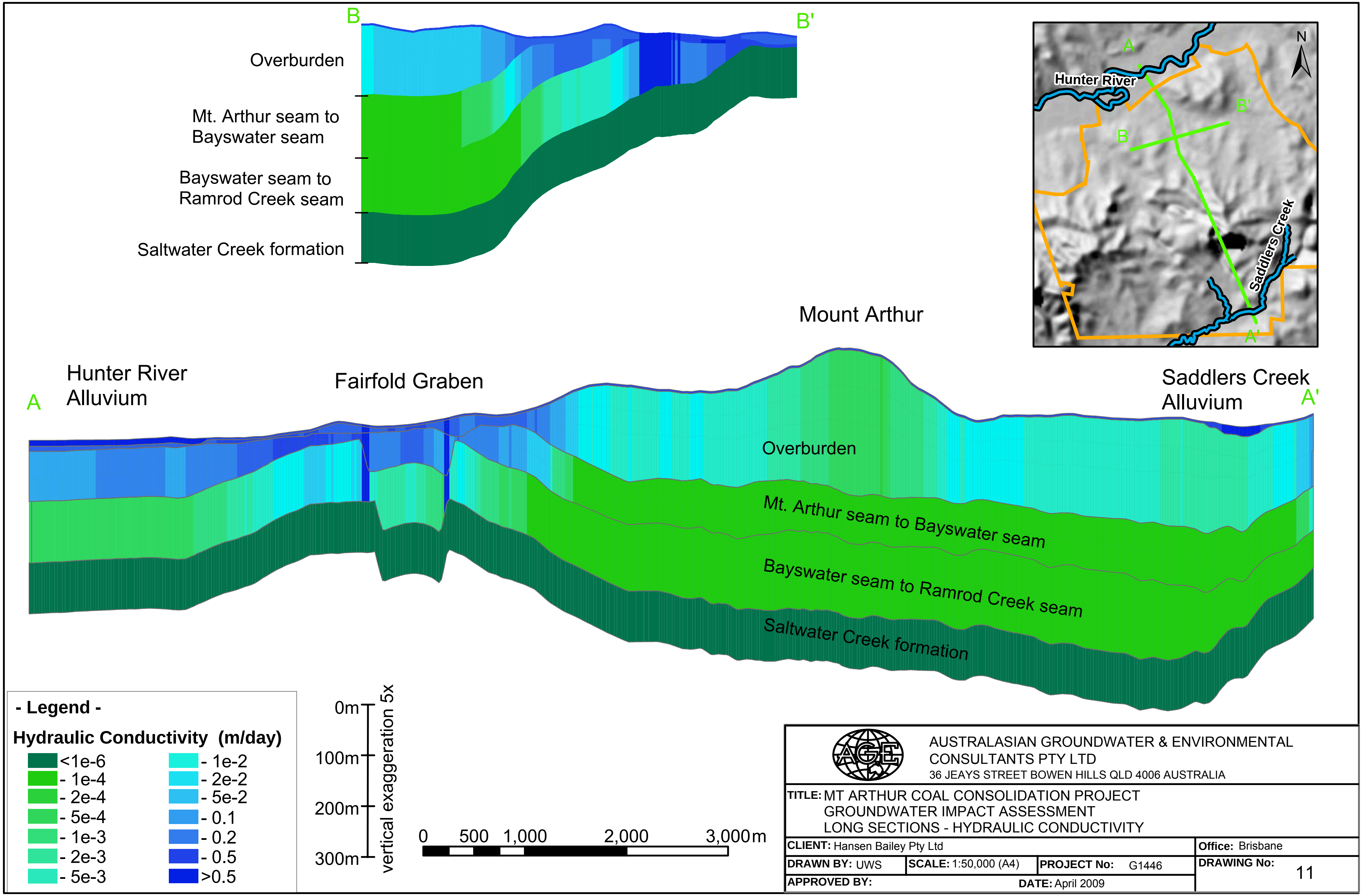
APPROVED BY:
DATE: April 2009



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TITLE: MT ARTHUR COAL CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
LONG SECTIONS - HYDRAULIC CONDUCTIVITY

CLIENT: Hansen Bailey Pty Ltd
Office: Brisbane
DRAWN BY: UWS
SCALE: 1:50,000 (A4)
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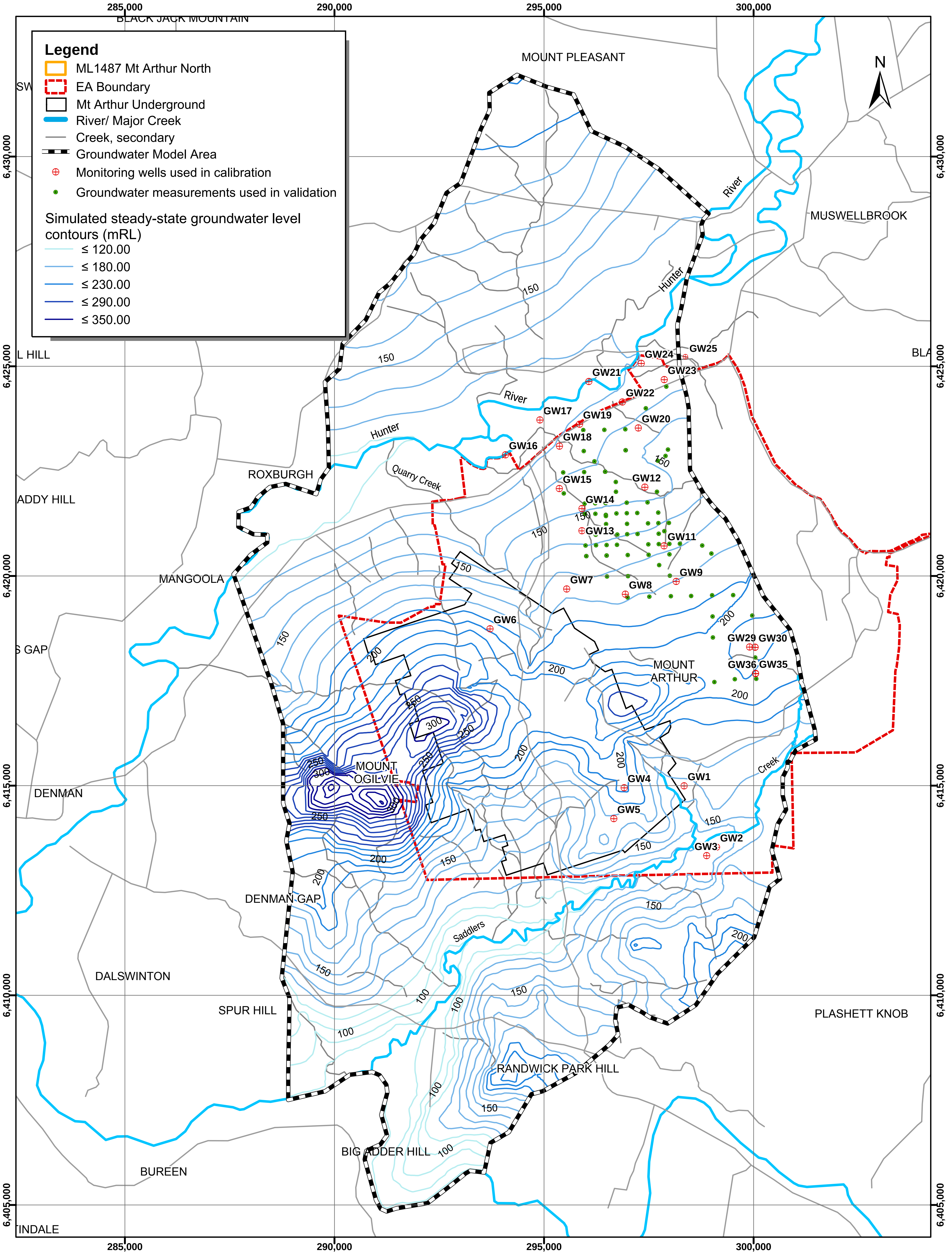
APPROVED BY:
DATE: April 2009



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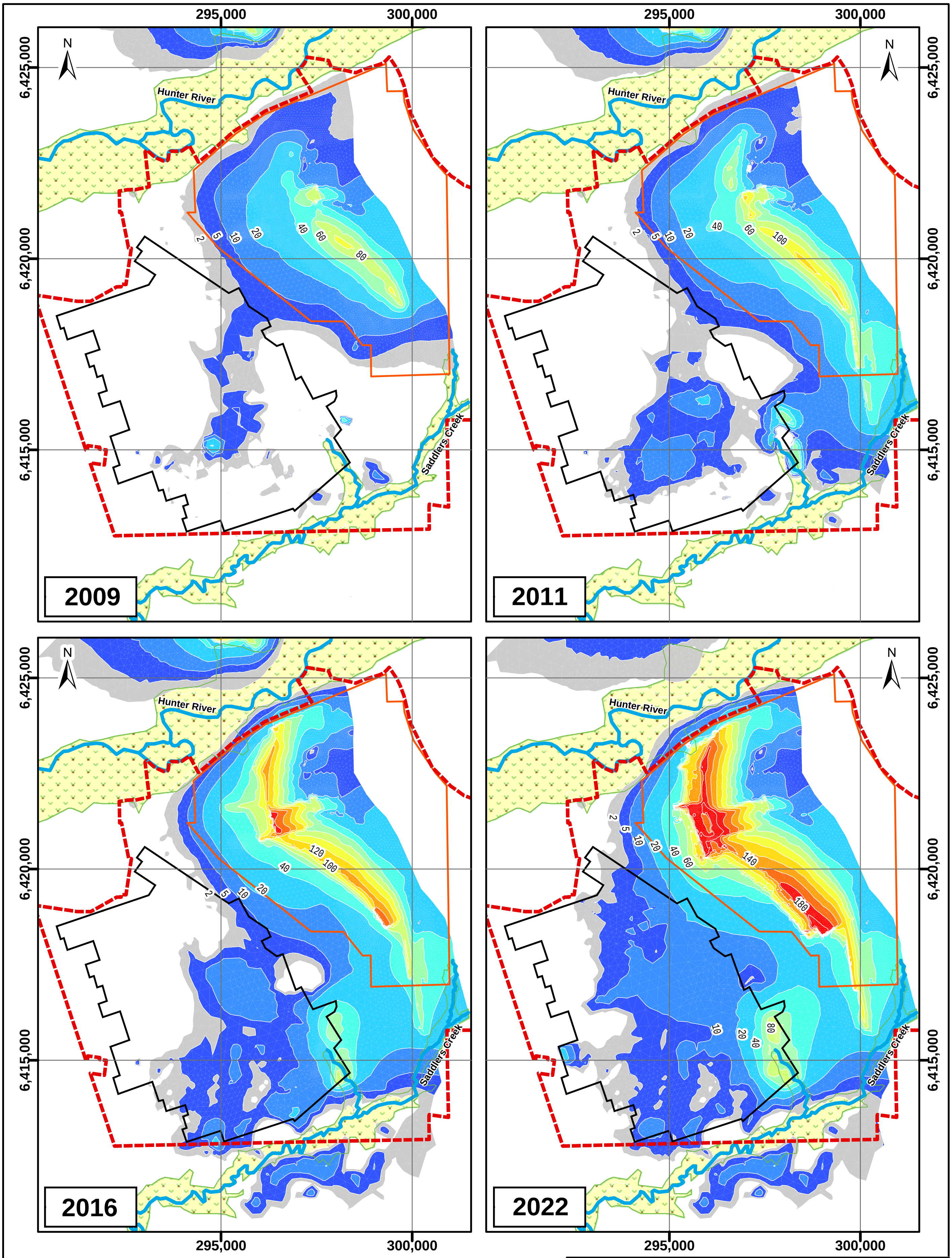
TITLE: MT ARTHUR COAL CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
CALIBRATED STEADY-STATE GROUNDWATER TABLE

CLIENT: Hansen Bailey Pty Ltd
Office: Brisbane
DRAWN BY: TMM
SCALE: 1:85,000 (A3)
PROJECT No: G1446
DRAWING No: 12
APPROVED BY:
DATE: April 2009



Groundwater Drawdown [m]

2 - 5	40 - 60	120-140
5 - 10	60 - 80	140-160
10 - 20	80 - 100	160-180
20 - 40	100-120	> 180

0 0.5 1 2 3 4 km

Isocontour Drawdown (m)
Mt Arthur Underground
EA Boundary
ML 1487 Mount Arthur

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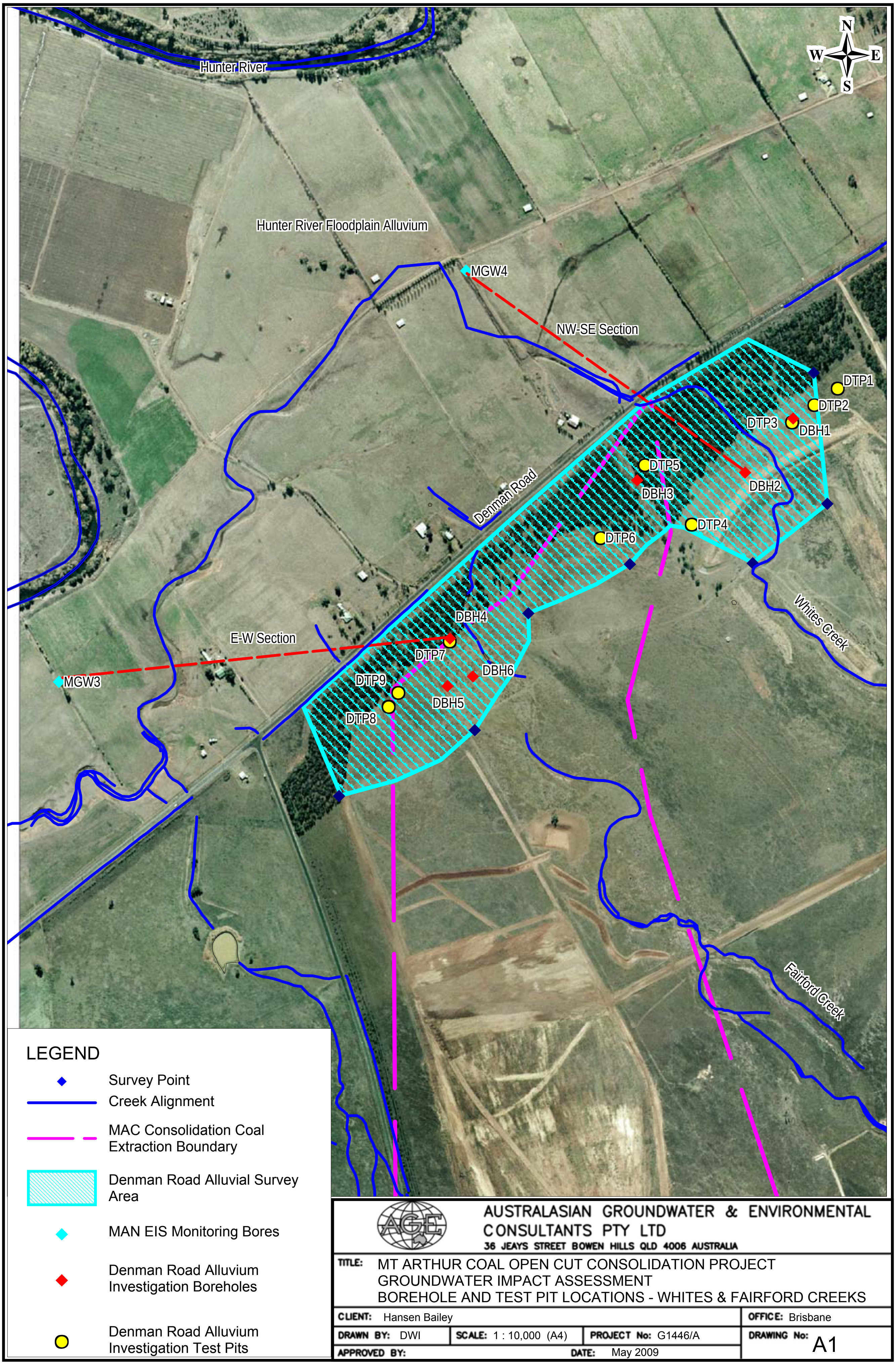
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: MT ARTHUR COAL CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
SIMULATED DRAWDOWN - 2009, 2011, 2016, 2022

CLIENT: Hansen Bailey Pty Ltd
Office: Brisbane
DRAWN BY: TMM
SCALE: 1:135,000 (A4)
PROJECT No: G1446
DRAWING No: 13
APPROVED BY:
DATE: April 2009

APPENDIX 1

Alluvial Test Pit Data



AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: MT ARTHUR COAL OPEN CUT CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
BOREHOLE AND TEST PIT LOCATIONS - WHITES & FAIRFORD CREEKS

CLIENT: Hansen Bailey
OFFICE: Brisbane
DRAWN BY: DWI
SCALE: 1 : 10,000 (A4)
PROJECT No: G1446/A
DRAWING No: A1
APPROVED BY:
DATE: May 2009

TEST PIT SOIL LOGS

Whites and Fairford Creeks Area

Test Pit Number	Depth (m)	Soils Description
DTP1	0 – 0.15	**Silty SAND**, fine to medium grained, dark brown, loose, dry to slightly moist. TOPSOIL.
	0.15 – 0.5	**Gravelly Sandy CLAY**, low to medium plasticity clay, dark brown with white mottling, rounded gravel and cobbles, dry. COLLUVIUM.
	0.5	**Sandy Gravelly CLAY**, high plasticity, red brown, dry. RESIDUAL SOIL.
	0.5	End of Test Pit
DTP2	0 – 0.25	**Silty SAND**, fine to medium grained, brown, loose, dry to slightly moist. TOPSOIL/ALLUVIUM.
	0.25 – 0.6	**Sandy CLAY**, medium plasticity, brown to red brown, dry. Base of ALLUVIUM/COLLUVIUM.
	0.6 – 1.0	**Sandy CLAY**, high plasticity, red brown, dry. RESIDUAL SOIL.
	1.0	End of Test Pit
DTP3	0 – 0.3	**Silty SAND**, fine to medium grained, brown, loose, dry to slightly moist. TOPSOIL/ALLUVIUM.
	0.3 – 1.5	**Silty CLAY**, high plasticity, dark brown, dry to slightly moist. ALLUVIUM.
	1.5 – 2.0	**Sandy CLAY**, high plasticity, yellow brown, moist. ALLUVIUM.
	2.0 – 4.0	Sandy CLAY, medium to low plasticity, yellow brown to orange brown, moist. ALLUVIUM.
	4.0	End of Test Pit
DTP4	0 – 0.25	**Silty SAND**, fine to medium grained, brown, loose, dry to slightly moist. TOPSOIL.
	0.25 – 0.7	**Sandy CLAY**, high plasticity, red brown, dry to slightly moist. RESIDUAL SOIL.
	0.7	End of Test Pit
DTP5	0 – 0.2	**Silty SAND**, fine to medium grained, light brown, loose, dry. TOPSOIL/ALLUVIUM.
	0.2 – 1.0	**Silty CLAY**, medium to high plasticity, light brown to brown, dry. ALLUVIUM.
	1.0 – 1.5	**Clayey SAND/Sandy CLAY**, medium plasticity clay/fine to medium grained sand, red brown to brown, dry, hard. ALLUVIUM.
	4.0	End of Test Pit
DTP6	0 – 0.1	**Silty SAND**, fine to medium grained, dark brown, loose, dry to slightly moist. TOPSOIL.
	0.1 – 1.3	**Gravelly Sandy CLAY**, low to medium plasticity clay, dark brown with white mottling, rounded gravel, cobbles and boulders to 150mm, dry. COLLUVIUM.
	1.5 – 1.5	**Gravelly Silty CLAY**, high plasticity, red brown, dry to slightly moist. RESIDUAL SOIL.
	1.5	End of Test Pit

Test Pit Number	Depth (m)	Soils Description
DTP7	0 – 0.2	**Silty SAND**, fine to medium grained, brown, loose, dry to slightly moist. TOPSOIL/ALLUVIUM.
	0.2 – 1.3	**Silty CLAY**, high plasticity, black, dry to slightly moist. ALLUVIUM.
	1.3 – 2.0	**Sandy CLAY**, high plasticity, dark brown, dry to slightly moist. ALLUVIUM.
	2.0	End of Test Pit
DTP8	0 – 0.2	**Silty SAND**, fine to medium grained, brown, loose, dry to slightly moist. TOPSOIL.
	0.2 – 0.5	**Sandy CLAY**, high plasticity, red brown, dry to slightly moist. RESIDUAL SOIL.
	0.5	End of Test Pit
DTP9	0 – 0.2	**Silty SAND**, fine to medium grained, brown, loose, dry to slightly moist. TOPSOIL.
	0.2 – 1.2	**Sandy CLAY**, high plasticity, red brown, dry. ALLUVIUM.
	1.2 – 1.6	**Silty CLAY**, high plasticity, red brown, dry to slightly moist. RESIDUAL SOIL.
	1.6	End of Test Pit

STP 3: Upper Alluvial Profile

STP6: Colluvial Gravelly Sandy Clay

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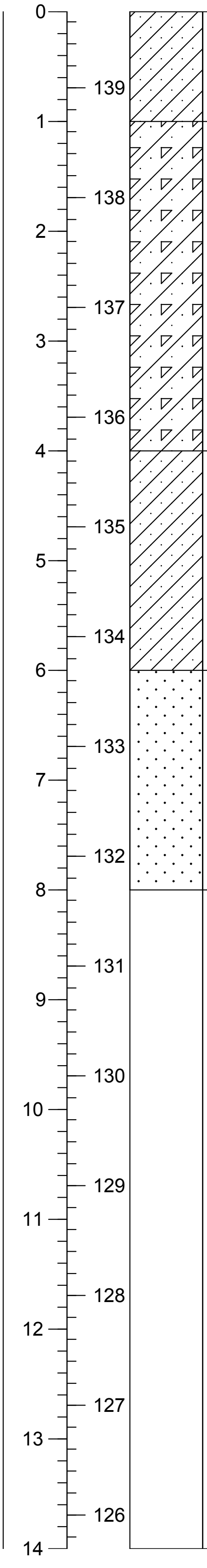
BOREHOLE LOG

BOREHOLE ID: **DBH1** Page 1 of 1

PROJECT NO.	**G1446**	DRILLER:		DATUM:	**MGA 1994**
PROJECT NAME:	**Mt Arthur**	DRILLING METHOD:	**Rotary air**	GROUND LEVEL:	**136.69mAHD**
DATE:	**20 April 2009**	DRILL RIG:	**Schramm T450WS Rotadrill**	TOP OF CASING LEVEL:	
CONTRACTOR:	**Mitchell Drilling Contractors**	COORDINATES:	**295644.933mE, 6423267.549mN**	LOGGED BY:	**DWI**

Depth / Elevation	Graphic	Lithologic Description	SWL	Bore Construction	Bore Description
		SANDY SILTY CLAY: high plasticity, brown, medium stiff, slightly moist. TOPSOIL/ALLUVIUM.	No groundwater intersected	Hole backfilled	
		SANDY GRAVELLY CLAY: high plasticity, brown to yellow/orange brown, medium to coarse rounded to sub angular gravel, stiff, slightly moist. ALLUVIUM.			
		SANDY CLAY: high plasticity, red brown, moist. RESIDUAL SOIL.			
		SANDSTONE: highly weathered, light brown, fine to medium grained, clay matrix, dry. END OF HOLE 8m No groundwater intersected			



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BOREHOLE LOG

BOREHOLE ID: **DBH2**

Page 1 of 1

PROJECT NO. **G1446**

PROJECT NAME: **Mt Arthur**

DATE: **20 April 2009**

CONTRACTOR: **Mitchell Drilling Contractors**

DRILLER:

DRILLING METHOD: **Rotary air**

DRILL RIG: **Schramm T450WS Rotadrill**

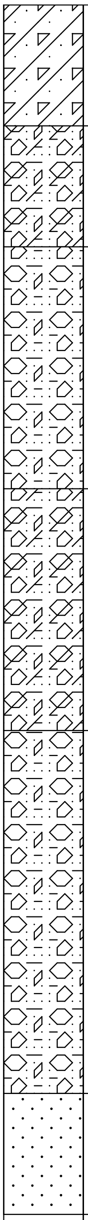
COORDINATES: **295552.700mE, 6423158.912mN**

DATUM: **MGA 1994**

GROUND LEVEL: **136.59mAHD**

TOP OF CASING LEVEL:

LOGGED BY: **DWI**



Depth	Elevation	Lithologic Description	SWL	Bore Construction	Bore Description
0	136	SANDY GRAVELLY CLAY: medium plasticity, brown, medium stiff, dry. TOPSOIL/ALLUVIUM.		Hole backfilled	
1	135	CLAYEY GRAVELLY SAND: medium to coarse grained, dark brown, medium plasticity clay, medium to coarse rounded to sub angular gravel, slightly moist. ALLUVIUM.			
2	134, 133	SANDY GRAVEL: fine to coarse rounded to sub angular gravel, yellow brown to dark brown, moist. ALLUVIUM.			
4	132, 131	SANDY CLAYEY GRAVEL: some clay, fine to medium rounded gravel, dark yellow brown to dark brown, moist. ALLUVIUM. Notable groundwater inflow intersected at 6m.			
6	130, 129, 128	SANDY GRAVEL: fine to coarse rounded gravel, brown, wet. ALLUVIUM. BASE OF ALLUVIUM	▼		
9	127	SANDSTONE: highly weathered, light grey, medium grained, clay matrix, dry. END OF HOLE 10m			
10	126				
11	125				
12	124				
13	123				
14					

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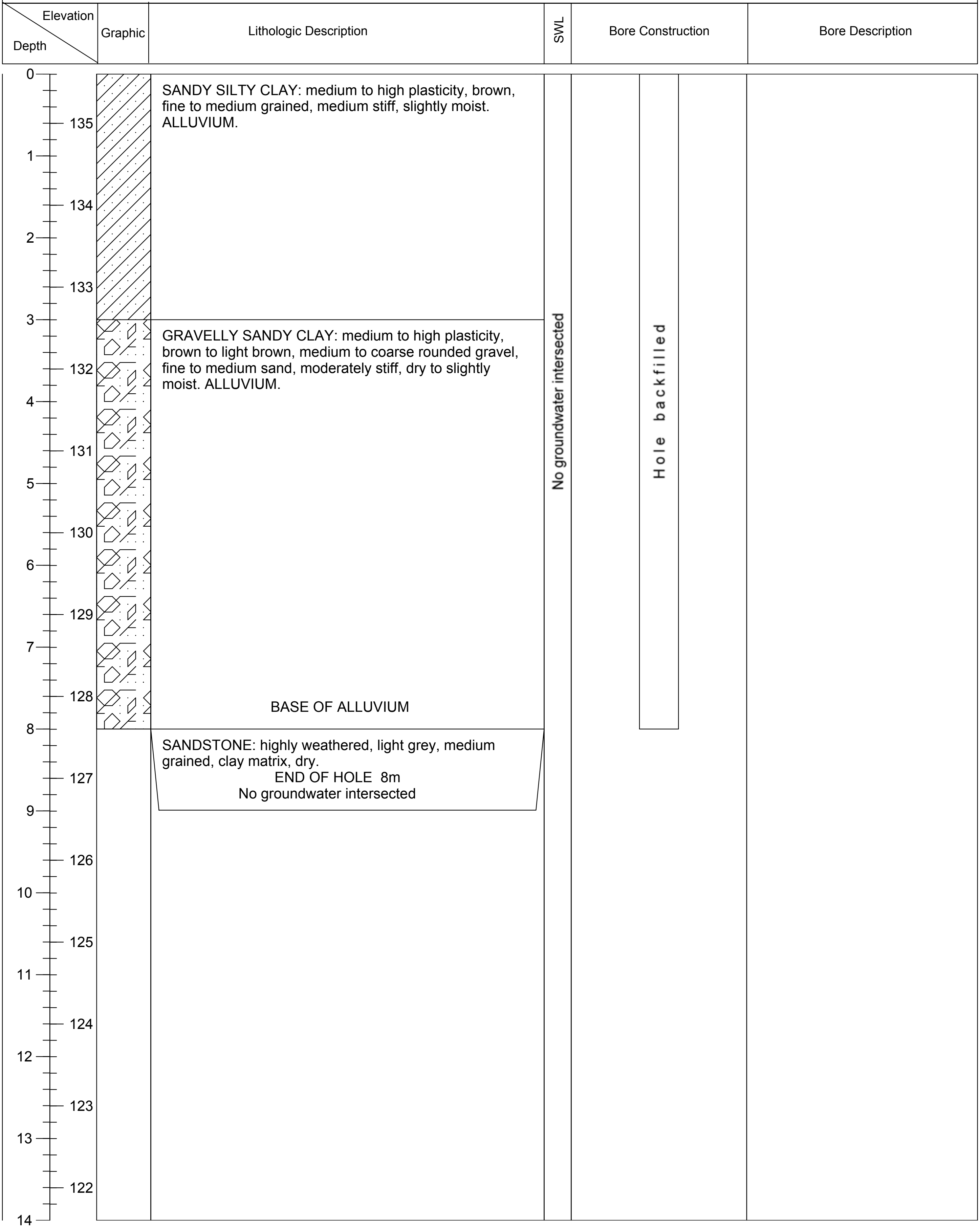
BOREHOLE LOG

BOREHOLE ID: **DBH3** Page 1 of 1

PROJECT NO.	**G1446**	DRILLER:		DATUM:	**MGA 1994**
PROJECT NAME:	**Mt Arthur**	DRILLING METHOD:	**Rotary air**	GROUND LEVEL:	**135.60mAHD**
DATE:	**20 April 2009**	DRILL RIG:	**Schramm T450WS Rotadrill**	TOP OF CASING LEVEL:	
CONTRACTOR:	**Mitchell Drilling Contractors**	COORDINATES:	**295337.909mE, 6423152.212mN**	LOGGED BY:	**DWI**



SANDY SILTY CLAY: medium to high plasticity, brown, fine to medium grained, medium stiff, slightly moist. ALLUVIUM.

GRAVELLY SANDY CLAY: medium to high plasticity, brown to light brown, medium to coarse rounded gravel, fine to medium sand, moderately stiff, dry to slightly moist. ALLUVIUM.

BASE OF ALLUVIUM

SANDSTONE: highly weathered, light grey, medium grained, clay matrix, dry.

END OF HOLE 8m

No groundwater intersected

No groundwater intersected

Hole backfilled

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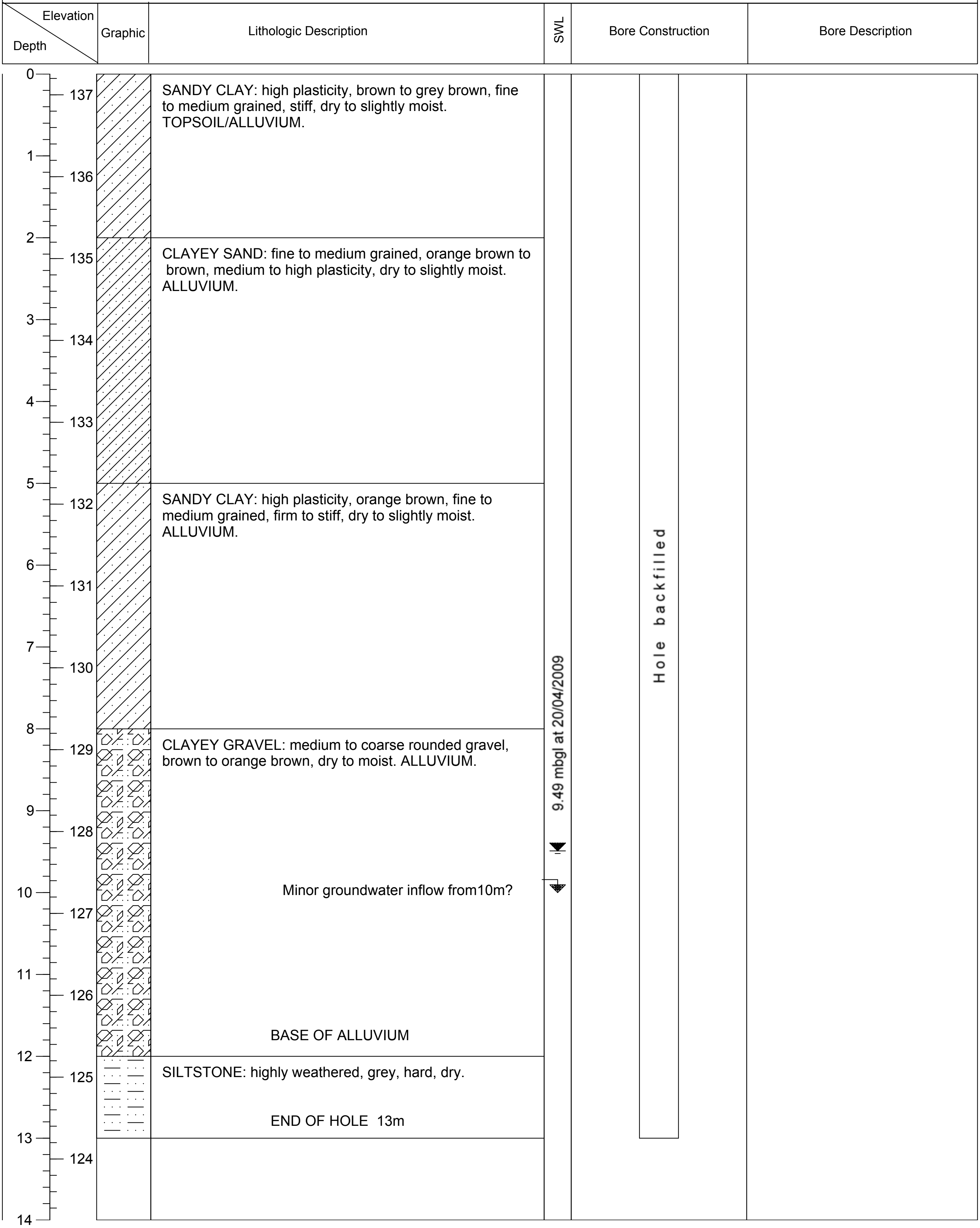
BOREHOLE LOG

BOREHOLE ID: **DBH4**

Page 1 of 1

PROJECT NO. **G1446**
PROJECT NAME: **Mt Arthur**
DATE: **20 April 2009**
CONTRACTOR: **Mitchell Drilling Contractors**
DRILLER:
DRILLING METHOD: **Rotary air**
DRILL RIG: **Schramm T450WS Rotadrill**
COORDINATES: **294965.606mE, 6422837.971mN**
DATUM: **MGA 1994**
GROUND LEVEL: **137.25mAHD**
TOP OF CASING LEVEL:
LOGGED BY: **DWI**



SANDY CLAY: high plasticity, brown to grey brown, fine to medium grained, stiff, dry to slightly moist. TOPSOIL/ALLUVIUM.

CLAYEY SAND: fine to medium grained, orange brown to brown, medium to high plasticity, dry to slightly moist. ALLUVIUM.

SANDY CLAY: high plasticity, orange brown, fine to medium grained, firm to stiff, dry to slightly moist. ALLUVIUM.

CLAYEY GRAVEL: medium to coarse rounded gravel, brown to orange brown, dry to moist. ALLUVIUM.

Minor groundwater inflow from10m?

BASE OF ALLUVIUM

SILTSTONE: highly weathered, grey, hard, dry.

END OF HOLE 13m

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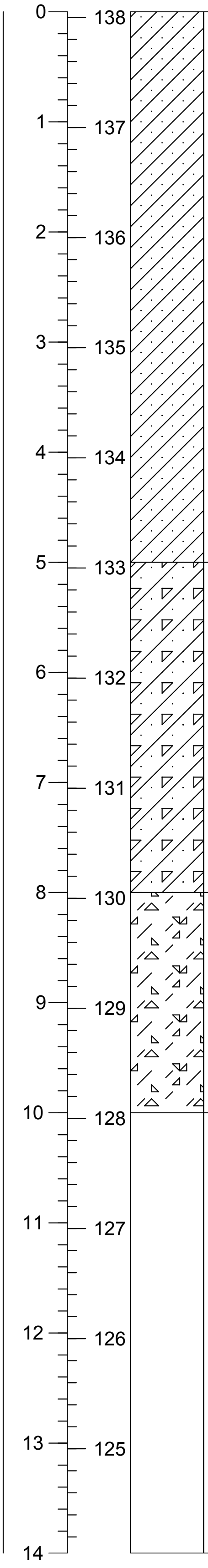
BOREHOLE LOG

BOREHOLE ID: **DBH5**

Page 1 of 1

PROJECT NO.	**G1446**	DRILLER:		DATUM:	**MGA 1994**
PROJECT NAME:	**Mt Arthur**	DRILLING METHOD:	**Rotary air**	GROUND LEVEL:	**138.05mAHD**
DATE:	**20 April 2009**	DRILL RIG:	**Schramm T450WS Rotadrill**	TOP OF CASING LEVEL:	
CONTRACTOR:	**Mitchell Drilling Contractors**	COORDINATES:	**295011.765mE, 6422762.620mN**	LOGGED BY:	**DWI**

Depth / Elevation	Graphic	Lithologic Description	SWL	Bore Construction	Bore Description



SANDY CLAY: high plasticity, orange brown, fine to medium grained, firm to stiff, slightly moist to moist. ALLUVIUM.

SANDY GRAVELLY CLAY: high plasticity, orange brown, fine to medium rounded to sub angular gravel, firm to stiff, moist.

BASE OF ALLUVIUM

GRAVELLY SANDY CLAY: medium to high plasticity, orange brown to brown, medium to coarse gravel rounded to sub-angular gravel, firm, dry to slightly moist. Weathered CONGLOMERATE?

END OF HOLE 10m
No groundwater intersected

No groundwater intersected

Hole backfilled

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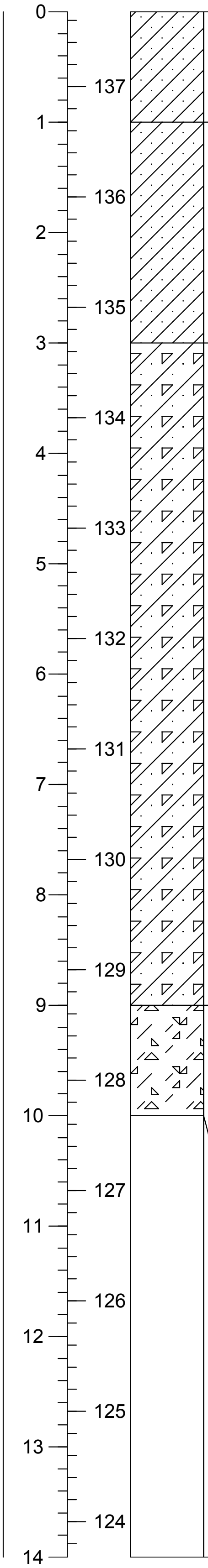
BOREHOLE LOG

BOREHOLE ID: **DBH6** Page 1 of 1

PROJECT NO.	**G1446**	DRILLER:		DATUM:	**MGA 1994**
PROJECT NAME:	**Mt Arthur**	DRILLING METHOD:	**Rotary air**	GROUND LEVEL:	**137.67mAHD**
DATE:	**20 April 2009**	DRILL RIG:	**Schramm T450WS Rotadrill**	TOP OF CASING LEVEL:	
CONTRACTOR:	**Mitchell Drilling Contractors**	COORDINATES:	**294957.957mE, 6422741.996mN**	LOGGED BY:	**DWI**

Elevation / Depth	Graphic	Lithologic Description	SWL	Bore Construction	Bore Description



SANDY CLAY: high plasticity, dark grey to black, fine to medium grained, firm to stiff, moist. TOPSOIL/ALLUVIUM.

SANDY CLAY: high plasticity, orange brown, fine to medium grained, firm to stiff, moist. ALLUVIUM.

SANDY GRAVELLY CLAY: high plasticity, orange brown, fine to medium rounded to sub angular gravel, firm to stiff, moist. ALLUVIUM.

BASE OF ALLUVIUM

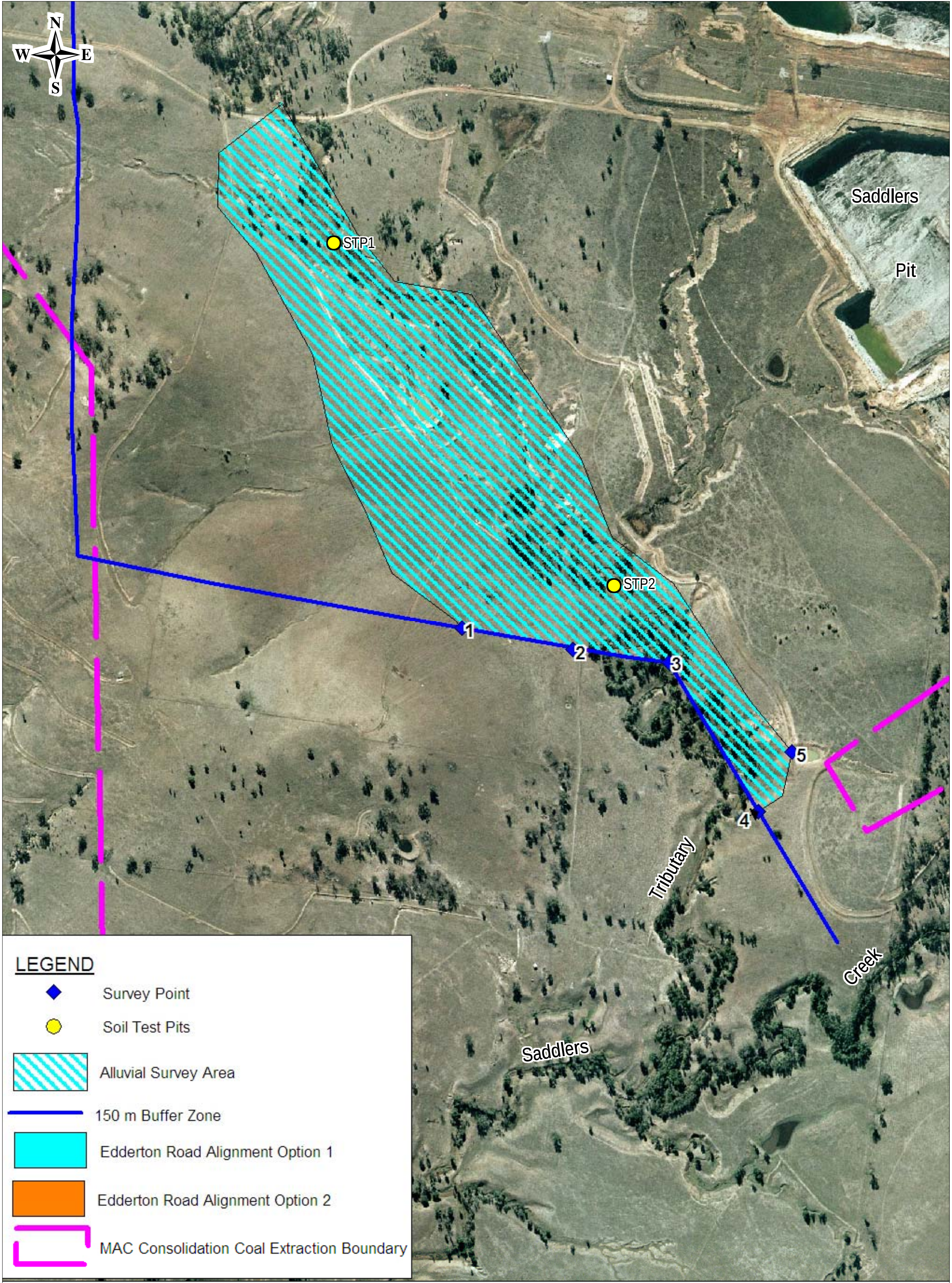
GRAVELLY SANDY CLAY: medium to high plasticity, brown to grey brown, medium to coarse gravel rounded to sub-angular gravel, firm, dry to slightly moist. Weathered CONGLOMERATE?

END OF HOLE 10m

No groundwater intersected

No groundwater intersected

Hole backfilled



AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL
CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: MT ARTHUR COAL OPEN CUT CONSOLIDATION PROJECT
GROUNDWATER IMPACT ASSESSMENT
TEST PIT LOCATIONS - SADDLERS CREEK ALLUVIAL AREA

CLIENT: Hansen Bailey Pty Ltd
OFFICE: Brisbane
DRAWN BY: TMM
SCALE: 1 : 10,000 (A4)
PROJECT No: G1446A
DRAWING No: A2
APPROVED BY:
DATE: April 2009

TEST PIT SOIL LOGS

Saddlers Creek Tributary

General view of tributary creek alluvial area with Mount Arthur in the background

Test Pit Number	Depth (m)	Soils Description
STP1	0 – 0.3	**Silty SAND**, fine to medium grained, brown, loose, dry to slightly moist. TOPSOIL/ALLUVIUM.
	0.3 – 1.8	**Clayey Gravelly SAND**, medium to coarse grained, grey brown to brown, medium plasticity clay, fine gravel, moist to wet. Groundwater inflow at 1.5m. ALLUVIUM.
	1.8	End of Test Pit
STP2	0 – 2.5	**Clayey SAND**, fine to medium grained, brown, low to medium plasticity clay, loose, moist. ALLUVIUM.
	2.5	End of Test Pit

STP1: Showing Groundwater Seepage

STP2: Dry Clayey Sand to 2.5m

APPENDIX 2

Summary of DWE Registered Bores

SUMMARY OF DEPARTMENT OF WATER AND ENERGY REGISTERED/LICENSED BORES

Registration No.	License No.	Drilled	mE	mN	Depth (m)	SWL (m)	Yield (L/s)	Salinity (ppm)	Aquifer	Potential Impact of Project	Use/ Comments
GW011295	20BL004472	08/55	290420	6424960	29.0	6.90	0.43	-	Coal seam	no impact	stock
GW018298	20BL010355	01/60	294290	6423320	9.1	7.90	-	-	Alluvium	no impact	irrigation/stock
GW019116	20BL011210	12/51	295350	6424830	11.90	-	-	good	Alluvium	no impact	irrigation/stock
GW024700	-	-	295480	6423080	-	-	-	-	Alluvium	may dry up	hand dug well
GW027311	20BL019829	11/67	291951	6422598	11.60	9.40	1.52	-	Alluvium	no impact	irrigation
GW029646	20BL023938	01/14	292725	6414700	9.10	-	-	-	Alluvium/ Overburden	may dry up	stock
GW029647	20BL023417	01/14	290910	6413720	36.60	-	-	-	Glen Munro Seam	may dry up	stock/domestic
GW029648	20BL023418	01/12	290775	6413680	31.10	-	-	-	Glen Munro Seam	may dry up	stock/domestic
GW029660	20BL023412	01/38	290095	6412890	74.70	39.60	0.51	-	Glen Munro Seam	may dry up	stock
GW029661	20BL023406	01/14	292955	6414510	42.70	-	-	-	Glen Munro Seam	may dry up	stock
GW030745	-	06/79	295940	6422650	220.0	-	-	-	N/A	removed by open pits	coal exploration
GW031622	20BL024276	10/69	294345	6415755	91.40	28.7	0.38	-	Woodlands Hill Seam	may dry up	stock
GW031623	20BL023652	06/69	294015	6417270	38.10	18.30	2.27	-	Blakefield Seam	may dry up	stock
GW031859	20BL024674	10/69	294540	6415275	61.0	22.9	0.68	-	Glen Munro Seam	may dry up	stock
GW032077	20BL024716	11/69	294150	6416595	53.30	28.7	1.52	-	Blakefield Seam	may dry up	stock
GW032517	20BL024338	01/69	294275	6418450	33.50	-	-	-	Blakefield Seam	may dry up	stock
GW033193	20BL026154	04/71	293590	6416845	46.90	12.80	0.88	-	Blakefield Seam	may dry up	stock
GW033547	20BL026898	02/72	296070	6415280	12.0	4.30	-	-	Overburden	may dry up	stock
GW033915	20BL024261	06/71	294080	6419320	39.60	21.0	0.32	-	Glen Munro Seam	may dry up	stock
GW038607	20BL029567	09/73	290110	6420720	13.40	11.5	0.38	-	Alluvium	no impact	stock
GW045469	20BL103870	05/76	295440	6420350	49.10	33.10	0.25	-	Bowfield Seam	removed by open pits	stock
GW049223	20BL106334	01/79	298015	6413480	67.10	-	0.63	-	Glen Munro Seam	water level decline	stock
GW053299	20BL136255	06/81	291030	6422920	10.10	2.5	-	3000	Alluvium	no impact	stock/domestic
GW053572	20BL118120	01/81	291830	6422580	10.50	8.0	-	1000	Alluvium	no impact	domestic/irrigation

SUMMARY OF DEPARTMENT OF WATER AND ENERGY REGISTERED/LICENSED BORES											
Registration No.	**License No.**	**Drilled**	**mE**	**mN**	**Depth (m)**	**SWL (m)**	**Yield (L/s)**	**Salinity (ppm)**	**Aquifer**	**Potential Impact of Project**	**Use/ Comments**
GW053700	20BL120419	08/81	291362	6423062	8.0	6.0	-	-	Alluvium	no impact	domestic/stock
GW053701	20BL137142	01/81	291375	6423015	8.40	-	-	3000	Alluvium	no impact	domestic/stock
GW057807	20BL124108	09/81	294787	6424262	10.00	7.0	15.2	-	Alluvium	no impact	domestic/irrigation
GW059131	20BL119201	01/81	294850	6424750	11.60	-	-	3000	Alluvium	no impact	domestic/irrigation
GW073576	20BL166372	08/95	291491	6424485	20.0	-	-	-	Coal seam	no impact	domestic/stock
GW078707	20BL167441	-	289383	6413347	43.0	-	13.0	-	Blakefield Seam	no impact	stock
GW078708	20BL167442	-	290723	6413036	43.0	-	-	-	Blakefield Seam	no impact	stock
GW078709	20BL167443	-	290583	6412201	50.0	-	-	-	Glen Munro Seam	may dry up	stock

Note: i) the aquifer has been nominated by the author of this report based on:

- the location of the bore,
- the bore depth, and
- the isopachs of the overburden for each coal seam (Drawing Nos. 4 to 12)

ii) 🟧 registered bores located on land owned by Mt Arthur Coal

APPENDIX 3

Validation Results

MODEL VALIDATION RESULTS

SITE ID	Location		End Depth (m)	Water Level (mRL)		Difference Observed-Simulated (m)
	(mE)	(mN)		Observed	Simulated	
ID1024	296997	6420498	28.34	174.39	167.48	6.91
ID1017	299021	6419032	32.31	178.01	194.26	-16.25
ID1023	298026	6419516	-1.8	182.32	182.87	-0.55
ID1025	297495	6420504	49.05	178.08	169.11	8.97
ID1028	298003	6420008	32.32	178.75	177.98	0.77
ID1011	296502	6419986	-62.13	177.53	171.02	6.51
ID1014A	296993	6419486	-33.54	185.9	179.15	6.75
ID1032	297005	6419997	2.91	182.91	172.61	10.30
ID1026	297715	6422748	151.57	167.86	151.20	16.66
ID1027	297898	6422863	159.36	166.75	152.69	14.06
ID1029	297919	6424515	126.84	139.25	136.24	3.01
ID1030	295938	6423477	-47.39	137.53	134.06	3.47
ID1035	295472	6421967	-136.35	139.65	143.32	-3.67
ID1031	296975	6421495	30.64	166.63	152.51	14.12
ID1037	299010	6419539	73.72	174.6	189.16	-14.56
ID1033	295957	6422477	-38.02	139.73	140.29	-0.56
ID1038	300040	6418053	148.06	219.31	210.98	8.33
ID1039	298994	6420533	160.13	167.27	178.61	-11.34
ID1041	299512	6419542	126.41	167.05	192.35	-25.30
ID1043	297871	6421069	105.65	167.54	163.09	4.45
ID1046	300065	6417546	135.64	221.17	208.87	12.30
ID1048	297696	6422008	116.25	151.56	148.09	3.47
ID1051A	298774	6420726	145.92	177.7	174.00	3.70
ID1040	296494	6420486	-28.13	174.87	165.63	9.24
ID1044	297994	6420514	70.29	175.08	171.36	3.72
ID1054	295948	6422977	-53.9	139	137.18	1.82
ID1056	296948	6422997	96.32	145.46	143.41	2.05
ID1058	296985	6420996	55.99	164.9	159.71	5.19
ID1042	299610	6418518	66.75	223.91	210.78	13.13
ID1052	297513	6419505	-10.67	184.51	182.12	2.39
ID1053	299552	6417539	11.48	224.5	208.66	15.84
ID1055	299065	6417471	-54.89	230.84	208.56	22.28
ID1040A	296494	6420486	127.86	175.02	165.63	9.39
ID1057	296457	6422485	27.2	143.11	141.75	1.36
ID1064	295457	6422468	-112.03	141.75	138.76	2.99
ID1056A	296945	6422997	134.84	143.31	143.28	0.03
ID1057A	296459	6422484	124.85	140.58	141.51	-0.93
ID1060	299030	6418534	-3.63	213.83	208.16	5.67
ID1065	298511	6419522	24.63	180.3	185.49	-5.19
ID1066	296939	6423496	75.68	153.52	140.63	12.89
ID1067	296439	6423484	9.78	178.63	137.68	40.95
ID1068	296007	6420473	-159.49	170.9	163.67	7.23
ID1069A	295976	6421475	30.78	156.56	151.09	5.47
ID1068A	296011	6420472	-48.71	167.27	163.70	3.57

MODEL VALIDATION RESULTS						
SITE ID	**Location**		**End Depth (m)**	**Water Level (mRL)**		**Difference Observed-Simulated (m)**
	(mE)	**(mN)**		**Observed**	**Simulated**	
ID1070	297957	6423011	163.24	169.29	153.86	15.43
ID1071	299967	6419054	182.73	200.83	209.71	-8.88
IR2001	296480	6421236	-19.26	160.44	156.19	4.25
IR2002	296476	6421456	-32.65	161.55	153.52	8.03
IR2003	296477	6421427	-26.57	160.53	153.94	6.59
ID1072	297428	6423996	86.02	139	139.09	-0.09
IR2005	296226	6421482	-54.59	156.46	152.12	4.34
IR2006	297226	6421500	64.07	158.67	153.20	5.47
IR2008	297471	6421755	52.45	158.5	150.66	7.84
IR2007	297726	6421510	94.47	166.42	155.15	11.27
IR2009	296235	6420981	-67.97	157.53	157.43	0.10
ID1073	297739	6420759	76.59	171.72	166.16	5.56
ID1074	297729	6421260	113.4	166.61	159.46	7.15
ID1075	298242	6420768	105.98	166.96	169.15	-2.19
IR2004	295972	6421727	-42.83	152.72	148.65	4.07
ID1069	295976	6421477	-87.23	156.48	151.06	5.42
ID1102	296242	6420731	-47.24	171.76	160.72	11.04
IR2019	295991	6420727	-132.24	166.86	160.04	6.82
ID1101	296221	6421732	2.13	142.91	149.08	-6.17
IR2010	296469	6421737	44.18	141.56	149.60	-8.04
IR2012	296727	6421489	-10.2	161.45	153.38	8.07
IR2013	296981	6421244	34.96	163.53	157.62	5.91
ID1096	297747	6420260	41.24	178.32	173.93	4.39
IR2018	296493	6420736	2.16	170.81	161.87	8.94
ID1103	296741	6420741	32.95	173.68	162.50	11.18
IR2011	296974	6421747	78.93	158.82	150.11	8.71
IR2014	297481	6421254	91.43	165.91	158.71	7.20
IR2015	297736	6421007	88.79	167.44	163.00	4.44
IR2016	297233	6421002	59.08	168.03	160.59	7.44
IR2017	296717	6422007	68.05	142.9	146.66	-3.76
IR2021	297990	6420764	89.3	168.7	167.70	1.00
IR2023	297980	6421264	126.21	162.51	161.44	1.07
IR2024	297489	6420756	62.85	168.95	165.20	3.75
IR2025	296748	6420987	-19.67	161.48	159.22	2.26
ID1107	296712	6422242	73.99	144.22	144.60	-0.38
ID1111	296203	6422732	-17.68	139.75	139.70	0.05