

Appendix I

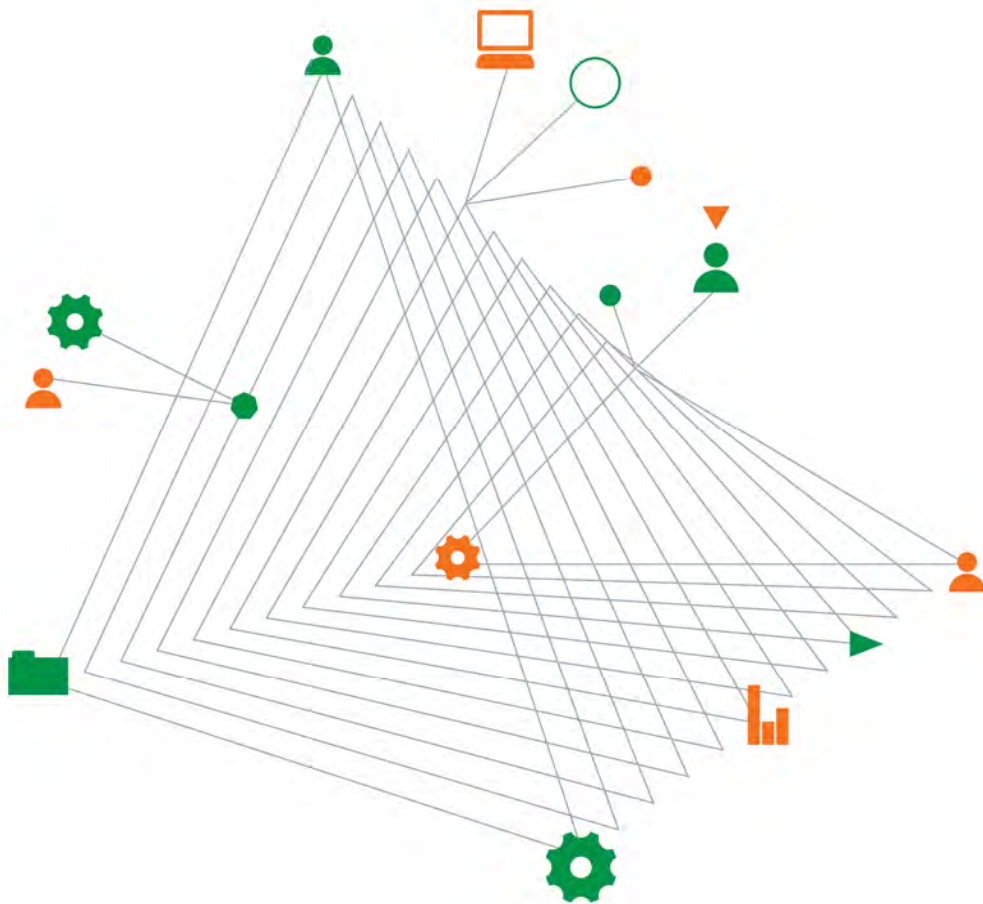
Groundwater Assessment, Volume Two Numerical Modelling and Impact Assessment

Hume Coal Pty Limited

Hume Coal Project

Groundwater Assessment Volume 2: Numerical Modelling and Impact Assessment

17 November 2016



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Hume Coal Project

Prepared for
Hume Coal Pty Limited

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Executive Summary

A regional numerical groundwater flow model was developed for the Hume Coal Project. Model calibration was successful in reproducing shallow groundwater discharges (stream baseflow), deep groundwater discharges (discharge to the Berrima mine void), and hydraulic heads, and has adhered strongly to the observed hydraulic conductivity distribution.

The combination of observations from the pumping tests undertaken by Hume, with shallow and deep discharge observations, allows the calibrated Kv distribution to be applicable to an appropriate scale and is considered to have a high level of reliability, including reliable representation of the effects of the high density of open bores present in the area, and the tectonic activity that has occurred in the area.

This has reduced the uncertainty in model outputs. The model is considered to be acceptably calibrated and fit for its purpose in simulating the groundwater system with application of the magnitude of the stress defined by the Hume mine schedule.

The model was subsequently used in a predictive capacity to assess impacts from Hume mining operations using the Pine Feather layout and method. Model predictive simulation results are as follows:

- The total volume of groundwater inflow that reports to the sump is calculated as 8.4 GL during the time the effects of mining are active in the groundwater system. The maximum inflow rate to the sump is 2.7 ML/day (1000 ML/year) in year 17 of mining.
- The total volume of groundwater inflow that reports to the void is 24.3 GL during the time the effects of mining are active in the groundwater system. The maximum inflow rate to the void is 5.1 ML/day (1860 ML/year) in year 15 of mining.
- The drawdown footprint achieves a maximum size at about 17 years since the start of mining. The zone of highest drawdown in the footprint migrates according to worked areas. At 17 years, the 2 m differential drawdown* contour at the water table extends a maximum of about 2 km past the southeast corner of the mine footprint. The duration of differential drawdown of the water table varies between about 15 years and 60 years. Recovery of the water table over most of the area, to 2 m differential drawdown, is largely complete within about 60 years after the start of Hume mining.
- Maximum total drawdown of the water table greater than 2 m occurs at several locations where there are shallow water levels. These areas have been provided to the ecology team to consider potential impacts to ecosystems that may be present at these locations.
- No direct leakage from the Wingecarribee River, induced by Hume operations, is calculated by the model. Model results indicate that 98% of the total inflow to the Hume mine workings is satisfied by interception of baseflow to streams, and release of groundwater storage from media. 2% of the inflow is satisfied by leakage from Medway Reservoir (a total leakage of approximately 804 ML over 22 years, or an overall average over the period of approximately 0.1 ML/day). Baseflow interception induced by Hume operations is largest for Medway Rivulet. Baseflow analysis of flow observations from Medway Rivulet suggests the average baseflow measured at these gauges (over the monitoring period) is about 3 times larger than the calculated future maximum baseflow interception.
- Of the 117 private bores identified as residing in the potential drawdown zone, 99 bores are assessed as being subject to a differential drawdown of 2 m or more. The overall average proportion of the maximum total drawdown that is caused by Hume operations is 87%. Groundwater extraction by private users accounts for the remaining 13%. The duration of the period for each bore where differential drawdown is greater than 2 m ranges between 2 months and 65 years, with an average of 34 years. The majority of these bores have recovered back to 2

m differential drawdown by 60 years since the start of mining. Five of these bores are likely to be intersected by mining because they penetrate the mined zone.

* Differential drawdown is calculated as the difference between drawdowns from the active Hume mining scenario (which gives the total drawdown) and a null scenario where the Hume operation is inactive (giving a null case drawdown). The differential drawdown is thus that drawdown due only to the Hume operation.

1. Introduction

This is the second of two volumes that present the results of a groundwater assessment for the Hume Coal Project. The assessment was undertaken by Coffey Geotechnics Pty Ltd (Coffey) for Hume Coal Pty Limited (Hume). The purpose of the assessment was to assess impacts on the groundwater system and groundwater users due to the proposed mining. Results of the assessment will be used to support an application for development consent.

Approval for the Hume Coal Project is being sought under Part 4, Division 4.1 of the NSW Environmental Planning and Assessment Act 1979 (EP&A Act) and the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). An environmental impact statement (EIS) is a requirement of the approval processes. This groundwater assessment forms part of the EIS. It documents the groundwater assessment methods and results, and outlines initiatives built into the project design to avoid and minimise impacts on the groundwater system.

The assessment comprised compilation and analysis of a groundwater database, development of a hydrogeological conceptual model, and development of a groundwater flow numerical model to simulate drawdown on the groundwater system and on private water bores from mining. This volume presents numerical model development, calibration, and predictive simulations and results.

An analysis of a substantial database of observations compiled from data provided by Hume and published sources, was undertaken to support development of the hydrogeological conceptual model and subsequent numerical model development and calibration. That analysis is reported in Volume 1. This volume should be read in conjunction with Volume 1.

1.1. Background

Hume proposes to develop and operate an underground coal mine and associated mine infrastructure (the 'Hume Coal Project') in the Southern Coalfield of NSW. Hume is a wholly owned subsidiary of POSCO Australia. Hume holds exploration Authorisation 349 (A349), which covers an area of 89 km² to the west of Moss Vale, in the Wingecarribee local government area (LGA). A349 adjoins the southern boundary of the Berrima Colliery lease (CCL748). The underground mine will be developed within A349 and associated surface infrastructure facilities will be developed within and north of A349. The project area and its regional setting are shown in Drawing 1. Drawing 1 shows the interrelationship between A349, the mining lease application area, the proposed workings, and the model domain boundary; the latter two features are further discussed in this report and the numerical simulation report.

The project has been developed following several years of technical investigations to identify and address potential environmental, social and economic constraints. This has allowed for the development of a well-considered, practical and economic project design that will enable effective resource recovery, while minimising adverse impacts to the environment and community.

Hume proposes to use a non-caving first workings mining layout and method, which is a low impact method having negligible subsidence effects, and offering a significant amount of protection to overlying hydrostratigraphic media and surface features. The mining target is the Wongawilli Coal Seam of the Permian Illawarra Coal Measures.

1.1.1. Project description

The project involves developing and operating an underground coal mine and associated infrastructure over a total estimated project life of 23 years. A full description of the project, as assessed in this report, is provided in Chapter 2 of the main EIS (EMM 2016). In summary, the project involves:

- Ongoing resource definition activities, along with geotechnical and engineering testing, and other low impact fieldwork to facilitate detailed design.
- Establishment of a temporary construction accommodation village.
- Development and operation of an underground coal mine, consisting of approximately two years of construction and 19 years of mining, followed by a closure and rehabilitation phase of up to two years, leading to a total project life of 23 years. Some coal extraction will commence during the second year of construction during installation of the drifts, and hence there will be some overlap between the construction and operational phases.
- Extraction of approximately 50 million tonnes (Mt) of run-of-mine (ROM) coal from the Wongawilli Seam, at a rate of up to 3.5 million tonnes per annum (Mtpa). Low impact mining methods will be used, which will have negligible subsidence impacts.
- Following processing of ROM coal in the coal preparation plant (CPP), production of up to 3 Mtpa of metallurgical and thermal coal for sale to international and domestic markets.
- Construction and operation of associated mine infrastructure, mostly on cleared land, including:
 - One personnel and materials drift access and one conveyor drift access from the surface to the coal seam.
 - Ventilation shafts, comprising one upcast ventilation shaft and fans, and up to two downcast shafts installed over the life of the mine, depending on ventilation requirements as the mine progresses.
 - A surface infrastructure area, including administration, bathhouse, washdown and workshop facilities, fuel and lubrication storage, warehouses, laydown areas, and other facilities. The surface infrastructure area will also comprise the CPP and ROM coal, product coal and emergency reject stockpiles.
 - Surface and groundwater management and treatment facilities, including storages, pipelines, pumps and associated infrastructure.
 - Overland conveyors.
 - Rail load-out facilities.
 - Explosives magazine.
 - Ancillary facilities, including fences, access roads, car parking areas, helipad and communications infrastructure.
 - Environmental management and monitoring equipment.
- Establishment of site access from Mereworth Road, and minor internal road modifications and relocation of some existing utilities.
- Coal reject emplacement underground, in the mined-out voids.
- Peak workforces of approximately 414 full-time equivalent employees during construction and approximately 300 full-time equivalent employees during operations.
- Decommissioning of mine infrastructure and rehabilitation of the area once mining is complete, so that it can support land uses similar to current land uses.

The project area, shown in Figure 1.1, is approximately 5,051 hectares (ha). Surface disturbance will mainly be restricted to the surface infrastructure areas shown in Figure 1.2, though will include some other areas above the underground mine, such as drill pads and access tracks. The project area generally comprises direct surface disturbance areas of up to approximately 117 ha, and an underground mining area of approximately 3,472 ha, where negligible subsidence impacts are anticipated.

A construction buffer zone will be provided around the direct disturbance areas. The buffer zone will provide an area for construction vehicle and equipment movements, minor stockpiling and equipment laydown, as well as allowing for minor realignments of surface infrastructure. Ground disturbance will generally be minor and associated with temporary vehicle tracks and sediment controls as well as minor works such as backfilled trenches associated with realignment of existing services. Notwithstanding, environmental features identified in the relevant technical assessments will be marked as avoidance zones so that activities in this area do not have an environmental impact.

Product coal will be transported by rail, primarily to Port Kembla terminal for the international market, and possibly to the domestic market depending on market demand. Rail works and use are the subject of a separate EIS and State significant development application for the Berrima Rail Project.

General site description

The project area is approximately 100 km southwest of Sydney and 4.5 km west of Moss Vale town centre in the Wingecarribee LGA (refer to Drawing 1 and Figure 1.1). The nearest area of surface disturbance will be associated with the surface infrastructure area, which will be 7.2 km northwest of Moss Vale town centre. It is in the Southern Highlands region of NSW and the Sydney Basin Biogeographic Region.

The project area is in a semi-rural setting, with the wider region characterised by grazing properties, small-scale farm businesses, natural areas, forestry, scattered rural residences, villages and towns, industrial activities such as the Berrima Cement Works and Berrima Feed Mill, and some extractive industry and major transport infrastructure such as the Hume Highway.

Surface infrastructure is proposed to be developed on predominately cleared land owned by Hume Coal or affiliated entities, or for which there are appropriate access agreements in place with the landowner. Over half of the remainder of the project area (principally land above the underground mining area) comprises cleared land that is, and will continue to be, used for livestock grazing and small-scale farm businesses. Belanglo State Forest covers the northwestern portion of the project area and contains introduced pine forest plantations, areas of native vegetation and several creeks that flow through deep sandstone gorges. Native vegetation within the project area is largely restricted to parts of Belanglo State Forest and riparian corridors along some watercourses.

The project area is traversed by several drainage lines including Oldbury Creek, Medway Rivulet, Wells Creek, Wells Creek Tributary, Belanglo Creek and Longacre Creek, all of which ultimately discharge to the Wingecarribee River, at least 5 km downstream of the project area (Figure 1.1). The Wingecarribee River's catchment forms part of the broader Warragamba Dam and Hawkesbury-Nepean catchments. Medway Dam is also adjacent to the northern portion of the project area (Figure 1.1).

Most of the central and eastern parts of the project area have very low rolling hills with occasional elevated ridge lines. However, there are steeper slopes and deep gorges in the west in Belanglo State Forest.

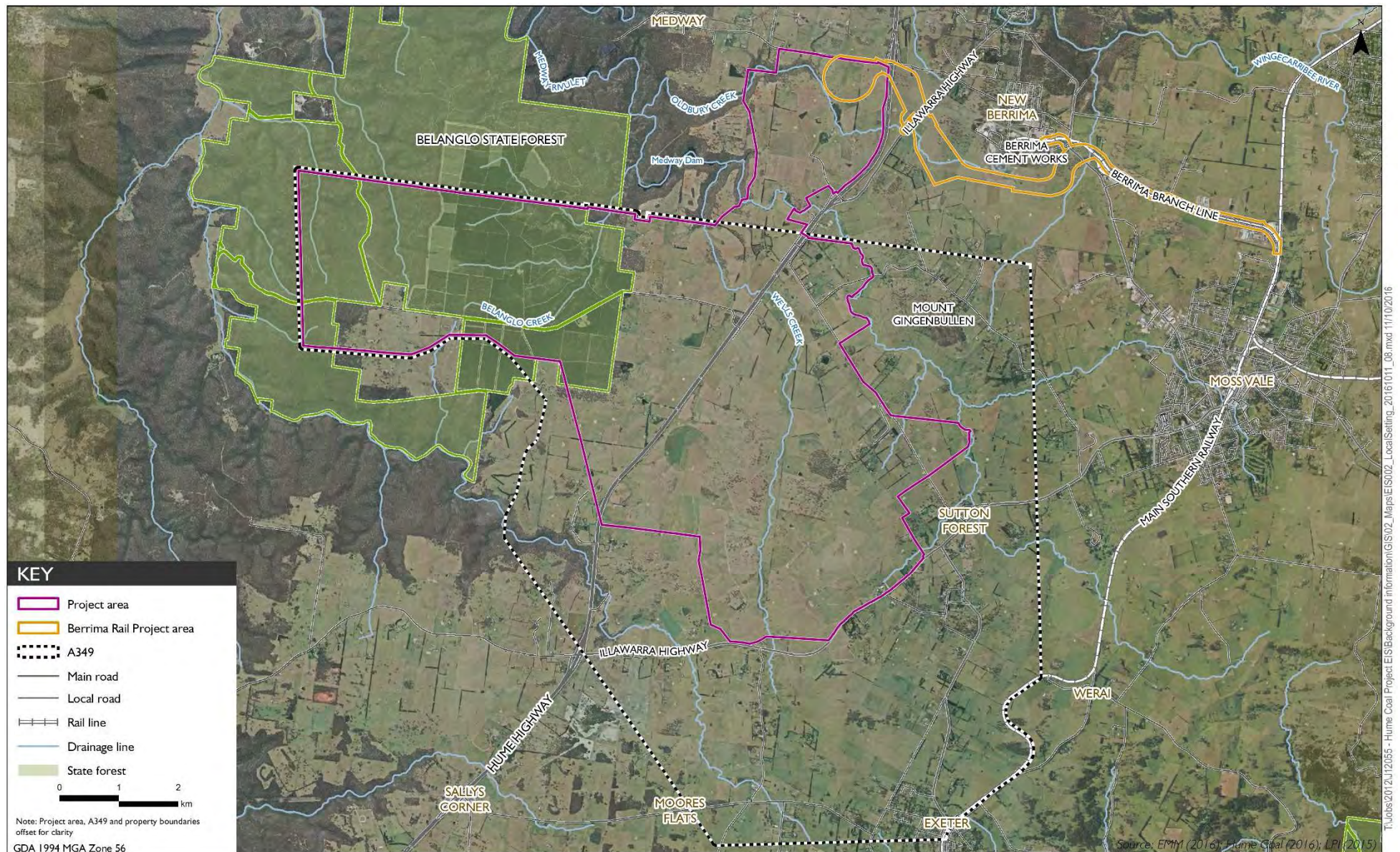


Figure 1.1. Local context
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Figure 1.2. Indicative surface infrastructure layout.
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17 November 2016

Existing built features across the project area include scattered rural residences and farm improvements such as outbuildings, dams, access tracks, fences, yards and gardens, as well as infrastructure and utilities including roads, electricity lines, communication cables and water and gas pipelines. Key roads that traverse the project area are the Hume Highway and Golden Vale Road. The Illawarra Highway borders the south-east section of the project area.

Industrial and manufacturing facilities adjacent to the project area include the Berrima Cement Works and Berrima Feed Mill on the fringe of New Berrima. Berrima Colliery's mining lease (CCL 748) also adjoins the project area's northern boundary. Berrima colliery is currently not operating with production having ceased in 2013 after almost 100 years of operation. The mine is currently undergoing closure.

1.1.2. Assessment guidelines and requirements

This groundwater assessment has been prepared generally in accordance with the following:

- Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapp A, and Boronkay A. 2012. Australian groundwater modelling guidelines. Waterlines Report Series, Number 82. National Water Commission, Canberra.
- NSW Department of Primary Industries (Office of Water). 2012. NSW Aquifer Interference Policy: NSW Government policy for the licensing and assessment of aquifer interference activities. September.

1.2. Previous mining

Mining has occurred in the area since the 1800s. Mines in the area are now abandoned, all believed to be underground, comprising (see Drawing 1):

- Berrima Mine, located to the north of Wingecarribee River on the Berrima Mine lease. The workings are the most extensive of any mine in the area and comprise 1st workings and pillar extraction in the Wongawilli seam. Mining operations commenced in 1926 and ceased in 2013. Mechanisation (and full extraction) commenced in 1968 (EMGA 2011). Production varied between 0.13 and 0.46 Mt/year and was reported as 0.25 Mt/year in 2009 (EMGA 2011). The workings are currently under care and maintenance, remaining largely empty and draining to the Wingecarribee River. Groundwater impacts from this mine can be identified in monitoring piezometer hydrographs. The owner is considering sealing the mine to reduce or eliminate drainage to the river. Groundwater and surface water quality, and groundwater levels, around the mine are monitored by Boral.
- The Loch Catherine Mine (abandoned), opened in 1924 with an anticipated maximum possible production of 200 t/day. It is located underneath the current Berrima Colliery stockpile on a localised zone of Hawkesbury Sandstone bounded by Medway Rivulet and the Wingecarribee River. The mine worked the Wongawilli Seam and ceased in 1958 (BCSC 1993). It included some mechanised workings utilising shuttle cars. Full extraction is thought to have occurred based on the shape of the mine footprint, and its presence in the Mine Subsidence Compensation Act on the list of compulsory contributors to the compensation fund. The adits are still open, and iron staining is evident in the water pooled at the mine entries.
- Southern Colliery (abandoned), located on Foxgrove Road about 5 km from the Hume lease boundary. Mining appears to have occurred in the Tongarra Seam. This was a small scale mine which ceased operations many years ago.
- Numerous adits at coal seam outcrops along escarpments (see Drawing 1, not all identified) for pre-mechanisation (manual) abandoned workings. Typical examples are Black Bobs, Belanglo (abandoned in the 1950s), Belanglo Extended, and Flying Fox collieries to the west and the north

of the Hume lease, and Erith Colliery near Bundanoon. These were likely to be very small operations, probably mining less than 100,000 t in total. Most are not sealed and drain into local watercourses. They typically consist of two headings extending in from outcrop by a few hundred metres. Belanglo was a small operation along Black Bobs Creek, presumed to be on the southern side of the creek, to the west of the Hume Highway. Murrimba Colliery was on the eastern side of Black Bobs Creek in approximately the same location and was abandoned after hitting a full face of stone a few hundred metres from the creek (coincident with a high magnetic anomaly). Belanglo Colliery is located in the Berrima lease in a tributary of Medway Rivulet.

Two adits have also been discovered along Longacre Creek. The workings are of unknown length. They are above one another (in the Tongarra and Wongawilli seams). Historical literature discusses a number of old mines in the area around the Loch Catherine mine, and it is likely that other small scale abandoned mine workings are present along the coal seam outcrop in this area.

2. Proposed mining

Hume will undertake a first workings mining layout and method. Mining is to be carried out in separate compartments known as panels. A panel consists of a number of plunges (parallel tunnels driven into the seam with unmined coal between plunges) connected by gate roads driven along the long dimension of the panel. A panel of the Hume first workings method is dissimilar to a panel in longwall mining with respect to post-mining deformation. All tunnels in a panel occur within the seam. Each panel is separated from the next by unmined coal. A group of panels forms a mining block, where each panel in the block is connected by a set of main headings that allow access for workers, equipment and ventilation, and also provide mined coal during their development. The set of headings remains open until mining of the last panel in the block is finished. Figure 2.1 is a detail of two panels for reference in the following discussion.

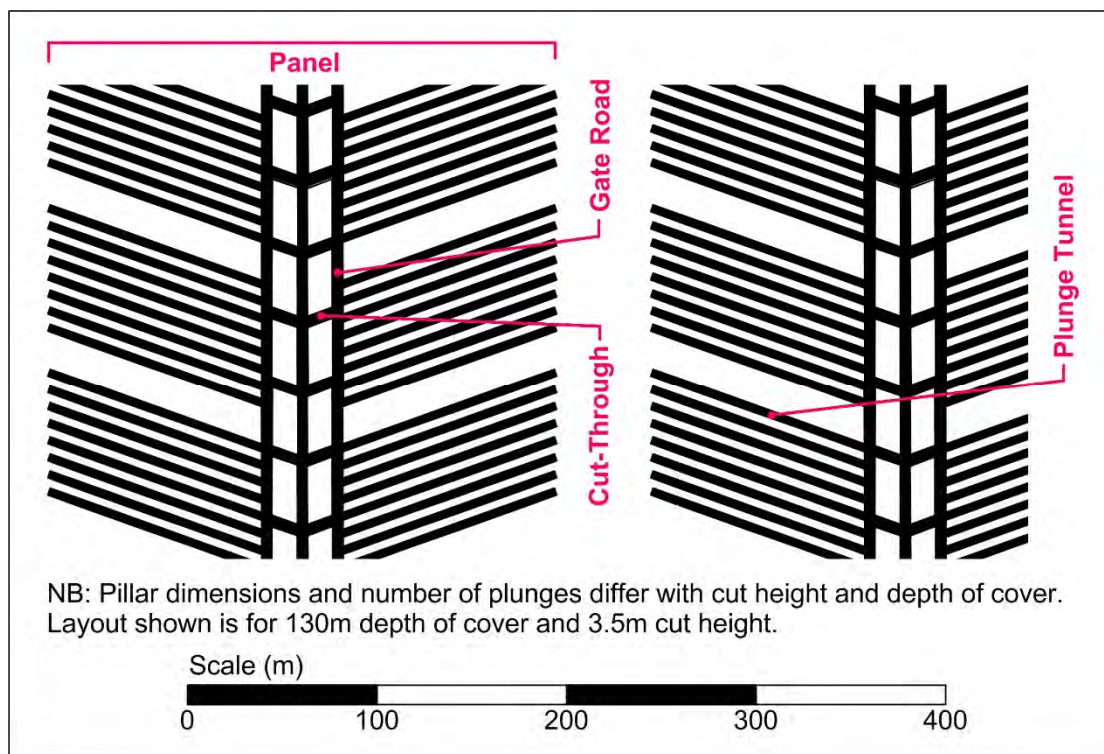


Figure 2.1. Detail of mine openings for the first workings mining method. Black areas indicate removed coal. Refer to Table 1 for panel dimensions and other information.

A mining height of 3.5 m has been adopted. Where the coal seam is thinner than 3.5 m, a cutoff height of 1.8 m has been assumed. All panels are initially developed with gate roads (and associated cut-throughs) that are driven off the main headings in a direction parallel to the panel long dimension. Gate roads are positioned down the centre of the panel. The mining method is non-caving, with additional workings comprising plunges (tunnels) that are driven off the gate roads. These openings are separated by pillars that are designed not to fail post-mining. This results in openings remaining open post-mining, without caving (goaf is not created). Relaxation in the immediate roof over the openings is generally limited to less than 3 m into the overlying roof.

Figure 2.2 shows the panel layout to be used for the Hume mine, and made the subject of predictive simulations. Panel and headings names are also shown. Mining comprises 54 panels, four main headings (three of which have flanking plunges attached directly to them), two shafts, and one sump.

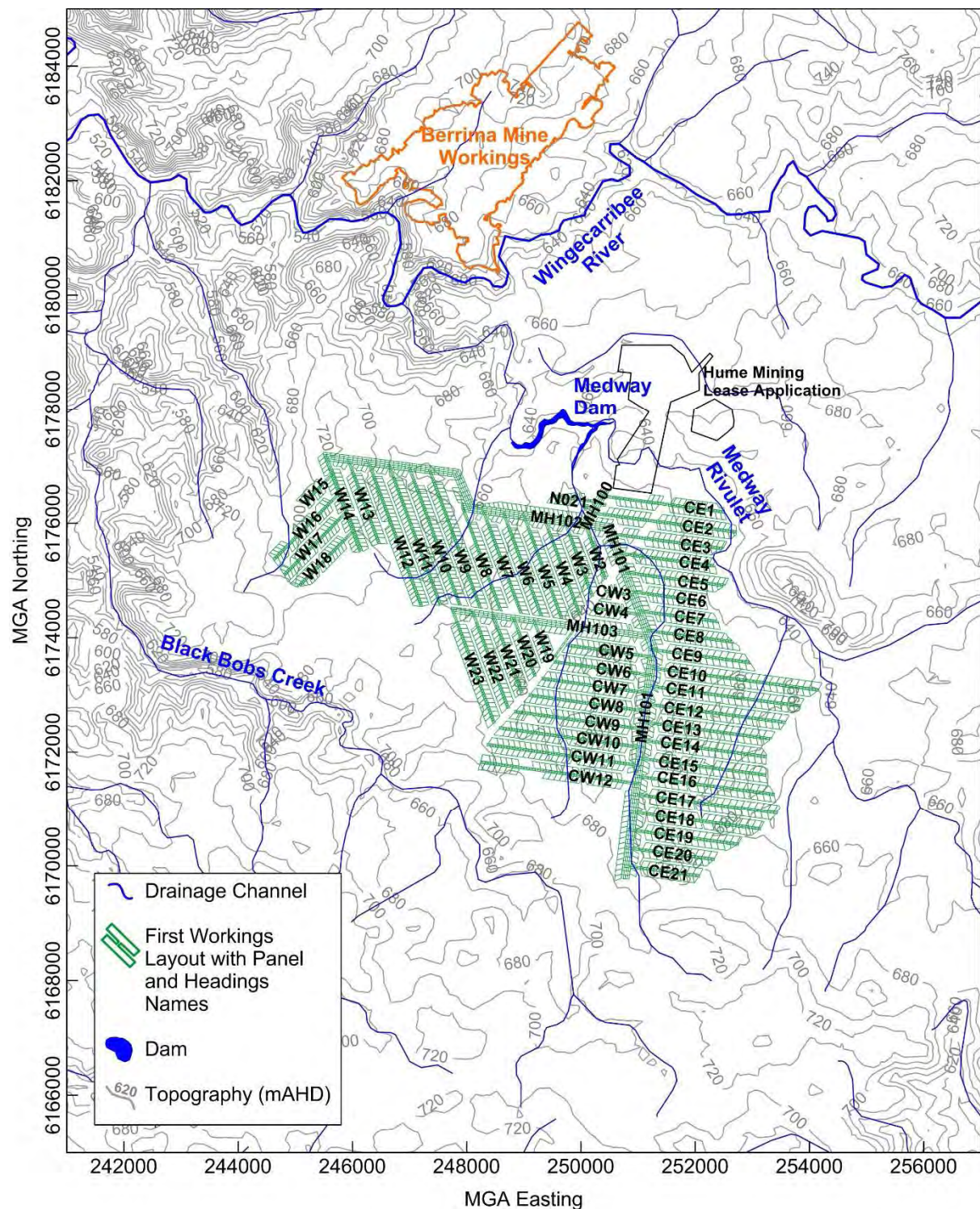


Figure 2.2. Hume mine panel layout used in predictive simulations.

Table 1 lists salient features of the mine layout. Appendix A provides tables listing mined volumes on a panel and annual basis, a plan showing the variation of mining height over the mined area, and the mining schedule. The schedule illustrates the direction of mining.

Table 1. Hume first workings mining method characteristics.

Maximum Mining Height (m)	3.5
Typical Panel Width (m)	270
Inter-panel Distance (m)	50
Calculated Height of Desaturation (H) (m above working section roof)	2
Total extracted coal volume (ML) *	32666
Mine Life (years)	19
Method Details	Non-Caving. Spine of 3 gate roads along panel centreline. 120 m tunnels (plunges) extending from gate roads.

* 1000 m³ = 1 ML.

Rock and coal fragments left over from washing and processing of coal (tailings) are combined with mine water to form a mixed slurry. Disposal of the slurry is known as co-disposal. For the Hume mine, co-disposal will be made to the underground voids.

Several groundwater drawdown mitigation measures have been modelled, comprising backfilling of the mined void with co-disposed tailings, sealing individual panels as they are mined (using bulkheads rated to withstand equilibrated hydraulic heads), and injection of mine inflow back into the void through the bulkheads (should excess water be available). These measures are designed to reduce the total groundwater drainage into the workings and thereby reduce drawdown in the overburden.

3. Model development

A regional groundwater flow numerical model has been developed to simulate underground mining in the Hume lease. The model was developed using MODFLOW-SURFACT Version 3, distributed by Hydrogeologic, Inc. (Virginia, USA). It is an advanced version of the standard USGS MODFLOW algorithm and is able to simulate variably saturated flow. The software can accommodate unsaturated zones at depth. MODFLOW-SURFACT is operated within the Visual Modflow (Version 2009) pre- and post-processing environment, developed by Schlumberger Water Services.

3.1. Layers and grid

The active model area (the model domain) is shown in Drawing 1. It covers 752 km². Its boundary follows natural features and has been selected so that the hydraulic heads in the model are controlled by rainfall recharge and groundwater sinks at the extremities of the model area (in conjunction with interior boundary conditions such as the mines and drainage channels). This eliminates difficulties associated with the uncertainty in, and control of, groundwater fluxes to or from constant head cells or general head boundaries on the boundary of the model area. An exception is Wingecarribee Reservoir (on the eastern model boundary) which is considered valid to simulate using a local constant head condition in the top model layer (see below).

The model grid comprises 15 layers (two of which are inactive) with 379 columns and 425 rows. Cell dimensions are 50 m x 50 m over the Hume lease, expanding to 50 m x 100 m over the Berrima lease, then to 200 m x 200 m over the remaining area. The finer grid is placed where detail is required during model calibration and predictive simulations.

13 model layers are used to represent hydraulic contrasts between hydrostratigraphic units, maintain adequate depth resolution, and permit modelling of behavioural changes arising from deformation. These layers and their average thicknesses are listed in Table 2.

Based on the assessment of hydraulic heads in the southeastern basalt body (see Volume 1), the Robertson Basalt is not explicitly simulated in the main model. A large vertical hydraulic head gradient is present between the basalt and underlying media, and a desaturated zone is interpreted to occur underneath most of the Wianamatta Group (WG) underlying the basalt. The basalt was therefore modelled separately (Appendix H). The basalt is conceptualised as a stable source of recharge to the WG and its presence is incorporated in the recharge rate for the WG underlying the basalt. This greatly facilitates the functioning of the model and reduces the requirement to estimate further parameters for which observations are not available.

Structure contours for the model layers were created by first resolving six key horizons in detail (bases of the Tertiary Basalt, Wianamatta Group, Hawkesbury Sandstone, Wongawilli Seam, Illawarra Coal Measures (ICM), and Shoalhaven Group). Additional structure contours for other layers (for example, subdivision of the Hawkesbury Sandstone) were developed from these six fundamental surfaces using constant offsets or proportioned thicknesses.

The Hawkesbury Sandstone is represented by six layers to facilitate the development of hydraulic head profiles in proximity, and allow the effects of deformation to be incorporated. The bottom two layers for the Hawkesbury Sandstone (Layers 6 and 7) are to accommodate roof relaxation from mining where the interburden or plies above the working section are absent.

Layer 8 represents sediment dominant lithologies, and contains the Wongawilli Seam R ply (WWR Ply).

Table 2. Model layer thicknesses.

Stratum	Model Layer	Average Layer Thickness (m)
Wianamatta Group	1	55 (where present)
Hawkesbury Sandstone	2	53 (where overlain by WG). Reduces from this average, to nil (from edge of WG to limit of sandstone)
	3	30
	4	34
	5	7
	6	2
	7	2
Interburden (Narrabeen Group, WWR Ply, and Farmborough Claystone)	8	4*
Wongawilli Seam above mined section	9	2*
	10	2*
Wongawilli Seam mined section	11	3.5
Illawarra Coal Measures	12	19 (min. 2, max. 49)
Shoalhaven Group	13	120

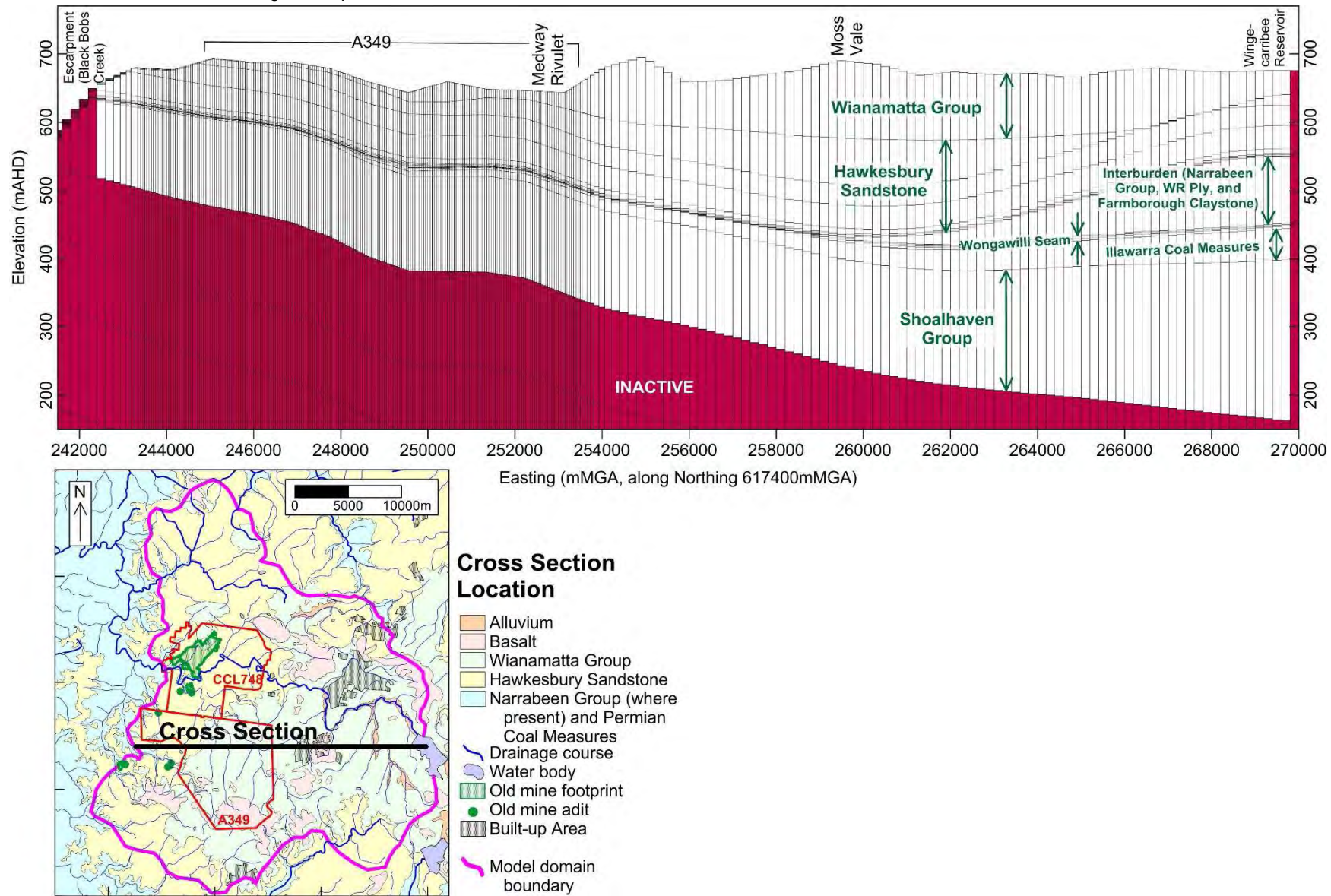
* Hume lease area. Not present everywhere (minimum model layer thickness is 0.1 m).

The Mt Gingenbullen intrusion (see Drawing 1) occurs on the northeastern lease boundary. A detailed analysis of the potential role of intrusions has been undertaken in Volume 1. Given the observed extents of disturbed zones in the Berrima lease area, and observations made at other coal mines, the intrusion is not explicitly modelled (see Volume 1).

A discussion on the Cement Works Fault is provided in Volume 1. Available hydraulic head observations show no perturbation due to this fault. Given the large change in displacement over a relatively short distance, and comparison to the magnetic intensity field, the fault has not been explicitly modelled since, in the absence of intersection, and due to its relatively localised nature, its ability to influence the evolution of the hydraulic head field from Hume mining operations is considered limited.

Hydraulic parameters for rock are defined according to depth below ground. 15 parameter zones have been used to discretise the decrease in hydraulic conductivity (K) and storativity with depth. Anisotropy in the K field is modelled for the vertical direction.

Figure 3.1 shows a cross section of the model layering (along Row 242, MGA Northing 6174000) through the mine lease from west to east. The finer grid over the Hume mine area and coarser grid to the east can be seen.



3.2. Boundary conditions

All layers were designated as variable type layers (a layer that will allow both unconfined and confined behaviour).

The model boundary has been selected sufficiently distant from the mine area to significantly reduce the potential for flow normal to the boundary occurring due to stresses imposed at the mine. The boundary conditions at the extremity of the model area consist of:

- No-flow at topographic divides.
- Discharge zones at drainage channels.
- Local constant head at Wingecarribee Reservoir.
- Discharge zones at escarpments.

Escarpments are treated as a line of drain cells to simulate consumption of groundwater at the escarpment by seepage and evapotranspiration. The western escarpment (limit of the Illawarra Coal Measures) approaches the proposed workings in some areas. Interpretation of observed hydraulic heads indicates drawdown decreases rapidly below the mined coal seam (see Figure 6.1 of Volume 1); a behaviour observed at virtually all mines in stratified sedimentary systems (where K_v is smaller than K_h). Drawdown from the proposed Hume mine can only migrate west of the western escarpment through the Shoalhaven Group.

Wingecarribee Reservoir provides a strong, reasonably constant hydraulic control in the upper model layer. Vertical gradients at Government piezometer GW075033 are negligible and reservoir water levels are reasonably constant.

3.2.1. Rivers and creeks

The Wingecarribee River was simulated using the River package, due to its quasi-permanent nature and proximity to the proposed mine. This allows two-way transfer of water between the channel and the subsurface. Two groups of river cells are used (for 50 m x 50 m cells and 50 m x 100 m cells) to allow the use of a single notional vertical K (K_v) of 0.1 m/day for the notional riverbed material. This is considered reasonable and moderately high, providing strong hydraulic connection between water in the channel and groundwater in the underlying media.

Medway Dam, an in-stream storage on Medway Rivulet, was also simulated using the River Package. No information was available for the base of the dam. Riverbed conductance was set to 25 m²/day for 50 m x 50 m cells, based on simulation of leakage from Avon and Cordeaux dams in the Dendrobium mine area (HC 2010, Coffey 2012). It assumes the presence of residual soil at the dam base. For this cell size, and a soil thickness of 2 m at the dam base, K_v of the soil is 0.02 m/day. This is high for soils of WG origin and is considered conservative.

Remaining drainage channels were simulated using the Drain package due to their ephemeral nature, or distance from the imposed stresses. Flow monitoring for streams on the mine lease indicate these drainage channels are ephemeral. Drain conductance was set to a high value of 1000 m²/day, allowing the media hydraulic properties to control leakage to the channels. Elevations for the inverts of these and other channels over the model domain are based on digital elevation information available from the Australian Government, checked against LiDAR topographic survey data for the Hume Lease.

3.2.2. Reservoirs

Wingecarribee reservoir, on the eastern model boundary, was simulated with a local constant head condition in the top model layer. Analysis of its water levels indicates a minimal change with time, with virtual equilibrium over the last several years. Water may exchange with the subsurface in either direction. The reservoir storage capacity is considered large compared to any changes in groundwater exchange rates caused by mining, so that the specified head is approximated as invariant with changes in groundwater exchange. The water level elevation was held invariant at 676 m AHD for all simulations.

3.2.3. Rainfall recharge and evapotranspiration

Rainfall recharge was applied as a constant percentage of incident rainfall recorded at Moss Vale (Bureau of Meteorology (BOM) Station 68045) over quarterly periods. The average long-term annual rainfall for the mine lease is estimated as 957 mm, similar to the average rainfall at Moss Vale. Rainfall recharge is applied to the topmost active cell in each vertical column. Net recharge to the saturated zone from irrigation is considered minor in comparison to rainfall recharge and is therefore not considered separately in the model.

Evapotranspiration (ET) was applied over the entire domain with a maximum rate of 3 mm/day and extinction depth of 1.5 m, based on land surface types and proportions.

3.2.4. Unconsolidated sediments

According to the published geology map, alluvium occurs only along the upper reach of the Wingecarribee River (see Drawing 1). Its extent is limited to close proximity to the river channel, and is a small proportion of the total recharge area encompassed by the mine capture zone. While it may afford greater rainfall recharge, most of the recharge is considered to be in intimate connection with the river channel, and would discharge to the channel. Its extent is considered minor. Borehole logs identifying the strata between the alluvium and rock were unavailable. However, alluvial sequences such as this one commonly overlie a layer of residual soil, present at the start of the depositional phase, which may compact with increasing alluvial thickness. For this case, any compacted residual soil would be of Wianamatta Group origin and be clay-dominant. On an area basis, recharge to underlying fractured media from the alluvium is considered a negligible component of the total recharge to these media.

Leakage from the alluvium into the mine void is therefore considered a small component of the total inflow, with rock providing the majority of the inflow. For the current study the assumption is made that the contribution to mine inflow (or to dewatered rock) from unconsolidated sediments is negligible compared to rock, based on the site geology and borehole logs (see Volume 1).

Major pumping is not known to occur from the alluvium, and it is not considered by the NSW DPI to be a separate groundwater source in the relevant water sharing plan.

3.2.5. Mine workings

Height of drainage above non-caving workings

The first workings mining method to be adopted by Hume is non-caving. Some parts of the existing Berrima and Loch Catherine voids, are also non-caving workings where the height of deformation is nominally 2 m into the roof. The deformation height is also the adopted height of groundwater drainage. This type of mining was extensively practised prior to the advent of mechanisation but is

rarely undertaken now. It is the preferred mining method for the Hume project as it significantly minimises groundwater impacts compared to full extraction mining.

Deformation (dilation) from 1st workings consists of enlargement of defect apertures and minor cracking in the roof above mine openings, extending upwards a maximum of approximately 3 m above the roof of the working section, depending on road width, horizontal stress magnitudes, roof rock strength, and rock bolting (or other support) strategy. This is based on typical published measurements from extensometers placed in headings roofs (see for example Sweby 1997, Whittles 1999, and British Coal Corporation 1996). Dilation typically extends approximately 2 m into the roof for common 1st workings mine plans. Extensional strains in the overburden are significantly smaller, and extend a shorter vertical distance, than full extraction mining.

The anticipated roof bolting strategy for the proposed PF mine layout is as follows:

- Bolting of gate roads at a density of between 4 x 1.8 m bolts per 1.5 m, up to 6 x 2.1 m bolts per 1 m. The most likely scenario would be 4 x 1.8 m bolts per 1 m.
- Gate road intersections may have higher bolt densities, with 4 x 4 m flexi bolts common practice, or alternatively, moving from a 4-bolt pattern to a 6-bolt pattern through the intersection and for 10 m either side.

The bolted interval is the most likely region of the roof to experience deformation, however current roof bolt installation practice is for installation under pre-tension of between 5 t and 10 t which assists in closing roof delaminations. For resin-encapsulated bolts, the resin backpressure may create additional fracturing in some cases, however the roof support system for the Hume mine plan has been designed to avoid these effects.

A 3 m relaxation height is considered to be excessively conservative if applied over the entire mine footprint, since:

- The mine roof will act more stiffly in some areas, particularly in the shallower areas of the mine (for example, less than 150 m overburden thickness).
- First workings recovery is approximately 35%, which will have the effect of increasing pillar stiffness.

To estimate a reasonable relaxation height, a sensitivity analysis was undertaken with the model, prior to predictive simulation, to assess the change in mine inflows for relaxation heights of 2 m and 4 m. This was applied over an area representative of the typical extent of an actively draining area at an instant in time. This analysis is reported in the sensitivity section. Results indicate an increase in inflow of 4.3% between 2 m and 4 m relaxation heights. Observational databases indicate a relaxation height of less than 2.5 m is common for first working mines. Given the small change in inflow between 2 m and 4 m heights, and the design of the Hume mine plan, the most representative relaxation height applicable over a large area of non-caving workings is considered to be 2 m, and this was adopted for predictive simulations.

Height of drainage above caved workings

Parts of the existing Berrima and Loch Catherine voids are full extraction workings where caving has occurred. These comprise panels of extracted 1st workings pillars. Heights of desaturation (H) above full extraction panels are calculated according to the equation of Tammetta (2013) for longwall panels. Local and international observations indicate H for pillar extraction panels is between 50% and 60% of H for a longwall panel with equivalent geometry (Tammetta 2013). 60% is used in this work.

For calibration purposes H above the Berrima and Loch Catherine voids was first calculated for individual panels. Figure 3.2 shows the full extraction panels for the Berrima and Loch Catherine voids, and their calculated H. Refer to Drawing 1 for the locations of these mines with respect to each other. These are old workings with variable panel shapes. To simplify calibration, an average H of 53 m above the roof of the working section was adopted for the full extraction panels for these voids,

based on the general similarity in H amongst the panels (see Figure 3.2). 1st workings areas of the Berrima void are given a relaxation height of 2 m above the working section roof.

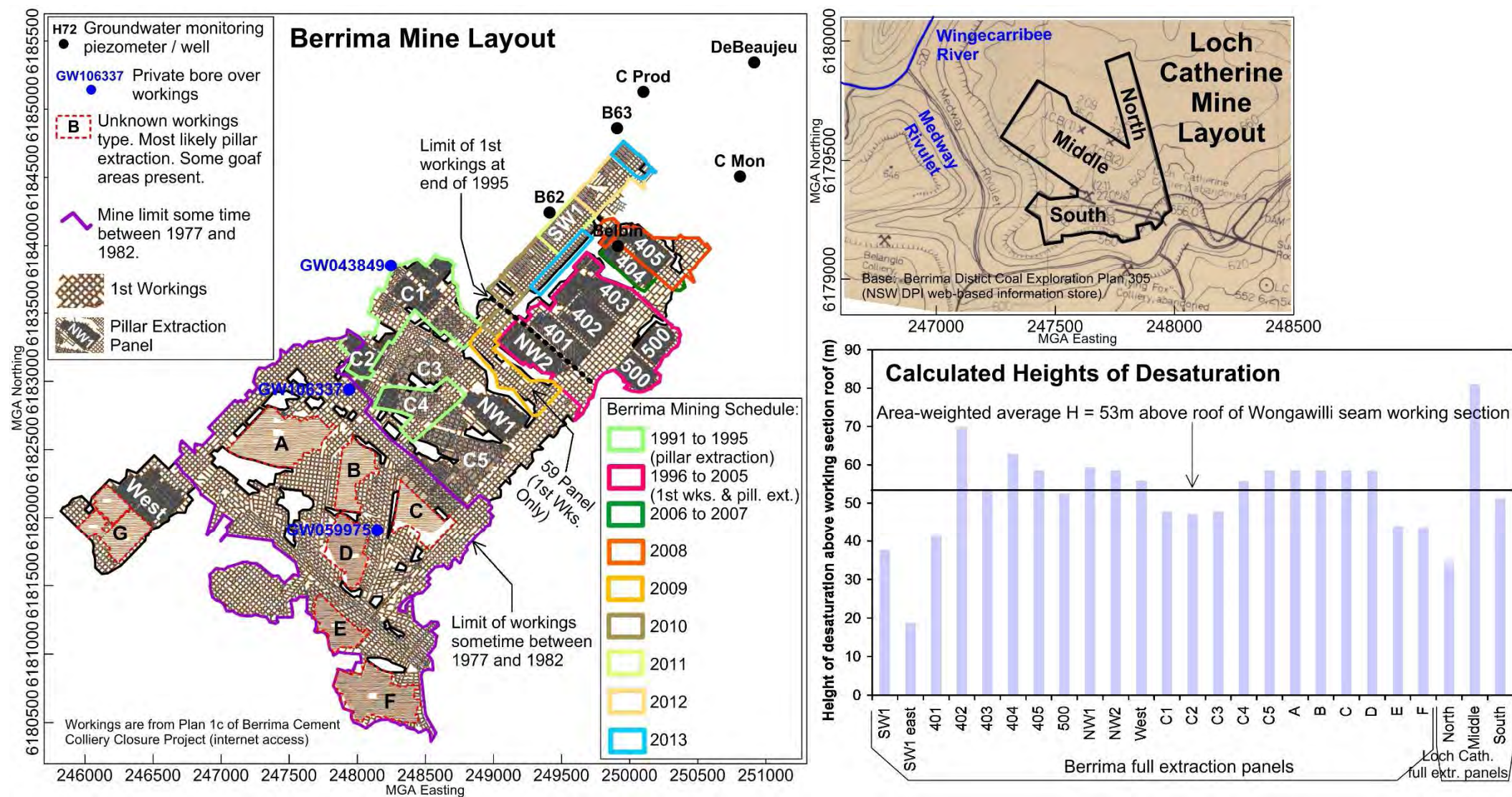


Figure 3.2. Full extraction panels for Berrima and Loch Catherine mines, and calculated heights of desaturation.

Model implementation

The creation of mine openings, and the associated ground deformation, creates a compressional zone (the pressure arch and abutments; Booth 1986) around the deformed zone due to changes in the stress field caused by deformation. Figure 3.3 illustrates the warping of vertical and horizontal stress vectors around both full extraction panels and 1st workings openings. For non-caving first workings no goaf occurs (because pillars do not fail) and stress perturbations occur over a smaller area (compared to caving systems).

For mining techniques that involve full extraction, caving creates a complex change in the K field, with increases and decreases in pre-mining K occurring (Tammetta 2015). Figure 3.3 shows interpreted areas of K reduction, assuming flanking of workings by other same-type workings, based on Tammetta (2015). Changes in the K field occur over a significantly smaller zone for non-caving mine openings. Detailed spatial simulation of the resulting K field would require micro-discretisation, untenable for a regional model with numerous panels or non-caving mine openings. For a regional model, the resulting K field imparted by the stress concentration zone around an opening is incorporated using the conductance of drains used to simulate mine openings and the overlying drained zones. This also avoids the problem of estimation of post-mining K in the drained zone (where desaturation occurs and estimation of K via calibration is not possible).

H is estimated a-priori for full extraction (caved) and non-caving workings, and drains are used to simulate drainage in each layer intersected by the deformed zone (the collapsed zone for full extraction, and the relaxation zone for non-caving workings). H for non-caving workings is a few metres whereas H for full extraction panels is comparable to the panel width (depending on panel geometry and overburden thickness).

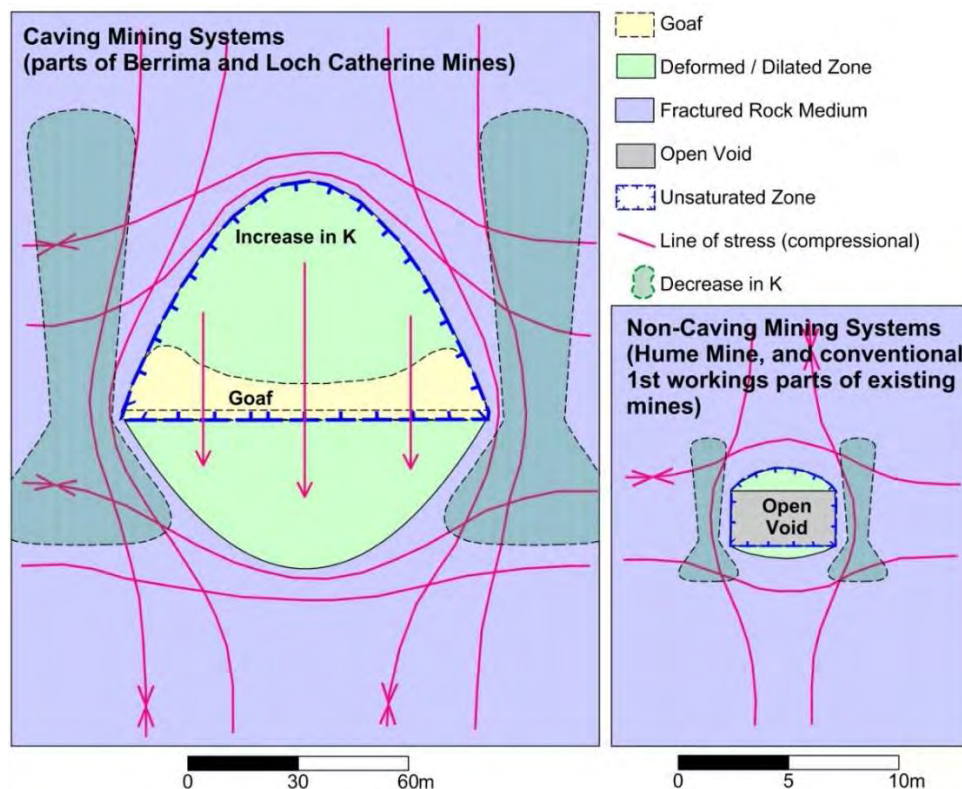


Figure 3.3. Conceptualisation of the perturbation of stress trajectories and changes in K in fractured media caused by underground mining.

Potential changes in hydraulic conductivity above the relaxed zone

An assessment of mine subsidence (MA 2015) used the work of Ditton and Frith (2003) to assess the likely maximum localised values of horizontal strain (compressive and tensile) in the Hawkesbury Sandstone in the mine lease. Results are predictive horizontal strains above the workings of 0.01% and 0.018%, using two different methods of calculation. An upper threshold of 0.02% was used for assessment of impacts. Results in MA (2015) indicate that predicted extensional strains for the first workings method, above the relaxed zone adopted in the model, will be insufficient to activate movement of defect apertures, since the relaxation will be consumed by elastic expansion of the matrix, with negligible change in defect aperture. These results support the modelling assumption of nil change in the hydraulic conductivity field above the relaxed zone in the Hume Mine.

Berrima Mine

A review of available literature provided useful observations made during the course of mining at the Berrima Colliery, for use in model implementation. A summary is provided below.

Panels mined near the end of mine life generally comprised five gate roads driven at 5.5 m width and 2.3 m height. Pillar dimensions varied from 37.5 m to 45 m centres. Development and extraction of runouts on the left panel side was undertaken concurrently with panel development. The right runouts were extracted on retreat but were sometimes split on advance. Full extraction of pillars occurred after splitting, at 25 m centres (once parallel to the cut-through).

Mining conditions were generally good with minimal roof support required. Roof bolting was undertaken at 2 m spacing with 2 roof bolts per row at 3 m spacing (1.25 m from each rib wall). Spacing was decreased when passing through sections of soft roof.

3.2.6. Pumping from private bores

The model simulates pumping from the following private water bores located in the model domain:

- 83 high extraction bores with associated aquifer access licences. These bores are generally used for irrigation or other industrial purposes. The combined level of entitlement is 14.5 ML/day (5300 ML/year).
- 299 bores approved for stock and/or domestic use.

No metering of actual usage is known to be undertaken by regulatory agencies for the area. Pumping was therefore a variable. Stock / domestic bores were assigned a constant pumping rate of 3 ML/year (0.008 ML/day) (Lowe et al 2009, SAMDBNRMB undated). The total pumping rate for high-extraction bores was varied slightly during calibration, with the optimal rate found to be 14.1 ML/day, or 97% of the allocation. This rate most probably takes into account pumping from unlicensed bores, and / or possible pumping in excess of allocation at licensed bores.

For bores whose hydraulic interval penetrates multiple model layers, pumping is partitioned according to the transmissivity of the layer compared to the transmissivity of the total penetrated interval. This means pumping rates may decrease should one or more intersected layers dry during the course of the simulation.

4. Model calibration

Given the age of the Berrima and Loch Catherine mines, model calibration was undertaken in two stages as follows:

- Stage 1: Mining at Berrima finished recently but had been active between 1926 and 2011. The first stage of calibration comprised a transient simulation simulating a notional period of 32 years, as an approximation for the evolving hydraulic head field due to mining effects between 1926 and 2011, to obtain a reasonable starting head distribution for the point in time at the beginning of the main calibration period (January 2011). The modelled January 2011 hydraulic head distribution is used as the starting hydraulic head field for the main transient calibration.
- Stage 2: Transient calibration over the main calibration period (1 January 2011 to 31 December 2014), covering mining of the last stages of the Berrima workings.

Observations for the period 1 January 2015 up to the dates of observation availability in mid 2015 (ranging between March and July), as at the time of calibration, were reserved for the verification phase. Parameter change was performed manually.

4.1. Calibration targets

Calibration targets comprised:

- Hydrographs of hydraulic head from the Berrima and Hume monitoring networks (Parsons Brinckerhoff 2015). Target hydrographs were selected according to the following criteria:
 - Characterisation of mining-induced drawdown.
 - Longer monitoring periods.
 - Smaller screen intervals.

The calibration hydraulic head dataset comprised hydrographs covering intervals of between 1 and 3 years at 49 points in the subsurface, at 23 locations. The calibration target piezometers and their locations are listed in Appendix B. Appendix B also lists piezometers not used for calibration and the reasons for their exclusion. There is evidence that water levels at the DeBeaujeu and Culpepper monitoring bores are influenced by Berrima mining. These bores, while having long hydraulic intervals, were retained as the best available monitoring points for characterisation of mining-induced drawdown at distance from the Berrima workings.

- Observed shallow groundwater discharges (estimated baseflow to drainage channels).
- Observed deep groundwater discharges (estimated discharge to the Berrima mine void).
- The observed K distribution for moderate observation scales (similar to the model discretisation).

4.2. Sources of uncertainty in hydraulic head calibration targets

Numerical simulation of regional groundwater systems requires calibration to observations. The reliability of results is generally a function of the reliability in observations, and the ability of the model to replicate these observations. In comparing modelled hydraulic heads from the discretised medium of a model domain to measured hydraulic heads from a natural continuum, the following sources of uncertainty are introduced, regardless of calibration quality:

- Accuracy of VWP data. The accuracy of VWP data is considered to be not better than ± 10 m.

- Model layer thickness and the vertical position of a piezometer screen interval with respect to the model layer. Vertical hydraulic gradients in proximity to mining may be significant. Away from mining, smaller gradients are observed. In a finite difference numerical model, a layer will have only one head value per cell (an average value, applicable to the centre of the cell). Assuming a 50 m thick layer and a vertical hydraulic gradient of 0.5, with a measurement point located at either the top or the bottom of the layer, then if the model is perfectly replicating the system, the observed and modelled heads will differ by half of 25 m, or 12.5 m. This difference depends on several factors, the most significant of which are the layer thickness and the vertical hydraulic head gradient.
- The Berrima mine schedule. The mining schedule for Berrima is not known in detail, and generally only to a resolution of yearly blocks. An attempt has been made to replicate it based on typical mining practices and experience. Plans available in various publications show the extent of workings, and the mine footprint, at a few points in time. Coal extraction is assumed to have ceased in early 2013.
- Large screen intervals in bores. Observations from private bores DeBeajeu and C Prod are considered important targets for calibration however their screened intervals (greater than 40 m) span two or more model layers. A reasonable departure of modelled water levels from observed water levels is therefore expected for these bores, regardless of calibration quality.

4.3. Calibration results

Transient calibration was undertaken for the period 1 January 2011 to 31 December 2014 with monthly stress periods. Rainfall recharge was applied as a percentage of incident rainfall. Parameter change was performed manually. Verification was undertaken for the period 1 January 2015 to 27 August 2015. Hydraulic head observations were available up to July 2015 and Berrima discharge observations to August 2015.

Prior to calibration, it was suspected that subvertical groundwater flow barriers associated with the southern basalt bodies (see Volume 1) might be critical in replicating the hydraulic head field. These barriers were interpreted from analysis of the three-dimensional hydraulic head field, and airborne geophysical survey data. The calibration phase indicated that hydraulic head observations at southern piezometer nests (east to west) H56X, H37, H42, and H136 could not be replicated without inclusion of such barriers. Therefore, during the calibration phase, sub-vertical flow barriers were incorporated as follows (see Figure 4.1):

- Vertical barriers to groundwater flow offering significantly reduced K normal to their planes, but unimpeded K along their planes.
- 10 m thick with a fault core K of 0.001 m/day, based on observations from large scale barriers elsewhere.
- The barriers do not penetrate into the basalt.

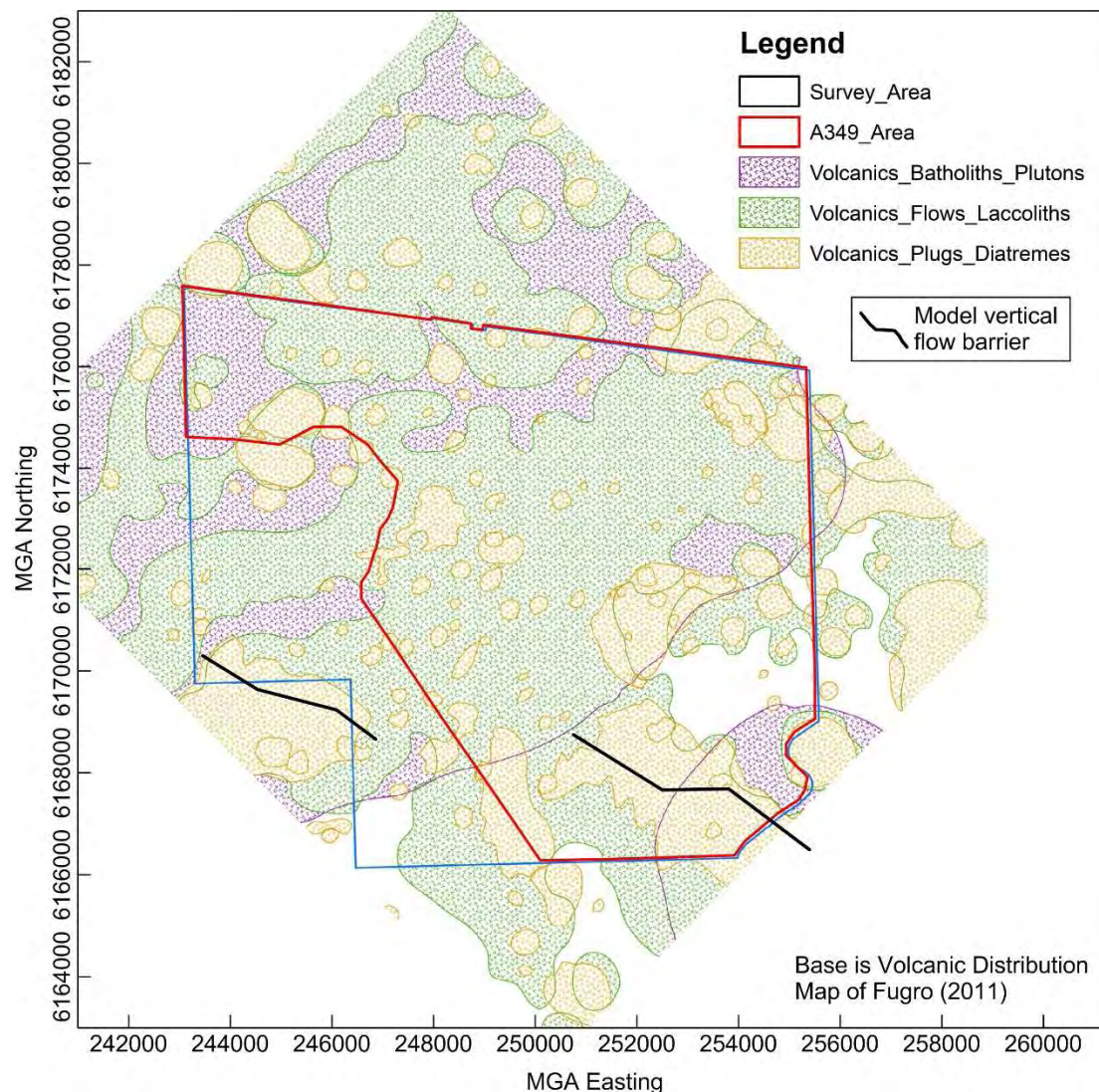


Figure 4.1. Modelled flow barriers incorporated during the calibration phase. The volcanic interpretation is after Fugro (2011).

4.3.1. Hydraulic heads

27 August 2015

Figure 4.2 shows modelled and observed hydraulic heads for the end of the verification period (modelled water levels for 27 August 2015, compared to actual observations ranging between April and June 2015). The normalised root-mean-squared (NRMS) error is 11.9 % and considered reasonable, given the VWP outliers B62_Upper and B63_WW, comparison of non-coincident modelled and observed water levels, and other factors. B62_Upper and B63_WW are poorly matched however these are VWPs and their reliability is lower than for standpipes. Residuals are reasonably normally distributed.

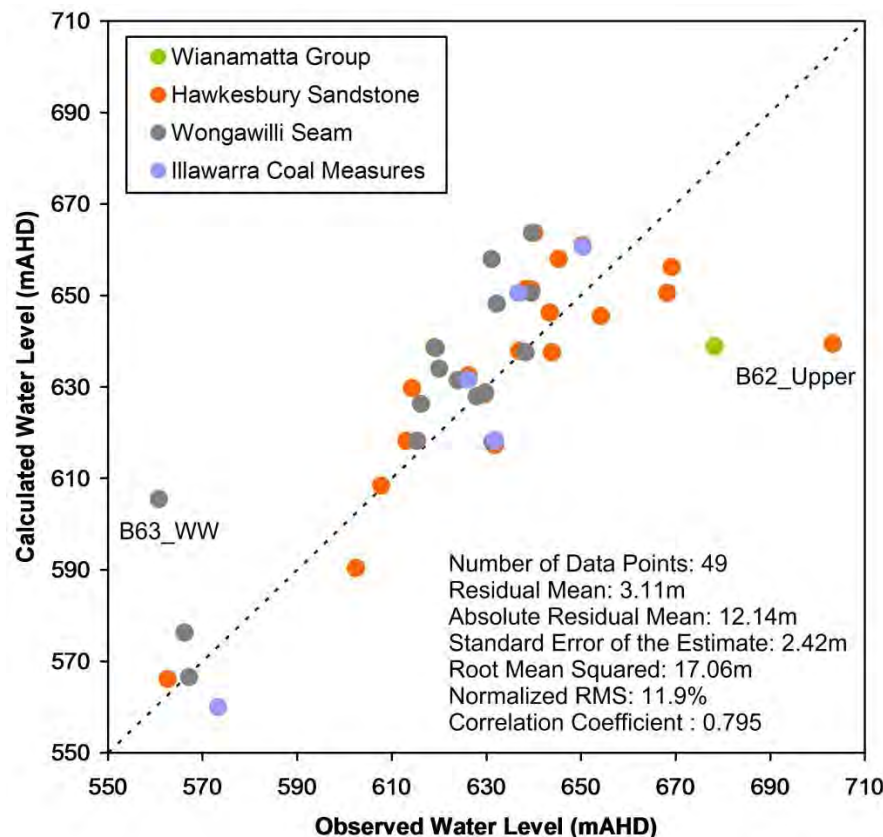


Figure 4.2. Comparison of last available observed water levels (March to July 2015) and model-calculated water levels for 27 August 2015.

The residual mean is 3.1 m, small compared to the total variation in head during the calibration (and predictive) phases, and a small proportion of the saturated thickness above the mined horizon. The offset will overestimate mine inflows by less than 5%. The offset is mainly due to:

- Uncertainty in stream invert elevations.
- Uncertainty in private pumping.

A proportion of modelled stream invert elevations are higher than actual, in the central model area. The digital elevation model (DEM) for the entire model domain was obtained from the Geoscience Australia web-based data service. This model was compared to detailed laser-based elevations (LiDAR, considered more accurate than the DEM) obtained by Hume for the mine lease. The comparison indicated good agreement but with a variation of about ± 8 m AHD. The proportion of inverts that are higher than the LiDAR equivalents, combined with the defined drainage channel lines not occurring precisely over the minima in the DEM, have influenced the calibration results.

The mean residual for the seven Berrima network observations is smaller than overall, indicating the stronger control of the Wongawilli Seam hydraulic head condition in the mined zone on hydraulic heads surrounding the Berrima mine.

Figure 4.3 presents a north-south cross section of modelled hydraulic head through the Berrima mine for 27 August 2015, for comparison to the interpreted hydraulic head cross section for late 2013 / early 2014 (also shown). Recognising the offset of the modelled cross-section down hydraulic gradient, and the difference in times, the replication of the vertical hydraulic head distribution is considered reasonable. The model calculates saturation to be present above partial extraction (1st workings) areas of the Berrima, and the absence of saturation above full extraction areas.

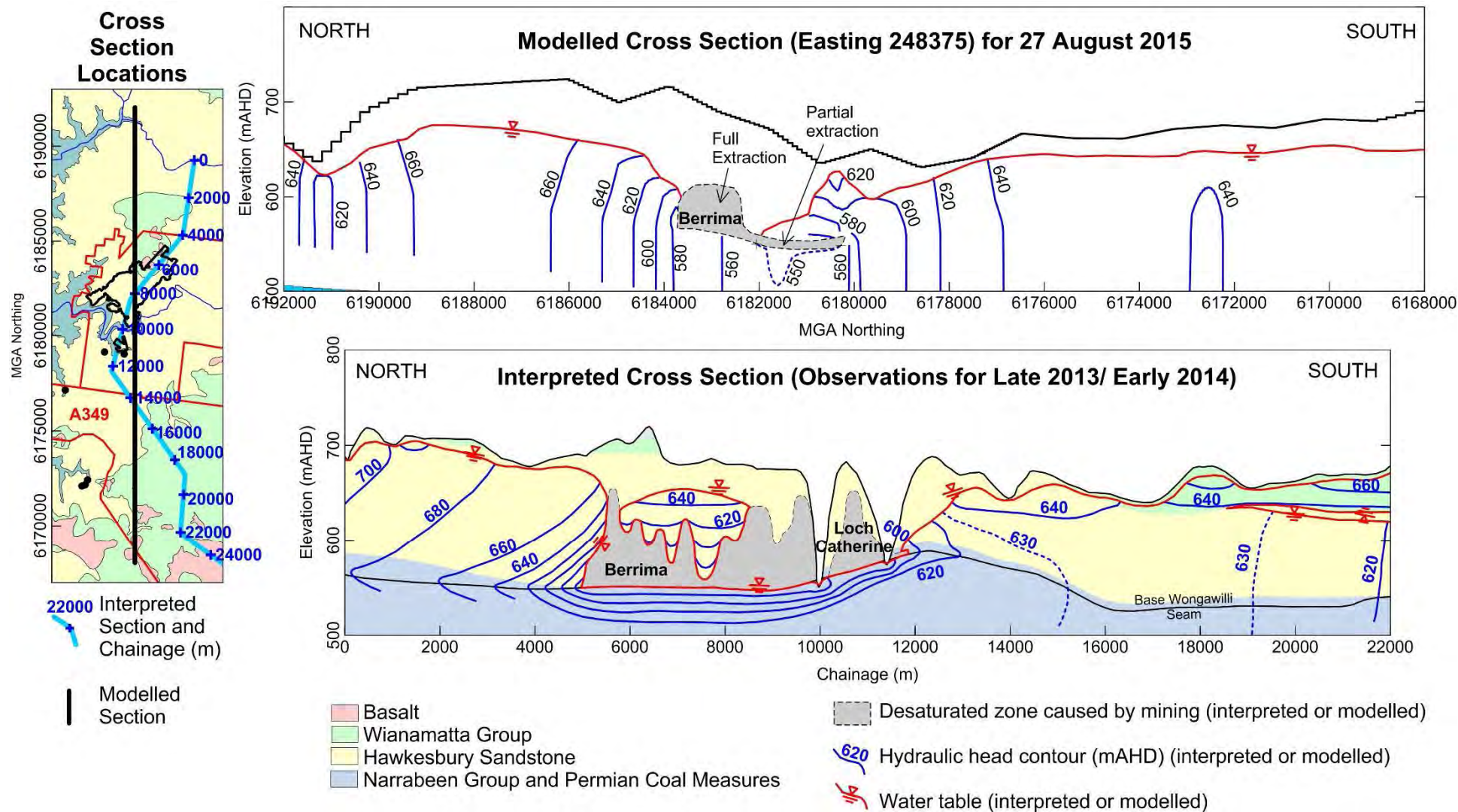


Figure 4.4 shows the modelled water table for 27 August 2015, representative of conditions prior to mining at the proposed Hume mine. Flow along the water table surface is from outcrop sandstone areas along the western boundary (rainfall recharge to sandstone), and Wingecarribee reservoir on the eastern boundary (reservoir leakage), to drainage channels to the south, northeast, and west. The lower reaches of Wingecarribee River and Medway Rivulet are groundwater discharge areas.

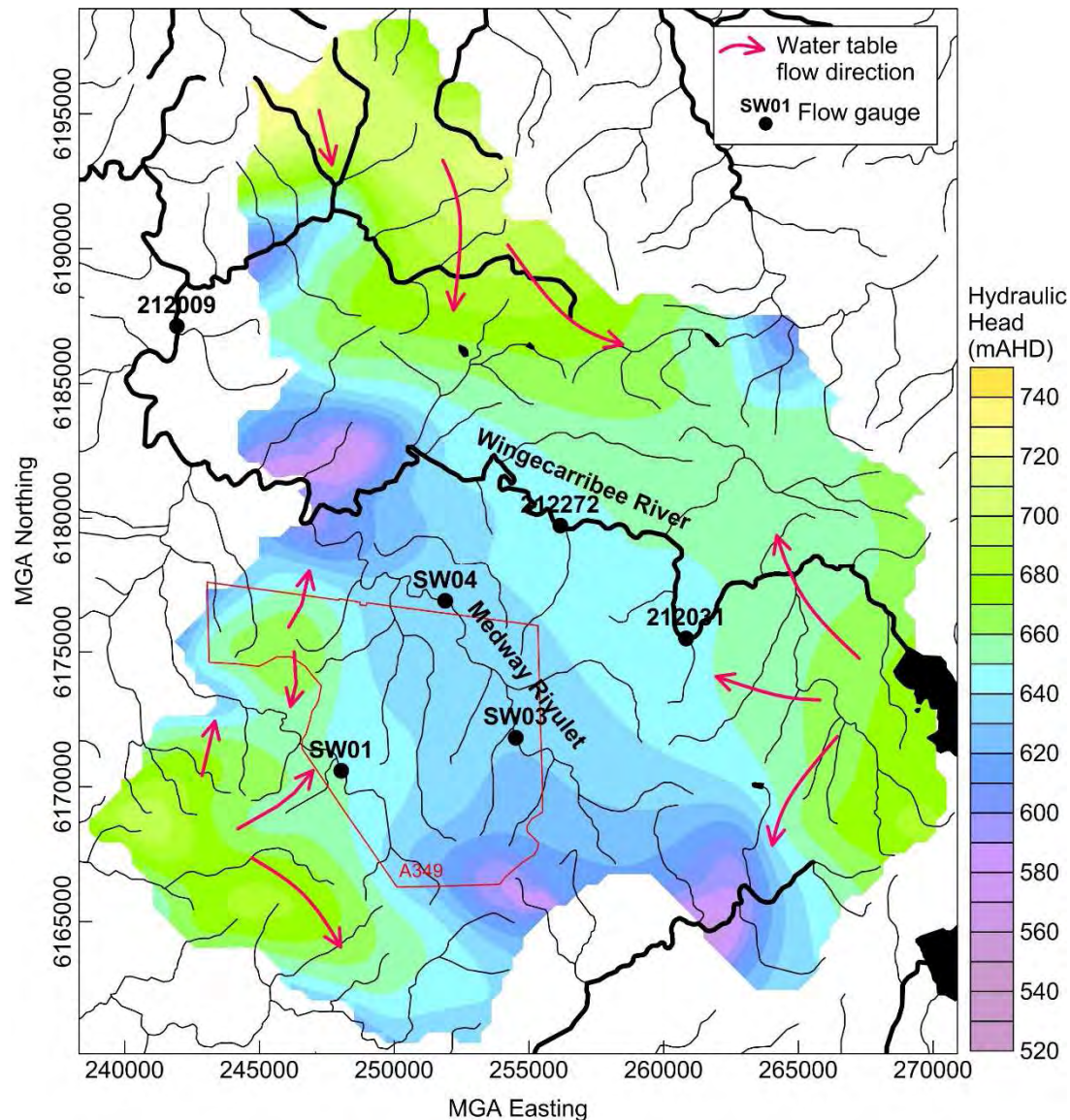


Figure 4.4. Modelled water table for 27 August 2015.

Hydrographs

Appendix B presents modelled and observed hydrographs of hydraulic head. Observed heads are reasonably reproduced overall. Drawdown from Berrima mining (seen at B62, B63, DeBeaujeu, and C Prod) is also reasonably reproduced. B62_Upper and B63_WW are poorly matched, however the other four observation datasets for B62 and B63 are reasonably matched.

4.3.2. Hydraulic properties

Calibrated media properties are listed in Table 3.

Table 3. Calibrated media properties.

Stratum	Model Layer	Average Depth to Base in Hume Lease (mbgl)	Kh ^a (m/day)	Kv ^b (m/day)	Specific storage (m ⁻¹)	Specific yield	Kv/Kh
Wianamatta Group	1	30	1	0.01	1 x 10 ⁻⁶	0.01	0.01
Hawkesbury Sandstone	2	56	0.6	0.001	1 x 10 ⁻⁶	0.01	0.0017
	3	86	0.05	0.003	7 x 10 ⁻⁷	0.008	0.06
	4	120	0.03	0.0005	7 x 10 ⁻⁷	0.008	0.017
	5	127	0.01	0.0005	7 x 10 ⁻⁷	0.005	0.05
	6	129	0.005	0.001	5 x 10 ⁻⁷	0.005	0.2
	7	131	0.005	0.001	5 x 10 ⁻⁷	0.003	0.2
Interburden*	8	133	0.005	0.001	5 x 10 ⁻⁷	0.003	0.2
Wongawilli Seam above mined section	9	135	0.005	0.001	5 x 10 ⁻⁷	0.003	0.2
	10	137	0.005	0.001	5 x 10 ⁻⁷	0.003	0.2
Wongawilli Seam mined section	11	140	0.005	0.001	5 x 10 ⁻⁷	0.003	0.2
Illawarra Coal Measures	12	160	0.0001	0.0001	5 x 10 ⁻⁷	0.003	1
Shoalhaven Group	13	250	0.0001	0.0001	5 x 10 ⁻⁷	0.003	1

a. Kh denotes lateral hydraulic conductivity (K). b. Kv denotes vertical K. mbgl denotes metres below ground level. * Narrabeen Group, WWR Ply, and Farnborough Claystone.

Figure 4.5 compares calibrated and observed K (refer to Volume 1 for a discussion of K measurements). Large-scale measurements of K are mostly representative of the lateral component of the K tensor (except where specifically analysed for Kv, where measurements allow). The calibrated Kh distribution is considered to reasonably represent K observations. Large scale Kv for the Hume area is heavily affected by its tectonic history and associated intrusive activity, and the high density of private open water bores. The calibrated Kv distribution is considered a reasonable replication of the large scale Kv distribution in the subsurface. It is supported by calibration to shallow and deep groundwater discharges, and important large scale Kv estimates from the two long-term pump tests undertaken by Hume on the mine lease in 2014. These three datasets are independent of each other.

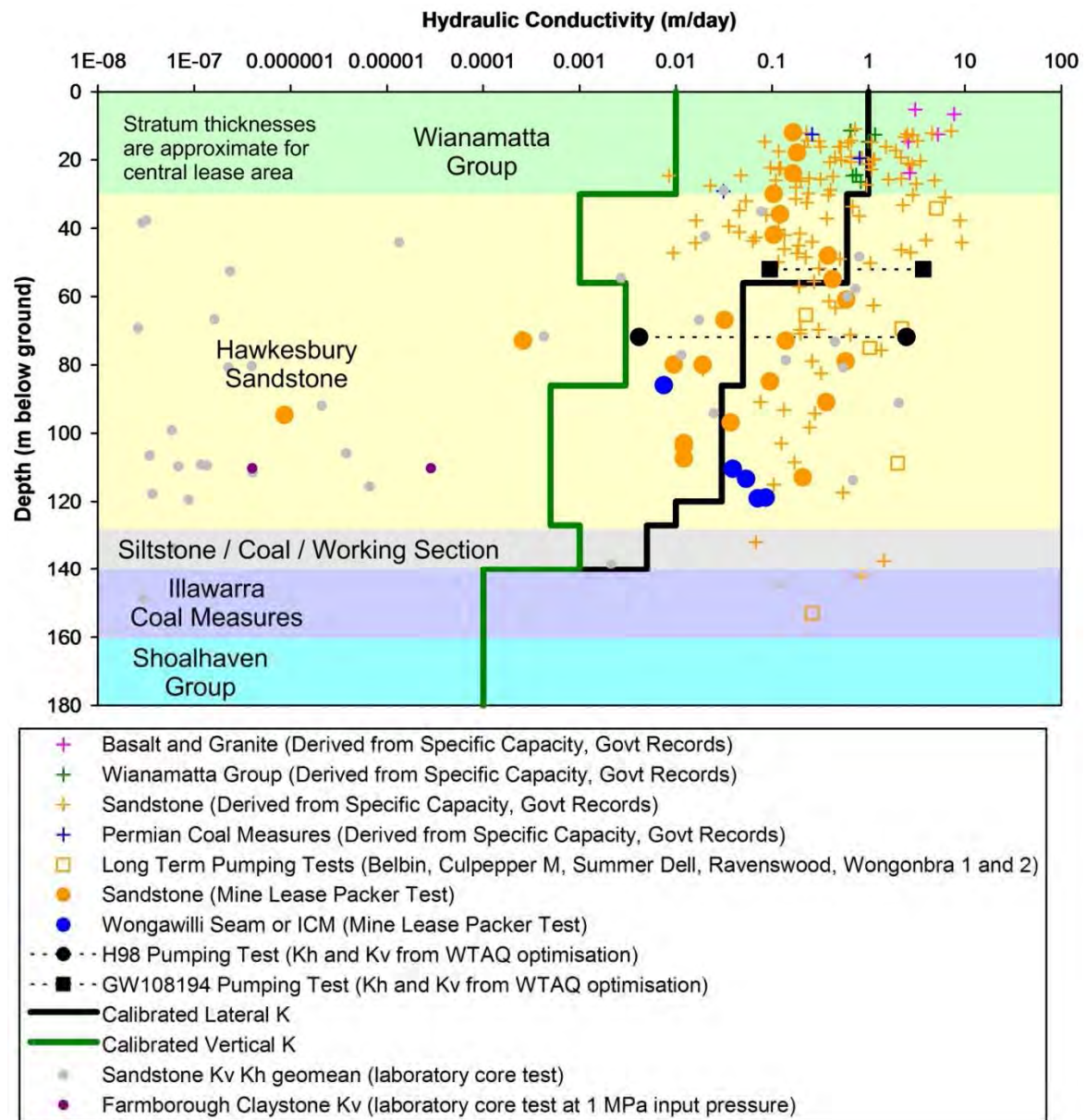


Figure 4.5. Comparison of calibrated and observed hydraulic conductivity.

Berrima Mine drain conductance

The calibrated drain conductance for Berrima mine workings is 0.1 m²/day (for 50 m x 100 m cells). For 50 m x 50 m cells (the cell size over the Hume mine footprint), the equivalent conductance is 0.05 m²/day (see the discussion in the Predictive Simulation section below).

For the case of numerical simulation of development headings for proposed mining in Area 3B in the Dendrobium mine lease (Coffey 2012), a drain conductance of 0.1 m²/day was calibrated for a depth of around 300 m, for 50 m x 50 m cells. For this model also, hydraulic heads, K, and flows (shallow and deep) were simultaneously reasonably replicated. The similarity between calibrated conductances at Berrima and Dendrobium indicates that the application of the calibrated conductance for predictive simulation of the Hume mine is reasonable.

4.3.3. Recharge and discharge

Recharge

The mine lease and model domain have estimated area-weighted long-term average annual rainfalls of 957 mm and 949 mm respectively. The actual rainfall applied to the model domain over the simulation period (Moss Vale) was 4.81 m, slightly above average. The calibrated rainfall recharge rate is 1.8% of incident rainfall.

Shallow discharge

78% of the catchment for flow gauge 212009 (or 467 km²) occurs within the model domain. The estimated baseflow at this gauge is 1.5% of average annual rainfall over the catchment. Assuming this rate is applicable over the calibration period, the estimated baseflow to the intersected part of the catchment would be about 18 ML/day. The modelled baseflow to the Wingecarribee River and its tributaries in the model domain was 12 ML/day at the end of the simulation period. The model does not simulate basalt; when an estimate for the basalt baseflow component (between 30% and 40%) is removed from the observationally-based estimate, the modelled baseflow is considered to compare favourably with it.

Deep discharge

Figure 4.6 shows the observed discharge from the Berrima mine void and the modelled inflow over the calibration period. The adopted observation dataset for Berrima Mine inflow is discussed in Volume 1. The observed discharge from the void is assumed to be a reasonable representation of the discharge to the void from surrounding media.

David (2015) reports that the most accurate period of discharge readings is April to November 2014. Modelled inflows are considered to accurately replicate observed discharge over this period. Modelled inflows slightly overestimate other less reliable measurements. Some overestimation by the model is likely to be due partly to calculation of H (the vertical extent of desaturation) for pillar extraction panels as 60% of their longwall equivalents; 55% is likely to be a better representation in this case (see Tammetta 2013). Modelled inflows are considered to accurately match the observation dataset.

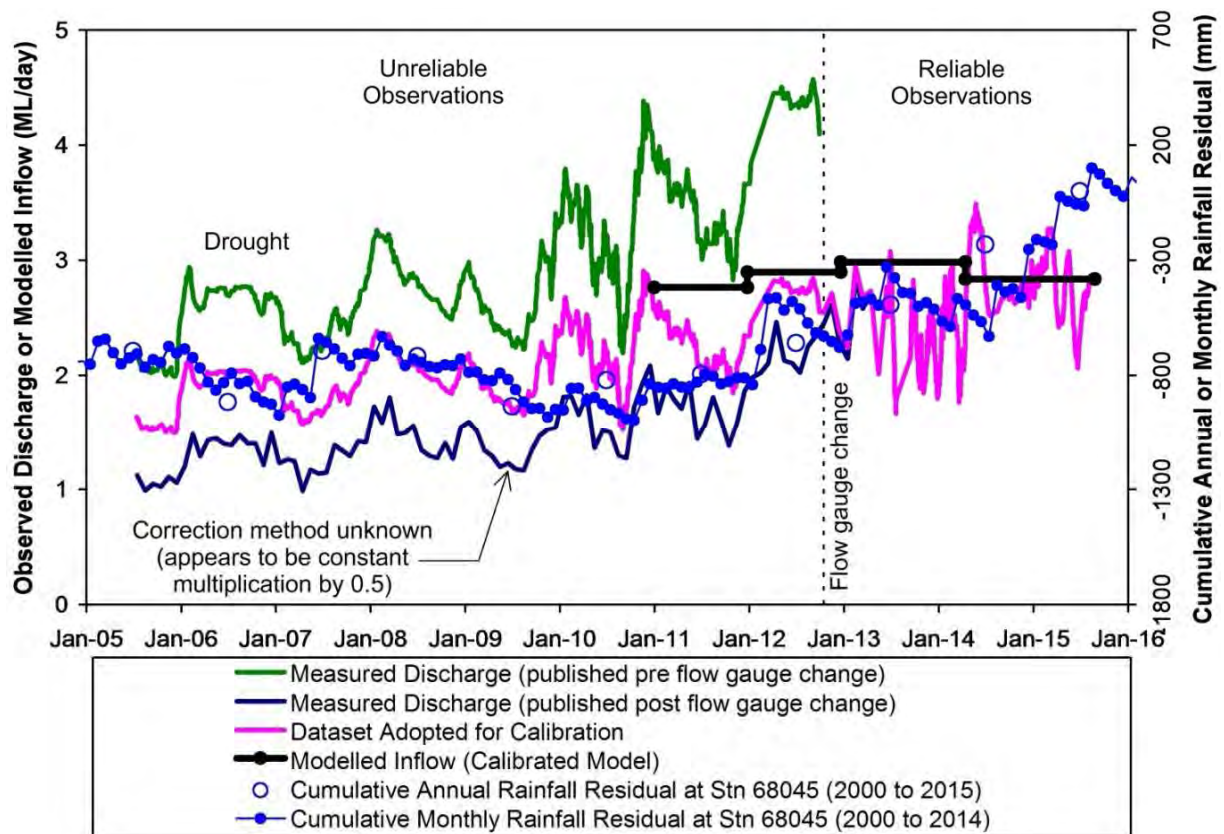


Figure 4.6. Observed discharge from, and calibrated inflows to, the Berrima mine void over the calibration and verification periods combined.

4.3.4. Flow budget

The modelled average flow budget for the domain over the calibration and verification periods combined (1 January 2011 to 27 August 2015) is listed in Table 4. The flow budget discrepancy is considered reasonable.

Table 4. Modelled average flow budget over the calibration and verification periods combined.

IN (ML/day)		OUT (ML/day)	
Rainfall Recharge	37.5	Baseflow to Wingecarribee River	11.9
Release from Media Storage	12.2	Baseflow to other Rivers and Creeks	10.3
Leakage from Reservoirs	2.3	Berrima Mine Inflow (to river)	2.9
Leakage from Medway Dam	0.5	Loch Catherine Mine Inflow (to river)	0.5
		Inflow to Other Mines (to rivers)	0.7
		Private Pumping	14.6
		Evapotranspiration	14.2
TOTAL	52.7	TOTAL	54.9
Discrepancy: -2.2 ML/day (-4.1%)			

4.3.5. Model fitness for purpose

The hydrogeological conceptual model and numerical groundwater model have been developed based on the following four crucial, large, and totally independent observation datasets:

- Hydraulic heads.
- Hydraulic conductivity.
- Shallow groundwater discharge (baseflow to streams).
- Deep groundwater discharge (drainage to the existing Berrima mine void).

The numerical model is simultaneously reasonably replicating all four datasets, which considerably reduces uncertainty in outputs, and has allowed a reliable estimation of the Kv versus depth distribution (fundamental for predictive simulation of deep discharges). The model Kv distribution also accords with a 5th group of critical observations: Kv estimated from the long-term pumping tests undertaken by Hume on the mine lease in 2014. Calibrated storage parameters accord with several observations in the database. The model is therefore considered fit for estimating impacts from proposed mining in the Hume lease area, and is considered to provide a reliable basis for predictive simulation.

The model is expected to conform to approximately 70% of the criteria for Class 3 models, with remaining aspects of the model conforming to Class 2 criteria, according to the classification system in the Australian Groundwater Modelling Guidelines (Barnett et al 2012).

For the Class 3 model criterion that predictive “stresses are not more than 2 times greater than those included in calibration”, the quantity to be used in defining the stress is not explicitly stated in the guidelines. However, most of the examples used to define stress in the guidelines are fluxes (for example, rainfall recharge or pumping). The document defines stress as a process that leads to the removal or addition of water from or to a groundwater system. Using a spatial extent criterion, the model calibrated herein would conform to the Class 2 criterion for predictive stress magnitude. However, using a flux criterion, predictive modelling indicates that the predictive stress (the Hume mine) generates about 6 ML/day, compared to around 3 ML/day for the main calibration stress (the Berrima mine). With the inclusion of the Loch Catherine mine, and other mines, the model would conform to the Class 3 predictive stress magnitude criterion.

5. Predictive simulation

The calibrated model has been used as the basis for a predictive model that simulates mining in the Hume Lease area. The predictive model is used for impact assessment.

5.1. Model settings

The following settings have remained unchanged from the calibration model:

- Subsurface media geometry and hydraulic parameters.
- Rainfall recharge applied at 1.8% of the area-weighted long-term annual average rainfall of 949 mm for the model domain, without variation).
- Wingecarribee reservoir water level (676 m AHD).
- Kv of 0.1 m/day for the Wingecarribee River.
- Riverbed conductance of 25 m²/day (for 50 m x 50 m cells) for Medway Dam.
- Existing mine workings (extent and drain conductance), passively draining to rivers. It is understood the owners of Berrima Colliery are considering sealing the discharge adit. It is not known if this will occur.
- Drain and river invert elevations, and other imposed boundary conditions at the model extremities.

Hume mining occurs in 50 m x 50 m cells. The calibrated mine drain conductance for the Berrima mine applies to 50 m x 100 m cells. Under the assumption that the major part of the induced flow field is vertical (with the conductance parameter behaving similarly to a riverbed conductance) the drain conductance for Hume mine workings is set to 0.05 m²/day. This also assumes similar stress distributions around mine openings for the existing Berrima and proposed Hume workings. This parameter is the subject of a sensitivity analysis (see section 5.2.2).

The starting hydraulic head field for predictive simulations is the modelled hydraulic head distribution of 27 August 2015, obtained from the calibration model. Proposed mining comprises the main change to the calibration model to create the predictive model; implementation is discussed below.

5.2. Pumping from Hume-owned bores

There are several Hume-owned bores which will be used during mining. These bores are listed in Table 5. The total volume of entitlement that is expected to be available for these bores is 962 ML/year. In predictive simulations, allocations for these bores are used for mining, with farming activities utilising any unused allocation. The predictive scenario pumping schedule for these bores is as follows:

- GW108194 and GW108195 are never pumped.
- The remaining five bores are pumped at full annual entitlement, less the volume required to cover total mine take (inflow to the sump and inflow to the void), while mine take is less than the entitlement.
- The pumped water is used first for water balance deficit satisfaction, then for irrigation. The pumped amount reduces as mine take increases, and is extinguished when mine take reaches 962 ML/year.
- When mine take is higher than the total Hume entitlement, bores are not pumped.

Table 5. Private bores passing to Hume ownership prior to mining.

Bore Number	Easting (mMGA)	Northing (mMGA)	Licence Number	Allocation (ML/year)	Licensed Purpose	Use during mining
GW053331	251462	6177338	10CA111696	488	Domestic / stock / irrigation	Pumping at maximum licensed rate, except when allocation is applied to mine inflow.
GW031686	251953	6178061				
GW059306	252123	6178404				
GW057908	250955	6176276	10CA111712	179	Domestic / stock / irrigation	
GW106491	249802	6173568	10CA112150	100	Irrigation	
Assumed future purchase				75	To be confirmed	
GW108195	250939	6172001	10CA112196	120	Irrigation	No Pumping
GW108194	251005	6172692				
GW025588	252124	6178343	10WA109649	N/A	Stock	Minor pumping
GW031684	253137	6178647	10WA109694	N/A	Domestic	
GW031685	252179	6178221	10WA109707	N/A	Domestic	
GW031687	252013	6178679	10WA109708	N/A	Domestic	
GW109084	250446	6170161	10WA111035	N/A	Stock / domestic	

5.2.1. Mine water balance

Calculation of an approximate mine water balance was required for the predictive simulation. The mine water balance deficit is satisfied by

- Pumping from Hume bores; and /or
- Withdrawal of water from recovering mine voids.

Pumping from Hume bores is available only in early years, since their allocation is required to cover increasing mine take as mining progresses.

Changes in bore pumping (both Hume and private bores) and withdrawal from recovering voids caused changes in mine inflows and therefore changes in the water balance deficit and mine take amounts. This therefore required an iterative simulation process.

Table 6 lists the components comprising mine water inputs and demands, and the resulting deficit, using results from the final simulation run (further discussed below in the results section).

Table 6. Mine water inputs and demands (using optimised results).

Mining Year	IN (ML/year)		OUT (ML/year)								Net Water Balance (ML/year)
	Ground runoff + pond rain- on less pond evaporation ^A	Ground- water Inflow to mine sump	Net CHPP process water demand ^B	Tailings makeup water demand ^D	Product coal handling demand ^C	ROM coal stockpile demand ^C	Underground Operations		MIA demand ^C	Bathhouse, crib rooms, etc ^B	
							ROM coal added water ^D	Ventilation loss ^D			
1	125	127	6	0	110	28.1	13	30	5	14	46
2	125	181	27	166	110	28.5	58	49	16	14	-162
3	125	282	47	257	111	28.7	96	49	20	14	-216
4	125	326	54	220	112	29.5	86	49	36	14	-150
5	125	331	81	296	113	29.8	96	49	41	14	-264
6	125	332	94	355	112	29.5	105	49	39	14	-341
7	125	595	81	367	112	29.6	107	49	43	14	-83
8	125	373	58	392	113	29.7	107	49	43	14	-308
9	125	434	59	382	113	29.7	113	49	44	14	-245
10	125	389	65	261	113	29.8	98	49	46	14	-162
11	125	428	60	284	113	30	93	49	46	14	-135
12	125	457	69	283	113	29.9	100	49	44	14	-120
13	125	492	77	364	113	29.9	112	49	46	14	-188
14	125	409	75	471	113	29.7	112	49	45	14	-375
15	125	425	71	553	112	29.6	103	49	42	14	-424
16	125	489	65	310	112	29.6	88	49	41	14	-95
17	125	985	76	293	113	29.8	105	49	44	14	386
18	125	792	47	254	112	29.5	87	49	38	14	287
19	125	513	24	110	111	28.8	39	49	20	14	242

A. Long-term runoff coefficient 0.2. Average rainfall 0.957 m/year. Ground: area 735110 m²; net accession 0.191 m/year. Water: area: 202900 m²; net accession -0.078 m/year.

B. Specified by Hume.

C. Parsons Brinckerhoff. 2015. Hume Coal Project - Stage 1 (Preliminary) Water Balance Report. Report 2200538A-WAT-REP-001 Rev2, prepared for Hume Coal. September.

D. "HUM1652-373 Water Balance Spreadsheet mdb060516.xlsx" received 7 May 2016 from Palaris.

Withdrawal from recovering voids is undertaken only when bulkheads are established at the entries to the respective panels. Specific voids were targeted, comprising panels sealed during mining years 3 to 7, as follows:

- Panels W6 to W8.
- Panels W9 and W10.
- Panels W11 to W13.
- Panels W14 to W18.

Deficits and mine take beyond year 7 were satisfied by withdrawal from panels W14 to W18.

Initial withdrawal from voids would be carried out by pumping water from behind the bulkhead (through pipes and valves in the bulkheads, or from bores penetrating the voids and sealed throughout overburden media). Once panels W14 to W18 are sealed, withdrawal from them would be undertaken using permanent bores penetrating those voids and sealed throughout overburden media.

5.3. Proposed mining

Mining occurs for a period of 19 years (nominally 2021 to 2039 inclusive). Approximately 50 Mt will be mined. Table 7 lists the yearly mining schedule and other information discussed below.

Mining advance is simulated by activation of drains when a part of the seam is mined. The drain elevation is set to 0.1 m above the mined floor level. The drain condition is imposed in any layer intersected by the drained zone above a panel or mine opening. The model simulates development of main headings and panel gate roads prior to secondary extraction. Figure 5.1 illustrates the typical progress of mining for the first workings method. The majority of changes in media hydraulic properties occur in the drained zone, but since this zone is maintained in a dewatered state, these changes do not significantly impact the functioning of the model. Changes in media properties above the drained zone are considered negligible for non-caving methods, and the overall vertical K field between ground surface and the top of the relaxed zone does not change.

Figure 5.2 illustrates the adopted heights of desaturation with respect to model layering.

Table 7. Yearly mined volume and co-disposed tailings emplaced.

Calendar Year	Mining Year	Run-of-Mine Coal (Mt)	Mined Volume (m ³)	Co-Disposed Tailings Emplaced (m ³)
2021	1	0.38	247980	0
2022	2	1.69	1102692	345471
2023	3	2.82	1839725	534062
2024	4	2.54	1665325	456877
2025	5	2.82	1841464	613792
2026	6	3.08	1994056	737812
2027	7	3.15	2045160	762305
2028	8	3.16	2040342	813945
2029	9	3.31	2154903	794062
2030	10	2.87	1888687	542602
2031	11	2.73	1772364	589989
2032	12	2.95	1915615	587177
2033	13	3.28	2132458	756667
2034	14	3.29	2102426	978965
2035	15	3.04	1853594	1148742
2036	16	2.59	1671060	644259
2037	17	3.08	2013607	609421
2038	18	2.55	1640445	526792
2039	19	1.14	743896	227761
2040				75316
TOTAL		50.48	32665796	11746020
Total co-disposed tailings volume as a proportion of total mined volume				0.36

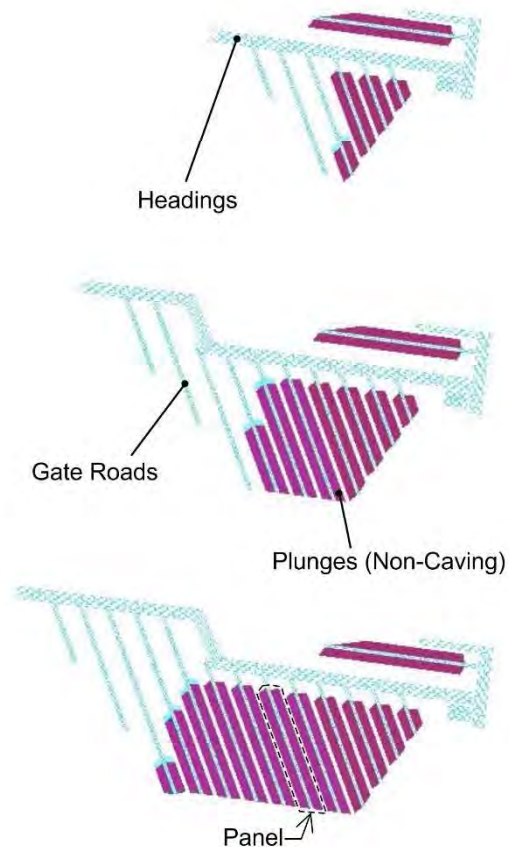


Figure 5.1. Evolution of headings and workings for the Pine Feather method over three instants in time (time moves forward from top to bottom).

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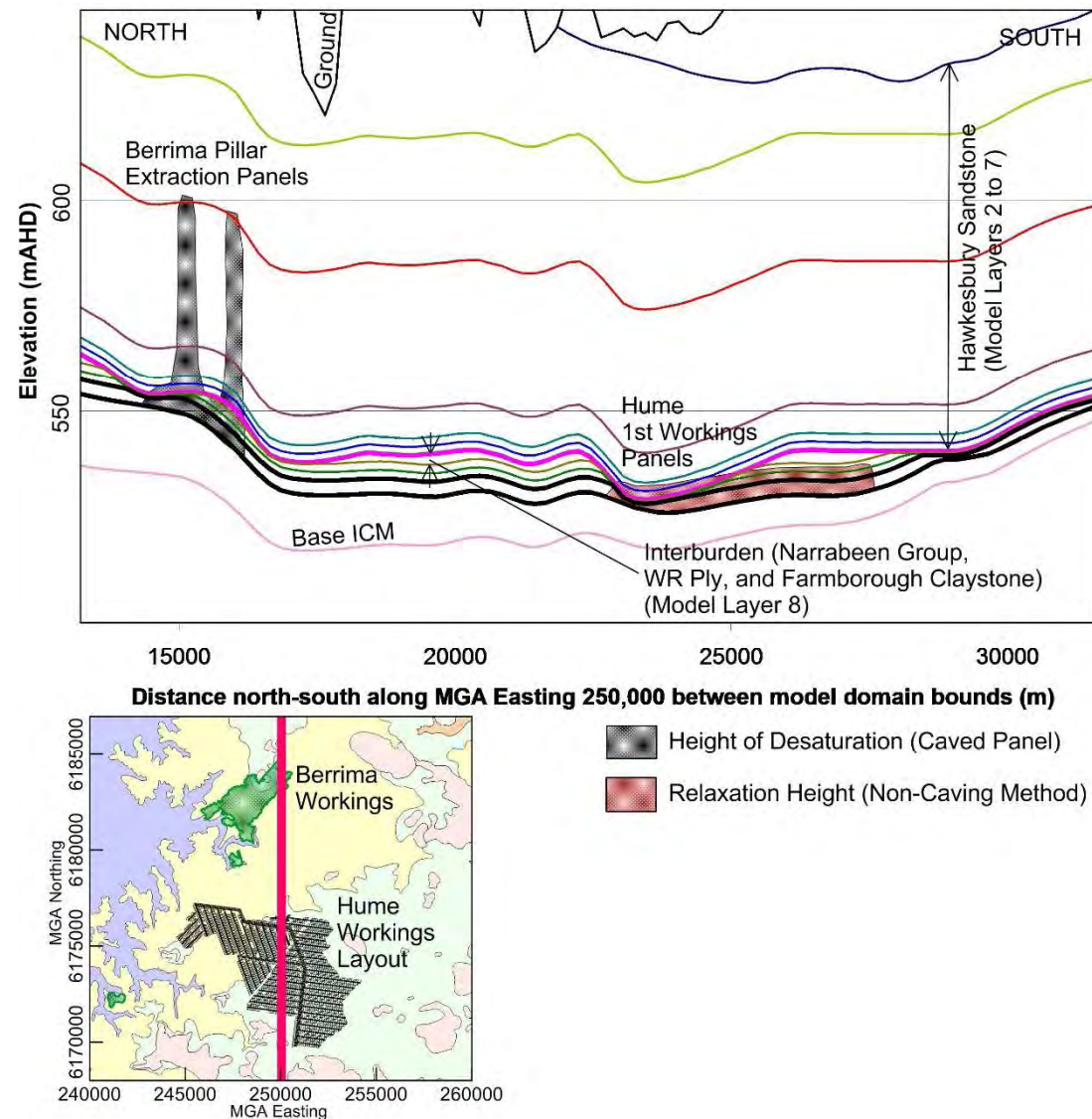


Figure 5.2. Interrelationship between model layering and adopted heights of desaturation above workings types.

5.3.1. Mitigation measures

The following three groundwater mitigation measures for the Hume mine were simulated:

- Sealing individual panels as they are mined, using bulkheads rated to withstand equilibrated hydraulic heads. Bulkheads are water-tight seals placed in panel gate roads at their juncture with main headings, when the panel is complete. They are also placed at the start of main headings when the headings are no longer required.
- Backfilling of the mined void with co-disposed tailings. In its final state (following extraction of decanted water) it is non-draining (it neither accepts nor releases water, and is inert with respect to groundwater fluxes). The decanted water is not included in co-disposed tailings volumes used in numerical simulation.
- Injection of mine water back into the void through the bulkheads, should excess water be available. Bulkheads will be constructed to provide a seal capable of withstanding the applied water pressures at post-mining equilibration of the hydraulic head field. Injection would be carried out through access pipes built into the bulkheads.

These measures operate during mining. Mine water balance calculations undertaken during iterative predictive simulation indicate that negligible water was available for bulkhead injection.

Panels are sealed about one week after completion. Co-disposal of tailings begins prior to this, following extraction in plunges; it lags the workings area by about 200 m. Co-disposed tailings emplacement is estimated to fill approximately 36% of the total mine void space. Main headings are sealed after the block of panels serviced by them is completed.

During mining, active void dewatering is not undertaken where water pools downdip of the workings area. Figure 5.3 conceptualises the fate of groundwater inflow to the mine void depending on the direction of mining with respect to the dip of a panel. Appendix C presents a plan of estimated inflow areas where pumping will not be required, based on mined seam structure contours and mine layout. Inflow to these zones contributes to void refilling. The mining rate is faster than the encroachment of the beach (formed by the mine pool) in these situations.

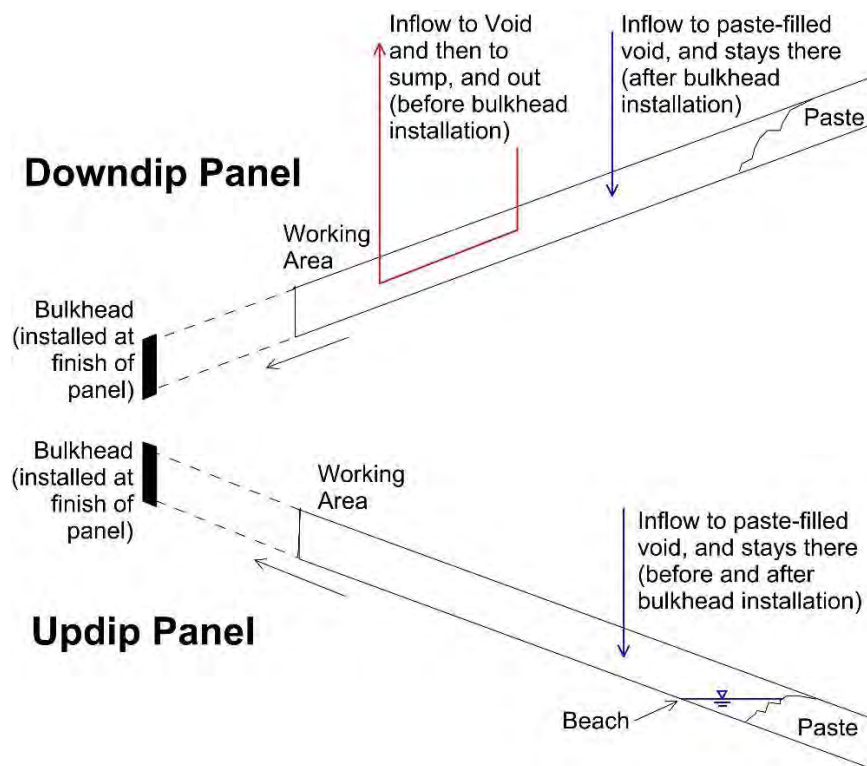


Figure 5.3. Conceptualisation of the fate of groundwater inflow to the workings, depending on panel dip with respect to mining direction.

Model implementation

Model implementation of the mitigation measures and post-mining water level recovery is carried out in a simplified way to reduce uncertainties.

During mining, drainage into the mined void is carried out using the drain mechanism (see above). To simulate the mitigation measures, the drain cells for a panel are active only for the time required for the total drained water to be equivalent in volume to the remaining void of that panel after injection behind the bulkheads and co-disposed tailings emplacement. The remaining void is calculated from a-priori schedules of injection behind bulkheads and co-disposed tailings emplacement (listed in Table 7). Predictive simulation was undertaken in an iterative fashion until the modelled total water exiting the drains for a panel was within 1% of the remaining mined volume for that panel (that is, with co-disposed tailings emplacement and injection volumes removed), and taking account of water withdrawn to satisfy water deficits. This methodology is illustrated in Figure 5.4.

This approximation circumvents the difficulty inherent in using a Darcian flow algorithm (flow in a resistive medium by the action of a potential energy field) to simulate a void that fills by hydrodynamic processes. Since the vast majority of the remaining mined volume is present in the roadways (rather than the roof), and the K field above the drained zone undergoes negligible change, and H penetrates only 2 m into the roof, the approximation negligibly impacts the head differential applied to the drained zone during recovery, and negligibly impacts the post-mining hydraulic head field above the relaxed zone (see Figure 5.4). The post-mining storage capacity in the model in the void zone is less than 1% of the actual storage capacity, which results in the void zone being filled quasi-instantaneously relative to the time-scale of recovery, and negligibly impacts recovery times. The lateral hydraulic head gradient in the mined seam is also small in the fully recovered state, as it would be in the actual state.

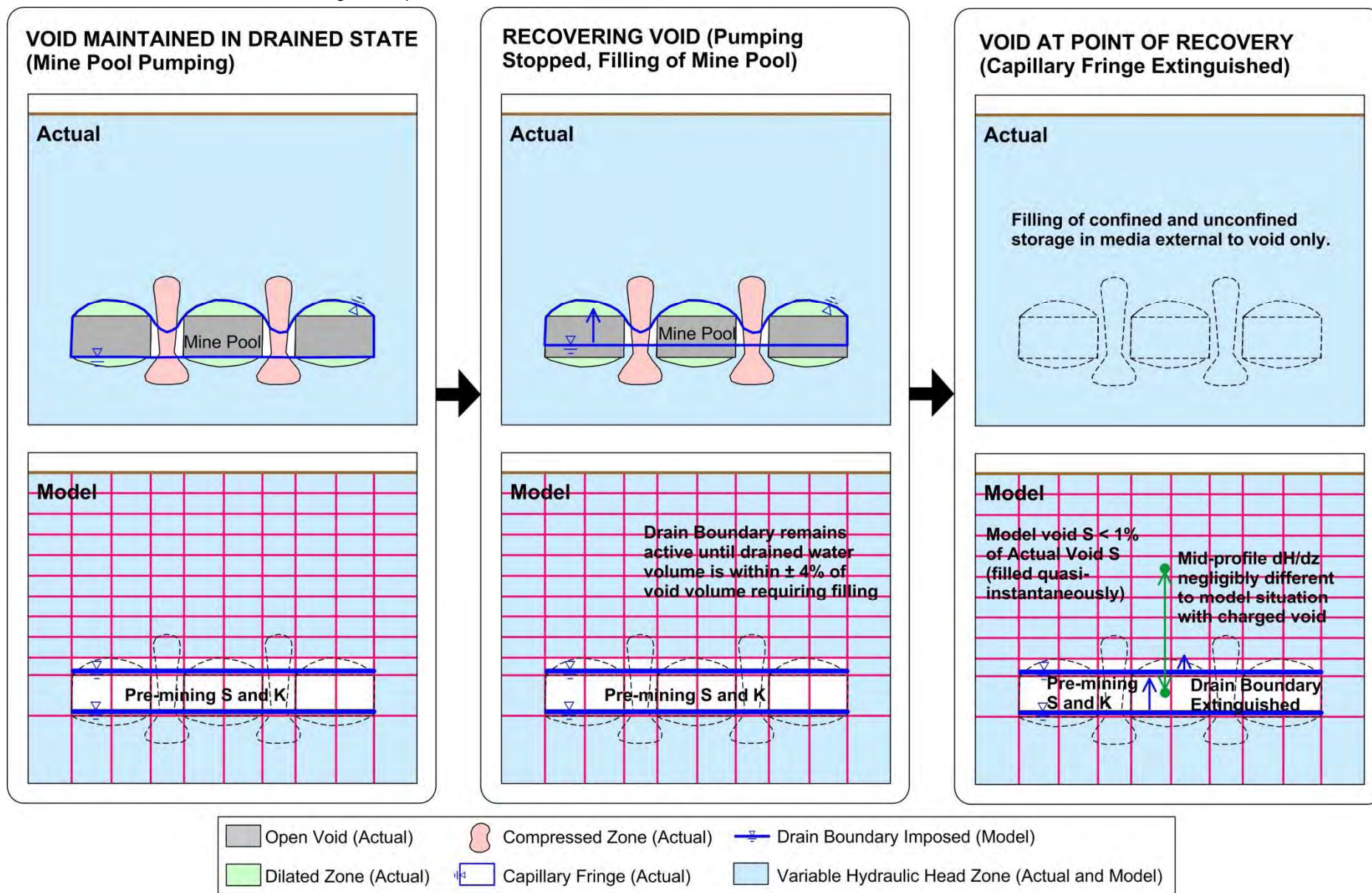


Figure 5.4. Methodology used in the numerical model to simulate mine drainage and post-mining recovery.

5.3.2. Modelled scenarios

Predictive simulation was undertaken for a period of 100 years for the most probable future scenario. Predictive model simulation years and mining schedule years are equivalent. The future scenario comprises:

- Use of the first workings mining method and layout.
- Average rainfall.
- Co-disposed tailings emplacement filling 36% of the mined void.

Three sensitivity simulations were also undertaken. Modelled scenarios are listed in Table 8. Run 1 comprises the simulation used for predictive impact assessment.

The sensitivity runs were undertaken for a scenario excluding bulkhead injection, considered to be more sensitive to the changes specified in Table 8.

Table 8. Simulated future scenarios

Run Identifier	Details	Purpose
1	First workings method BASE CASE Co-disposed tailings void filling proportion 36%. Injection behind panel bulkheads active. Average rainfall.	Impact Assessment
Null	Identical to Run 1 except no Hume mining.	Differential Impact Calculation
S1	Relaxation Height: 2 m and 4 m.	Sensitivity Analysis
S2	Kv: Calibrated and x 3 down the profile, for layers 1 to 5 (WG and HAW)	
S3	Hume Mine Drain Conductance: 0.05 and 0.1 m ² /day.	

6. Predictive results

9 iterations were required to reduce the total water balance error for the mine, and its interaction with the mine take, to 0.009 (0.9%). The mine water balance is in deficit for 15 of the 19 mining years (years 2 to 16 inclusive). Negligible amounts were available for reinjection behind bulkheads.

6.1. Inflows to mine workings

Figure 6.1 shows the modelled inflows to the mine workings. Inflow to the active mine area (the sump) ceases after year 19, when pumping within the mine ceases. Inflow behind the sealed bulkheads (mine void) ceases at the end of year 22 following the start of mining (3 years after cessation of mining), beyond which groundwater recharge is consumed by media storage around the void (recovery of elastic storage and recovery at the water table). The time of overall maximum impact for groundwater storage release and drawdowns (discussed below) is at approximately 17 years since the start of mining.

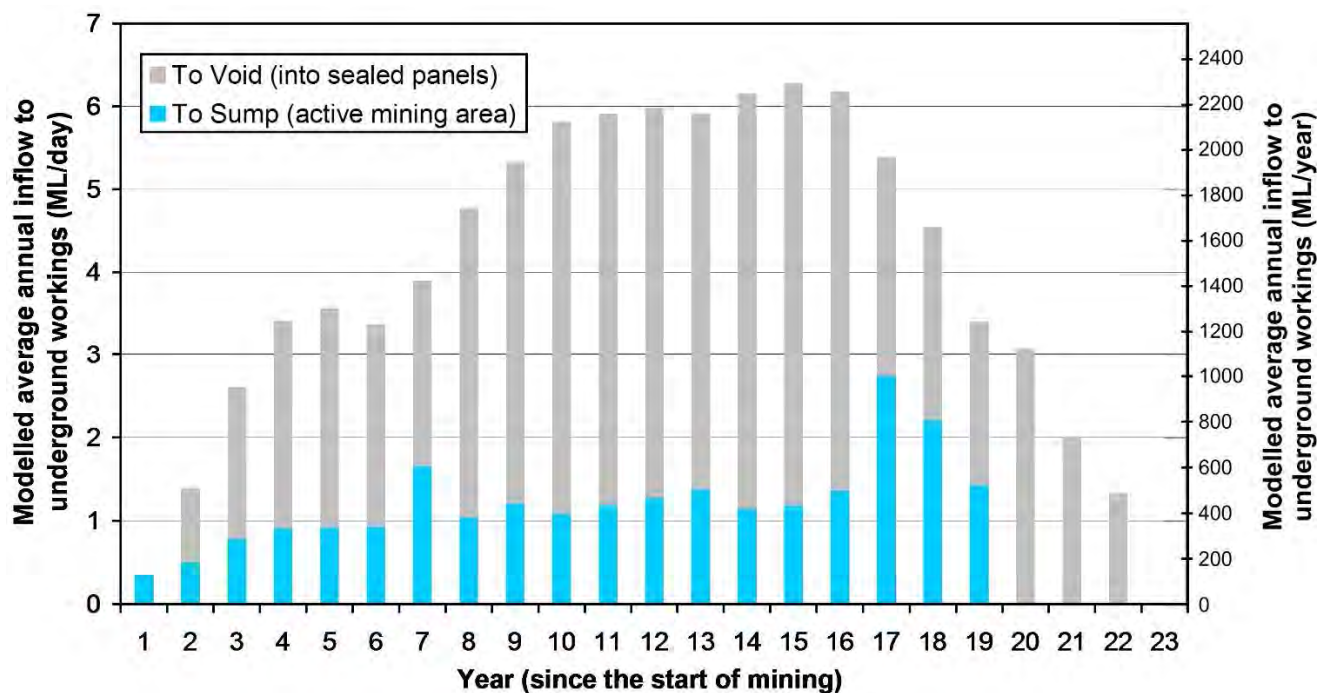


Figure 6.1. Modelled inflows to the mine void for the active mining case.

Table 9 lists maximum inflows and total accounts.

Table 9. Maximum flow rates and total accounts during the period of active stress induced by the mine.

Maximum Rates over the Period of Active Stress*		
Mine Inflow Component	GL/year	ML/day
Sump	1.00	2.74
Void	1.86	5.10
Total	2.29	6.28
Total Accounts over the Period of Active Stress		
Component	Total (GL)	
Mined Volume	32.7	
Inflow to Mine Void (Modelled) (3.3 GL pumped out to satisfy mine water demand deficit)	24.3	
Co-disposed tailings Volume (36% of Mined Volume)	11.7	
Injected Volume (Modelled)	nil	
Inflow To Mine Sump (Modelled)	8.4	

* The time to reach maximum is not necessarily coincident for each item.

6.2. Flow budget

The modelled average flow budget for the domain over the period of mine inflow (mining, and simulation, years 1 to 22 inclusive) is listed in Table 10 for the case where Hume mining is active. The flow budget discrepancy is considered reasonable. The increased leakage from reservoirs from 2015 (0.2 ML/day) is mostly due to private pumping.

Table 10. Modelled average flow budget over the period of mine inflow (mining and simulation years 1 to 22 inclusive) for the case of active Hume mining.

IN (ML/day)		OUT (ML/day)	
Rainfall Recharge	34.9	Baseflow to Wingecarribee River	10.2
Release from Media Storage	7.4	Baseflow to other Rivers and Creeks	10.9
Leakage from Reservoirs	2.4	Berrima Mine Inflow (to river)	2.5
Leakage from Medway Dam	0.6	Loch Catherine Mine Inflow (to river)	0.4
		Inflow to Other Mines (to rivers)	0.6
		Private Pumping	11.0
		Hume Mine Inflow	2.6
		Evapotranspiration	10.4
TOTAL	45.4	TOTAL	48.6
Discrepancy: -3.2 ML/day (-6.8 %)			

Comparison to the null case indicates that at 17 years since the start of mining, baseflow interception of overlying streams makes up approximately 23% of the total inflow.

The water balance deficit is satisfied by pumping from the following voids:

- Panels W6 to W8: 6% of deficit.
- Panels W9 and W10: 17% of deficit.

- Panels W11 to W13: 25% of deficit.
- Panels W14 to W18: 52% of deficit.

The modelled average flow budget for the domain over simulation years 1 to 22 inclusive for the null case (Hume mining is not active) is listed in Table 11. The flow budget discrepancy is considered reasonable.

Table 11. Modelled average flow budget over simulation years 1 to 22 inclusive for the null case (Hume mining is inactive).

IN (ML/day)		OUT (ML/day)	
Rainfall Recharge	34.9	Baseflow to Wingecarribee River	9.0
Release from Media Storage	6.4	Baseflow to other Rivers and Creeks	11.2
Leakage from Reservoirs	2.4	Berrima Mine Inflow (to river)	2.5
Leakage from Medway Dam	0.5	Loch Catherine Mine Inflow (to river)	0.4
		Inflow to Other Mines (to rivers)	0.6
		Private Pumping	13.0
		Hume Mine Inflow	0.0
		Evapotranspiration	10.3
TOTAL	44.3	TOTAL	47.0
Discrepancy: -2.8 ML/day (-6.0 %)			

6.3. Drawdown

Changes to the hydraulic head field from Hume mining operations are discussed as the following:

- Total drawdown (cumulative; includes Hume and other users). This is the drawdown from the beginning of the simulation period, for the scenario where all stresses in the model are operating, including the Hume mining operation, the draining mine void at Berrima, and private pumping. This is the active Hume mining scenario. The total drawdown is thus the cumulative drawdown due to all stresses.
- Differential drawdown (Hume only; excludes other users). This drawdown is calculated as the difference between drawdowns from the active Hume mining scenario (which gives the total drawdown) and the null scenario where the Hume operation is inactive (giving a null case drawdown). The differential drawdown is thus that drawdown due only to the Hume operation.

6.3.1. Temporal drawdown

Apart from private bores (discussed below), temporal drawdown has been obtained at the following 16 virtual monitoring piezometer locations (shown in Figure 6.2):

- Locations G1 to G11: Drawdown at potential groundwater dependent ecosystem (GDE) areas.
- Locations A1 to A5: Drawdown over the Hume mine footprint, and along a line extending away from it in a southeasterly direction.

Actual piezometers are not used since they are not precisely located at required horizons, and many will be eliminated by mining with time. For virtual piezometer locations, the uppermost virtual piezometer provides the modelled water table elevation, since it is located in the layer where the water table resides (the model provides a single hydraulic head value for a single layer).

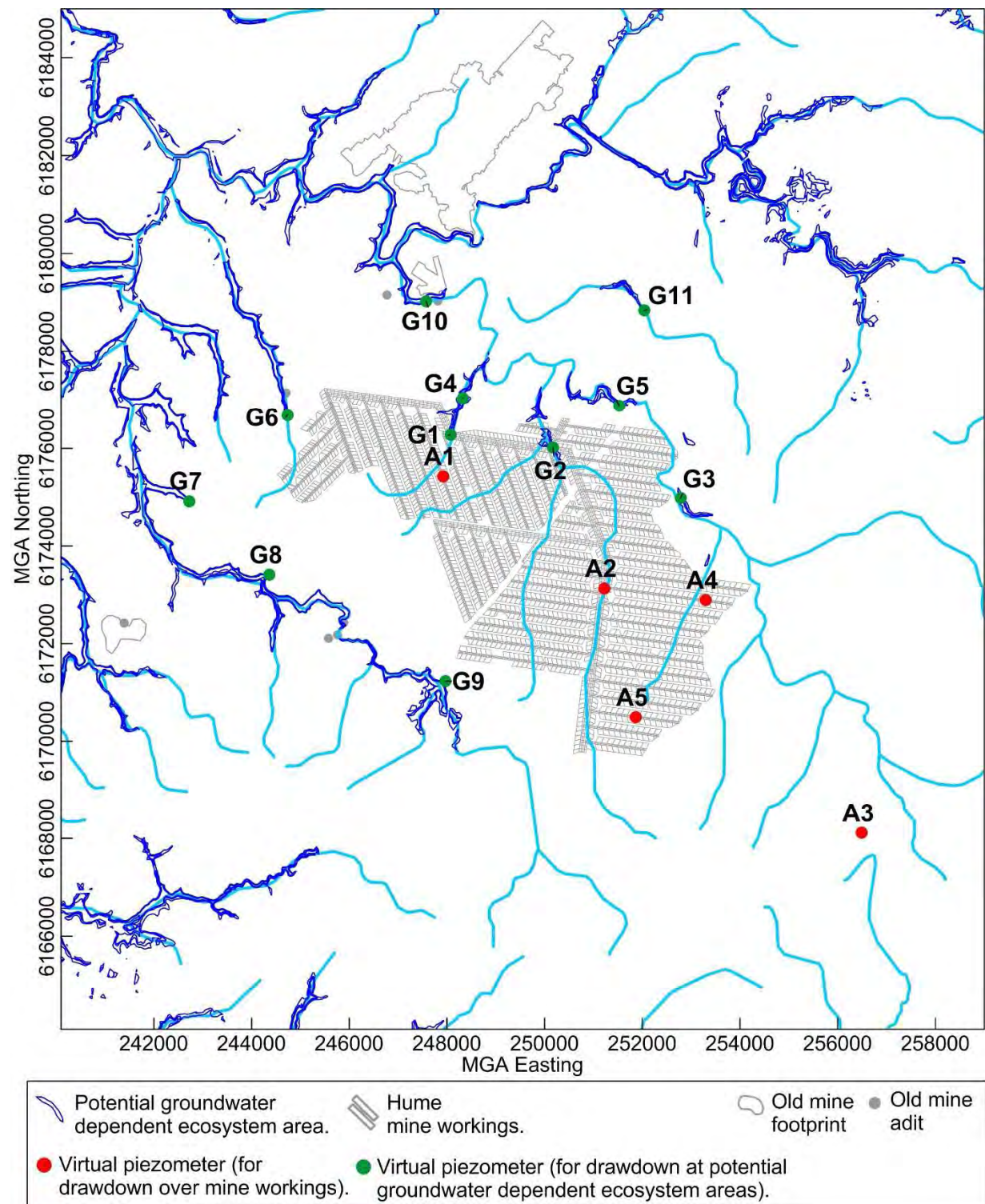


Figure 6.2. Locations of virtual piezometers used for obtaining hydraulic head and drawdown information at specific locations.

Figure 6.3 shows the modelled differential drawdown over the main headings (piezometer nest A2) and over the southern part of the workings (piezometer nest A5), showing the vertical hydraulic head gradient that is generated by the mine in overlying strata. Virtual piezometer A2 is located over the main headings and this is the more impacted area of the mine as the mains remain open throughout mining.

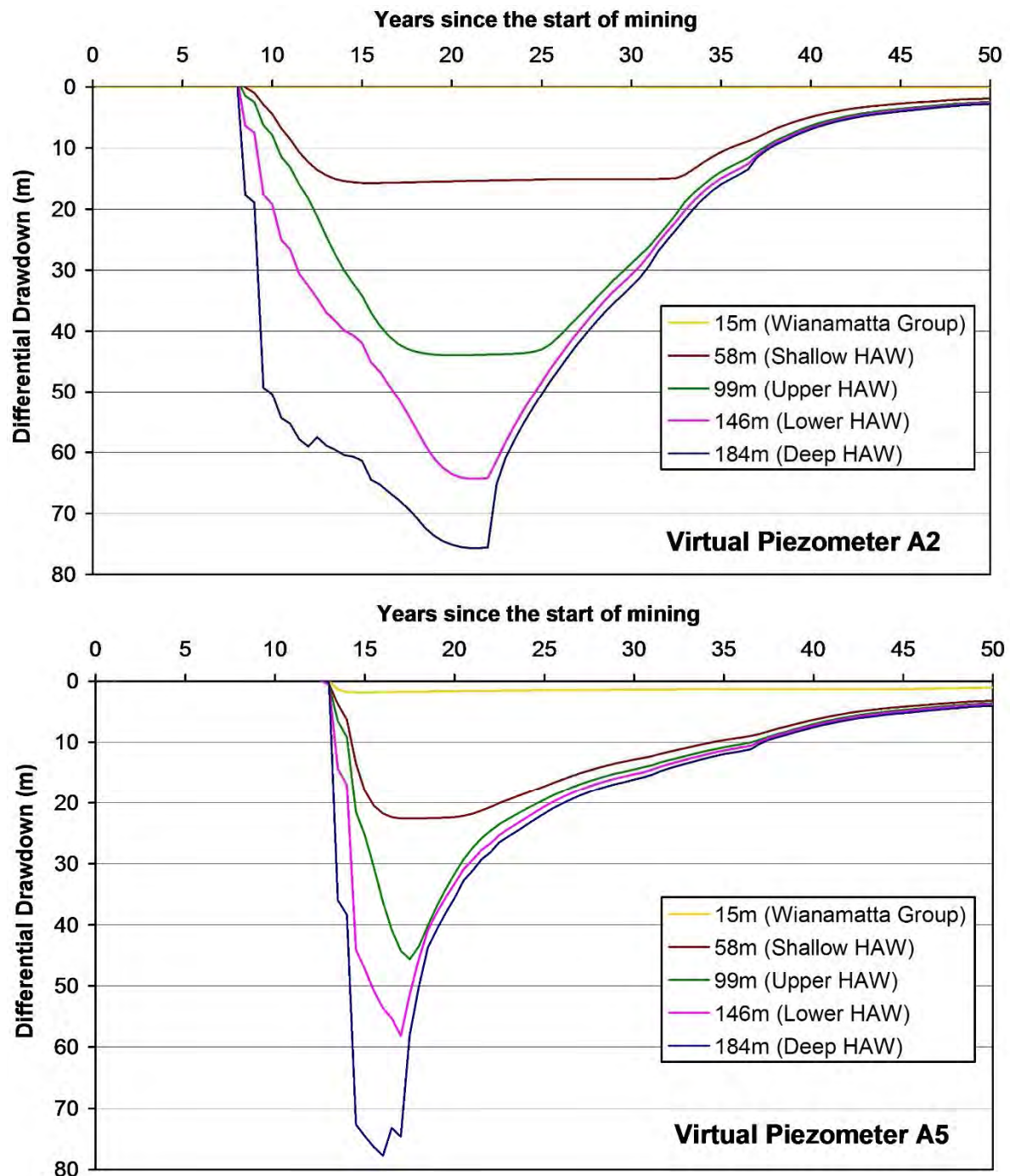


Figure 6.3. Differential drawdown at virtual piezometer nests A2 and A5.

Table 12 lists the modelled maximum total and differential drawdowns at the water table at each of the virtual piezometer nests, and the proportion of the total drawdown caused by Hume operations.

Table 12. Maximum drawdown of the water table at virtual piezometer nests.

Piezometer Nest*	Location Relative to Mine Footprint	Maximum Drawdown (m)		Proportion of Total Drawdown caused by Hume operations (%)
		Total	Differential	
A1	Inside	25.28	22.84	90
A2	Inside	0.22	0.02	11
A3	Outside	8.05	0.88	11
A4	Inside	9.02	5.35	59
A5	Inside	6.06	1.82	30
G1	Inside	23.21	20.95	90
G2	Inside	0.18	0.00	2
G3	Inside	5.02	2.51	50
G4	Outside	20.31	18.14	89
G5	Outside	0.31	0.01	2
G6	Outside	6.63	3.57	54
G7	Outside	5.00	1.44	29
G8	Outside	4.61	1.50	33
G9	Outside	7.09	4.89	69

* Nil differential drawdown calculated at G10 and G11 at the water table.

Nil differential drawdown was calculated at G10 and G11 at the water table. The maximum differential drawdown of the water table reaches to 25.3 m (at A1) at locations inside the mine footprint and to 20.3 m (at G4) at locations outside the mine footprint. Hume operations account for the majority of the total drawdown inside the mine footprint.

Maximum total drawdown of the water table greater than 2 m, of which a component is due to Hume mining, occurs at all virtual piezometer locations except A2, G2, G5, G10, and G11. Significant drawdown of the water table at potential GDE locations has the potential to affect groundwater dependent ecosystems that may be present.

Appendix D provides total and differential drawdowns for the water table and the base of the Hawkesbury Sandstone for the virtual piezometers. The modelled differential drawdown at G10 and G11 was nil for all horizons.

Figure 6.4 shows modelled differential drawdown of the water table at the virtual piezometer nests. Drawdowns follow relatively complex trends that result from a combination of mitigation measures active during mining, and the ground surface elevation with respect to lithological horizon structure contours. Hydrographs indicate that the overall time instant of maximum impact to the groundwater system (in conjunction with drainage to the mine void; see Figure 6.1) is at about 17 years since the start of mining (2 years before the end of mining).

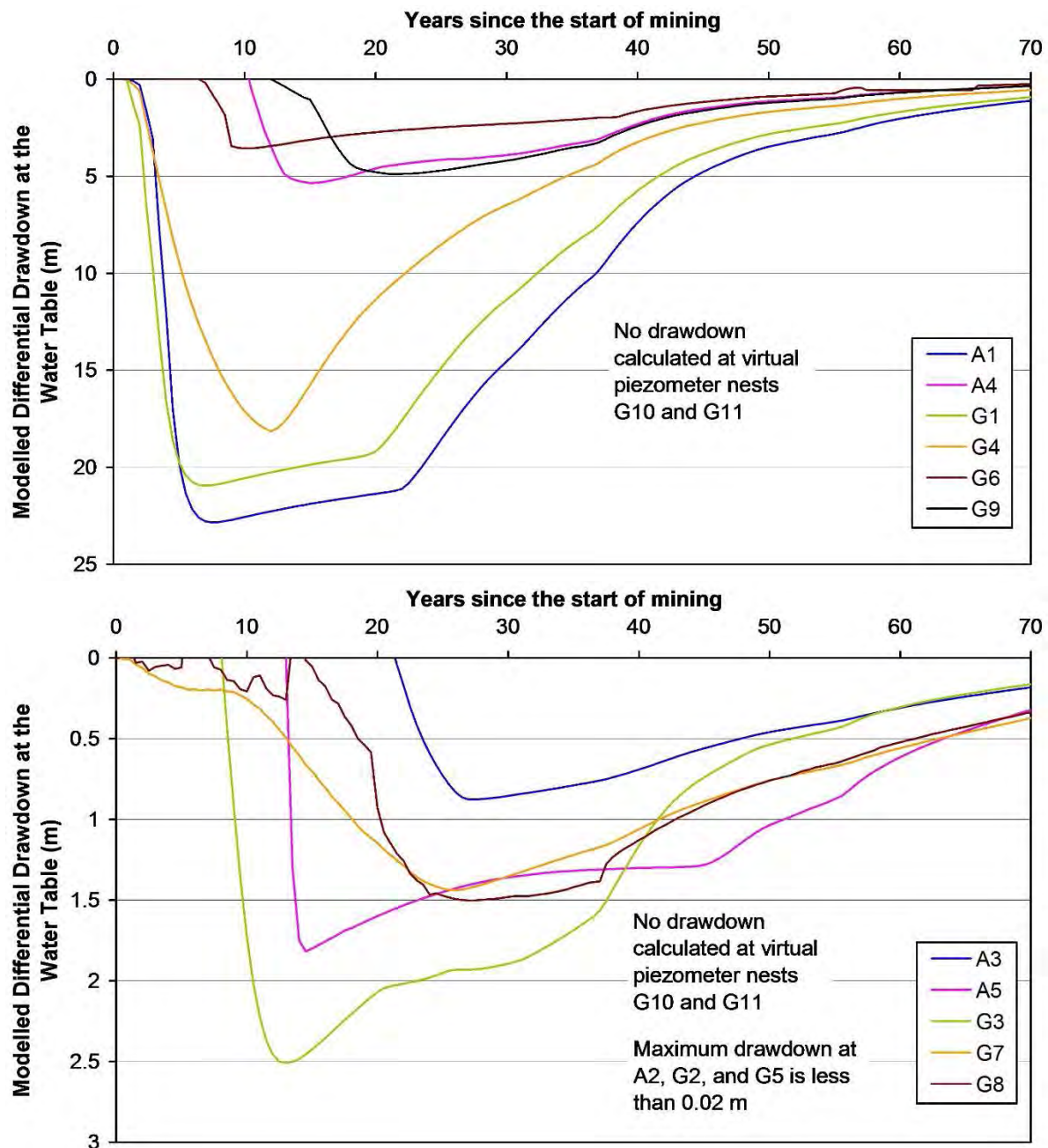


Figure 6.4. Differential drawdown of the water table at virtual piezometer nests.

Recovery time

Recovery of drawdown is presented for differential drawdowns. Total drawdown does not recover to less than 2 m at several virtual locations, due to the effects of private pumping and continued drainage at the Berrima void.

Figure 6.5 shows the duration of time for which differential drawdown of the water table is 2 m or greater, at the virtual piezometer locations. This situation occurs only at seven of the 16 virtual piezometer locations.

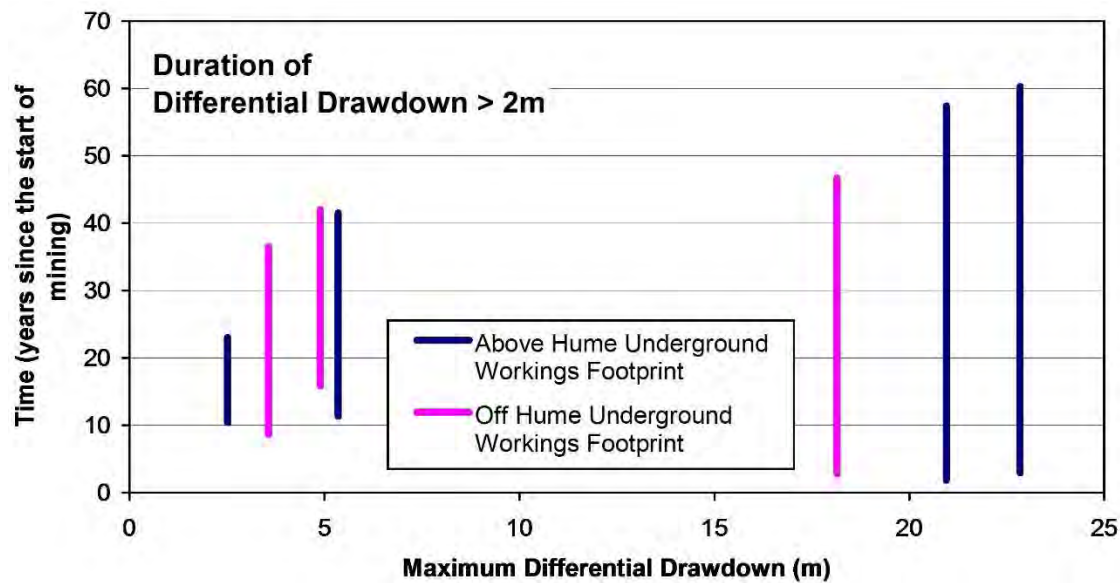


Figure 6.5. Duration of time for which differential drawdown of the water table is 2 m or greater, at virtual piezometer locations.

Differential drawdowns greater than 2 m occur for longer times over the workings footprint. The duration varies between about 15 years and 60 years. Recovery of the water table over most of the area, to 2 m differential drawdown, is largely complete within about 60 years since the start of mining.

6.3.2. Spatial drawdown

Water table

Figures 6.6 and 6.7 show the differential drawdown of the water table at 17 and 30 years since the start of mining, respectively. Contours of total drawdown of the water table for these times are shown in Appendix E.

Contours for differential drawdown of the water table form a complex pattern that results from a combination of mitigation measures active during mining, and the ground surface elevation with respect to lithological horizon structure contours. At 17 years, a maximum differential drawdown of about 45 m occurs in a small localised area over the western footprint.

The drawdown extent expands to the east, due to the recharge influx at the western sandstone extremity and the effect of the regional easterly stratigraphic dip on the K field. At 17 and 30 years the 2 m differential drawdown contour extends about 2 km and 4 km respectively past the southeast corner of the mine footprint.

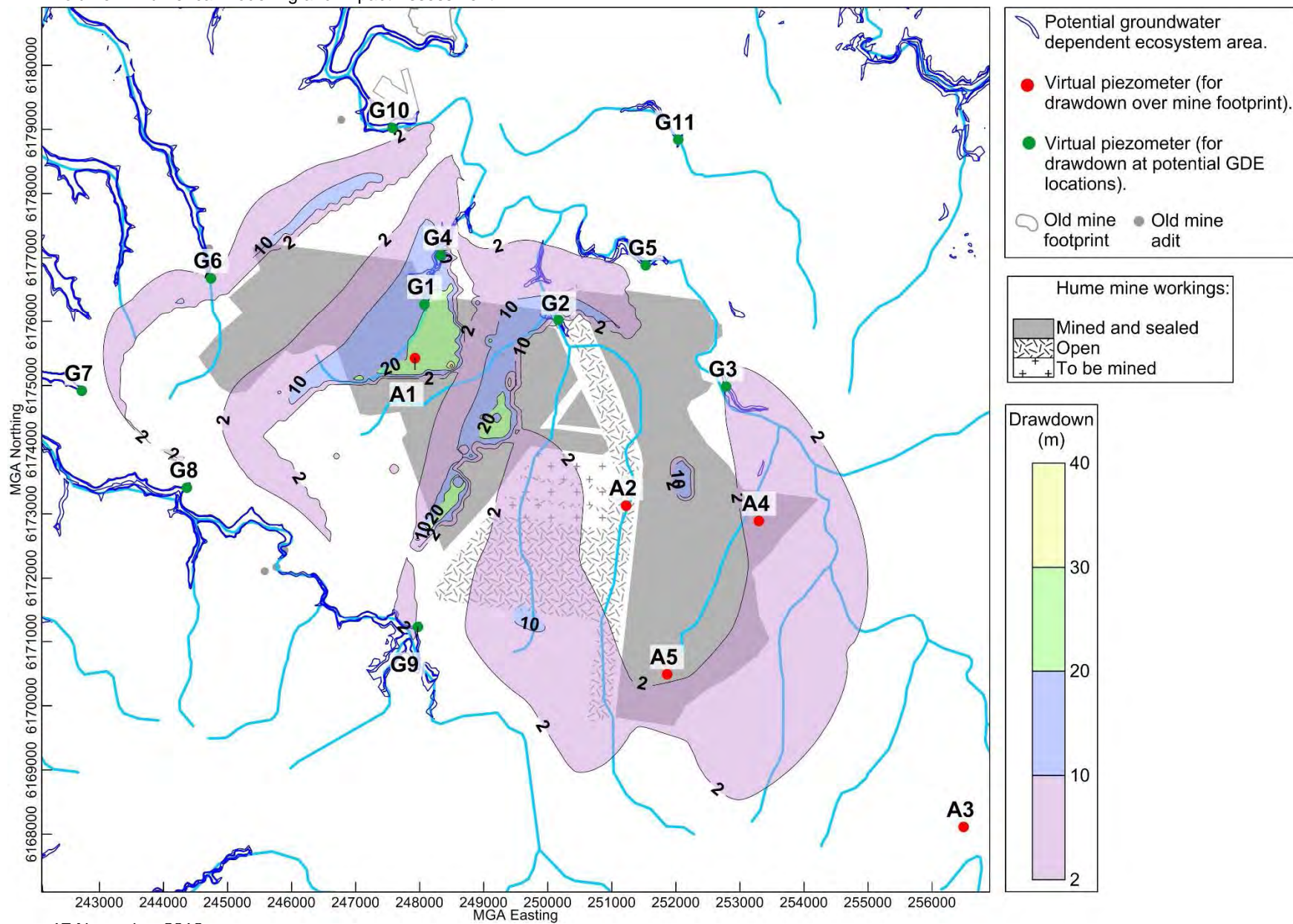


Figure 6.6.
Differential drawdown of the water table at 17 years since the start of mining.

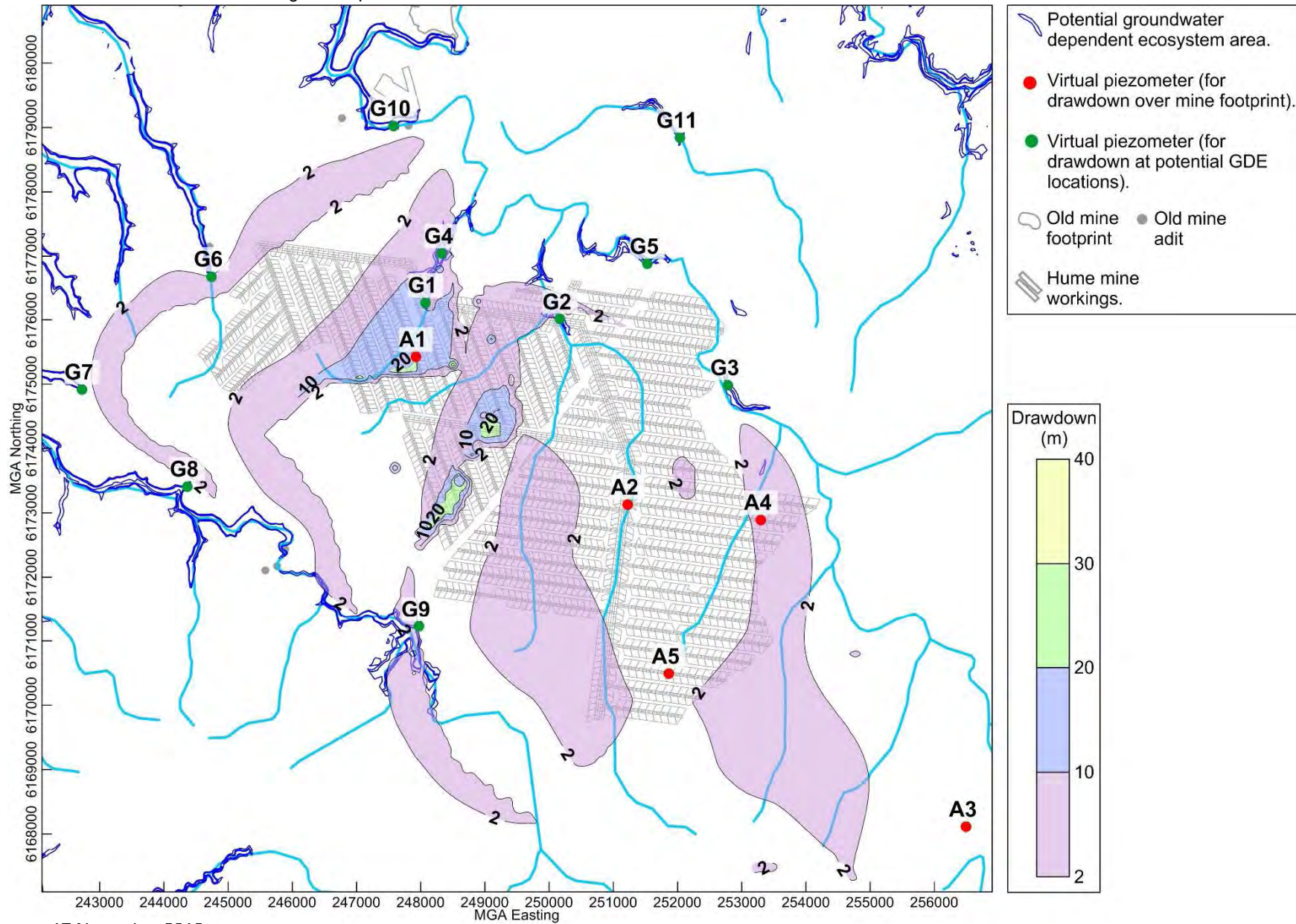


Figure 6.7.
Differential
drawdown
of the water
table at 30
years since
the start of
mining.

Cross Section

Figure 6.8 shows a north-south cross-section of modelled total head, pressure head, and total drawdown through the mine footprint. The total hydraulic head illustrates quasi-horizontal contours above the workings that indicate downward vertical hydraulic head gradients. Gradients can achieve values greater than one for short periods following emplacement of a void. The duration for gradients greater than one depends on recharge and discharge fluxes, and the hydraulic characteristics of the media. Pressure head contours illustrate decreases in pressure moving down through the profile over the workings.

Drawdown contours show the shape of the drawdown envelope, and the increase in drawdown moving down through the profile over the mine footprint. The shape of the drawdown contours is typical for depressurisation induced in a horizontally stratified resistive medium by drainage at depth.

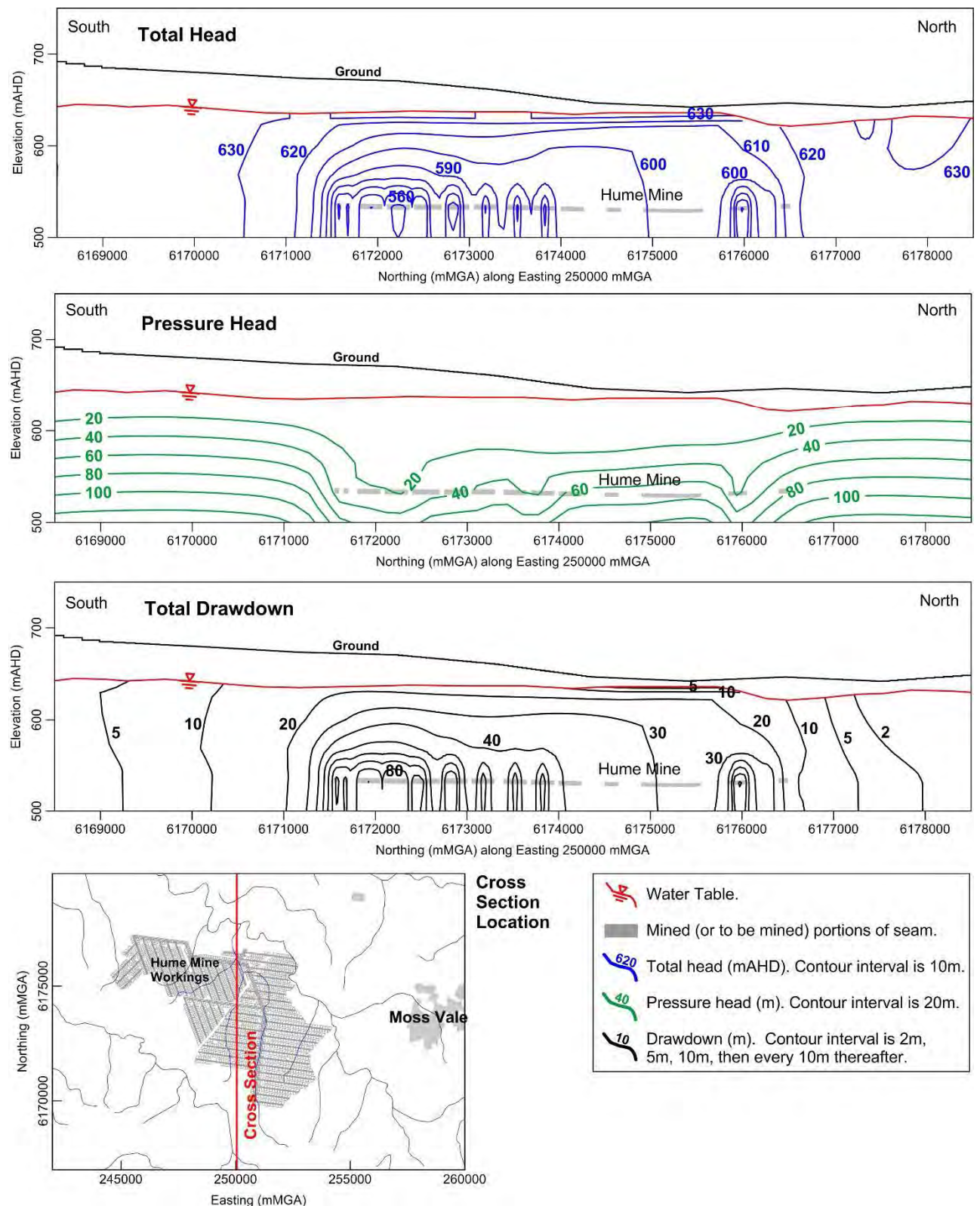


Figure 6.8. Modelled total head, pressure head, and total drawdown (depressurisation) along a north-south cross section at 17 years since the start of mining.

7. Impact assessment

7.1. Water sources

Under the AIP the NSW Government requires mines to consider how their water take may impact upon adjacent and connected water sources. The Water Sharing Plans for the Greater Metropolitan Region (DPI 2011a, 2011b), outline the delineation of both groundwater and surface water sources in this area. Table 13 lists the sources that overlie and are adjacent to the Hume area and Figure 7.1 shows the zones defining these sources.

For the assessment of surface water for the Hume project, the Lower Wingecarribee River and Medway Rivulet surface water zones have been further divided into smaller catchments.

Table 13. Water source zones and numbering adopted in the model

Source Type	Source Zone	Hosting Groundwater Source Zone
Ground-water	Nepean Management Zone 1 (NMZ1)	N/A
	Nepean Management Zone 2 (NMZ2)	
	Sydney Basin South (SBS)	
Surface Water	Upper Wingecarribee River	NMZ1
	Lower Wingecarribee River in groundwater zone NMZ1	NMZ1
	Lower Wingecarribee River in groundwater zone NMZ2	NMZ2
	Black Bobs Creek	NMZ1
	Longacre Creek	NMZ1
	Medway Rivulet Oldbury Creek Belanglo Creek Wells Creek Wells Creek Tributary	NMZ1
	Lower Wollondilly River	NMZ1
	Nattai River in groundwater zone NMZ1	NMZ1
	Nattai River in groundwater zone NMZ2	NMZ2
	Bundanoon Creek	SBS

Estimation of water drawn from streams and from media storage, within the various source zones, requires these components to be disaggregated for each groundwater source. A surface water source may straddle two or more groundwater sources, in which case the surface water source needs to be disaggregated into the relevant groundwater source areas.

In the current work, release from groundwater storage is decomposed into:

- Storage release that is normally baseflow, but is reduced by mining (referred to as intercepted baseflow).
- Storage release that is caused by mining.

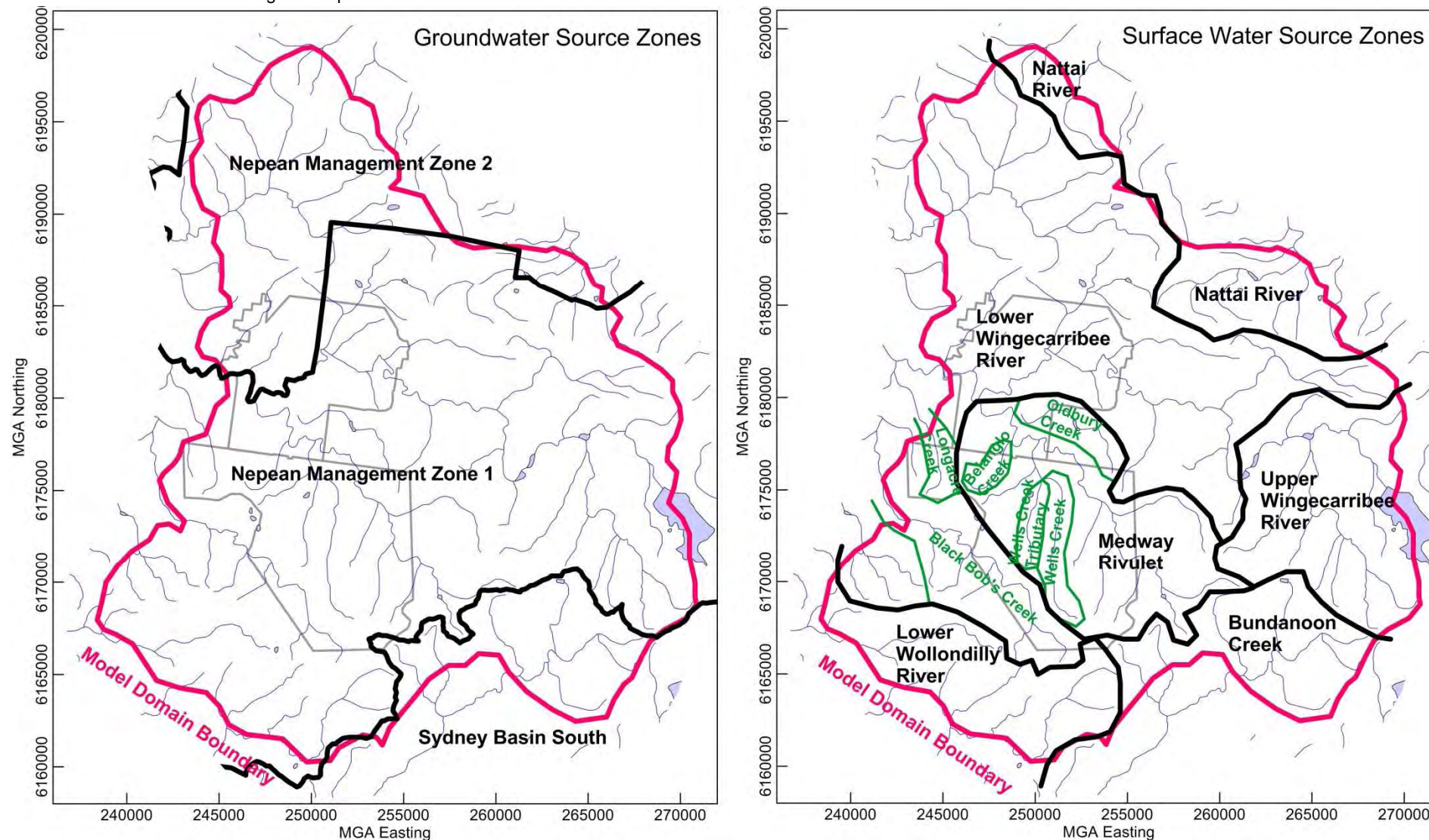


Figure 7.1. Groundwater and surface water sources and zones.

DPI (2011a) defines water of surface water sources as that water:

- occurring naturally on the surface of the ground within the boundaries of the water sources as shown on the DPI (2011a) Plan Map, and
- in rivers, lakes, estuaries and wetlands within the boundaries of these water sources as shown on the DPI (2011a) Plan Map.

This definition excludes water contained in coastal sands, any fractured rocks or porous rocks, the area below the mangrove limit, any alluvial sediments, or the Kangaroo River, Mooney Mooney Creek, and Mangrove Creek water sources.

7.1.1. Model results

No loss from the surface water body residing in the Wingecarribee River channel was calculated by the model. Model results indicate that 98% of the total inflow to the Hume mine workings is satisfied by interception of baseflow to streams, and release of groundwater storage from media. 2% of the inflow is satisfied by leakage from Medway Reservoir (a total leakage of approximately 804 ML over 22 years, or an overall average over the period of approximately 0.1 ML/day).

Intercepted baseflow and released storage are regenerated by rainfall recharge direct to the media. The loss from Medway Reservoir is regenerated by rainfall recharge direct to the media, and the portion of surface runoff from the catchment that collects and remains stationary in the reservoir. The overall modelled source / sink discrepancy is -1.3%.

Table 14 lists the maximum intercepted baseflow induced by the Hume Mine for each surface water source in the model domain. Table 15 lists the maximum flow emanating from media storage induced by the Hume Mine for each groundwater source in the model domain.

Table 14. Induced maximum intercepted baseflow for surface water sources in the model domain.

Surface Water Source	Maximum rate of baseflow interception induced by the Hume Mine (ML/day)	Time to Maximum rate (years since the start of mining)
Upper Wingecarribee River	N/A*	
Lower Wingecarribee River (whole source)	0.849	13
Lower Wingecarribee River excluding Black Bobs and Longacre Creeks.	0.800	17
Black Bobs Creek	N/A*	
Longacre Creek	0.311	13
Medway Rivulet (whole source)	0.927	11
Medway Rivulet excluding Oldbury, Belanglo, and Wells Creeks, and Wells Creek Tributary.	0.841	11
Oldbury Creek	0.002	11
Belanglo Creek	0.017	9.5
Wells Creek	0.075	1.5
Wells Creek Tributary	0.033	1.5
Lower Wollondilly River	0.050	26
Nattai River	N/A*	
Bundanoon Creek	0.024	28

* Nil baseflow interception calculated.

Table 15. Induced maximum groundwater flow losses (release from media storage) for groundwater sources in the model domain.

Groundwater Source	Maximum rate of release from groundwater storage induced by the Hume Mine* (ML/day)	Time to Maximum rate (years since the start of mining)
Nepean Management Zone 1 (NMZ1)	5.206	15
Nepean Management Zone 2 (NMZ2)	0.003	2
Sydney Basin South (SBS)	0.042	25

* Intercepted baseflow is not included (it is reported in Table 14).

Baseflow interception is a maximum for Medway Rivulet (0.9 ML/day at 11 years since the start of mining). The average total flow at flow gauge SW04 over the period of monitoring is 51.8 ML/day, with an average estimated baseflow of 3.3 ML/day. Insufficient data were available for SW04 to undertake an assessment of annual baseflow proportion versus rainfall. These functions usually have an element of curvature (see Volume 1), however a linear relation can be used for a reasonably small interval around the data collection condition. The average baseflow during average rainfall would be about 3 ML/day, about triple the maximum intercepted baseflow calculated by the model.

These results suggest the drainage channels in the Medway Rivulet catchment are likely to be able to sustain the loss in baseflow over a large range of climate conditions, without impacting other users of the Medway Rivulet water supply.

Six-monthly accounts as calculated by the model for intercepted baseflow and groundwater storage release due to Hume operations are listed in Appendix F.

7.2. Drawdown in private bores

Registered private bores within a 9 km radius of the mine footprint centroid were extracted from the NSW DPI groundwater database in December 2015. This identified 363 private bores (excluding Hume monitoring piezometers and two abandoned bores). Predictive simulation provided the extent of the 2 m differential drawdown (drawdown due only to Hume operations) contour for model layers. Private bores were selected for impact analysis according to the following criteria:

- Bores located inside the 2 m differential drawdown contour for the mined seam at 17 years, and outside the contour to the southeast. The seam is where the largest drawdowns in any hydrostratigraphic unit are developed, and the time of such drawdown in the seam is at 17 years since the start of mining.
- Bores located inside the 2 m differential drawdown contour for the water table at 17 years and outside the contour to the southeast. Inclusion of bores outside the contour takes account of the migrating drawdown of the water table following Year 17.

These criteria ensure that calculated differential drawdowns of 2 m or more are captured. The drawdown footprint generally contracts moving upward, except to the southeast where some migration in a southeasterly direction occurs (see Figure 6.6). These criteria define the potential impact zone for private bores from Hume operations. The model calculates differential drawdowns of less than 2 m outside these criteria.

117 private bores were identified as residing in the potential drawdown zone. Available bore logs suggest 116 bores are completed in Triassic and Permian media of the Sydney Basin and one is completed in basalt (GW106103). For bores that are located in the area of outcrop of the basalt body, the majority of those that are screened in basalt are located south of the major subvertical hydraulic

barrier under the basalt body (see Volume 1), where the basalt thickness is significantly greater than north of the feature.

Table 1 in Appendix G lists the private bores and relevant information as obtained from government records, or as estimated. Map 1 in Appendix G shows bore locations. Drawdown in the basalt bore was assessed using a separate model as discussed below.

The lithology log for bore GW067521 lists basalt as the intersected stratum, however it is interpreted to be in shale of the Wianamatta Group (WG) based on the following:

- The elevation of the logged basalt is grossly inconsistent with structure contours for the base of the basalt developed from nearby bores. The latter indicate termination of the basalt along a line similar to current published geology maps.
- The bore is located north of the basalt limit as shown on current geological maps.
- Dark grey to black shale of the WG is known to have been mistaken for basalt in lithology logs for other registered bores in the Sydney Basin.

The drawdown at each bore was calculated as the transmissivity-weighted average of drawdown in each model layer intersected by the bore hydraulic interval (the interval over which water in the bore communicates with the external medium).

7.2.1. Drawdown in the basalt bore

Due to the method of emplacement, basalt bodies host a palaeosol horizon at the interface with underlying media that has been significantly heat affected and may typically be highly weathered. This horizon is typically of significantly lower K than surrounding media, and usually acts to retard vertical drainage from the basalt body to underlying media. If several lava flow events comprise the basalt body, palaeosol horizons may also be dispersed throughout the basalt sequence, imparting a strong vertical anisotropy to the basalt body.

Hydraulic head observations for the basalt bodies in the Hume area indicate negligible vertical hydraulic head gradients in the basalt, suggesting the body was emplaced over a relatively short period. There is a large vertical hydraulic head gradient between the basalt bodies and underlying media, suggesting the palaeosol horizon at the base of the basalt retards vertical drainage.

To assess drawdown impacts to the private bore in basalt (GW106103) due to mining, a separate numerical model, targeting a smaller area than the main model, was developed. The conceptualisation of the system upon which the model is based is as interpreted in Coffey (2016). Use of a separate model greatly facilitates characterisation of Kv of the retarding layer underlying the basalt, which is the main parameter upon which drawdown in the basalt body depends. Appendix H provides information regarding the basalt model.

7.2.2. Model results

Drawdowns are discussed as both of the following:

- Total drawdown (cumulative; includes Hume and other users): The drawdown actually developed at the bore for the active Hume mining scenario. This is the drawdown which must be used to assess the functioning of the bore following impacts.
- Differential drawdown (Hume only; excludes other users): The drawdown caused only by Hume operations. It is calculated as the difference between a null case (all processes operating, except for Hume operations) and the active Hume mining scenario. It is used to calculate the proportion of total drawdown at a private bore that is caused by Hume operations only.

Total drawdowns have only been used to assess whether any bores go dry, and to calculate the proportion of total drawdown caused by Hume operations. A large number of total drawdown hydrographs also do not recover to within 2 m of pre-mining water levels (that is, the effects of private pumping and drainage at Berrima, in the absence of Hume operations, causes drawdowns in excess of 2 m by the end of the simulated period).

Of the 117 private bores identified as residing in the potential drawdown zone, 99 bores are assessed as being subject to a differential drawdown of 2 m or more. Table 2 in Appendix G lists the maximum total and differential drawdown developed at each private bore, and the times required to achieve these maximums. This table also provides the times (in years since the start of mining) when 2 m differential drawdown first occurs at a private bore, and when the differential drawdown recovers back to 2 m. Appendix G also shows total and differential drawdown hydrographs for each bore for reference.

Figure 7.2 shows a histogram of the maximum differential drawdown at private bores. 18 bores have a maximum differential drawdown of 2m or less. The overall average proportion of the maximum total drawdown that is caused by Hume operations is 87%.

The drawdown developed at each bore is heavily dependent on bore location (whether on the mine footprint or more distant) and bore hydraulic interval (and particularly the proportion of shallower media intersected). At a given location, shallower media undergo smaller drawdowns than deeper media.

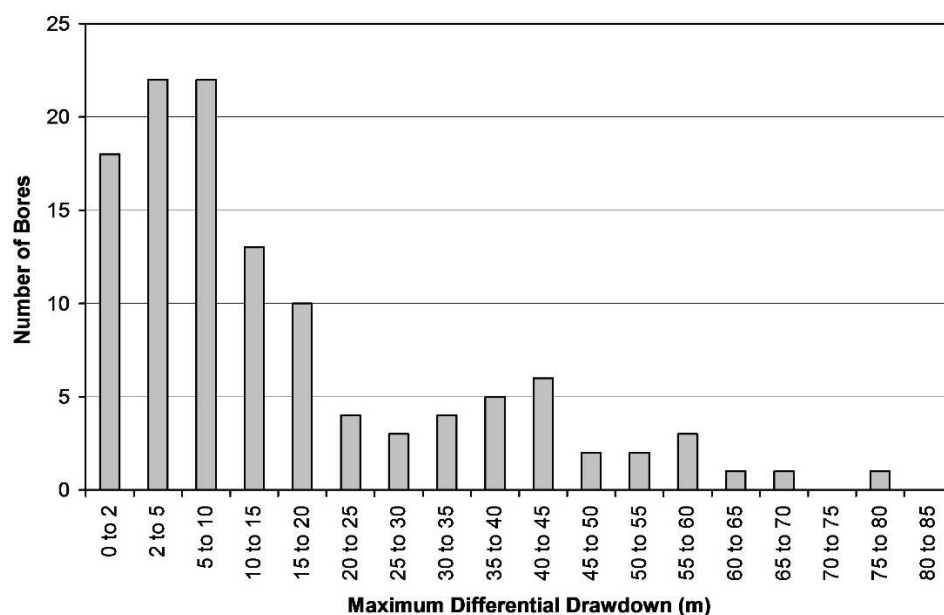


Figure 7.2. Histogram of maximum differential drawdown in private bores.

Figure 7.3 provides a spatial summary of the modelled maximum differential drawdown (for bores where it is 2m or greater), at the private bores, and bore screened strata. Also shown is the time to maximum differential drawdown (in years since the start of mining, for clarity). Year 1 of mining is provisionally 2021. Larger drawdowns generally occur over the mine footprint.

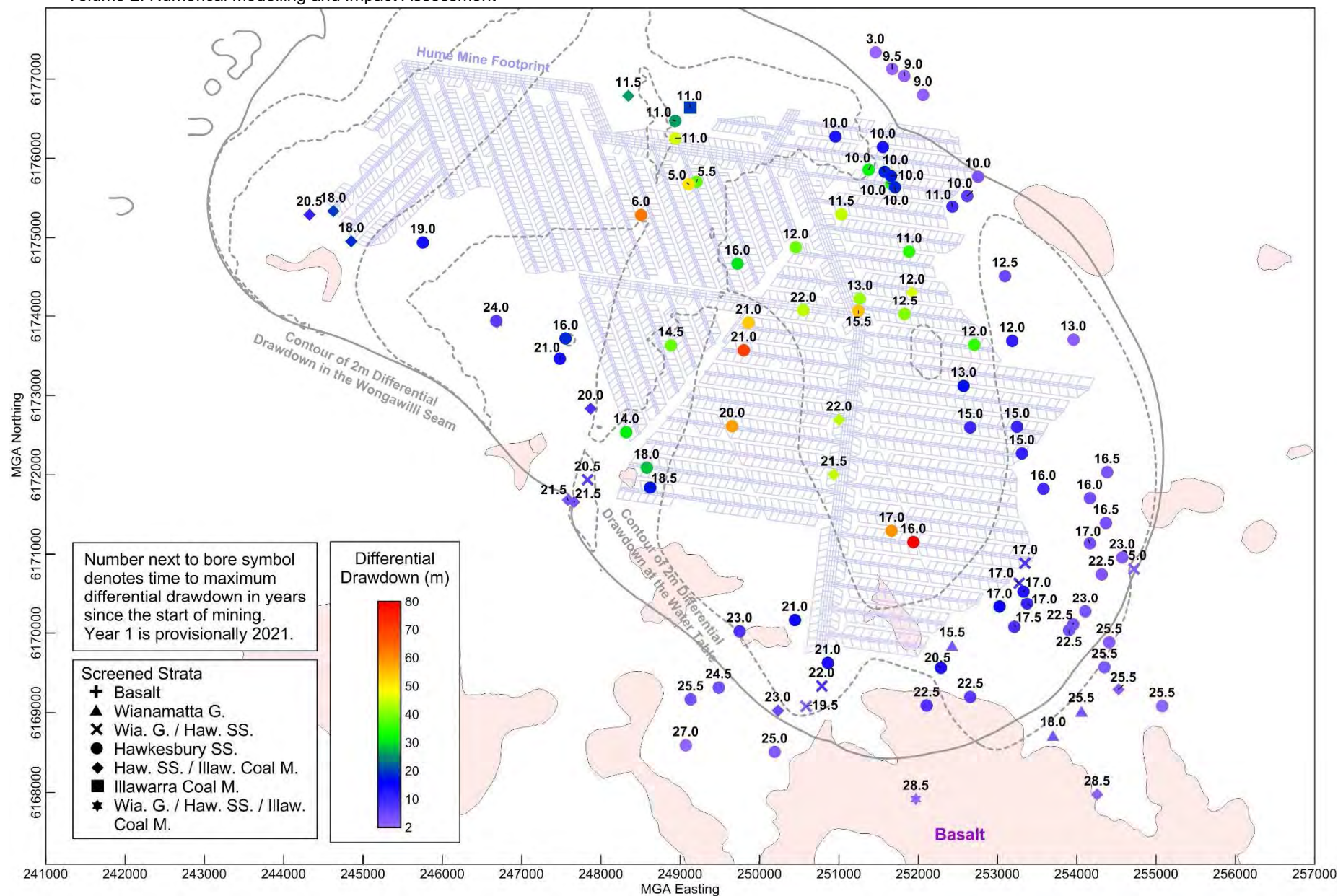


Figure 7.3.
Spatial
distribution
of modelled
maximum
differential
drawdown
at private
bores (and
the time to
maximum
differential
drawdown)
and private
bore
screened
strata.

Figure 7.4 shows the duration of the period for each bore where differential drawdown is greater than 2 m. The start and end of each period is given as years since the start of mining. Durations of these periods range between 2 months and 65 years, with an average of 34 years. The majority of private bores have recovered to less than 2 m differential drawdown by 60 years since the start of mining.

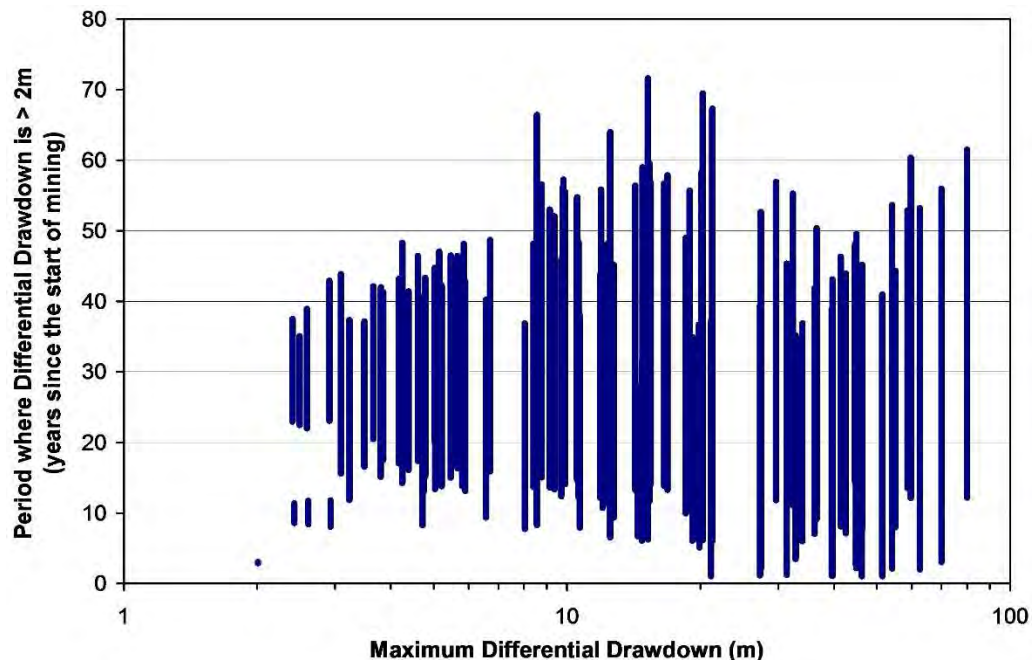


Figure 7.4. Duration of the period for each private bore where differential drawdown is greater than 2m.

Table 16 provides a summary of bores that may require replacement during mining, due to the nature of the impact. They are identified on Map 1 in Appendix G. Impacts include potential structural impacts which the groundwater models cannot simulate. Of these bores, five are likely to be intersected by mining.

In developing a threshold for the maximum distance between the base of a bore and the roof of the mined section, within which there may be structural impact, provision was made as follows:

- A mined section height of 3.5 m above the floor of the Wongawilli seam.
- A relaxation zone of 2 m with an additional 2 m for uncertainty.
- An error of ± 8 m in relating the adopted digital elevation model to true ground level, and to bore logs.
- An error of ± 2 m for bore depth in incorporating government database roundoff error and measurement error.

Table 16. Private water bores that may require replacement during mining.

Bore	Impact	Proportion of total drawdown due to Hume operations at start and end of dry period (%)	
GW106710	Over mine footprint and penetrates to within 14 m of working section roof (allowance for uncertainty). May be drained by mining.	N/A	
GW107535			
GW110236			
GW108195	Over mine footprint and penetrates to within 4 m of working section roof. May be drained by mining.		
GW052538	Over mine footprint and penetrates to working section roof or below. Likely to be intersected by mining during Year 7.		
GW072672	Over mine footprint and penetrates to working section roof or below. Likely to be intersected by mining during Year 8.		
GW102588	Over mine footprint and penetrates to working section roof or below. Likely to be intersected by mining during Year 7.		
GW104745	Over mine footprint and penetrates to working section roof or below. Likely to be intersected by mining during Year 8.		
GW108194	Over mine footprint and penetrates to working section roof or below. Likely to be intersected by mining during Year 10.		
GW023322	Goes dry approximately for the period 13 to 15 years since the start of mining.	99	99
GW026136	Goes dry approximately for the period 13 to 27 years since the start of mining.	93	94
GW032319	Goes dry approximately for the period 9 to 11 years since the start of mining.	98	99
GW035590	Goes dry approximately for the period 16 to 33 years since the start of mining.	57	68
GW047157	Goes dry approximately for the period 4 to 6 years since the start of mining.	99	99
GW048345	Goes dry approximately for the period 10 to 13 years since the start of mining.	95	97
GW064613	Goes dry approximately for the period 2 to 13 years since the start of mining.	98	99
GW066798	Goes dry approximately for the period 8 to 12 years since the start of mining.	96	99
GW104486	Goes dry approximately for the period 10 to 17 years since the start of mining.	91	95
GW106489	Goes dry approximately for the period 18 to 22 years since the start of mining.	95	96
GW106491	Goes dry approximately for the period 18 to 24 years since the start of mining.	96	97
GW108825	Goes dry approximately for the period 8 to 12 years since the start of mining.	94	92
GW037851	Water column* reduces to < 4 m	N/A	
GW067305			
GW067319			
GW068965			
GW105744			

* The distance between the base of the bore and the bore water level.

8. Parameter sensitivity analysis

Results of the three parameter sensitivity runs (see Table 8) are as follows:

- Relaxation height of 2 m and 4 m. These heights were applied over an area representative of the typical extent of an actively draining area at an instant in time (about 11 km²). Results indicated an increase in inflow of 4.3%.
- Kv distributions as follows:
 - The calibrated Kv distribution (listed in Table 3).
 - Calibrated Kv of model layers 1 to 5 (see Table 3) multiplied by 3. These layers comprise the Wianamatta Group and Hawkesbury Sandstone between the water table and the mine workings.

The higher Kv case produces an overall 28% increase in mine inflow. Inflows are considered sensitive to the Kv distribution, in comparison to other parameters.

- Hume mine drain conductance of 0.05 m²/day (calibrated) and 0.1 m²/day. Only a comparatively small change in inflows occurs between these cases.

The results of the sensitivity analysis indicate that the Kv distribution is one of the most important parameters for the simulations. This parameter is one of the most difficult to characterise. For the model reported herein, this parameter has been reasonably resolved by calibration to the following three crucial and completely independent sets of observations:

- Shallow groundwater discharges (stream baseflow).
- Deep groundwater discharges (Berrima mine inflow).
- Kv estimated from the two long-term pumping tests undertaken by Hume in 2014. Both tests were conducted with multiple observation piezometers down the depth profile, and drawdowns were assessed taking into account partial penetration and vertical anisotropy.

The combination of observations from the pumping tests undertaken by Hume, with shallow and deep discharge observations, allows the calibrated Kv distribution to be applicable to an appropriate scale and is considered to have a high level of reliability, including reliable representation of the effects of the high density of open bores present in the area, and the tectonic activity that has occurred in the area.

9. Conclusions

A regional numerical groundwater flow model has been developed for the Hume Coal Project. Model calibration has been successful in reproducing shallow groundwater discharges (stream baseflow), deep groundwater discharges (discharge to the Berrima mine void), and hydraulic heads, and has adhered strongly to the observed hydraulic conductivity distribution.

The combination of observations from the pumping tests undertaken by Hume, with shallow and deep discharge observations, allows the calibrated Kv distribution to be applicable to an appropriate scale and is considered to have a high level of reliability, including reliable representation of the effects of the high density of open bores present in the area, and the increased hydraulic conductivity imparted by tectonic activity that has occurred in the area.

This has reduced the uncertainty in model outputs. The model is considered to be acceptably calibrated and fit for its purpose in simulating the groundwater system with application of the magnitude stress defined by the Hume mine schedule.

The model was subsequently used in a predictive capacity to assess impacts from Hume mining operations using the Pine Feather layout and mining method. Model predictive simulation results are as follows:

- The total volume of groundwater inflow that reports to the sump is calculated as 8.4 GL during the time the effects of mining are active in the groundwater system. The maximum inflow rate to the sump is 2.7 ML/day (1000 ML/year) in year 17 of mining.
- The total volume of groundwater inflow that reports to the void is 24.3 GL during the time the effects of mining are active in the groundwater system. The maximum inflow rate to the void is 5.1 ML/day (1860 ML/year) in year 15 of mining.
- The drawdown footprint achieves a maximum size at about 17 years since the start of mining. The zone of highest drawdown in the footprint migrates according to worked areas. At 17 years, the 2 m differential drawdown contour of the water table extends a maximum of about 2 km past the southeast corner of the mine footprint. The duration of differential drawdown of the water table varies between about 15 years and 60 years. Recovery of the water table over most of the area, to 2 m differential drawdown, is largely complete within about 60 years after the start of mining.
- Maximum total drawdown of the water table greater than 2 m occurs at several locations where there are shallow water levels. These areas have been provided to the ecology team to consider potential influence on ecosystems that may be present at these locations.
- No direct leakage from the Wingecarribee River, induced by Hume operations, is calculated by the model. Model results indicate that 98% of the total inflow to the Hume mine workings is satisfied by interception of baseflow to streams, and release of groundwater storage from media. 2% of the inflow is satisfied by leakage from Medway Reservoir (a total leakage of approximately 804 ML over 22 years, or an overall average over the period of approximately 0.1 ML/day). Baseflow interception induced by Hume operations is largest for Medway Rivulet. Baseflow analysis of flow observations from Medway Rivulet suggests the average baseflow measured at these gauges (over the monitoring period) is about 3 times larger than the calculated future maximum baseflow interception.
- Of the 117 private bores identified as residing in the potential drawdown zone, 99 bores are assessed as being subject to a differential drawdown of 2 m or more. The overall average proportion of the maximum total drawdown that is caused by Hume operations is 87%. Groundwater extraction by private users accounts for the remaining 13%. The duration of the period for each bore where differential drawdown is greater than 2 m ranges between 2 months and 65 years, with an average of 34 years. The majority of these bores have recovered back to 2

m differential drawdown by 60 years since the start of mining. Five of these bores are likely to be intersected by mining because they penetrate the mined zone.

10. Limitations

Modelling is a useful tool to simulate complex subsurface media and to predict water balances and water levels when groundwater stresses are applied. In fractured media with large mining stresses, the modelling results will not exactly represent conditions on a local scale but are more representative on a medium to regional scale. Actual observations made in the future, during Hume mine operation, may differ from predictions made herein.

Model results also do not take into account disturbance of significant but unknown extraordinary defects or extraordinary structural features (those occurring as significant outliers of the typical defect population), which can extend the drained zone associated with the workings, as estimated herein, via the creation of extreme permeability pathways extending beyond the estimated drained zones.

Model results should be reviewed following 12 months of mine operation. Should predictions differ significantly from observations, model recalibration may be necessary.

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Important information about your **Coffey** Report

As a client of Coffey you should know that site subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report is based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Coffey and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking Coffey to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Coffey cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of Coffey through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other project design professionals who are affected by the report. Have Coffey explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.



Important information about your **Coffey** Report

Data should not be separated from the report*

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Geoenvironmental concerns are not at issue

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment. Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Coffey for information relating to geoenvironmental issues.

Rely on Coffey for additional assistance

Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

Responsibility

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.