BHP BILLITON ILLAWARRA COAL PTY LTD

APPIN AREA 7
LONGWALLS 705 to 710
GROUNDWATER ASSESSMENT

Douglas Park, NSW

BHP41-R1B

27 JUNE, 2008

GeoTerra PTY LTD **ABN 82 117 674 941**

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BHP4-R1B (27 JUNE, 2008)

GeoTerra

BHP Billiton Illawarra Coal Holdings Pty Ltd
PO Box 514
UNANDERRA NSW 2526

Attention: Richard Walsh

Richard,

RE: BHP Appin Area 7 Longwall 705 – 710 Groundwater Assessment

Please find enclosed a copy of the above mentioned report.

Yours faithfully

GeoTerra Pty Ltd

Andrew Dawkins (AuSIMM CP-Env)
Managing Geoscientist

Distribution:	Original	GeoTerra Pty Ltd
	1 electronic copy	BHPB Illawarra Coal Pty Ltd

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Authorised on behalf of Geoterra Pty Ltd:	
Name:	Andrew Dawkins
Signature:	
Position:	Managing Geoscientist
Date:	27.06.2008

Date	Rev	Comments
9.06.08		Initial Draft
21.06.08	A	Incorporate BHPB comments
27.06.2008	B	Incorporate BHPB comments

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EXECUTIVE SUMMARY

BHP Billiton Illawarra Coal Holdings Pty Ltd (BHPB) Appin Colliery propose to extract the Bulli Seam within Longwall Panels 705 to 710 near Douglas Park as an extension of the Appin Longwall 701 to 704 mining area. All of the longwalls are proposed to be extracted in 325m wide panels with 45m wide chain pillars. The panels vary from 3325m to 5065m long and are located to the northwest of the Nepean River gorge, with the panel ends being no closer than 180m from the edge of the river channel. Depth of cover over the Bulli Seam increases to the northwest, and ranges from approximately 470 to 620mbgl over Panels 705 to 710. The Bulli Seam generally dips to the northwest and varies from 2.8m to 3.5m thick.

The SMP area lies within the Nepean River Valley and its associated gorge, with the north / west plateau of the gorge being primarily used for rural residential development with fringing undeveloped woodland along the cliff edge. The plateau over the SMP area generally rises from east to west, away from the incised Nepean River gorge which can be from 53 to 70m deep, with vertical cliff faces up to 30m. The gorge is steep sided with sandstone cliffs and scree slopes, whilst surface levels vary from approximately 110m at the top of the gorge up to approximately 210m over the western section of Longwall 706.

The river level in the SMP area is regulated by Menangle Weir, which is approximately 2.5km downstream of Panel 710. Douglas Park Weir is approximately 2km upstream of proposed Longwall 705, with both weirs being outside the potential subsidence area of Longwalls 705 to 710. Water levels fall by 260mm over the 14km between Appin Park and Menangle Weirs, with the water surface varying from 60.84m RL at Menangle Weir to 61.1m AHD at Douglas Park weir.

The Nepean River is a ‘gaining’ system, where groundwater flows from the plateau under a regional hydraulic gradient to the river. As the Nepean River is the largest regional river in the catchment, all drainage from surrounding groundwater systems and tributary streams is toward the base of the gorge. The river then flows under gravity along the gorge to Menangle Weir.

Surface water drainage on the plateau is mainly within ephemeral first and second order streams, with the majority of northerly drainage flowing toward the channels of Navigation and Foot Onslow Creeks. Drainage to the south-west flows to Harris Creek. Drainage in first and second order channels to the east flows into the Nepean River. All major creeks have a significant degree of dam construction within their channels and catchment areas.

The Hawkesbury Sandstone predominantly outcrops and underlies the Nepean River gorge, whilst the plateau dominantly contains outcropping Wianamatta Shale in the central-eastern section of Panels 705 to 710. The shale ranges from being absent (to expose the underlying Hawkesbury Sandstone) up to approximately 100m thick in the higher elevation and northern areas.

Fifteen DWE registered bores are located within or adjacent to the SMP area along with nine open standpipe BHPB piezometers drilled to approximately 10m below the base of the Nepean River gorge and one sealed vibrating wire piezometer bore drilled to the Bulli Seam. All private bores were drilled between 70m and 238m below surface, with water obtained primarily from sandstone aquifers, however some thin, perched horizons encountered water intersections in the Wianamatta Shale.

Yields range from 0.2L/sec and 1.63L/sec from inflow zones ranging between 9m and 219m below surface. DWE data indicates it is more likely that regionally significant aquifers are intersected 100m below surface, with the deepest bore at 238m below surface (GW105339), which is completed 8m into the Bald Hill Claystone.

Recharge to the deeper groundwater system occurs with an extended delay after rainfall, with some recharge also discharging from temporary seeps in the cliff face of the gorge, whilst drainage to stream beds out of the sedimentary interface between the Wianamatta Shale and the Hawkesbury Sandstone would also occur across the plateau.

Groundwater is generally fresh to brackish with salinity between 260mg/l and 2500mg/L, and can exceed ANZECC irrigation trigger values for sodium, chloride and hardness. All bores exceed the salinity guidelines for South East Australian Upland Rivers, as well as generally for total phosphorous and occasionally for pH and total nitrates. In addition, copper, lead, zinc, and to a lesser degree, nickel and aluminium can exceed the ANZECC 2000 trigger values for Protection of 95% of Freshwater Aquatic Species Guidelines.

Strata gas emissions have occurred in previously mined areas in the Nepean River gorge, as well as in plateau creeks and some limited bores. Analyses indicate that the coal seam is not the direct and major source of the gas and that the most likely source is the Hawkesbury Sandstone. The likelihood of gas emission on the plateau and/or within groundwater bores is possible, and in some instances, such as in Chicken Creek, gas emissions may last for over a year. The emitted gas can dissolve in water, depending on its concentration, composition, residence time in the water and consumption by bacteria.

The Hawkesbury Sandstone groundwater system drains to the Nepean River, with steeper gradients under the western plateau and has had a cyclic reduction and rise in response to rainfall and dry periods.

No response has been noted to date in the Hawkesbury groundwater system following extraction of Longwall 701. An anomalous reduction in water levels has been observed, however, in NGW10 of up to 13.5m, with no definitive reason available at this stage.

Extraction of longwalls in the vicinity of the NGW series piezometers has occurred in LW10-12, LW20 and LW701 in the Appin / Tower workings, as well as LW30-32 in the West Cliff workings.

Potential Subsidence Related Groundwater Impacts

Due to the short term nature of any groundwater level reductions it is concluded that there is unlikely to be a significant impact to groundwater resources in the plateau areas resulting from the proposed extraction.

- no adverse interconnection of aquifers and aquitards is anticipated within the surficial fracture zone to 20m beneath the plateau as there are no recorded aquifers within 20m of the surface. There may be an increased rate of rainfall recharge due to the increased porosity and permeability of the fractured sandstone / shales which can result in higher discharge volumes and duration of temporary rain dependent seeps, and/or higher recharge rates to underlying aquifers.
- vertical flow will continue down the strata until drainage is restricted by intact aquitards, where the flow resumes its horizontal dominance. Below the fractured zone, an increased horizontal flow component can occur due to dilation and

bending of strata, even though the layers are not breached by vertical fracturing.

- even though the regional piezometric surface lies beneath the potential surficial fracture zone, there still may be a temporary lowering of the piezometric surface over the subsidence area due to horizontal dilation of strata and resultant increase in secondary porosity. This effect will be more notable directly over the area of greatest subsidence and dilation, and will dissipate laterally out to the edge of the subsidence zone. Groundwater levels may reduce by up to 10m until maximum subsidence develops, with the duration of the effect depending on the time required to develop maximum subsidence, the time for subsidence effects to migrate away from a location as mining advances and that required to recharge the secondary voids.
- the impact on a bore is related to the degree of subsidence related groundwater level decline, by rainfall recharge as well as changes in the rate or duration of water extraction in the subject and adjacent bores.

On the basis that the pre-mining circumstances of rainfall recharge and bore pumping remain the same, then groundwater levels should recover over a few months as the newly developed secondary porosity is recharged by rainfall sourced water.

- there is generally no permanent post mining reduction in water level in the plateau unless a new outflow path develops, which may occur where extraction is close enough to the gorge edge and new or enhanced seeps are generated.

It is anticipated the 180m separation between the panel edges and the gorge will be sufficient to minimise the potential connection from occurring.

- four DWE registered bores within or near the application area may be affected by subsidence. Two are located over Longwall 703 (GW101437 and GW104154) and two are located on the edge of the application area, northwest of Longwall 705 (GW102584 and GW103161). Horizontal displacement of strata can occur which could make the bores inaccessible. Strata dilation and subsequent refilling of the secondary voids can temporarily lower standing water levels by up to 10m, whilst increasing the potential yield of a bore through enhanced permeability and secondary porosity.

Should the accessibility, available drawdown or yield of a bore be impacted due to subsidence, the Colliery is required to provide an alternative water supply until the bore recovers. If the level does not sufficiently recover and the effect is due to subsidence rather than regional climatic or anthropogenic factors, repairs or maintenance to a bore can be undertaken after maximum subsidence has developed. At this time the pump intake can be lowered, the bore extended to a greater depth or a new bore can be established. With these mitigation measures in place it is unlikely that water supply to private properties will be significantly impacted by the proposed mining.

- previous observations indicate that water quality of subsided bores in the Southern Coalfield has not generally been adversely affected, however, there may be increased iron and manganese hydroxide precipitation due to subsidence related exposure of previously unweathered iron and manganese carbonates along with a lowering of pH and increased iron hydroxide precipitation if the aquifer is exposed to previously unweathered iron sulfides (marcasite) in the strata. The lowering of pH can be ameliorated, however, if there is sufficient bicarbonate in the water. The effect can range from no observable change to a distinct orange-red discolouration. The discolouration does not pose any health hazard, however it can result in clogging of pumping equipment and piping in extreme cases. Many bores in the Southern Coalfield already have significant iron hydroxide levels.

If groundwater quality impacts resulting from subsidence are identified, alternate supplies of water should be provided to any affected water user until a similar supply can be re-established with similar water quality characteristics. With these mitigation measures in place it is unlikely that there will be any significant impacts to water quality supplies from the proposed mining.

- lowering of perched ephemeral seeps along the cliffs of the Nepean River gorge may occur after subsidence through fracturing of underlying confining, low permeability layers. Fracturing can enable pre-mining perched water to seep out at lower levels down the cliff compared to pre subsidence levels. The current seeps are generally short lived, with the volume and duration of flow directly related to the amount and intensity of rainfall. No large seeps were identified during the study along the potentially affected stretch of the river. The volume of flow from the seeps may increase due to enhanced rainfall recharge through the plateau, whilst the duration of seepage may reduce.
- no plateau springs have been identified in the area that may be affected by subsidence, however, based on observations on the western plateau associated with previous longwalls, it is possible that interface drainage ferruginous (brackish to saline) seeps may be generated in streams on the plateau over Longwalls 705 to 710.

The low order creeks on the plateau will be subjected to relatively low tensile strains and are not expected to be significantly impacted by subsidence related surface cracking.

- it is not expected that buckling or fracturing of exposed bedrock in the plateau creek beds will occur. Similarly, it is not expected that observable loss of water from the creeks will occur.

Due to the low levels of strain on the plateau area and limited potential for fracturing of rock, cracking of soil and water loss, it is unlikely that the proposed mining will significantly impact lower order streams, seeps, springs and flow to the Nepean River.

- loss of stream flow or groundwater to the underlying workings has not been observed in any mines in the Southern Coalfield at similar depths of cover to the proposed mining. Vertical hydraulic connection to the workings is essentially blocked from entering the mine as the Bald Hill Claystone acts as a confining layer. It is highly unlikely that this layer would be breached after subsidence as it is from 150m to 200m below the surface and well below the depth of surface cracking and overburden dilation. The Bald Hill Claystone is also sufficiently higher up in the overburden such that it is not anticipated to be affected / intersected by the height of goaf fracturing.

Modelling indicates that the horizontal permeability above the Bald Hill Claystone may be enhanced after subsidence but that there is no additional vertical permeability connectivity and that the hydrologic systems above and below the Claystone will remain separate.

- it is not anticipated that significant strata gas will be discharged in private bores over Longwalls 705 to 710.

Overall, there is a limited potential for strata gas emissions into private bores, and any emissions that may occur will be localised and may last for approximately one year.

1. INTRODUCTION

1.1 Project Location

BHP Billiton Illawarra Coal Holdings Pty Ltd (BHPB) Appin Colliery propose to extract the Bulli Seam within Longwall Panels 705 to 710 near the township of Douglas Park, which is situated to the west of Wollongong in the Southern Coalfield of New South Wales.

1.2 Proposed Mine Development and SMP Application Area

The proposed extraction is an extension of the Appin Longwall 701 to 704 mining area.

All of the longwalls are proposed to be extracted in 325m wide panels with 45m wide chain pillars. The panels vary from 3325m to 5065m long and are located to the northwest of the Nepean River gorge, as shown in **Drawing 1,** with the panel ends being no closer than 180m from the edge of the river channel.

Depth of cover over the Bulli Seam increases to the northwest, and ranges from approximately 470 to 620mbgl over Panels 705 to 710. The Bulli Seam generally dips to the northwest and varies from 2.8m to 3.5m thick.

The Subsidence Management Plan (SMP) Application Area is defined as the surface area that is likely to be affected by the proposed mining of Longwalls 705 to 710 and encompasses the following limits (MSEC, 2008);

- 35^0 Angle of Draw Line for the 620m maximum depth of cover (i.e., a horizontal distance of up to 435 m outside the limit of the proposed extraction area),
- The 20 mm predicted limit of vertical subsidence, which is generally within the 35^0 Angle of Draw Line, and
- Features sensitive to far-field movements, which includes horizontal, valley closure and valley upsidence movements in the Nepean River gorge which may be outside the 20 mm subsidence zone.

2. SCOPE OF WORK

Geoterra was commissioned by BHPB Illawarra Coal to address the existing hydrogeological status of the area and to assess potential hydrogeological impacts relating to subsidence during and following extraction of Longwalls 705 to 710.

The report will be incorporated into a Subsidence Management Plan (SMP) application to the Department of Primary Industries – Minerals.

3. PREVIOUS STUDIES

Numerous associated studies have been conducted in the vicinity of the application area as outlined in the references section. Relevant studies incorporated into this document include:

- Tower Longwalls 18, 19 and 20 and baseline Appin surface water in the Nepean River and its tributaries,
- Groundwater level and water quality monitoring by BHPB in the NGW series and EAW5 piezometers,
- Baseline and post mining surface water and groundwater monitoring by Coffey Partners International Pty Ltd (later becoming Coffey Geosciences Pty Ltd) for Longwall 16 and 17,
- Subsidence predictions by Mine Subsidence Engineering Consultants Pty Ltd (MSEC) for Longwalls 701 to 704,
- Subsidence predictions by Mine Subsidence Engineering Consultants Pty Ltd (MSEC) for Longwalls 705 to 710,
- Two dimensional finite element modelling and chloride balance assessment of groundwater recharge in the Cataract River gorge by Coffey Partners International Pty Ltd,
- Two dimensional geomechanical modelling of three mining scenarios in the vicinity of the Nepean Gorge by the CSIRO, and
- Groundwater and Surface Water Assessments for Longwalls 701 to 704 by Geoterra Pty Ltd

Other references utilised in this study are outlined in the text as appropriate.

4. EXISTING ENVIRONMENT

4.1 Rainfall and Evapotranspiration

Daily rainfall recorded at Douglas Park (St Marys Towers) since June 2004 is shown in **Figure 1**.

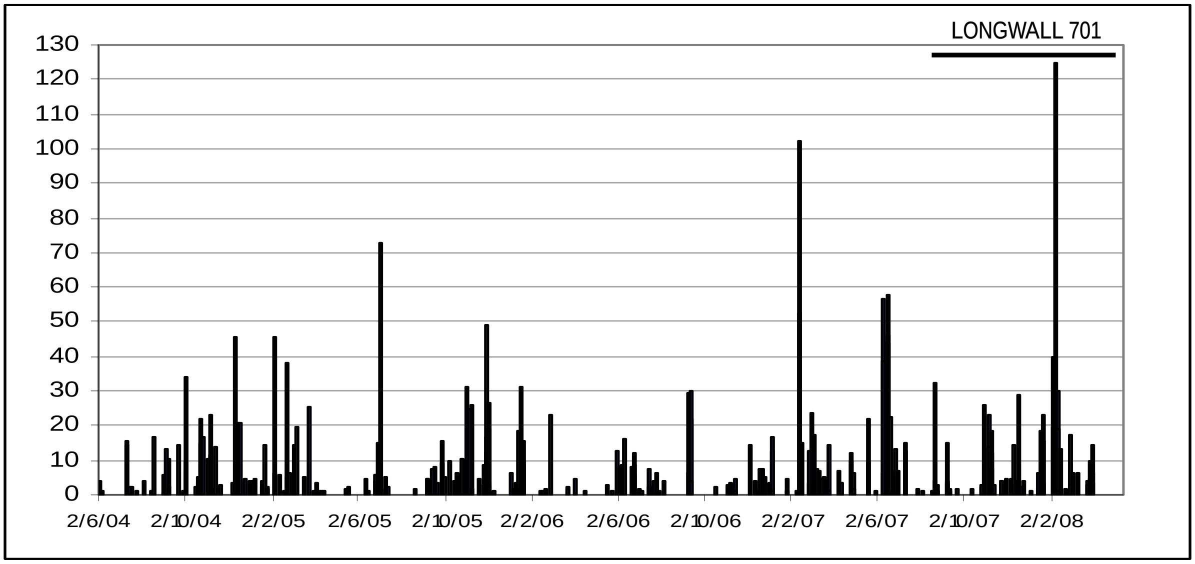


FIGURE 1 Douglas Park (St Marys Towers) Daily Rainfall

Evapo-transpiration on the plateau averages around 2.1 mm/day based on a 0.9 factoring of records from Cataract Dam. Summer evapo-transpiration in the gorge can be estimated by factoring Cataract Dam records by 0.5 to account for partial shading in the gorge and lower wind effects compared to the plateau, giving an estimated average potential of 1.1 mm/day (Ecoengineers, 2005).

4.2 Land Use

The SMP area lies within the Nepean River Valley, with the Nepean River Gorge being incised within the valley on the east side of the SMP Area. The landscape on the north / west side of the river is primarily used for rural residential development with fringing undeveloped woodland along the cliff edge associated with the Nepean River gorge.

Some properties are or have been used for vegetable production, poultry farms, wholesale nurseries, pet farms, equestrian centres or light industrial operations. The SH2 Hume Highway and the Main Southern Railway traverse the surface above Longwalls 703 to 710.

Domestic water supply is generally obtained from rainwater tanks. Other supplies include 286 farm dams, as well as 6 pumps in the river and 15 Department of Water and Energy (DWE) registered groundwater bores that may be currently used or able to be used, within the 705 to 710 SMP area.

The river and its flanks are used for recreation, with activities such as fishing, canoeing and bushwalking.

4.3 Geology

4.3.1 Stratigraphy

4.3.1.1 Plateau to Nepean River

The Hawkesbury Sandstone predominantly outcrops and underlies the Nepean River gorge, whilst the plateau dominantly contains outcropping Wianamatta Shale in the central-eastern section of Panels 705 to 710. The shale ranges from being absent (to expose the underlying Hawkesbury Sandstone) up to approximately 100m thick in the higher elevation and northern areas.

Over the remaining western and eastern portions, outcropping Hawkesbury Sandstone is present as shown in **Figure 2**.

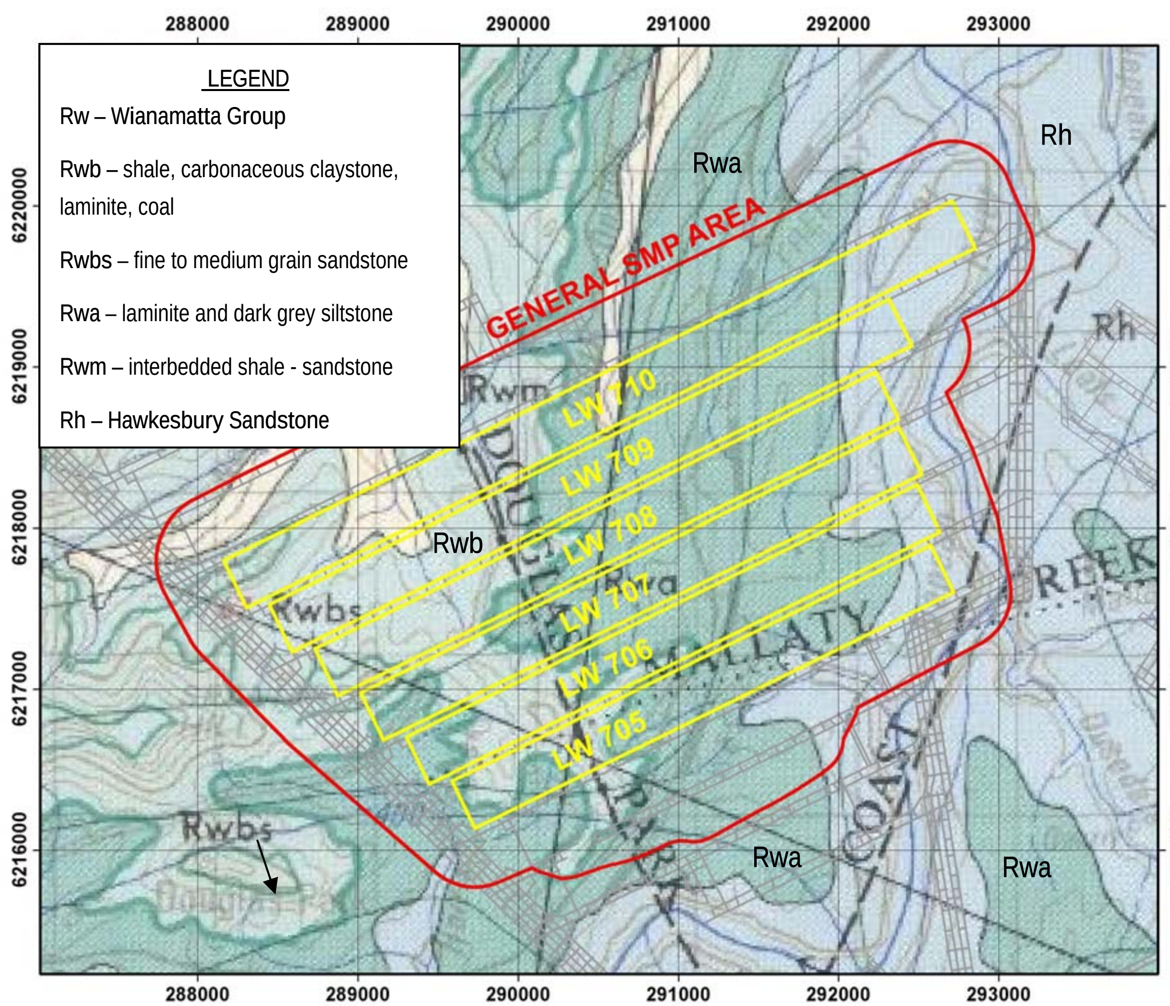


FIGURE 2 Local Geology

The Hawkesbury Sandstone extends to approximately 100m below the river and consists of fine to medium grain flat bedded sands over medium to coarse sands with minor shale. The units are highly localised and laterally variable across the area, with up to seven lithofacies identified from cores and cliff observations representing arenite (coarse sandstone facies) or lutite, which is a finer mudstone and siltstone facies (BHPB, undated).

Although some facies can be tentatively correlated to adjacent bores, no correlation of individual beds apart from the Wianamatta Shale and the L-MS Horizon was noted (BHPB, undated). The L-MS unit is a siltstone / shale / mudstone association with three major horizons which may or may not all be present. This laterally continuous lithology forms a significant vertical flow barrier and is located around 35m to 65m below the surface and ranges from 0.08m thick in NGW5 to 5.90m in NGW10 (Geoterra, 2006 GW). The locations of NGW5 and NGW10 are shown in **Drawing 1**.

Cavernous zones in the cliffs are often associated with leaching of the sandstone's granular cement by groundwater seeps sourced from "perched" ephemeral aquifers located above the regional piezometric surface.

The base of the Wianamatta Shale is a good mapping horizon which outcrops at the edge of major dissected river gorge, and the margin is clearly recognisable on the ground or in aerial photographs. The sequence of shale (where present) over sandstone is underlain by the generic sequence illustrated in **Figure 3.**

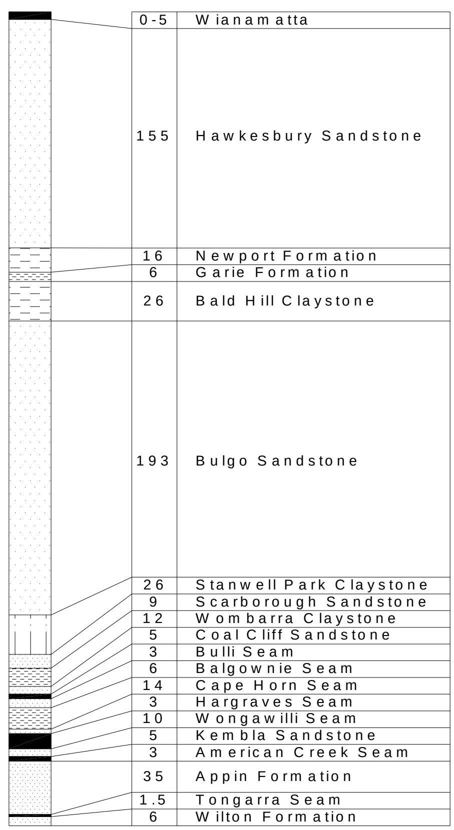


FIGURE 3 **Regional Stratigraphy**

The majority of the area is covered by agricultural land with minor outcrop, principally on the areas underlain by Wianamatta shales.

The Wianamatta Group is the uppermost unit in the sequence and occurs across much of Area 7.

The Hawkesbury Sandstone outcrops where drainage channels or erosion have removed the Wianamatta shale and consists of thickly bedded or massive quartzose sandstone (with grey shale lenses up to several metres thick) with an average thickness of 170m, depending on surface erosion. The Hawkesbury Sandstone characteristically has not been cleared for agricultural purposes.

4.3.1.2 Nepean River to Bulli Seam

The Hawkesbury Sandstone outcrops within the walls and floor of the gorge and can be up to 100m thick below the river.

In the Douglas Area 7, the Narrabeen Group sequence of about 350m is developed below the Hawkesbury Sandstone and above the Illawarra Coal Measures. The Narrabeen Group does not outcrop in Area 7.

The Newport Formation consists of interbedded grey shales and sandstones, about 24m thick.

The Bald Hill Claystone consists of the Garie Claystone, a generally hard, grey-brown "oolitic" claystone, about 14m thick, underlain by the characteristic brownish-red coloured "chocolate shale", a physically weak but lithologically stable unit about 26m thick. The "chocolate shale" is an easily recognised marker horizon and is a major aquitard to vertical migration of groundwater through the sequence and essentially divides the groundwater systems above and below the claystone.

The Bulgo Sandstone, averaging 220m thick, consists of strong, thickly bedded, medium to coarse grained lithic sandstone with occasional beds of conglomerate or shale. These strata can be gas bearing, particularly towards the base of the sequence. Oil is also present, particularly towards the western side of Area 7. Oil and gas, while present, are locked into the strata due to the lack of permeability and do not represent an economic resource. The gas can be released up the profile when mining-induced fracturing provides a secondary permeable path.

The Stanwell Park Claystone (10 to 20m thick) consists of greenish-grey mudstones and sandstones. These "green shales" are very weak lithologically and fret easily on exposure. The Stanwell Park Claystone becomes sandier in a northerly direction over Area 7 until it becomes unrecognisable from its bounding sandstone units. The absence of this seal may influence the movement of strata gas following mining.

The Scarborough Sandstone, averaging 20 to 30m in thickness, consists mainly of thickly bedded sandstone with shale and sandy shale lenses up to several metres thick.

The Wombarra Shale (30m average) has similar properties to the Stanwell Park Claystone described above. However this unit does not display a facies changes towards a sandier unit like the Stanwell Park Claystone.

The Coalcliff Sandstone varies from 20 to 30m thick. Away from the coast, the dominance of sandstone diminishes and in many areas the original roof strata of the Bulli Seam, a shale / mudstone unit, (which can become laminated in places) is prominent. The sandstone is common as erosive channels across the Appin, Tower area and has completely eroded the mudstone unit in several areas and in some instances into the Bulli Seam.

The Illawarra Coal Measures consist of interbedded shales, mudstones, lithic sandstones and coal seams of which ten named seams occur in the area.

The Bulli Coal has been worked extensively in the Appin area and produces a hard coking coal.

4.3.2 Faulting and Structures

The Bulli Seam gently dips to the north, north-west at 1 in 50 and reflects the synclinal structure of the Douglas Park Syncline.

Surface lineaments due to differential weathering on joint planes are well developed on outcropping Hawkesbury Sandstone, but are poorly developed in the Wianamatta Shale as straight stream courses, which are controlled by the underlying sandstone joint fabric and regional topography dip to the northwest.

Mapped and inferred geological structures (BHPB, undated) include a number of NNW trending faults and intrusive dykes with a subset of EW to ENE trending faults as shown in **Drawing 2**. Major regional geological structures include the Douglas Park Syncline and the South Coast Warp.

Fracturing identified in drilling the NGW series bores is predominately within 20° of horizontal and associated with bedding planes. The more significant water zones are associated with low angled fractures, whilst jointing and bedding plane fracturing are responsible for the main flow characteristics at river level (BHPB, undated).

Horizontal fractures in moderately weathered facies with slight cavities observed in the NGW core were associated with water loss during drilling and packer testing. A nearby bore drilled by BHPB (Appin 100) located 20m from NGW6 had significant water loss in several zones. NGW6 (**Drawing 1**) intersected the top of a major fracture zone in A-MS(c) around 23.4m that was also intersected by Appin 100 at 66.7m where grout was required to fill the fractures. This was taken to indicate that horizontal water flow through fractures is the main mechanism of water transmission (BHPB, 2005).

Tight to open vertical fractures were noted at river level in most NGW bores which had higher water intakes than vertical fractures in horizons above the river.

Facies with high angle to vertical fractures had significant water loss on drilling in moderate to intensely weathered zones with intersecting joints (e.g NGW6 at 13m depth) or zones with multiple joints, (e.g NGW9 around the 61m depth).

Major faulting is not apparent on the plateau or river bed, which does not preclude the presence of structures at depth or minor structures missed with the level of mapping conducted to date.

In the Southern Coalfield, faulting tends to decrease in displacement vertically upwards through the Narrabeen Group and Hawkesbury Sandstone. For example, neither the Saw Pit Fault nor the O'Hare's Fault is detectable at the surface although their displacement is tens of metres at coal seam level.

Faulting within Area 7 has not been well defined in some areas and confidence is generally medium-low for most known faults at seam level. A three dimensional seismic survey partially covering the southern section of the proposed mine plan did not detect any faulting to the resolution limits of the technique, which is approximately seam thickness. An inclined reflector indicating a possible thrust fault striking north-south and dipping to the west at an angle of 10-20^{o} has been picked from seismic surveys. 2D seismic in the north of the study area indicates horst and graben style faulting associated with anticlinal features with displacements up to 20m in the north eastern section.

A detailed description of the identified faults can be obtained in (BHPB, 2006)

The Nepean Fault Zone is interpreted as consisting of a 300 to 500m wide zone of faulted and fractured strata containing faults of 10 to 30m throw. The structure is difficult to target with surface exploration because the zone coincides with the Nepean River.

4.3.3 Igneous Intrusions

Few intrusions of significance are known in the northern part of the Southern Coalfield and they tend to be associated with synclinal structures, which is reflected in the general geology of the Douglas Park syncline over Area 7.

Igneous dykes have been mapped at surface and generally, the exposures support the continued extension of the known underground dyke zones, however due to extensive agricultural impacts, most dykes are not observable at surface.

Further details on dykes in the study area are contained in (BHPB, 2006).

There are no known igneous quarries in the study area and no diatremes have been identified in the study area.

4.4 Topography and Drainage

4.4.1 Plateau

The plateau over the SMP area generally rises from east to west, away from the incised Nepean River gorge which can be from 53 to 70m deep, with vertical cliff faces up to 30m. The gorge is steep sided with sandstone cliffs and scree slopes, whilst surface levels vary from approximately 110m at the top of the gorge up to approximately 210m over the western section of Longwall 706.

The Nepean is part of the Hawkesbury-Nepean River system which originates in the uplands west of Wollongong and flows northward past Camden to its junction with the Warragamba River near Wallacia.

The river level in the application area is regulated by Menangle Weir, which is approximately 2.5km downstream of Panel 710. Douglas Park Weir is approximately

2km upstream of proposed Longwall 705, with both weirs being outside the potential subsidence area of Longwalls 705 to 710.

Water levels fall by 260mm over the 14km between Appin Park and Menangle Weirs (Geoterra, 2006 SW), with the water surface varying from 60.84m RL at Menangle Weir to 61.1m AHD at Douglas Park weir.

The mining area catchment comprises minor, ephemeral unnamed 1st and 2nd order streams draining from the plateau to the Nepean River which generally contain earthen wall farm dams that harvest runoff to the gorge.

The larger, ephemeral, northerly draining Foot Onslow Creek overlies Panels 708 to 710, whilst the north-westerly draining Navigation Creek is within the north-west corner of the SMP area, but does not underlie any of the proposed panels. The south-westerly draining Harris Creek overlies the western ends of Panels 706 and 707, as well as being within the SMP area to the west of Panels 704 and 705.

All major creeks have a significant degree of dam construction within their channels and catchment areas.

4.4.2 Nepean Gorge and River Bed

The river has dissected the plateau, forming substantial scarps and discrete cliffs on either side of the gorge. Where the channel trends along the systematic joint direction, the cliff line is usually close to the channel. Cliffs are usually formed under competent sandstone which can contain stratigraphically controlled cavernous zones with ephemeral seeps.

The Nepean River gorge height diminishes and becomes a flood plain downstream of Menangle Weir.

Sandy alluvium is the dominant soil type located in the base of the gorge and on the alluvial flanks.

Three sections were measured across the river within the SMP area (Geoterra, 2006 SW).

4.5 Hydrogeology

The study area is situated at the southern end of the Permo-Triassic Sydney Basin.

Extraction is proposed from the Bulli Seam in the Illawarra Coal Measures from a depth of cover ranging from 470m to 620m under the western river plateau. No longwall extraction will take place under the gorge and the panel ends are planned to be no closer than 180m from the river’s edge.

The Nepean River is a ‘gaining’ system, where groundwater flows from the plateau under a regional hydraulic gradient to the river. These flows are dominantly horizontal, and are determined by confined flow along discrete layers underlain by fine grained or relatively impermeable strata within the Hawkesbury Sandstone.

The Hawkesbury Sandstone sequence exposed in the gorge is characteristic of sedimentary deposition and erosion in a braided stream with individual facies representing local sedimentary processes that generally do not persist across the SMP area as shown in **Figure 4**.

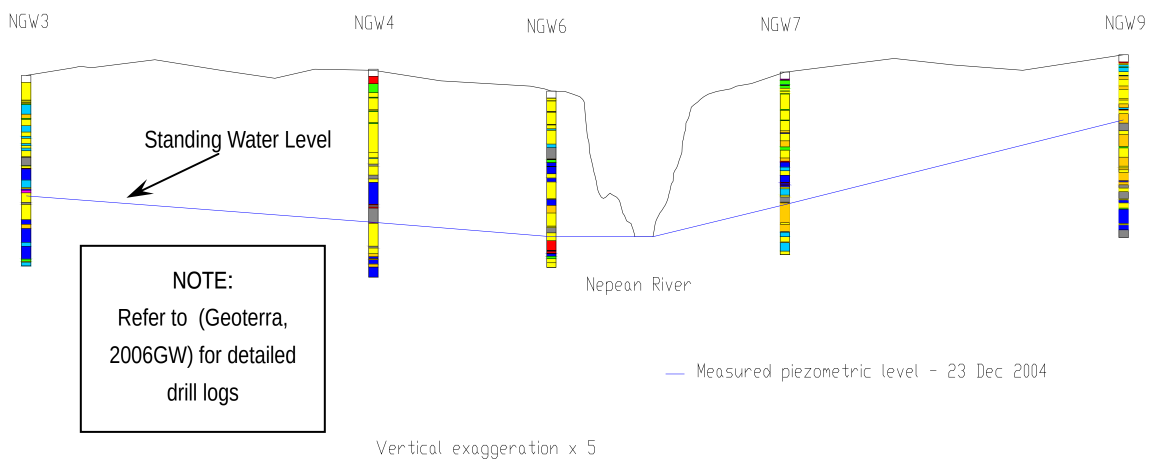


FIGURE 4 Local Stratigraphy and Piezometric Level

4.5.1 Existing Bores and Piezometers

Fifteen DWE registered bores are located within or adjacent to the SMP area along with nine BHPB piezometers as shown in **Drawing 1,** with selected details listed in **Table 1**.

All private bores were drilled between 70m and 238m below surface, with water obtained primarily from sandstone aquifers, however some thin, perched horizons encountered water intersections in the Wianamatta Shale (GW103161 at 17-18m, GW104602 at 30m, 105574 at 27-28.5m).

Yields range from 0.2L/sec and 1.63L/sec from inflow zones ranging between 9m and 219m below surface.

DWE bore data within the SMP area indicates it is more likely that regionally significant aquifers are intersected 100m below surface, however, according to available records, intersections as shallow as 9m may be present in shallow, perched aquifers with limited extent, as well as in limited, perched horizons within the Wianamatta Shale.

DWE data indicates that the deepest aquifer was intersected during drilling over the eastern end of Longwall 708 (GW105339) at 238m below the plateau. The shallowest aquifer was intersected in Wianamatta Shale between 17-18m below surface.

The actual intersected aquifer horizon is generally deeper than the measured piezometric surface of a bore, as when a confined aquifer is drilled into, formation water rises up the borehole due to a combination of confined lithostatic and hydrostatic pressure regimes. Based on this principle, and on assessment of the DWE data, the majority of aquifer intersections over the proposed mining area lie at or below the relative height of the Nepean River, even though the water levels may rise under pressure to higher elevations in a bore.

Eight open standpipe piezometers (NGW series) were installed by BHPB in June 2004 within the Hawkesbury Sandstone to 10m below the base of the Nepean River Gorge.

DWE Test Monitoring Bore Licences for the NGW series bores, along with a Water Access Licence for the underground workings as a whole have been applied for, but as yet, the licences have not been granted (G Brassington, pers comm.).

An additional BHPB sealed vibrating wire piezometer array in bore EAW5 was installed to the Bulli Seam in May 2008. As the bore was fully cement sealed on completion, a DWE licence is not required.

It is worth noting that the deepest bore (GW105339) was completed 8m into the Bald Hill Claystone at 238m below surface in a hole cased from surface to 30mbgl. The deepest recorded water intake in the bore was at 184mbgl in Hawkesbury Sandstone.

TABLE 1 Panels 5 To 10 SMP Area Bores and Piezometers

GW	N	E	SWL (m)	Depth (m)	Drilled	Aquifer	Lithology	YIELD (L/s)	EC (mg/L)	Purpose
101437	6216406	291651	75	128	1997	119 - 121	sandstone	0.7	2500	Farming
102584	6216255	289480	60	186	1999	54 - 60 64 - 70 108 -112 144 - 150 177 - 179	sandstone sandstone sandstone sandstone sandstone	0.9	1300	Dom / Stk
103161	6216499	289511	25	120	2000	**17 – 18** 54 - 56 83 - 84 108 - 110	shale sandstone sandstone sandstone	0.2	1450	Dom / Stk
104154	6215898	291128	74	165	2000	116 - 117 134 - 135 160 - 161	sandstone sandstone sandstone	1.3	2200	Dom / Stk
104602	6216148	288909	42	231	2002	**29.9 – 30** 161 - 161.5 213 - 213.5	shale sandstone sandstone	0.75	2500	Stock
104661	6216470	288973	68	219	2003	113 - 113.1 154 - 154.1 197 - 197.1 212 - 212.2	sandstone sandstone sandstone sandstone	1.05	fresh	Dom / Stk
105339	6218287	291802	-	238	2003	139 - 140 183 - 184	sandstone sandstone	0.25	-	Dom / Irrig
105376	6218380	289443	76	218.5	2002	180 - 180.1 191 - 191.2 204 - 204.2	sandstone sandstone sandstone	1.13 1.63 1.50	-	Dom / Stk
105388	6217892	289888	69	230	2002	104-104.1 191-191.2 219-219.2	sandstone sandstone sandstone	0.5 1.6 0.13	-	Dom / Stk
105531	6218430	287664	79	210	2003	96.2-96.8 110.5-113 175.5-177 188-188.2	sandstone sandstone sandstone sandstone	0.2 0.2 0.15 0.15	2070	Dom / Stk
105334	6217297	288655	92	207	2003	113-113.1 161-161.1 188-188.1 197-197.1	sandstone sandstone sandstone sandstone	0.1 0.5 0.68 0.43	-	Dom / Stk
105574	6218908	289656	-	210	2003	**27- 28.5** 85-86 145-147	shale sandstone sandstone	0.5 0.5 0.45	3630	Dom / Stk
106574	6218350	290123	-	-	2005	-	-	-	-	Domestic
106675	6218445	288685	-	-	2005	-	sandstone	-	-	Dom / Stk
108312	6217750	291535	84	175	2004	119 - 120 156 - 157	sandstone	0.16	500	Industrial
BHPB	**PIEZOS**									
NGW3	1216749.5	275027.4	77.33*	72.1	2004	-	sandstone	-	-	Monit.
NGW4	1216826.2	275789.9	68.56*	78.75	2004	-	sandstone	-	-	Monit.
NGW5	1216327.4	276124	66.71*	66.45	2004	-	sandstone	-	-	Monit.
NGW6	1216680.5	276403.3	66.33*	66.75	2004	-	sandstone	-	-	Monit.
NGW7	1216591.4	277016.7	74.01*	69.18	2004	-	sandstone	-	-	Monit.
NGW9	1217131	277737	105.9*	69.2	2004	-	sandstone	-	-	Monit.
NGW10	1217333.4	276952.2	63.4*	69.5	2004	-	sandstone	-	-	Monit.
NGW11	1217624	277105	79.68*	72.15	2004	-	sandstone	-	-	Monit.
EAW5			Various		2008	-	various	-	-	Monit.

Note: * swl in mAHD RL as at May 2008

4.5.2 Surface Water / Groundwater Interaction

Surface water drainage on the plateau is mainly within ephemeral first and second order streams, with the majority of northerly drainage flowing toward the channels of Navigation and Foot Onslow Creeks. Drainage to the south-west flows to Harris Creek.

Drainage in first and second order channels to the east flows into the Nepean River, adjacent to the proposed mining area, and from smaller gullies along the upper cliffs of the gorge which generally discharge into the Nepean River from elevated stream beds that cascade down the cliffs after sufficient rain.

The majority of rainfall in the small ephemeral catchments would infiltrate into the plateau soils.

Recharge to the groundwater system would occur over an extended delay after rainfall has infiltrated through the plateau's soil cover as well as the Wianamatta Shale and Hawkesbury Sandstone, with the majority of water discharging from temporary seeps in the cliff face of the gorge being due to the preferential horizontal rather than vertical flow regimes in sub horizontal faults, bedding planes or discontinuities in the sandstone or along the Wianamatta Shale / Hawkesbury Sandstone contact.

Drainage to stream beds out of the sedimentary interface between the Wianamatta Shale and the underlying Hawkesbury Sandstone would also occur across the plateau over the mining area.

The predominantly horizontal flow regime and restricted vertical recharge is essentially determined by the;

- horizontally bedded strata under both sides of the plateau with preferential flow along bedded zones with coarser grain size,
- claystone/mudstone banding at the base and tops of sedimentary facies which restrict vertical migration and enhance horizontal flow at the base of the unit,
- fracture zones enhancing horizontal flow through the strata, and
- bedding planes or unconformities located immediately above finer grained sediments or iron rich zones.

Groundwater under the plateau discharges to the river in a "gaining" system where it flows down gradient under gravity to the river, whilst a smaller component of flow will move from high to low piezometric pressure areas up from the base of the gorge to the river.

The Nepean River does not flow under gravity to the underlying groundwater body as a "losing" system as was noted in the Georges River over the West Cliff workings.

As the Nepean River is the largest regional river in the catchment, all drainage from surrounding groundwater systems and tributary streams is toward the base of the gorge.

The river then flows under gravity along the gorge to Menangle Weir, and subsequently along the Nepean River downstream of Warragamba Dam to the Hawkesbury River.

4.6 DWE Groundwater Chemistry

Groundwater in the DWE registered bores is generally fresh to brackish with salinity between 260mg/l and 2500mg/L, whilst previous sampling of private bores prior to extraction of Tower Longwall 17 on the eastern plateau (Coffey Partners International, 1998) indicates groundwater exceeded ANZECC irrigation trigger values for sodium, chloride and hardness as outlined in **Table 2**.

TABLE 2 REGIONAL GROUNDWATER QUALITY

Parameter	ANZECC 2000	Lot1	GW102798	Lot24/25	Tower 22	Tower 22
Sample Date		**2/2/98**	**2/2/98**	**2/2/98**	**8/1/98**	**25/6//98**
pH	**6 – 8.5**	6.95	6.91	7.13	6.4	6.64
EC (µS/cm)	**-**	2420	3100	2700	-	3900
TDS	**-**	1320	2270	1320	-	3350
Na	**115 – 460**	290	**560**	285	398	**760**
K	**-**	9	12	12	8	-
Ca	**-**	91	92	88	89	-
Mg	**-**	92	140	105	98	-
Hardness	**350**	**606**	**806**	**652**	**626**	-
Cl	**175 – 700**	520	**1030**	510	687	**1800**
HCO3	**-**	570	640	630	330	-
SO4	**-**	24	95	29	88	150
F	**-**	-	0.42	0.4	0.7	-
$NH4^+$	**-**	<0.1	0.3	0.23	-	-
NO3	**-**	<0.01	0.03	<0.01	<0.05	0.09
TKN	**-**	1.4	1.4	1.3	-	1.3
PO4	**-**	<0.01	<0.01	<0.01	-	<0.01
Fe	**10**	0.21	0.06	0.17	0.13	1.2
Mn	**10**	0.29	0.03	0.04	-	0.43

NOTE: all parameters in mg/L except as shown

ANZECC 2000 irrigation water quality trigger values for selected vegetables (tomato, cucumber) and general water use

4.6.1 Strata Gas and Oil

Gas emissions at the surface have typically occurred within river valleys such as the Nepean, Cataract and George Rivers, although some gas emissions have also been observed in smaller creeks and in water bores. Analyses of gas compositions indicate that the coal seam is not the direct and major source of the gas and that the most likely source is the Hawkesbury Sandstone.

Gas emissions on the plateau surface are rarely observed in the Southern Coalfields, although strata gas emission has been observed along the Nepean River Gorge in the vicinity of Longwalls 16, 17, 20 and 701 associated with upsidence and cracking of the sandstone at the base of the gorge.

The likelihood of gas emission on the plateau and/or within groundwater bores is possible, and in some instances, such as in Chicken Creek, gas emissions may last for over a year.

Subsidence causes fracturing of the strata above the coal seam which can release and generate upward movement of stored methane and other gases through the overburden with potential diffusion to the ground surface through connected cracks and fissures.

The lower permeability Bald Hill Claystone, which separates the Hawkesbury and Bulgo Sandstones, can inhibit the movement of water and gas if it is not breached. If the claystone is fractured by subsidence it is possible that the downward movement of water through the clay could cause it to swell and seal off the cracks, if they are small enough and inhibit further gas or water movement.

In addition to gas contained in the Bulli Seam, the Narrabeen Group (Newport Formation through to the Coalcliff Sandstone) also contains gas primarily within the Bulgo Sandstone, which is believed to be saturated, with low permeability. Coarse-grained lenses up to 3m thick within the Bulgo Sandstone are believed to be more porous and often flow gas when drilled. Because of the low permeability, significant gas release from the Narrabeen Group does not occur until goaf formation causes stress relief and fracture formation higher up in the strata. The Narrabeen gas composition is principally methane (72% to 99.5%) with some carbon dioxide, varying amounts of ethane and minor occurrences of higher hydrocarbons.

The emitted gas can dissolve in water, depending on its concentration, composition, residence time in the water and consumption by bacteria (Ecoengineers, 2008).

Strata gas in the present workings of Appin Colliery and Douglas Mine have had to use a system of surface drainage holes to manage the volumes of gas released from the Bulgo Sandstone over mine goafs. Gas in the strata below the Bulgo Sandstone has been minor in these southern areas.

Oil has been observed in the Narrabeen Group sandstones overlying the Bulli seam. Minor oil occurrences have been observed in the 200m interval above the seam within the Bulgo, Scarborough and Coal Cliff Sandstones. These formations consist of mainly of fine- to medium-grained lithic sandstones with minor pebbly conglomerates. Oil occurs predominantly in the coarser units consisting stacked alluvial channel sequences which are both laterally and vertically discontinuous and the reservoir appears to be confined to the Douglas Park Syncline, although it is not found within specific mappable horizons.

Analysis of the oil indicates that it is terrestrial in origin and, most likely, originated from the adjacent coal seams and carbonaceous units and has only been observed in very small quantities over short stratigraphic intervals (BHPB, 2006).

5. FIELD AND OFFICE ASSESSMENT

5.1 Appin Area 7 Drilling and Piezometer Installation

The hydrogeology of the SMP area was investigated by core drilling, packer testing and piezometer installation in eight bores installed to 10m below the base of the western bank of the Nepean River in the BHPB “NGW” series. The bores were completed with vibrating wire piezometer installations, with locations are shown in **Drawing 1**. In addition, a bore with multi-level sealed vibrating wire piezometers (EAW5) was installed down to the Bulli Seam to the north of Panel 10 in May 2008

These studies were conducted in order to;

- provide detailed information on the local stratigraphy and identify stratigraphic units associated with visible groundwater seeps on nearby cliffs,
- measure and assess changes to local groundwater levels in response to rainfall,
- measure the water bearing capacity, transmission characteristics and hydrostatic groundwater water pressures in the sequence to 10m below the river,
- understand any association between the plateau groundwater system and the Nepean River,
- develop a conceptual groundwater model in order to assess the potential impact of mining Longwalls 705 to 710 through obtaining a greater understanding of local groundwater flow dynamics in the Hawkesbury Sandstone sequence, and to
- allow groundwater monitoring to be conducted before, during and after mining in the area.

Bore locations were selected to represent the various stratigraphic sections where subsidence movements and impacts may occur. The program also has to account for restricted landholder access on some properties.

The four NGW bores on the river’s west bank are installed directly over the proposed mining and adjacent areas to enable monitoring of baseline and mining affected standing water levels above, at and below river level.

Hydraulic testing was performed with double inflatable packers spread 2.4m apart in selected stratigraphic units and fracture zones. Each interval was subjected to transient water injection and recovery tests, with the injection pressure held constant.

Water circulation loss during drilling was also recorded in each bore, however hydraulic permeability was not calculated in the NGW bore series due to the limitation of discrete bedding plane control and the unsaturated nature of most of the strata.

Depth intervals below the river in the “NGW” series were screened with slotted PVC pipe encased in a geotextile “sock” and graded sand, with blank casing and cement grout extending to the surface.

Each bore is protected by a 75 mm steel tube with a blank plate bolted to the upper flange that allows for manual water level monitoring and attachment of vibrating wire piezometers. The loggers are self-contained units that transfer data to a portable receiver.

The core drilling process uses injected water to lubricate the drill rods and flush out cuttings. This restricts the ability to directly identify shallow or perched aquifers with low water inflows, which are effectively over printed by circulation of the injected core drilling water.

As a result, interpretation of hydraulic parameters in the completed bore is limited to packer test data and monitoring in the slotted or vibrating wire piezometer intake section, with low yielding perched aquifers above the monitored zones not being identified.

The EAW5 bore was drilled packer tested in selected lithologies down to the Bulli Seam, with sealed vibrating wire piezometers installed at selected horizons in May 2008. As the bore has only recently been completed, only the packer test data and initial piezometric heads are available at this stage.

5.2 Hydraulic Parameters

5.2.1 Hawkesbury Sandstone "NGW" Series Tests

No consistent water bearing horizons were identified above the base of the Nepean River during drilling the "NGW" series bores. No water bearing horizons were identified either because they are not present or because the intersection flows were too small to be observed during core drilling.

Potential water migration zones were assessed through interpretation of the drilling, packer testing and cliff inspection data. This data indicates generally low permeability with no discrete continuous permeable zones that can be extrapolated over the study area.

Water injection testing intakes below the pervasive L-MS facies were generally low, with migration along joint planes restricted to strata above the river and in close proximity to the cliffs where lack of horizontal confinement enables seeps to develop.

Bore yields in the general area obtained from the DWE database, indicates the sandstone is generally low yielding (up to 1.8L/s).

Higher permeabilities were found to occur in low-angle cross-stratified to crudely stratified coarse sandstones and large-scale planar/tabular cross-stratified medium to coarse sandstones. Lower permeability zones occur in small-scale trough to planar/tabular cross-stratified, fine-medium grained sandstones and lutites (BHPB, undated).

Coarser sandstones were found to have higher water inflows during packer testing compared to finer grained facies.

Groundwater flow is primarily controlled by the presence of finer grained aquitards which underlie higher porosity, coarser sandstones, with the finer grained layers appearing as fresh (grey) to moderately weathered and heavily stained (orange to deep red) bands.

Packer tests indicate that water intake is generally low in the sandstone, with lower relative intakes on the western side of the river. Intake between holes was variable, with no systematic higher permeability zones identified, although the large water intake of NGW9 and NGW10 is more likely to be due to intensely jointed zones or fractures along bedding planes in the test interval (Geoterra, 2006 GW).

Circulation loss was experienced when major fracture or joint systems were drilled through. The fractures did not generally relate to observed standing water levels with the loss likely to occur on bedding plane surfaces. No consistent loss could be attributed to natural joint systems.

No obvious water intake horizons were identified from the packer test recoveries, with NGW6, 9, 10 and 11 experiencing the greatest drop in water head once the packers were deflated.

The lack of homogeneity in the packer tests can be attributed to:

- the partially saturated to unsaturated nature of the strata,
- a highly variable sandstone sequence at similar depths with varying permeabilities,
- localised barriers in the strata, such as siderite and clay lenses and joints,
- variable sample interval thickness, where several units with potentially different characteristics may be included in one test,
- thin water transmission zones compared to the sample thickness,
- concentration of high permeability zones on bedding planes and unconformities, and
- lack of visual geological characteristics to define test intervals.

Miall and Jones (2003) inferred that seeps observed through remnant iron staining on cliffs indicate the presence of a vertical permeability barrier, such as mudstone. Liu *et. al.* (1996) observed that permeability was more variable vertically than horizontally and that permeability in the Hawkesbury Sandstone is extremely variable and primarily relates to sedimentary structures, such as types of cross-bedding, along with variations in grain size and sorting.

5.3 Hawkesbury Sandstone to Scarborough Sandstone “EAW” Series Tests

Packer based permeabilities for Bore EAW5 obtained in May 2008 between the Wianamatta Shale and the Scarborough Sandstone as shown in **Figure 5** (GHD Geotechnics Pty Ltd, 2008) indicate permeabilities below 1×10^{-6} m/sec which decrease with the depth of cover generally to around 1×10^{-7} and 1×10^{-8} m/sec.

One anomalous zone in EAW5 returned a permeability in the Hawkesbury Sandstone of 1×10^{-3}m/sec from 134.3 to 140.3mbgl.

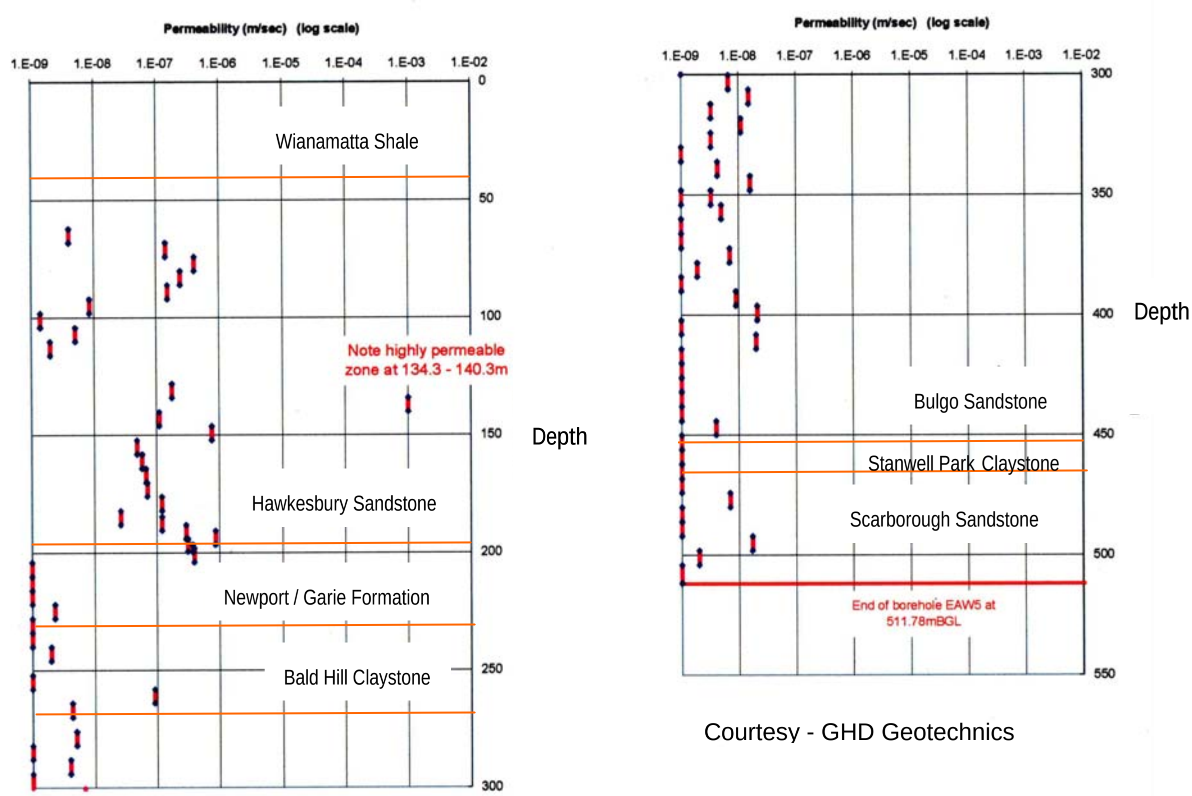


FIGURE 5 Bore EAW5 Packer Test Permeability

5.3.1 Groundwater Levels

The contoured piezometric surface for the NGW series bores as shown in **Drawing 3**, which all have piezometer intake zones at approximately 10m beneath the level of the Nepean River up to 72 mbgl, indicate that in May 2008, both the east and west plateau groundwater systems within the Hawkesbury Sandstone, based on the intake intervals used, drain toward the Nepean River as a "gaining" system. It is noted the gradients are, however, steeper under the western plateau.

Standing water levels (swl) since June 2004 as shown in **Figure 6** in the "NGW" series piezometers indicate the following;

- NGW3 – the bore annulus appears not to be properly sealed, as the swl peaks every time after rainfall, with the swl then falling back to a longer term trend which shows a response to drought and rain periods. The piezometer shows a fall in water levels up to February 2007 from approximately 77.4mRL to 76.8mRL, followed by a rise back to 77.5mRL in May 2008.
- NGW4 – the initial trend was for a cyclic reduction and rise in response to rainfall and dry periods between 67.7mRL and 67mRL up to late August 2006, with the latter rise being a response to exploration bore drilling water injection in the vicinity. The piezometric level then generically rose following the February 2007 rains, and the subsequent ongoing wetter period since then up to May 2008, with

a rise in swl up to approximately 68.5mRL.

- NGW5 – this piezometer shows a similar, although subdued response to that observed in NGW4 during the initial dry / wet cyclical period up to August 2006, with variations between 66.5mRL and 66.7mRL. It also shows a similar response to exploration bore drilling water injection around August 2006 with SWLs rising up to approximately 69.4mRL in the vicinity. The piezometric level then fell once drilling had finished and then rose again up to approximately 66.6mRL in response to the ongoing wetter period that started around February 2007.
- NGW6 – was installed in late September 2004, and shows a continual rising piezometric level following its installation up to late January 2006, at which time it had a distinctive fall to 62.7mRL then a return back to 67.5mRL around the August 2006 exploration drilling period. During August 2006, there was no exploration close to this hole at the time, and in the water level record there are 3, as yet, unexplained sudden pressure decreases Feb 06, and 2 similar events in Nov06 and Feb08). Since August 2006 it has shown a gentle rise from approximately 65.9mRL to 66.3mRL in May 2008, with occasional short term rise of up to 0.5m following more significant rain events.

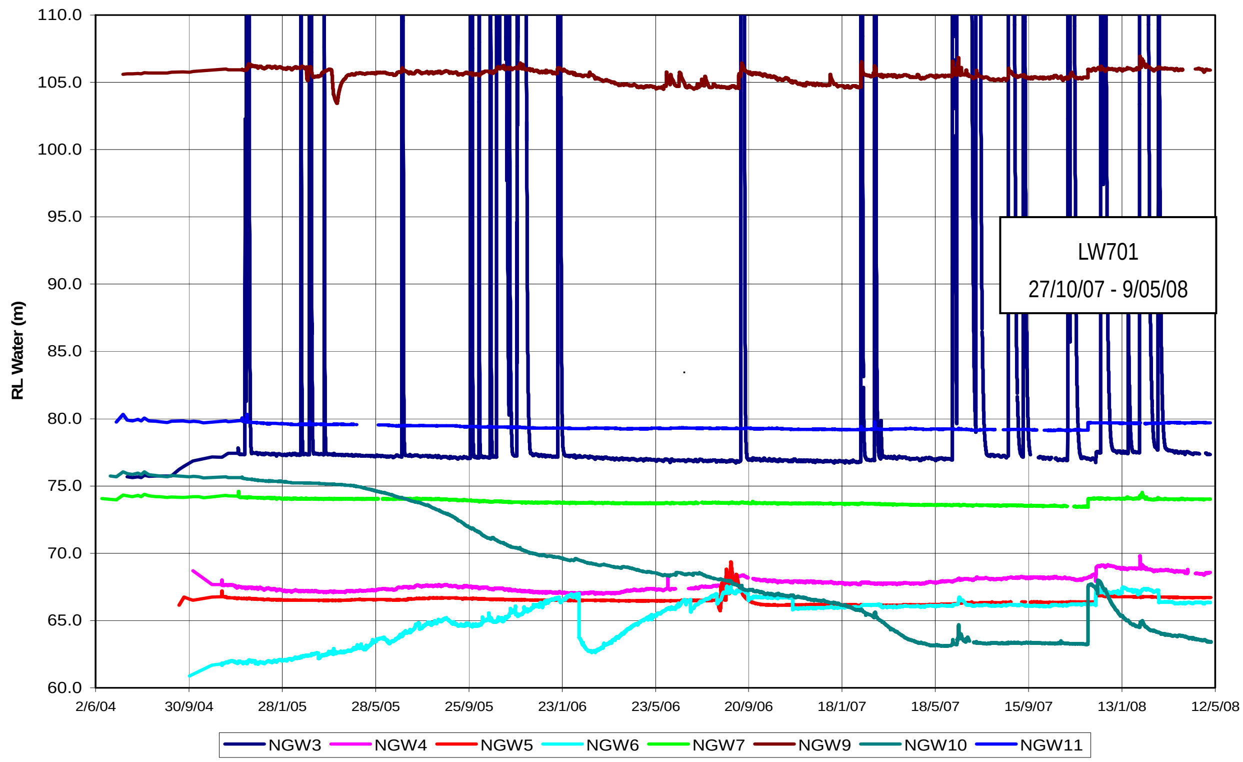
It is noted that all the piezometers installed on the western plateau (NGW3 to 6) all show a generic fall during the initial drier period between June 2004 and February 2007 followed by a generic rise in SWLs in the wetter period that began around February 2007 up to the present.

All piezometers show a jump in water level of up to 1m following a water sampling event in late November / early December 2007, as a result of extracting then replacing the vibrating wire piezometers. There are no observed changes in the eastern plateau piezometers (NGW7, 9, 10 and 11) in response to exploration drilling as no drilling occurred in their vicinity during the monitoring period.

- NGW7 – following its installation in June 2004, NGW 7 gradually fell from approximately 74.3mRL to around 73.5mRL, followed by a flattening out around late December 2007. A short term rise of around 0.4m was observed following the February 2008 rains.
- NGW9 – over the monitoring period, NGW9 has risen and fallen between 104.6 and 106mRL, with an overall, generic “flat” piezometric surface with short term rises following the more intense rain events of up to 1m. There may be an external influence in April 2005 when Sydney Water was drilling near NGW9.
- NGW10 – has had a generic fall in SWL since June 2004 of up to 13.5m, which is anomalous compared to all the other NGW piezometer records, with a fall from 76mRL to 62.5mRL. At this stage there is no definitive reason why this fall is occurring, however it may be due to NGW10 being the closest to the Nepean River gorge along with a possible extension / connection with the Nepean Fault Zone, or due to far field displacement of structures, fault activation or post subsidence movement. It is noted that the standing water level started to stabilise

before the June 2007 rains and that possibly the February 2007 rains started to recharge the piezometric surface around NGW10. The piezometric surface “flattened out” following the late June 2007 rains. The sampling effect in December 2007 was larger than observed in other bores (approx 5m), however the water level has subsequently returned to around 62.5mRL in May 2008.

- NGW11 – this piezometer also shows a generic reduction in swl as seen in the other eastern plateau bores, with a fall from approximately 79.9mRL to 79.2mRL. along with the December 2007 “sampling” rise of approximately 0.5m. The piezometric surface essentially flattened out following the February 2007 rains, which started the return to a “wetter” period following the initial drought period observed in the monitoring record.



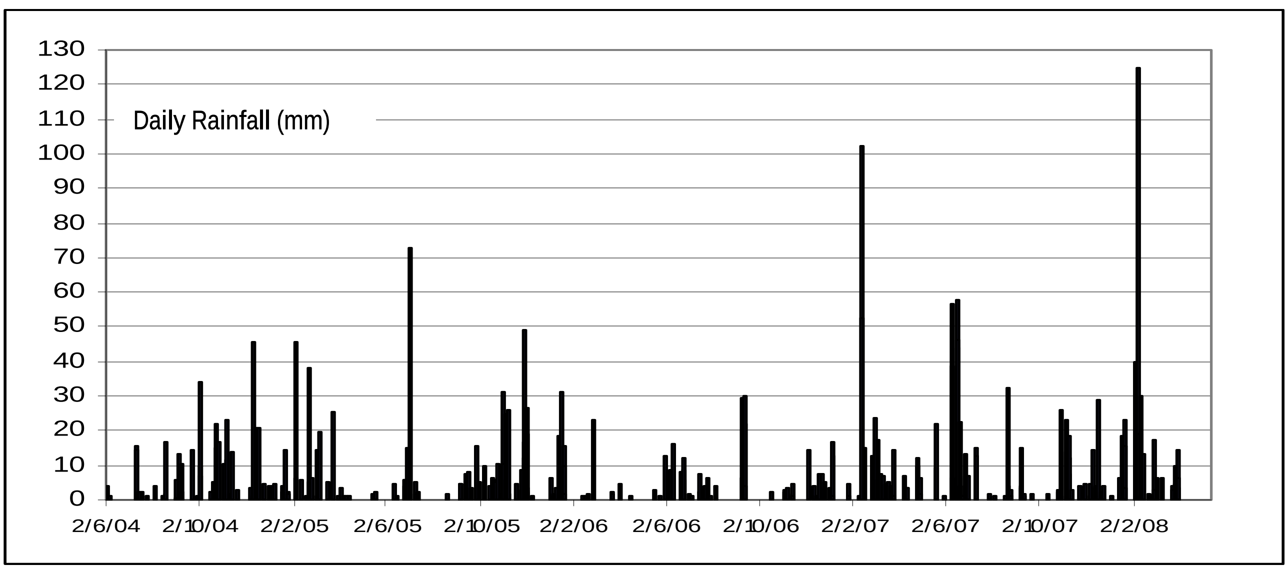


FIGURE 6 Area 7 Standing Water Levels and Rainfall

Only limited standing water level records for EAW5, which was installed in May 2008 are available to date as shown in **Figure 7**.

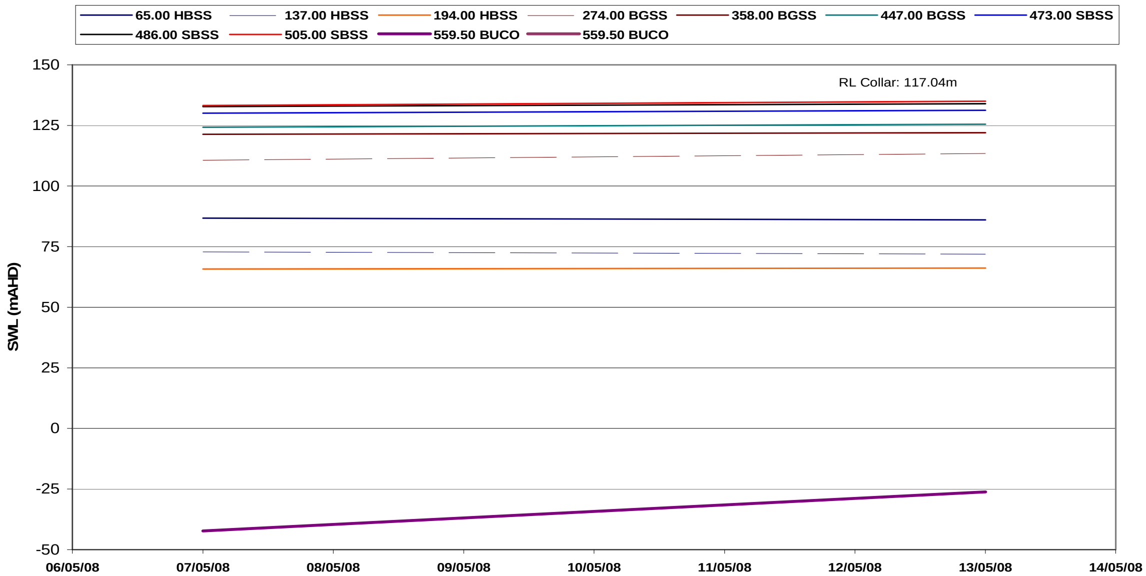


FIGURE 7 Piezometer EAW5 Standing Water Levels

5.3.2 Effects of Longwall Extraction in the NGW Piezometer Vicinity

Extraction of longwalls in the vicinity of the NGW series piezometers has occurred in LW10-12, LW20 and LW701 in the Appin / Tower workings, as well as LW30-32 in the West Cliff workings.

Monitoring of the NGW series began in June 2004, subsequent to the extraction of Tower Longwalls 10-12 and 20. Monitoring was, however, in place during extraction of Appin Longwall 701 (27 Oct 07 to 9 May 08) and the West Cliff Longwalls 30 to 32, whose extraction dates are shown below;

- Longwall 30 (29 July 2004 to 3 June 2005)
- Longwall 31 (29 July 2005 to 29 December 2006)
- Longwall 32 (12 Feb 2007 and will finish in late June 2008)

No observable drawdown effects from extraction of Longwall 701 are noted in the nearest piezometer to the panel (NGW5) during the Longwall 701 extraction period, although the effect of rainfall recharge appears to be more obvious as the previous falling piezometric surface flattens out around late November 2007.

There are no observable drawdown effects from the extraction of West Cliff Longwall 30 to 32 on the NGW series piezometers.

5.3.3 Groundwater Quality

Groundwater sampling and detailed laboratory analysis was conducted in selected BHPB Area 7 piezometers in November / December 2007 as shown in **Tables 3** and **4**.

Access with landowners for sampling and analysis of private bores in the approved Panel 702 to 704 SMP mining area has been negotiated and sampling is planned to be undertaken in July and August 2008 prior to the extraction of Longwall 702.

TABLE 3 NGW Piezometer Groundwater Quality 30/11/07 – 10/12/07

NGW	pH	EC µS/cm	TDS	Na	Ca	K	Mg	Cl	F	SO_4	T Alk	NOx as N	TKN	P_{tot}
3	7.15	**670**	404	53	41	8	31	30.9	-	33	283	0.018	3.3	**0.42**
4	**7.53**	**771**	434	110	32	9	7	56.7	-	134	137	0.016	0.7	**0.08**
5	**8.39**	**4520**	2330	682	104	94	3	1220	-	182	28	0.069	1.0	**0.03**
6	6.91	**2200**	1220	249	97	46	37	464	-	189	139	**0.136**	0.5	**0.04**
7	7.05	**1060**	574	82	82	27	25	79.8	-	128	261	0.02	0.8	**0.18**
9	6.91	**333**	178	26	20	4	7	51	-	1	62	0.026	2.0	**0.02**
10 (30/11)	6.71	**10100**	5530	1370	146	23	382	2650	4.28	232	797	0.016	0.2	**0.02**
10 (10/12)	6.69	**10100**	5560	1410	137	24	358	3050	-	222	748	-	0.6	**0.07**
11	6.83	**850**	560	45	52	32	26	113	-	19	118	**19.9**	2.4	**0.43**
ANZECC	6.5-7.5	30 – 350	-	-	-	-	-	-	-	-	-	0.15	-	0.02

NOTE: all units in mg/L except as shown **T Alk** = HCO3

(highlighting indicates values outside ANZECC 2000 criteria)

ANZECC 2000 default trigger values for risk of adverse effects from physical and chemical stressors in SE Aust. Upland Rivers

Sampling of the NGW piezometers indicates that all bores exceed the salinity guidelines for South East Australian Upland Rivers in all bores, as well as generally for total phosphorous and occasionally for pH and total nitrates.

It is noted that the salinity of NGW10 is significantly higher than the other NGW piezometers, and may indicate that the water is much "older" and / or potentially from a more confined aquifer or fracture network, thereby being more responsive to depressurisation following mining.

This may also tie in with the observations that NGW10 standing water levels have fallen anomalously compared to the other bores in the series by around 13.5m. It also may be due to the extended drought in the early phase of monitoring, or as it is closest to river as mentioned previously.

TABLE 4 Groundwater Chemistry (metals - mg/L) 30/11/07 – 10/12/07

	Fe_{tot}	Fe_{filt}	Cu_f	Pb_f	Zn_f	Ni_f	Al_f	Mn_f	As_f	Se_f	Br_f	I_f	DOC
3	2.30	0.33	<0.001	<0.001	<0.005	<0.001	**0.07**	0.071	<0.001	<0.01	0.3	<0.1	18
4	4.82	0.18	<0.001	**0.007**	0.006	<0.001	0.01	0.055	<0.001	<0.01	0.1	<0.1	10
5	0.65	<0.05	**0.002**	<0.001	>0.005	0.001	0.04	0.012	<0.001	<0.01	3.8	0.5	13
6	1.45	<0.05	**0.002**	<0.001	**0.200**	**0.034**	**0.06**	1.6	<0.001	<0.01	1.2	<0.1	6
7	1.08	0.79	**0.003**	**0.004**	**0.019**	0.004	0.01	0.024	0.002	<0.01	0.3	<0.1	11
9	1.70	1.21	<0.001	**0.156**	**0.018**	<0.001	0.02	0.230	<0.001	<0.01	0.2	<0.1	15
10 (30/11)	2.32	1.45	0.001	<0.001	0.008	<0.001	<0.01	0.111	0.002	<0.01	11.3	<0.1	3
10 (10/12)	0.188	1.58	**0.004**	<0.001	**0.017**	0.001	0.02	0.156	0.002	<0.01	8.7	<0.1	2
11	2.18	0.23	**0.005**	**0.139**	**0.028**	0.002	**0.06**	0.066	0.002	<0.01	0.4	<0.1	14
ANZECC	-	-	0.0014	0.0034	0.008	0.011	0.055	1.9	0.024	0.011	-	-	-

Source : ANZECC 2000 trigger values for protection of 95% of freshwater aquatic species

f = filtered **(Highlighting indicates values outside ANZECC 2000 criteria)**

The NGW piezometer filtered metals analyses indicates that copper, lead, zinc, and to a lesser degree, nickel and aluminium can exceed the ANZECC 2000 trigger values for Protection of 95% of Freshwater Aquatic Species Guidelines.

6. POTENTIAL SUBSIDENCE IMPACTS

6.1 SUBSIDENCE PREDICTIONS

The following predicted cumulative subsidence movements relating to extraction of Longwalls 705 to 710 were developed using the Incremental Profile Method (MSEC, 2008), which incorporates monitoring of previous subsidence up to Appin Longwall 701, Tower Longwalls 18 to 20 and West Cliff Panels 30, 31 and 32.

6.1.1 Plateau

The maximum predicted subsidence after completion of all six longwalls is over Longwall 710 as shown in **Tables 5** and **6**.

TABLE 5 Maximum Predicted Cumulative Subsidence (Plateau)

LONGWALL	705	706	707	708	709	710
Subsidence (mm)	1365	1430	1495	1500	1505	1510
Tilt (mm/m)	7.2	6.9	7.2	6.9	7.2	8.0
Tensile Strain (mm/m)	1.3	1.3	1.3	1.3	1.3	1.3
Compressive Strain (mm/m)	2.0	2.0	2.0	2.0	2.1	2.3

TABLE 6 Maximum Predicted Cumulative Subsidence (Plateau Bores)

Bore (GW)	Subsidence (mm)	Tilt (mm/m)	Tensile Strain (mm/m)	Compressive Strain (mm/m)
102584	635	3.6	04	0.1
104154	1045	3.3	0.3	0.4
104602	<20	0.1	<0.1	<0.1
104661	120	1.1	0.1	<0.1
105339	1010	5.0	1.1	0.2
105376	330	3.7	0.7	<0.1
105388	1225	1.2	0.3	0.3
105534	425	3.7	0.5	<0.1
105574	<20	0.1	<0.1	<0.1
106574	925	2.1	0.4	0.2
106675	<20	0.1	<0.1	<0.1
108312	1055	4.5	1.2	0.2

6.1.2 Gorge

A summary of the maximum predicted subsidence parameters in the base of the gorge after each panel is shown in **Table 7**.

TABLE 7 Maximum Predicted Cumulative Subsidence (Gorge)

Parameter	705	706	707	708	709	710
Subsidence (mm)	60	60	60	60	60	60
Upsidence (mm)	315	320	320	320	340	380
Net Subsidence (mm)	<20	<20	<20	<20	<20	<20
Net Uplift (mm)	255	265	265	265	305	345
Valley Closure (mm)	535	545	545	545	545	545

MSEC (2008) indicate that the gorge has previously sustained up to 5mm of subsidence, up to 5mm of upsidence and a maximum observed closure of 18mm due to extraction of LW701, in addition to 60mm of subsidence, 150mm of upsidence and 260mm of closure due to extraction of Tower Longwalls 16 to 20.

It is predicted that the gorge will experience a further net uplift of up to 380 mm, although the amount will vary depending on a range of parameters (MSEC, 2008). Maximum cumulative uplift is predicted to occur near the eastern end of Longwall 707 (MSEC 2008, Figure F.02)

6.1.3 Potential Strata Horizontal Movement

The maximum predicted systematic local horizontal movement is estimated at approximately 120 mm (8.0 mm/m tilt x a factor of 15) (MSEC, 2008).

Based on an empirical database in the Southern Coalfield, it is possible that incremental far-field horizontal movements of up to 20 mm may occur up to 2km from an extracted longwall. It should be noted, however, that at the larger distances from the longwall extractions, the measured movements contain larger proportions of survey error, in addition to valley related closure movements and movements along geological anomalies.

As successive longwalls within a series of longwalls are mined, the magnitudes of the incremental far-field horizontal movements decrease. This is possibly due to the fact that once the in situ stresses in the strata within the collapsed zones above the first few extracted longwalls has been redistributed, the potential for further movement is reduced. The total far-field horizontal movement is not, therefore, the sum of the incremental far-field horizontal movements for the individual longwalls.

The predicted far-field horizontal movements resulting from the extraction of the proposed longwalls are very small and could only be detected by precise surveys. Such movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain, which are generally less than 0.1 mm/m.

The impacts of far-field horizontal movements on the natural features and bores in the vicinity of the SMP Area are not expected to be significant.

6.1.4 Potential Height of Fracturing

The height of the fractured zone above the proposed Longwalls 705 to 710 is estimated to be between 350 and 400m above seam level (MSEC, 2008)

The major claystone unit within the SMP Area is the Bald Hill Claystone, which lies above the Bulgo Sandstone at the base of the Hawkesbury Sandstone. This claystone varies in thickness and is, in some places, more than 25m thick. Due to the nature of this claystone, which swells when it is wetted, it tends to act as an aquiclude.

It is possible, therefore, that the height of the fractured zone above the proposed longwalls could extend up to the Bald Hill Claystone, which lies approximately 270 m above the base of the Bulli Seam. Some vertical dilation above the Bald Hill Claystone and below the Hawkesbury Sandstone is possible but this would not necessarily increase the vertical permeability through the Bald Hill Claystone, which is expected to continue to respond as an aquiclude.

The depths of cover directly above the proposed longwalls varies between 470 and 620m, which are greater than the predicted height of the fractured zone. It is expected, therefore, that a *Constrained Zone*, also called a *Continuous Deformation Zone*, would occur between the fractured zone and the surface.

The constrained zone comprises confined rock strata which have sagged slightly but, because they are constrained, have absorbed most of the strain energy without suffering significant fracturing or alteration to the original physical properties. Some bed separation or slippage can be present, as well as discontinuous vertical cracks, usually on the underside of thick strong beds. Weak or soft beds in this zone may suffer plastic deformation.

6.1.5 Potential Soil Cracking and Bedrock Fracturing

As subsidence occurs, surface cracks will generally appear in the tensile zone, ie: within 0.1 to 0.4 times the depth of cover from the longwall perimeters. Most of the cracks will occur within a radius of approximately 0.1 times the depth of cover from the longwall perimeters. The cracks will generally be parallel to the longitudinal edges of the longwalls (MSEC, 2008).

It is also possible that surface cracks could occur above and parallel to the moving longwall extraction faces, ie: at right angles to the longitudinal edges of the longwalls, as the subsidence trough develops. This cracking is, however, likely to be transient, since the tensile phase, which causes the cracks to open up, is generally followed by a compressive phase, that partially closes them.

Fracturing of exposed sandstone or near surface bedrock is likely to occur coincident with the maximum tensile strains, but open fractures could also occur due to buckling of surface beds that are subject to compressive strains. Fracture widths tend to increase as the depth of cover reduces and only minor fracturing is expected above the proposed longwalls, where the depths of cover vary between 470 and 620m.

Fractures are less likely to be observed in exposed bedrock where tensile strain levels are low, typically less than 2 mm/m, as has been predicted within the SMP Area. A joint spacing of ten metres is not unusual for Hawkesbury Sandstone and, therefore, fractures at the existing joints could be as wide as 10 mm, based the maximum predicted systematic tensile strain of 1.1 mm/m resulting from the extraction of the proposed longwalls.

The incidence of cracks on the surface due to mine subsidence is additionally dependent on the thickness and inherent plasticity of the soils that overlie the Hawkesbury Sandstone and Wianamatta Group shales.

The widths and frequencies of any cracks at the surface are also dependent upon the pre-existing jointing patterns in the bedrock. Large joint spacing can lead to concentrations of strain and possibly the development of fissures at the rockhead, which are not necessarily coincident with the joints.

At a depth of cover of 500m in relatively flat terrain, the maximum crack width in the surface soils, resulting from normal systematic subsidence movements, would generally be expected to be in the order of 25 mm. If a reasonable thickness of surface soil exists, it is more likely that the surface soil would exhibit a number of narrower cracks, rather than a single larger crack (MSEC, 2008).

Surface cracking in soils as the result of systematic subsidence movements is not commonly seen at depths of cover greater than 500m, such as at Appin Colliery, and any cracking that has been observed has generally been isolated and of a minor nature. Any significant cracking in the surface soils could be easily remediated, where required, by infilling with soil or other suitable materials, or by locally regrading and re-compacting the surface.

It is also likely that some cracking would also occur along the alignments of the watercourses as a result of valley related upsidence and closure movements.

6.2 PREVIOUS IMPACTS IN SIMILAR TERRAIN AND MINE LAYOUTS

This section outlines the observed effects of subsidence on groundwater systems over longwall mines located within similar terrain and with similar layouts to the proposed Appin Area 7 workings.

Mines used for comparative purposes are primarily located within the Southern Coalfield of NSW where the Bulli Seam has been mined at depths of cover between 400m and 550m below the surface and in areas dominated by Hawkesbury Sandstone and Wianamatta Shale plateaus with deeply incised gorges.

Observations used to assess the potential effects on groundwater in the application area are primarily from:

- Appin Colliery Longwall 701
- Tower Colliery:

  Longwalls 16 and 17 under the Nepean River plateau and gorge.

  Longwalls 18 to 20 under the plateau and gorge of the Nepean River.
- Longwalls 5A1 to 5A4 under the plateau and gorge of the Georges River at West Cliff Colliery.
- Tahmoor Colliery Longwalls 14 to 19 under a plateau and incised river.
- Metropolitan Colliery Longwalls under a plateau and incised stream.

There are two significant differences between the proposed Appin Area 7 mine plan and previous mining operations listed above.

1. The Appin Area 7 mine plan does not involve any longwall extraction directly beneath the Nepean River, and the other examples involved varying degrees of extraction directly beneath rivers.
2. Groundwater in the vicinity of Appin Area 7, as well as for Tower Colliery Longwalls 16 and 17, flows directly to the Nepean River, which is the lowest hydrological point in the combined groundwater / surface water system. By contrast, the streams impacted by Tower Longwalls 18 to 20, as well as the West Cliff and Tahmoor examples all drain into an upland stream, which, in turn, drains to a lower, major river such as the Nepean.

Due to these factors, the potential impacts of subsidence on the Nepean River and its groundwater interactions are greatly reduced compared to the case studies, which do, however, provide a useful comparison for impact assessment purposes.

The similarity between the proposed mine plan and the case studies is that the plateau was mined under at similar depths of cover and with similar mine layouts.

Depending on the range of factors affecting the groundwater system above a mine, it is possible that a lowered standing water level may not be solely due to subsidence effects but can result from a range of other regional and climatic factors. The frequency of monitoring can also alter the interpretation of water level trends, with a greater spread of data points potentially missing or incorrectly identifying shorter term changes.

The following section details generic groundwater responses to subsidence and the relevant issues involved.

6.2.1 Groundwater Levels

Sufficient longevity of pre and post mining monitoring of groundwater level variability in a range of rainfall situations is critical to assess the micro and macro scale changes in an area.

Groundwater systems experience standing water level (or piezometric head pressure) changes caused by bedrock fracturing due to subsidence. The new fracture voids fill with water, generating head drops, particularly in confined aquifers. In general, unconfined or unconsolidated aquifers are not significantly affected by mining (Booth, C.J., 2002).

After subsidence is completed, water levels may recover due to partial closure of fractures and by recharge flowing back to the affected area. This is usually premised on the basis that there is no sustained discharge from the subsided zone out of the system. These outflow paths could be through, for example, post subsidence springs flowing into valleys or by connection to enhanced permeability goaf zones over mined out panels.

The response to mining and permeability changes varies both spatially and temporally within a mined area. Factors such as topographic relief and stratigraphic variation have a significant effect on the observed response.

Overburden at the advancing front of the subsidence trough undergoes a sequence of horizontal tension and compression of the rock, known as a “subsidence wave” which manifests as volumetric dilation followed by compression of the strata. The strata movement occurs through fracturing, bedding separation and changes in existing joint apertures which can result in substantial changes in fracture porosity and rock permeability. This in turn leads to changes in piezometric heads, groundwater flow patterns and potentially well yields.

A rapid response and temporary decline in piezometric heads can be primarily related to in situ hydraulic property changes in bedrock aquifers caused by:

- a sudden increase in fracture porosity and drainage of groundwater into new void space, with confined aquifers potentially altering to an unconfined or threshold unconfined condition, whilst unconfined aquifers have a significantly less sensitive response.
- a secondary effect of transmitted drawdown around the potentiometric low which spreads laterally and exponentially from the subsided area. This regional effect generally spreads ahead of mining and is generally the first observed response in standing water levels, with greater regional responses usually observed in higher transmissivity aquifers. The actual observed drop in head relates to the depth of a bore, its intake lithology and its confined or unconfined nature, a bores distance

from the subsidence zone, its overburden thickness or separation distance from the bottom of the bore to the top of the disturbed goaf as well as the local relief.

- leakage from upper to lower aquifers through fractured aquitards, with discharge to lower aquifers or local surface water systems. Groundwater flow patterns are affected in areas with high topographical relief by a combination of the topography which drives vertical flow and the layered stratigraphy which favours lateral flow, with subsidence changing the balance toward the topographic driven system. Bores below the regional drainage level may rise due to dewatering of perched aquifers and increased recharge through subsidence fractured layers.
- changes in hydraulic gradients caused by increased permeabilities, as permeability is linked to hydraulic gradient and specific discharge.

If the permeability is increased due to secondary fracture generation, the hydraulic gradient must decline or the specific discharge must increase to maintain stasis. Heads can decline upgradient and rise downgradient from the affected area and groundwater discharges may increase. The overall effect will be seen as an increase in spring or stream flow and a lowering of groundwater levels and loss of stream flow in upland recharge areas.

Groundwater level recovery is driven by two separate mechanisms, which are compression and recharge of the overburden. Partial re-compression of faceline cracks generally follows the dilational subsidence phase, with tension fractures closing, causing a reduction in secondary void space in the bedrock and a resultant increase in groundwater head pressures. Settlement of beds may also result in some closure of bedding separations and groundwater level recovery.

Water level recovery can also occur as regional recharge water flows back to the temporary potentiometric low over a period of a few months. This recovery is dependent on connection to sources of groundwater recharge, the ability of the aquifer to transmit water back into the affected area and the amount of rainfall recharge. Areas of low transmissivity will require longer recovery periods than those in higher transmissive formations.

Changes in permeability can permanently affect the groundwater flow system, with the degree of recovery relating to the degree of fracture recompression. A higher permeability residual fracture network generally remains along the rib line tensional edges of the subsidence trough compared to the inner sections of the trough where faceline cracking has a higher post subsidence recompression ratio. Areas directly over the rib line area can have permanent head losses, with lesser changes in the mid or external panel areas. The combination of the two effects can make long term groundwater system recovery assessment difficult to predict although valley water levels are more likely to recover than hilltop areas or in lithologies below the regional water table compared to perched aquifers (Booth, C. J., 2002). An idealised plot of groundwater responses to mining and subsidence is shown in **Figure 8**.

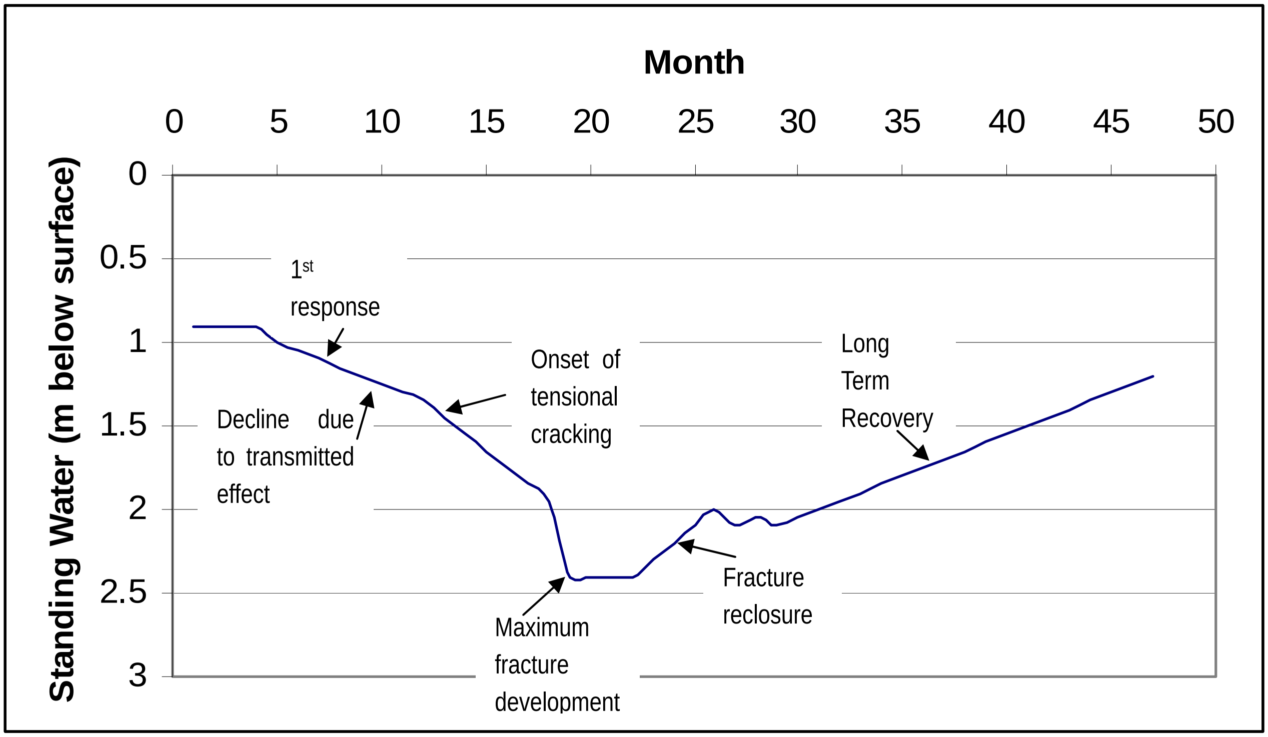


FIGURE 8 Idealised Water Levels During Subsidence (after Booth, C.J., 2002)

6.2.2 Plateau Groundwater Level Observations

As outlined in (MSEC, 2008), it is estimated that the closest corollary to the proposed mining of Longwalls 705 to 710 are observations of surface water and groundwater system changes over Tower Longwall 17, which directly mined under the Nepean River gorge, as well as observations from Tower Longwalls 16, 18, 19 and 20.

It should be noted, however that Longwall 17 directly mined under the Nepean River for approximately 800m, whilst Longwalls 16 and 20 either partially mined under, or were in close proximity to the gorge. Longwalls 705 to 710 are set back 180m from the edge of the river.

Other differences that affect direct correlation include the additional longwall width (between 90m to 120m) of the proposed longwalls compared to previous panels.

Based on their comparison (MSEC, 2008) concluded that the potential impacts on the Nepean River due to mining the proposed panels are likely to be greater than those observed through mining Longwalls 15 and 19 and less than the effects of Longwalls 16, 17 and 20.

A schematic representation of the Cataract and Nepean River systems over Longwalls 14 to 17 and the proposed Longwalls 705 to 710 is shown in **Figure 9**.

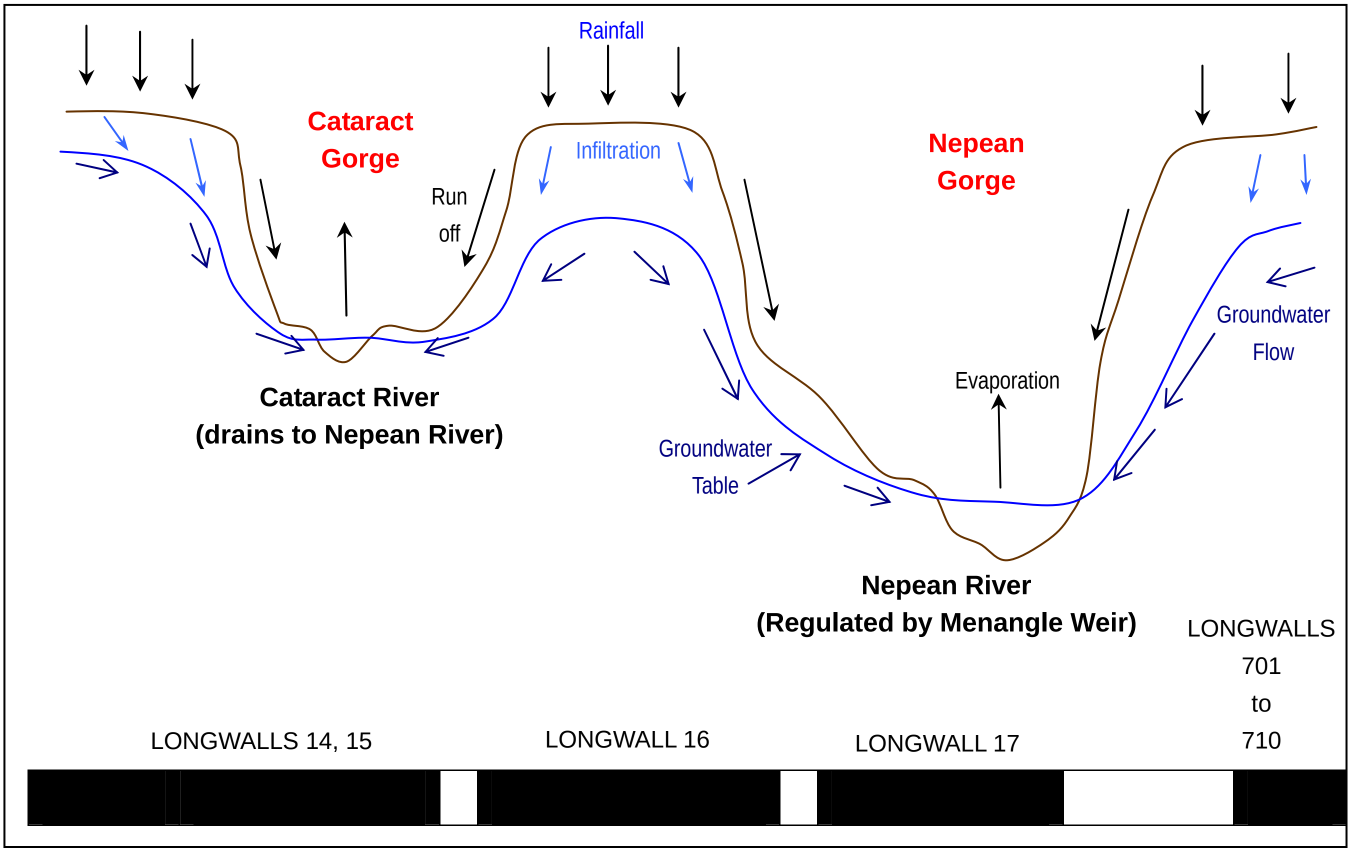


FIGURE 9 Schematic of Mining Areas of the Cataract and Nepean River Gorges

Groundwater monitoring at Tower Colliery did not measure standing water levels or water quality both before or after a panel was mined. A piezometer over Longwall 15 (Tower Longwall 22) was monitored for water level changes over Longwall 15 as it was being mined between January and July 1998 (Geoterra (GW), 2006). This data has limited usefulness for extrapolation to the potential changes that may occur in Panels 705 to 710 as the monitoring period did not include any pre-mining baseline groundwater levels.

Five private bores that were used for domestic or horticulture on the Nepean River plateau to the east of Longwall 17 were monitored before LW17 was extracted, with no adverse changes to standing water levels or water quality reported by the landowners.

Figure 10 illustrates piezometer water levels located adjacent to a panel at least 1.8km from the Bargo River gorge adjacent to the Tahmoor Colliery workings, with water level declines of up to 2m over one month in P1, followed by a gradual decline of a further 2m observed over four months.

Piezometer P1 was located on the edge of the 20mm subsidence zone, whilst P2 and P3 are located outside of the subsidence area.

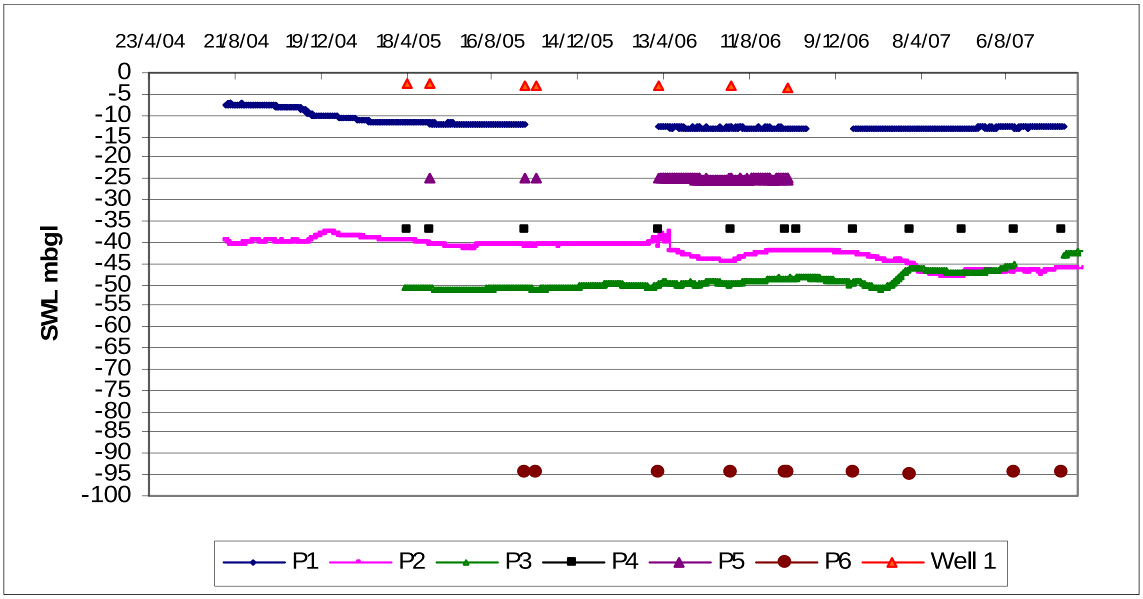


FIGURE 10 Groundwater Level Monitoring at Tahmoor Colliery

Prior to the monitoring outlined above, complaints were received from landowners with stock / domestic or agricultural bores located approximately 175m to 475m from a previous panel edge.

Bores were replaced or reconditioned where it was determined that mining had impacted on them. It was not possible to quantify the impact of mining on the bores as they had not been monitored prior to mining.

No pre and post subsidence effects on groundwater systems were monitored at Tower Colliery, whilst extensive monitoring with 67 piezometers are used to assess groundwater response to subsidence at West Cliff Colliery (BHPB, 2005).

It should be noted that the geomorphology and hydrological characteristics of the upland river systems over Tower and West Cliff Collieries are fundamentally different to the area over the proposed Longwalls 705 to 710. Any direct comparisons of subsidence effects between previous mined areas and this proposal should be done with due regard to these significant differences.

Groundwater monitoring at West Cliff includes shallow piezometers in direct connection to the Georges River and deeper piezometers in the Hawkesbury Sandstone under the plateau along the river.

This discussion only relates to the deeper piezometer data, as the response of the interconnected shallow groundwater / river system to subsidence at West Cliff is not directly applicable to Longwall 705 to 710 as the Nepean is not being mined under and it is not an upland losing river system.

Groundwater in the vicinity of, or directly over subsided panels at West Cliff generally fell by around 1.5m to 3m, although falls of up to 9m were observed in plateau sandstone piezometers such as GR50 overlying or near Longwall 29, where the current (mining affected) water table ranged from approximately 21m to 36m below surface as shown in **Figure 11.**

The absolute change in water levels over Panels 5A1 to 5A4 and Panel 29 could be greater than 9m as most piezometers did not monitor pre-mining standing water levels.

In the same period, piezometers located outside and north of the Longwalls 5A1-4/29 mined area in un-subsided ground have recorded relatively static water levels which vary by up to 0.5m.

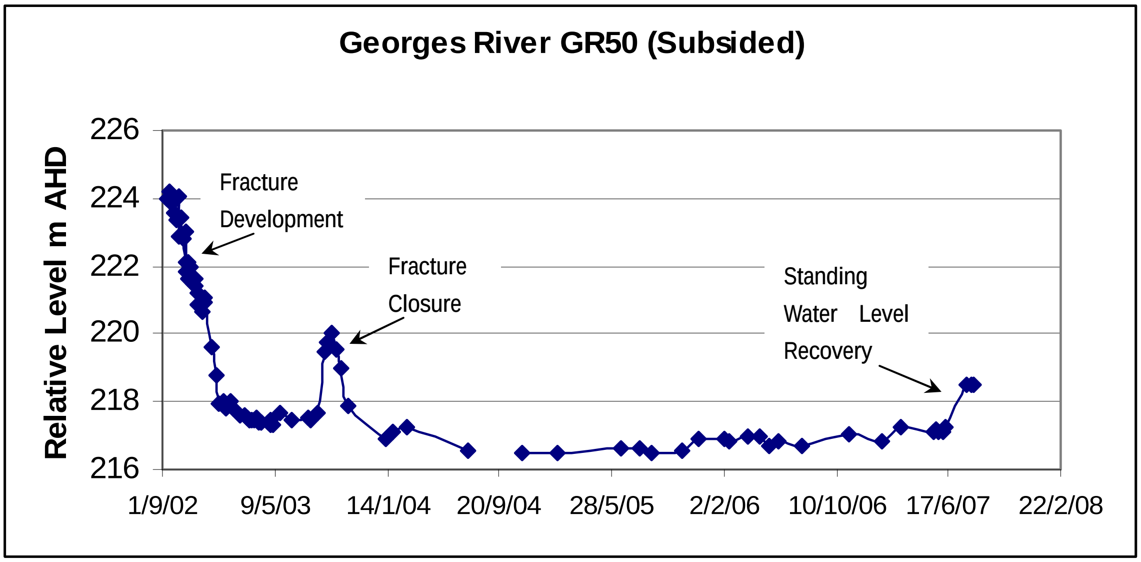


FIGURE 11 Subsided Groundwater levels at West Cliff Colliery

6.2.3 Yield

Bore yield is defined as the volume of water per unit time that is discharged from a well, and is usually quantified in either L/s or ML/day.

The yield relates to the combined effect of the standing water level and hydraulic properties of a bore. Faster water level recovery following hydraulic conductivity enhancement of a formation due to mining can enhance a bore's yield. However the water quality may be reduced due to interaction with a greater surface area of unweathered lithologies around the bore.

The yield can also be reduced if a bore runs "dry" due to lowering of the regional standing water level after subsidence so that the pump runs out of water. Reduced yields were reported following subsidence at Tahmoor Colliery, which was remedied by either redrilling the bore or cleaning and lowering the pump intake.

Assessing changes in yield due to mining has been difficult to date at Tahmoor as the bores were generally not monitored before mining. In these circumstances, a reported loss of yield could result from one or more of the following factors:

- mining,
- regional water level reductions after extended drought,
- neighbouring bores being extracted at increasing rates or duration,
- additional extraction from a nearby or connected system, and
- normal operational or maintenance related problems.

Quantification of the impacts from subsidence requires pre-mining baseline data as well as regular monitoring during mining and after the completion of mining if there have been effects identified. In addition to purpose built monitoring bores, other sites that should be monitored include extraction bores in the subsidence zone and neighbouring bores. The parameters to be monitored should, where possible, include usage patterns, flow rates, standing water levels and bore construction details. Ongoing monitoring of water levels and usage patterns should be assessed during and after subsidence has developed.

6.2.4 Groundwater Quality

Groundwater quality within subsidence affected aquifers is an important issue to consider when assessing the significance of potential impacts on streams, groundwater dependent ecosystems or groundwater use.

No significant adverse groundwater quality changes have been reported from bores within subsidence affected areas in the Southern Coalfields. However, it is likely that water quality changes have occurred, but not been observed due to the relatively low level of groundwater resources and use in mining areas.

Potential impacts likely to have occurred include increased iron concentrations and precipitation of iron hydroxide. This has the potential to impact pipes, dams or other water transfer systems through pumping and aeration of groundwater.

Other more subtle changes may occur with regard to dissolved nickel, zinc or manganese levels through oxidation and dissolution of iron and manganese carbonates (siderite, rhodochrosite) and iron sulfides (marcasite) following subsidence induced fracturing around a bore. Identification of subsidence related changes in dissolved metals requires the appropriate collection, preservation and laboratory analysis of samples during a range of pumping situations and durations that a bore is normally subjected to.

No comparative pre and post-mining observations on groundwater quality were conducted at Tower Colliery. The limited observations at Tahmoor Longwalls 22 and 23 do not indicate any significant observable change, primarily as focussed monitoring only began at the start of Longwall 23. Nevertheless, no complaints regarding groundwater quality (as opposed to bore yield) have been received from landowners within the subsided area of Longwalls 20 to 23 at Tahmoor.

Hawkesbury Sandstone groundwater quality in the Tahmoor area ranges from an electrical conductivity of 3,300µS/cm to 13,030µS/cm and a pH level of 3.53 to 6.49.

Extensive groundwater quality monitoring has been conducted in the Georges River shallow groundwater / surface water interface as well as the sandstone plateau system.

The deeper plateau bores indicate the Hawkesbury Sandstone has an electrical conductivity of 248µS/cm to 1922µS/cm and pH of 3.7 to 6.13, with the exception of one bore over the proposed Longwall 34 with an electrical conductivity up to 8826µS/cm and pH of 6.46 to 6.73.

6.2.5 Upland Plateau Ferruginous Springs

The generation or enhancement of shallow groundwater ferruginous springs following subsidence have been observed in similar plateau areas in the vicinity of the proposed 705 to 710 workings within sub-catchments of the Nepean River, as well as other areas in the Southern Coalfields.

Broad scale upland plateau subsidence can delaminate and dilate erosion surfaces and bedding planes within and between strata, such as on the interface between the Wianamatta Shale / Mittagong Formation and the underlying sub-cropping Hawkesbury Sandstone, giving rise to enhanced permeabilities and generation of upland springs.

This occurs due to the increased detention and storage of infiltrating meteoric waters in the shale and close to the shale/sandstone interface, with the stored water draining to a creek or river. In some cases it can also travel down natural or induced vertical cracks and along widened bedding planes in the sandstone and subsequently appear as well-defined springs. That significant water storage at the Wianamatta/Hawkesbury interface occurs and is pronounced is indicated by:

- water yields recovered from various shallow boreholes drilled over the last 15 years in the Southern Coalfield on plateaux mantled with Shale (i.e. those drilled just into the upper layers of the Hawkesbury);
- periodic longwall mining-induced seepages into the Cataract Tunnel; and by
- the emergence of highly visible ferruginous springs in the Upper Georges and Cataract Rivers.

Mining induced subsidence effects on shale-mantled upland catchments might generate ferruginous springs from upland catchments at a maximum recharge/discharge rate of about 0.8 mm/day and a mean recharge/discharge rate of about 0.2 mm/day. This would generate average flows of the order of 0.2 ML/day and maximum flows of around 0.4 ML/day per km^2 of catchment (Ecoengineers, 2008).

Previous geochemical investigations (Ecoengineers, 2008) indicate the shale based water has a geochemical signature of marine shale soil modified by cation exchange processes on clays for sodium, potassium, calcium, magnesium and strontium, clay adsorption (for boron), and iron / manganese oxide dissolution effects during percolation.

The shale based waters often exhibit elevated levels of dissolved iron and manganese typically ranging from 0.2 – 40 mg/L and 0.1 – 2 mg/L respectively through dissolution of Fe / Mn oxides after siderite and rhodocrosite carbonate minerals have weathered in the shale. Reductive dissolution of the Fe / Mn oxides (‘bleaching’) also occurs in subsoil storage under the influence of bacteria (Geobacter species) that oxidise percolating dissolved organic matter and use such oxides as their terminal electron acceptors (Ecoengineers, 2008).

As distinct from the oxidative dissolution of marcasite that can occur in freshly fractured Hawkesbury Sandstone, the reductive dissolution (bleaching) of disseminated Fe and Mn oxides in the Wianamatta Shales does not increase sulfate ion concentrations and does not produce acidity and hence lowering of pH in situ, although this does occur on emergence into the open air of such waters (Ecoengineers, 2008). As a result, these waters generally maintain constant sulphate ion concentrations, although it increases with greater depths of shale infiltration and the extent of salt leaching involved, and they generally have near-neutral to only weakly acidic pHs when properly sampled in situ or immediately upon emergence and if not subsequently passed through bulk fractured sandstone.

When a spring of this 'Wianamatta Shale-type water' emerges into the open air it tends to immediately react with the oxygen in the air or dissolved in the water of the creek or river it may flow into. This results in the precipitation of Fe and Mn hydrous oxides, generating acidity and consuming oxygen (Ecoengineers, 2008).

A ferruginous spring was detected southwest of the West Cliff Longwalls 34 – 36 in the "Ingham's" Tributary of Ousedale Creek in November 2005, on the eastern plateau, five months after the completion of Longwall 30 as shown in **Drawing 1**, whilst there are potentially pre-existing springs within or in close proximity to the West Cliff Longwalls 34 to 36 (Ecoengineers, 2008).

Iron precipitate was also observed in Upper Nepean Creek within the SMP Area in 2007, which possibly indicates a pre-existing spring in the upper reaches of Nepean Creek.

Monitoring in November 2007 identified an apparent semi-permanent series of pools upstream of the Eastern Gas Pipeline in mid Malatty Creek near the western end of West Cliff Longwall 31. The site would have been previously mined under at the time of monitoring. Elevated EC and one full unit lower pH was recorded downstream of the spring, along with low DO readings (8.9 to 37.3% saturation) due to DO consumption from oxidation/precipitation of dissolved Fe and Mn. Based on water quality data obtained prior to February 2007, the spring appears to have been in place prior to mining Longwall 32 (Ecoengineers, 2008).

On the basis of experience with the Georges River Pool 11 Spring, it is inferred that such springs, if they do arise, they:

- may be generated by a catchment of as small as approximately 0.2 km^2;
- are likely to have a lifetime of at least 4 years with or without significant diminution in intensity; and in the worst case
- may be relatively permanent once instigated, depending upon the size of the dilated catchment area providing their water supply.

The experience of the Cataract Gorge SW2 Springs suggests that a catchment size of the order of only 1 km^2 appears to be sufficient to confer a lifetime in excess of 10 years (Ecoengineers, 2008).

Further detailed discussion of this issue is contained in (Ecoengineers, 2008)

6.2.6 Groundwater Baseflow to the Nepean River

The development of new or relocated seeps or springs and resultant changes to baseflow have been observed through the interaction of shallow groundwater and stream systems in the Cataract, Georges and Bargo Rivers.

The change results from the effects of subsidence, valley closure and upsidence in the base of gorges increasing permeability and interconnection between the river bed and banks as shown in **Figure 12**.

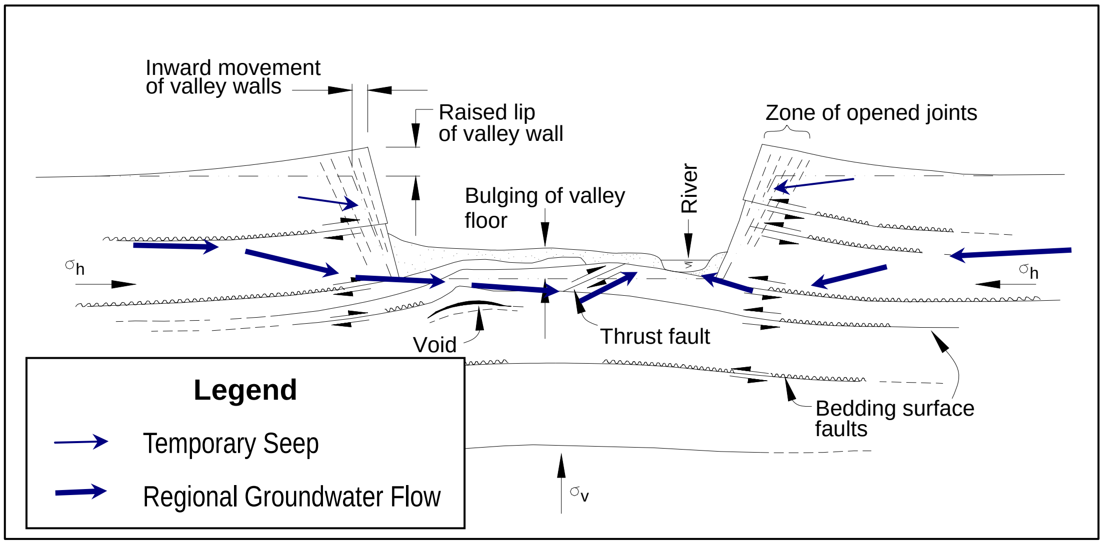


FIGURE 12 Schematic Effects on Groundwater Systems (after MSEC, 2005)

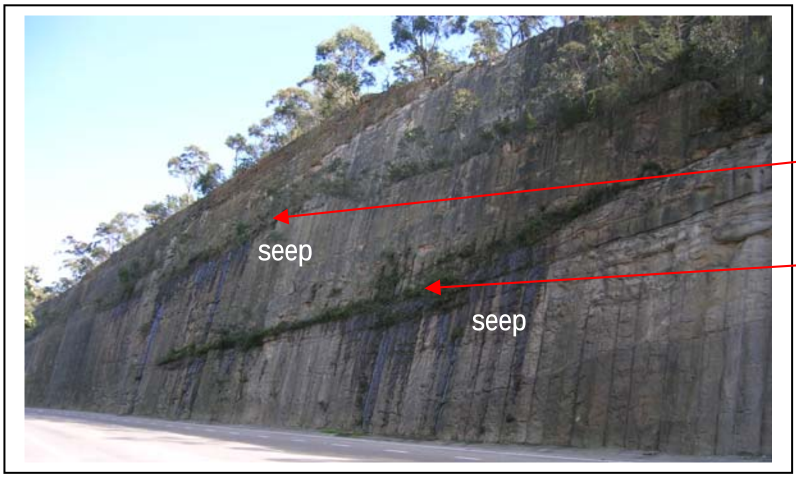
The most analogous situation is the extraction of Longwalls 16, 17 and 20 at Tower Colliery. Even though part or most of all three panels directly mined under the Nepean River gorge, no observable change to seeps, springs or baseflow to the Nepean River were noted despite regular inspections of the gorge.

Longwalls 705 to 710 are set back 180m from the river's edge.

Groundwater flow to the Nepean River is difficult to directly observe or measure as the gorge sides are mostly covered with vegetated scree slopes and alluvial terraces. There are only limited cliff exposures that enable observation of seeps in the SMP area.

Low volume and short duration seeps can be observed approximately 5m above the Nepean River near the Appin Park causeway, upstream of the extracted Longwall 17 after rain periods.

An example of a short duration, dual-level perched seep that flows for a few days to weeks after significant rainfall is shown in **Figure 13**. The illustrated seeps discharge at the interface between coarser and underlying finer sandstone or shale layers which restrict vertical flow through the bedrock. This enhanced lateral flow consists of a short duration rate estimated at less than 1L/s. It is anticipated that similar seeps would be present in the study area although they are difficult to observe due to sediment accumulations and vegetation.



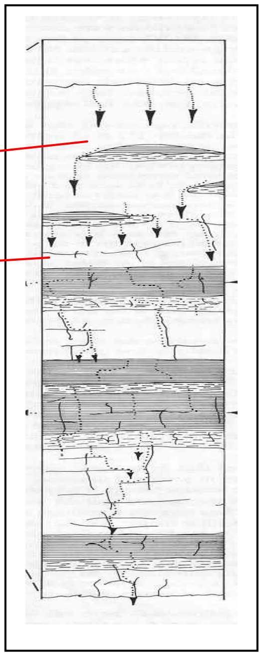


FIGURE 13 Dual Layered Seep on the F3 Freeway

Water chemistry assessments in the Cataract River estimated that 0.1ML/day of groundwater baseflow entered the gorge between Broughtons Pass and the Nepean River, which corresponded to 0.01mm/day of infiltration into the plateau over the mine (Coffey Partners International, 1998).

6.2.7 Inflow to Mine Workings

No observed inflows to workings have been noted in the Southern Coalfield where the mines range from approximately 400 to 550m below surface.

Field tests over selected collieries indicated vertical permeabilities in the overburden ranging from $3x10^{-1}$m/day in the goafed lithologies directly above the workings and disturbed shallow surface zones to 2×10^{-6} m/day in undisturbed strata, with the majority of intervals tested ranging from 10^{-7} to 10^{-8}m/day. Interpretation of the field tests indicated that vertical flow through the stratigraphy could occur, however it would be too small to measure, with flow dominantly in the horizontal direction (Reynolds, 1977).

In the Bald Hill Claystone, Bulgo Sandstone, Stanwell Park Claystone and Scarborough Sandstone permeability is variable, with the strata being unsaturated within 250m above the workings (Reynolds, 1977). At Tower Colliery, groundwater conditions were interpreted to be unsaturated from the workings to the Bulgo Sandstone (Coffey Partners International 1997).

Based on the low permeability of the Bald Hill Claystone and Stanwell Park Claystone aquitards both pre and post mining, it is assessed there would be no discernible flow into the workings under the proposed Appin Area 7 workings. The bulk permeability of the aquitards is essentially unchanged after subsidence and a possible flow of 0.03L/s could enter the workings (Coffey Partners International, 1997), which would be very difficult to detect.

A minimum thickness of unfractured overburden is required to maintain hydraulic separation between a mine and saturated aquifers, with the critical value depending on lithology, structure and topography.

The minimum separation has been established through observation and research in NSW mines as ranging from less than 90m up to 150m, although the separation distance may be less than 90m if suitable ductile confining layers are present, such as thick sequences of shale or clay (Booth, C.J., 2002). The separation distance over Longwalls 705 to 710 is well in excess of 150m under both the gorge and the plateau, where depth of cover ranges from 450 to 555m.

Two dimensional numerical modelling using the computer code (UDEC) indicated that general movement of rock and fracturing would occur, with the following features (Wold, W. B, 2005):

- loosening, fracturing and local shear on joints and bedding of rock blocks on the cliff lines and valley slopes,
- lateral convergence of cliff lines in the valley and associated shear on bedding planes at the valley floor,
- overall subsidence of the valley with a tendency for uplift of the valley floor relative to the cliff lines. Local buckling and uplift of blocky strata on the river bed due to horizontal thrusting, and
- fracturing and yield failure extending up to 150m above the workings. The interburden strata above this zone remains essentially intact and subsides with inter-laminar shearing on bedding planes.

The Bald Hill Claystone aquitard is situated at 210 to 250m below surface, with the upper groundwater system above this claystone being separated from the lower regime. The upper level is dominantly horizontal flow to the valley floor or locally upwards from below the river bed, along with potentially localised flow in mining induced shear zones on bedding planes at the base of the gorge.

6.2.8 Strata Gas Emissions in Bores

Very limited reports of gas adversely affecting groundwater supply bores in the Southern Coalfields over longwall subsided areas has been reported or investigated apart from one instance at the Morrison Dairy in 1998 (Ecoengineers, 1998).

This bore was drilled to 509mbgl, into and below the Bulli Seam, which is significantly different to the depth of private bores over Longwalls 705 to 710, which are mostly completed within the Hawkesbury Sandstone, apart from GW 105338, which was drilled 8m into the Bald Hill Claystone.

6.3 POTENTIAL GROUNDWATER IMPACTS

6.3.1 Aquifer / Aquitard Interconnection Under the Plateau

Mining induced fracturing of strata over the extraction area will occur on the plateau, and may potentially extend to 20m below surface (Seedsman, R., Dawkins, A., 2007) with potential for dilation of strata below the tensional zone.

In the upper 20m, subsidence has the effect of shifting the dominance of pre-mining horizontal flow along and above aquitards to a combination of vertical and horizontal flow as the aquitards are breached and water drains from higher to lower strata.

Vertical flow continues down the strata until drainage is restricted by intact aquitards, where the flow resumes its horizontal dominance.

Below the fractured zone, an increased horizontal flow component can occur due to dilation and bending of strata, even though the layers are not breached by vertical fracturing. The increased horizontal permeability extends across the subsided area, and gradually diminishes as the subsidence / dilation decreases to the edge of the subsidence zone.

No adverse interconnection of aquifers and aquitards is anticipated within 20m of the plateau surface as there are no recorded aquifers in this interval. There may be an increased rate of recharge into the plateau following rainfall due to the increased porosity and permeability of the fractured sandstone / shales. This can either result in higher discharge volumes and duration of temporary rain dependent seeps, and/or higher recharge rates to underlying aquifers.

The resultant enhanced seepage or altered vertical recharge patterns will depend on which preferential flow path, or paths, develops. Even though there is insufficient knowledge of the variables to predict which flow patterns will develop, the effect is not significant, and, in addition, the variability of the sandstone sequence is such that predictions would be difficult to develop between known bore data.

6.3.2 Groundwater Levels

Even though the regional piezometric surface lies beneath the potential fracture zone (20m from the plateau surface), there still may be a temporary lowering of the piezometric surface over the subsidence area due to horizontal dilation of strata and resultant increase in secondary porosity.

This effect will be more notable directly over the area of greatest subsidence and dilation, and will dissipate laterally out to the edge of the subsidence zone.

Based on observations in the Southern Coalfield, groundwater levels may reduce by up to 10m, and may stay at that reduced level until maximum subsidence develops at a specific location. The duration of the reduced levels depends on the time required to develop maximum subsidence, the time for subsidence effects to migrate away from a location as mining advances and the time required to recharge the secondary voids.

The impact of subsidence on a bore is related to the degree of groundwater level decline, which results from its proximity to a mined panel. It is also significantly affected by rainfall recharge to an aquifer as well as changes in the rate or duration of groundwater extraction in the bore and adjacent bores.

On the basis that the pre mining circumstances of rainfall recharge and bore pumping remain the same, then groundwater levels will recover over a few months as the newly developed secondary porosity is recharged by rainfall sourced water.

There is generally no permanent post mining reduction in water level in the plateau unless a new outflow path develops. This may occur in close proximity to cliffs where new or enhanced seeps may be generated. This effect will reduce with increased distance from the cliff.

It is anticipated there will be no permanent reduction in groundwater levels underneath the Nepean River, as once the subsidence induced cracks are filled with water, there is no vertical discharge path through which groundwater can flow out of the system, so there will be no ongoing water flow into the cracked basement of the gorge and riverbed. Any water loss that does potentially occur would be replenished by the large volume of water in the river pond (minimum of approximately 1,400 ML) and the daily flow down the river (minimum of 3 ML/day), as discussed in the EIS surface water report (Geoterra, 2006).

Due to the short term nature of any groundwater level reductions it is concluded that there is unlikely to be a significant impact to groundwater resources in the plateau areas resulting from the proposed extraction.

6.3.3 Well Yields and Bore Serviceability

Four DWE registered bores within or near the application area may be affected by subsidence. Two are located over Longwall 703 (GW101437 and GW104154) and two are located on the edge of the application area, northwest of the proposed Longwall 705 (GW102584 and GW103161).

Horizontal displacement of strata can occur which could make the bores inaccessible. Strata dilation and subsequent refilling of the secondary voids can temporarily lower standing water levels, whilst increasing the potential yield of a bore through enhanced permeability and secondary porosity.

Bores outside the application area are less likely to have observable subsidence effects.

Damage to bores can be readily managed. Should the accessibility, available drawdown or yield of a bore be impacted due to subsidence, the Colliery is required to provide an alternative water supply until the bore recovers.

If the level does not sufficiently recover and the effect is due to subsidence rather than regional climatic or anthropogenic factors, repairs or maintenance to a bore can be undertaken after maximum subsidence has developed. At this time the pump intake can be lowered, the bore extended to a greater depth or a new bore can be established.

With these mitigation measures in place it is unlikely that water supply to properties will be significantly impacted by the proposed mining.

6.3.4 Groundwater Quality

Previous observations indicate that water quality of subsided bores in the Southern Coalfield has not generally been adversely affected.

There may be increased iron and manganese hydroxide precipitation due to subsidence related exposure of previously unweathered iron and manganese carbonates along with a lowering of pH if the aquifer is exposed to previously unweathered iron sulfides (marcasite) in the strata

The degree of dissolved iron and/or manganese generation and pH change resulting from subsidence is difficult to predict, and can range from no observable change to a distinct discolouration of the pumped water.

The discolouration does not pose any health hazard, however it can result in clogging of pumping equipment and piping in extreme cases.

It should be noted that many bores in the Southern Coalfield already have significant iron hydroxide levels, and a pre-mining survey is required to assess the baseline water quality prior to mining the area.

Acidity (pH) changes of up to 1 order of magnitude can occur, however any change will be substantially reduced where there is sufficient bicarbonate ion levels.

Previous monitoring adjacent to Longwall 17 indicates a potential pre mining pH for the SMP area bores of between 6.4 and 7.2 and iron levels up to 0.21mg/L. It is recommended that direct monitoring of the bores within the application is conducted prior to development of subsidence at those locations.

If groundwater quality impacts resulting from subsidence are identified, alternate supplies of water should be provided to any affected water user until a similar supply can be re-established with similar water quality characteristics. With these mitigation measures in place it is unlikely that there will be any significant impacts to water quality supplies from the proposed mining.

6.3.5 Seeps, Springs and Baseflow to the Nepean River

Lowering of perched ephemeral seeps along the cliffs of the Nepean River gorge may occur after subsidence through fracturing of underlying confining, low permeability layers in the plateau strata.

Fracturing can enable pre-mining perched water to seep out at lower levels down the cliff compared to pre subsidence levels. The current seeps are generally short lived, with the volume and duration of flow directly related to the amount and intensity of rainfall. The seeps flow after wet periods and stop flowing after prolonged dry periods.

No large seeps were identified during the study along the potentially affected stretch of the river, however the large scree slope and thick vegetation cover along the gorge makes identification difficult.

The volume of flow from the seeps may increase due to enhanced rainfall recharge through the plateau after rain and the duration of seepage may reduce due to the increased ability for water to drain to the higher post subsidence permeability areas.

No plateau springs have been identified in the area that may be affected by subsidence, however, based on observations on the western plateau associated with previous longwalls, it is possible that interface drainage ferruginous (brackish to saline) seeps may be generated in streams on the plateau over Longwalls 705 to 710 .

The low order creeks on the plateau will be subjected to relatively low tensile strains and are not expected to be significantly impacted by subsidence related surface cracking.

It is not expected that buckling or fracturing of exposed bedrock in the plateau creek beds will occur. Similarly, it is not expected that observable loss of water from the creeks will occur.

It is not expected that any observable change to creek flows or ponding will occur due to the low predicted tilts, which are notably less than the natural gradient of the creeks.

Due to the low levels of strain on the plateau area and limited potential for fracturing of rock, cracking of soil and water loss, it is unlikely that the proposed mining will significantly impact lower order streams, seeps, springs and flow to the Nepean River.

6.3.6 Potential Inflow to Mine Workings

Loss of stream flow or groundwater to the underlying workings has not been observed in any mines in the Southern Coalfield at similar depths of cover to the proposed mining.

Vertical hydraulic connection to the workings is essentially blocked from entering the mine as the Bald Hill Claystone acts as a confining layer. It is highly unlikely that this layer would be breached after subsidence as it is from 150m to 200m below the surface and well below the depth of surface cracking and overburden dilation.

The Bald Hill Claystone is also sufficiently higher up in the overburden such that it is not anticipated to be affected / intersected by the height of goaf fracturing.

Modelling (CSIRO, 2005 and Coffey Partners International Pty Ltd, 1998) indicate that horizontal permeability above the Bald Hill Claystone may be enhanced after subsidence but that there is no additional vertical permeability connectivity and that the hydrologic systems above and below the Claystone will remain separate.

6.3.7 Gas

It is not anticipated that significant strata gas will be discharged in private bores over Longwalls 705 to 710.

Overall, there is a limited potential for strata gas emissions into private bores, and any emissions that may occur will be localised and may last for approximately one year.

6.4 Subsidence Prediction Sensitivity

Engineering predictions for subsidence, strain and tilt on the plateau and gorge using the Incremental Profile Method (MSEC, 2008) are based on applying measured subsidence parameters from past similar situations to the current mining area and model. This empirical modelling takes into account the influences of a wide range of variables on subsidence movements, including rock mechanics and topography.

The subsidence model is constantly reviewed as subsidence predictions are compared to monitored results. This improves future predictions through empirically understanding the mechanisms and variables involved.

Any deviation from predicted movements could alter stream bed and general plateau ground surface cracking, either through an increase or decrease in crack incidence and size.

If the actual plateau subsidence exceeds predictions, it is not anticipated there will be significant deviation in the potential effects except for possible minor additional soil or creek bed cracking. However, this would not result in any significant change in the actual impacts on ephemeral stream flows or quality, compared to the predictions in this report.

If greater than expected crack development occurs, it is not anticipated there will be any significant additional impacts on groundwater levels, groundwater quality or bore yields to that discussed in the previous sections.

If additional ground movement occurs above the predicted levels, it is not anticipated that additional observable change to seepage rates will occur in the cliffs.

7. RECOMMENDED MONITORING

7.1 BHPB Piezometer Standing Water levels

Standing water levels should continue to be measured and data logged at least twice daily in the pre-mining baseline, impact and post-mining period in the NGW and EAW5 bores.

Additional open standpipe bores should be preferably drilled by the dry open hole percussion method to investigate the existence of perched and regional aquifers to 10m below the base of the Nepean River bores at the indicative locations shown in **Drawing 4**.

7.2 BHPB Piezometer Groundwater Quality

At least one appropriately purged groundwater sample should be collected from each piezometer in the pre-mining phase and analysed for;

- field pH, electrical conductivity, temperature;
- total dissolved solids;
- filterable Na / Ca / Na / K / SO_4;
- Cl, F;
- total alkalinity;
- total / filterable Fe, Mn, Al;
- filterable Ni, Zn, As, Ba, Cs, Cu, Pb, Li, Rb, Se, Sr, B;
- total nitrogen, and;
- total phosphorous.

The pre mining water sampling and analysis should be repeated at the end of mining Longwalls 705 to 710 sequentially for the same suite of analytes to enable ongoing assessment of any subsidence related changes in groundwater quality.

7.3 DWE Registered Bore Standing Water Levels and Groundwater Quality

Standing water levels should be measured at least once before the area is mined under in all available private bores, as well as at least once after each bore is mined under.

At least one appropriately purged groundwater sample should be collected from each private bore in the pre mining phase and analysed for;

- field pH, electrical conductivity, temperature;
- total dissolved solids;
- filterable Na / Ca / Na / K / SO4;
- Cl, F;
- total alkalinity;
- total / filterable Fe, Mn, Al;
- filterable Ni, Zn, As, Ba, Cs, Cu, Pb, Li, Rb, Se, Sr, B;
- total nitrogen, and
- total phosphorous.

The pre-mining water sampling and analysis should be repeated after each bore is mined under for the same suite of analytes to enable post mining assessment of any subsidence related changes in groundwater quality.

7.4 DWE Registered Bore Yields and Groundwater Use

Each bore owner should be interviewed before and after the bore is mined under to describe their rate and duration of pumping. The bore yield should also be measured and details obtained on the type and set up of the pump in each bore, if installed.

The use of the water should be ascertained and observations made on the quantum of iron hydroxide precipitating from the pumped water before and after mining.

Consultation with bore owners and the monitoring of bores will be incorporated into the Property Subsidence Management Plans for relevant properties.

7.5 DWE Registered Bore Gas

Bore owners should be asked to monitor and report on any observed discharge of strata gas into their bores as part of the Property Subsidence Management Plans for relevant properties.

7.6 Cliff Seeps

The presence and duration of observable cliff seeps within the application area should be photographically and semi quantitatively recorded during field monitoring.

Where available and accessible, seep water samples should be collected and assessed for the same field and laboratory parameters outlined in Section 7.1.

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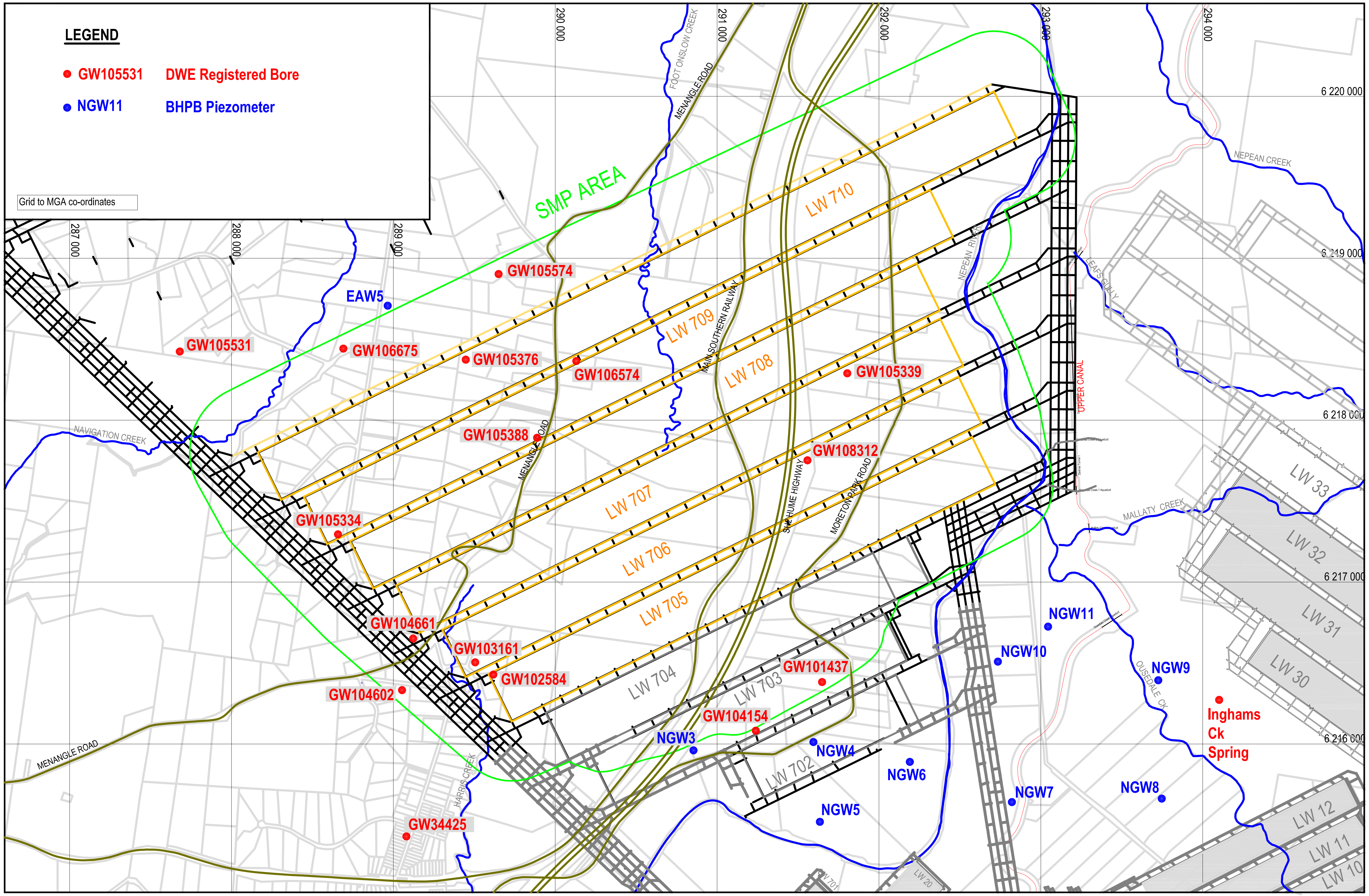
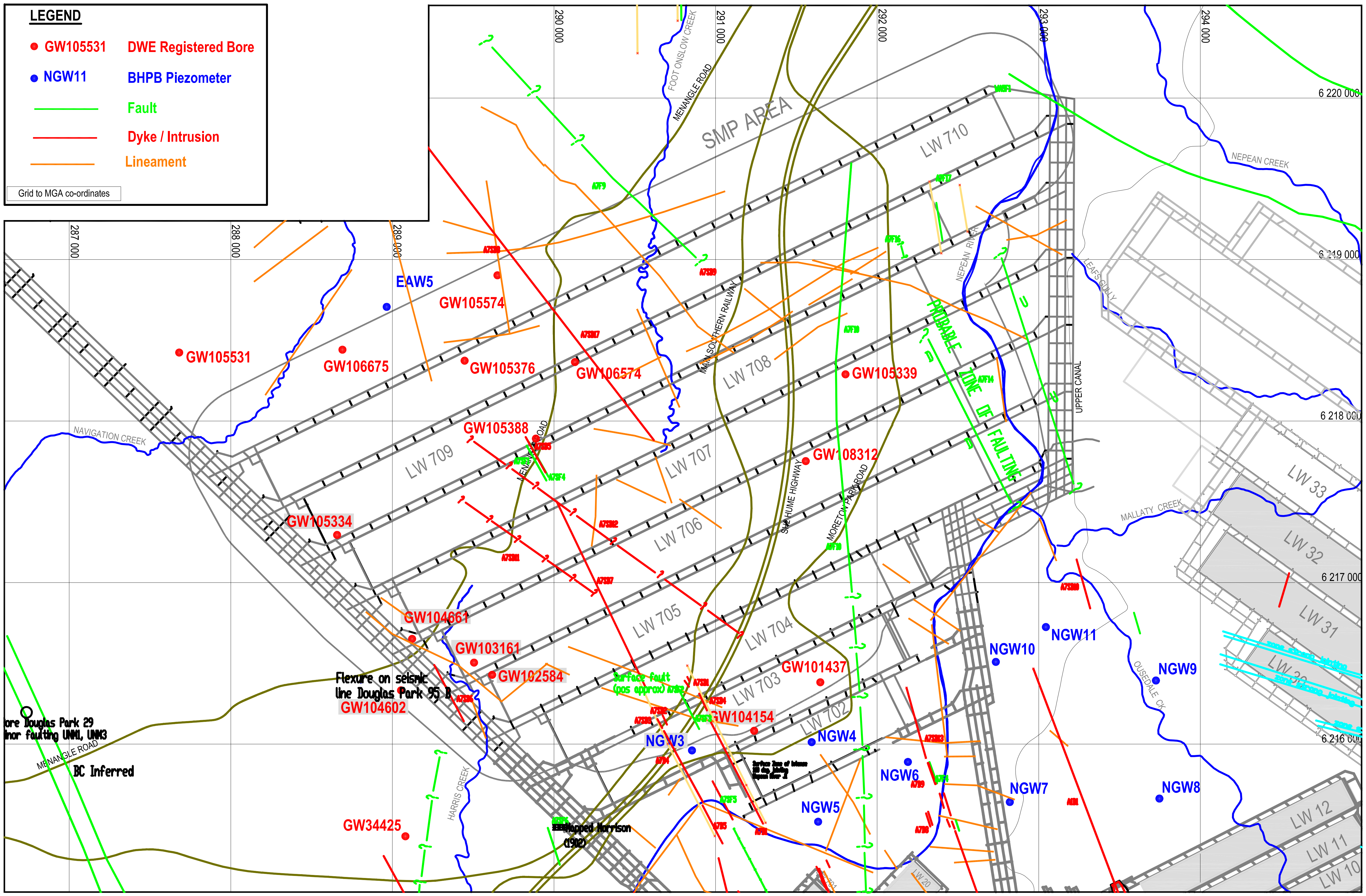


Drawing Base Courtesy MSEC

PROJECT:	BHPB4-R1	BHP BILLITON ILLAWARRA COAL P/L LONGWALLS 705 TO 710 DOUGLAS PARK Piezometer and Bore Locations
DRAWN:	A. DAWKINS	
DATE:	22 JUN 2008	
SCALE:	AS SHOWN	

GeoTerra

DRAWING 1



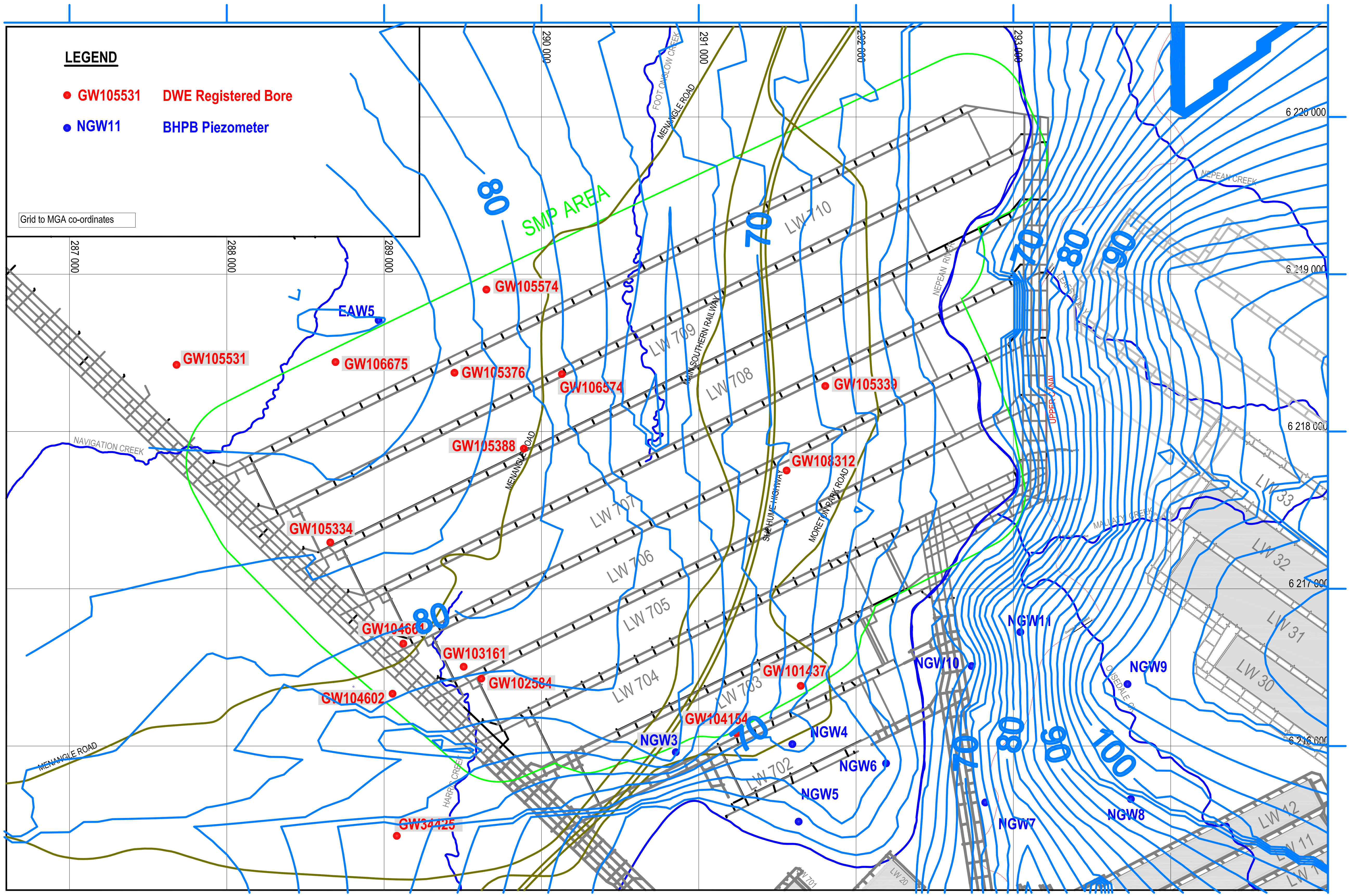
PROJECT:	BHPB4 - R1
DRAWN:	A. DAWKINS
DATE:	22 JUN 2008
SCALE:	AS SHOWN

BHP BILLITON ILLAWARRA COAL P/L
LONGWALLS 705 TO 710
DOUGLAS PARK

Geological Structures

GeoTerra

DRAWING 2



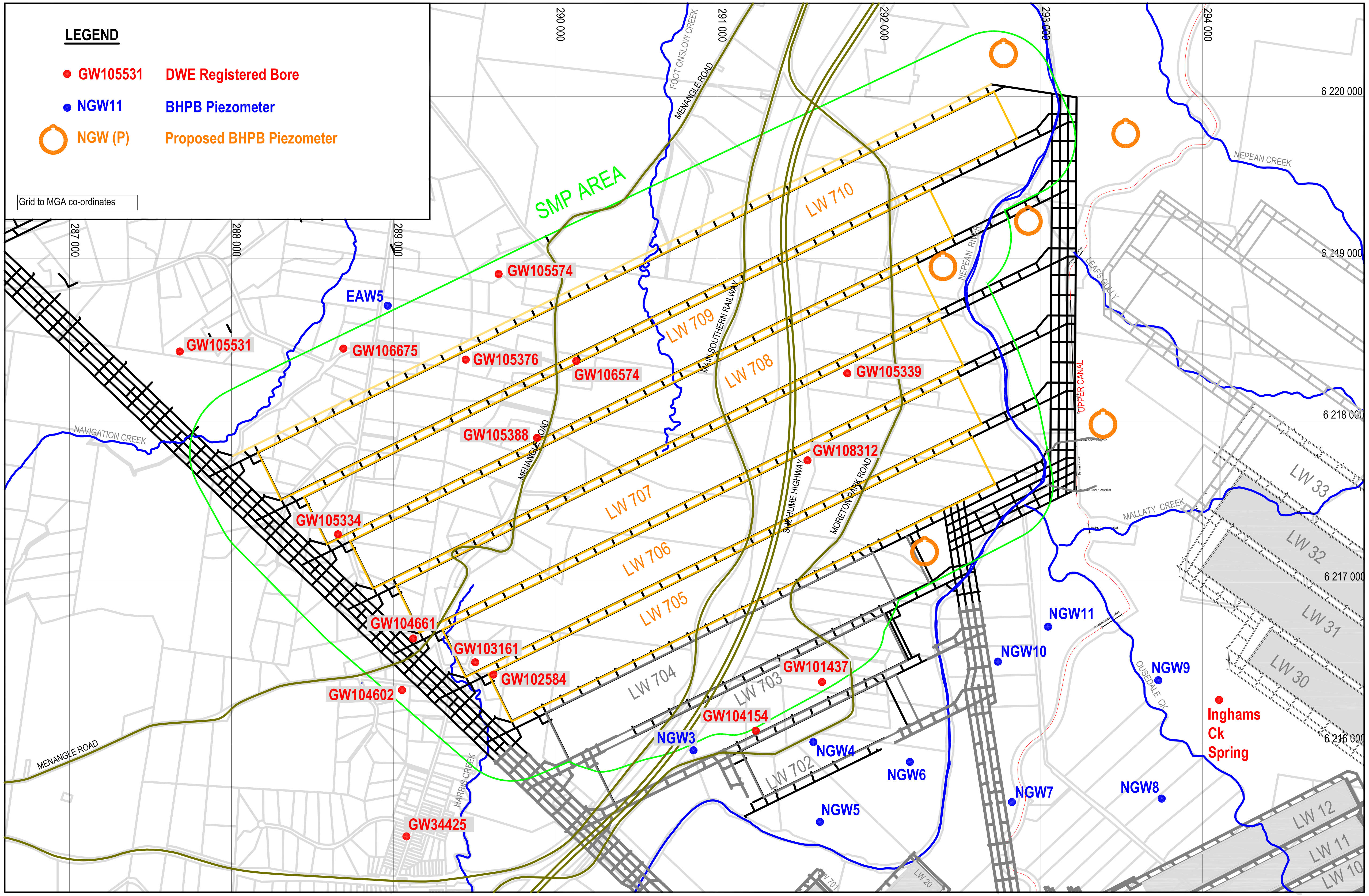
Drawing Base Courtesy MSEC

PROJECT:	BHPB4-R1
DRAWN:	A. DAWKINS
DATE:	22 JUN 2008
SCALE:	AS SHOWN

BHP BILLITON ILLAWARRA COAL P/L
LONGWALLS 705 TO 710
DOUGLAS PARK
Hawkesbury Sandstone May 08
Groundwater Piezometric Levels

GeoTerra

DRAWING 3



Drawing Base Courtesy MSEC

PROJECT:	BHPB4-R1
DRAWN:	A. DAWKINS
DATE:	22 JUN 2008
SCALE:	AS SHOWN

BHP BILLITON ILLAWARRA COAL P/L
LONGWALLS 705 TO 710
DOUGLAS PARK

Proposed Piezometer Locations

GeoTerra

DRAWING 4