Section 4B

Environmental Features, Management Measures and Impacts

This section describes the specific environmental features of the Mine Site and its surrounds that would or may be affected by the proposed Stage 2 Longwall Project. Information on existing conditions, proposed safeguards and controls and potential impacts the project may have after implementation of these measures is presented for those issues identified in Section 3 as being of greatest significance.

Where appropriate, proposed monitoring programs are also described.

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4B.1 SUBSIDENCE

The Mine Subsidence Predictions and Impact Assessment was undertaken by Ditton Geotechnical Services Pty Ltd. The full assessment is presented in Volume 1 Part 1 of the Specialist Consultant Studies Compendium, with the relevant information from the assessment summarised in the following subsections. The full assessment is referred to as DGS (2009) throughout this report. A peer review of the predicted subsidence was undertaken by Dr Bruce Hebblewhite. A copy of the review is included behind the subsidence assessment in the compendium.

4B.1.1 Introduction

Based on the risk analysis undertaken for the proposed Longwall Project (see Section 3.3 and **Table 3.5**), the potential environmental impacts related to subsidence requiring assessment and their unmitigated risk rating are as follows.

- Damage or destruction of structures / infrastructure (high risk).
- Alteration of local drainage resulting in ponding, realignment or other impacts on local drainage (moderate to high risk).
- Increased erosion along drainage lines and subsequent decrease in water quality (moderate risk).
- Change to structure or composition of vegetation communities and fauna habitat (high risk).
- Reduced availability of groundwater as a result of fracturing altering hydrogeological flow paths (high risk).
- Disturbance of, or damage to, Aboriginal sites or artefacts (moderate risk).

In addition, the Director-General’s Requirements issued by DoP identifies subsidence as a key issue for consideration within the *Environmental Assessment*.

The following subsections present a summary of existing conditions and impacts associated with subsidence, the method of assessment, predictions of subsidence and subsidence related impacts, the proposed management of identified sites and an assessment of the significance of the residual impacts (once the proposed management measures are implemented).

4B.1.2 The Existing Environment

4B.1.2.1 Surface Features

An overview of the principal surface features relating to the proposed mine subsidence is outlined as follows.

As noted in Section 4A.3.2, the Mine Site comprises privately owned land, the majority of which is owned by the Proponent and related companies, ie. 3 825ha or approximately 75% of the total area of ML1609. A small proportion of the Mine Site, predominantly with the southwestern corner, occurs within NSW State Forests (Jacks Creek and Pilliga East Stage

Forests). The Mine Site is used primarily for livestock grazing with some cereal crop farming over the eastern half of the Mine Site. The western half of the Mine Site is covered by native woodlands and the Jacks Creek and Pilliga East State Forests.

As noted in Section 4A.1.2, the terrain of the Mine Site is generally flat to undulating in the east with two low-level ridges with moderate slopes (up to 18°) in the west. Two ephemeral creeks (Kurrajong Creek and Pine Creek) and their tributaries drain towards the northeast across ML1609. Elevations above the mining area vary from 270m AHD above the eastern longwall panels to 370m AHD above the western longwall panels.

The maximum slope of approximately 18° occurs along the northeast-southwest trending ridge, with the minimum slopes of <1° common in the northeast, on ridge crests, foot slopes, valley floors and creek channels. No cliff lines are present above the mining area. **Figure 4B.1** illustrates the elevations, slopes and drainage features of the Mine Site.

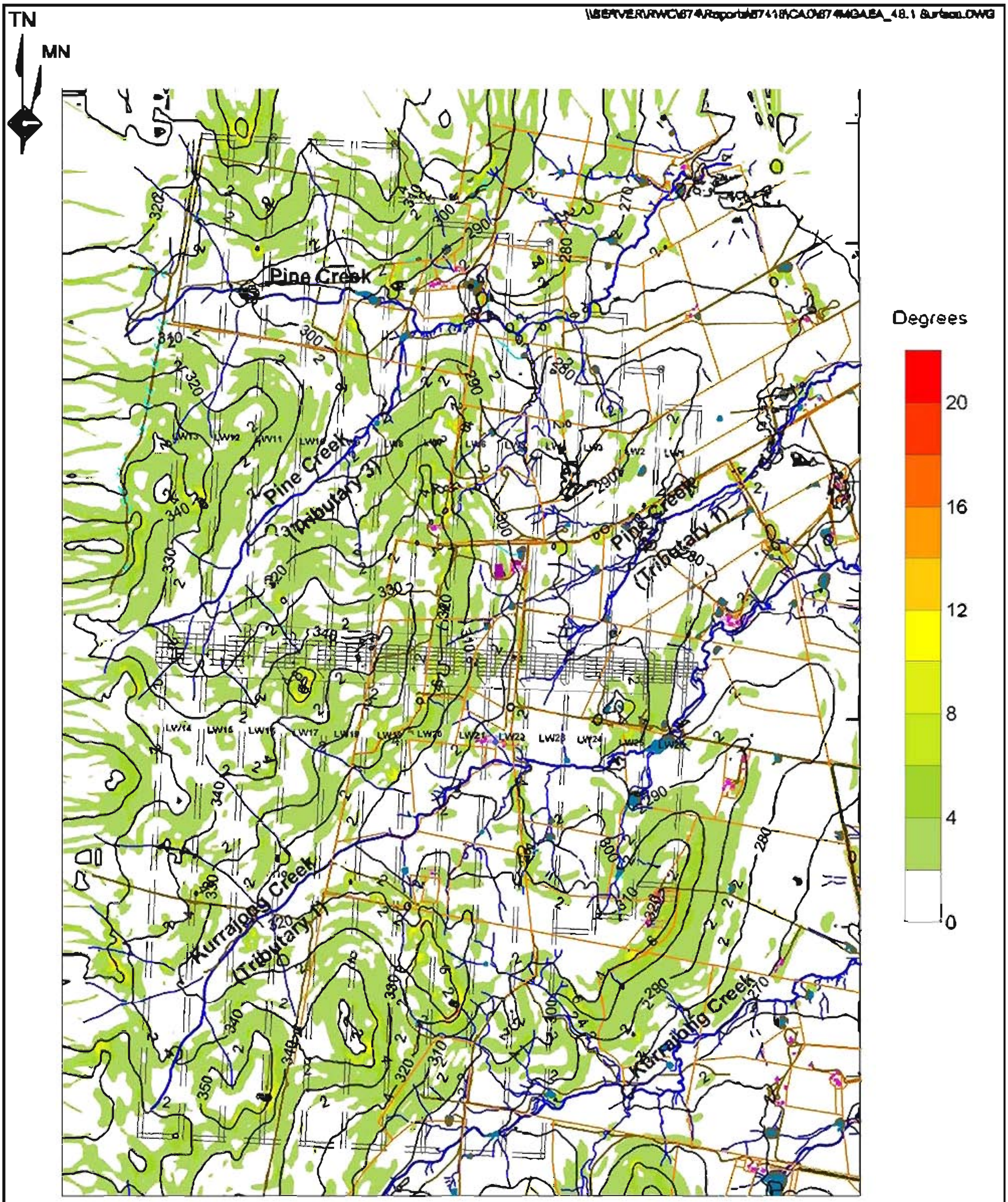
In order to accurately predict impacts related to subsidence, DGS (2009) assembled an inventory of significant surface, natural and archaeological features. DGS (2009) has identified the following features of significance on the Mine Site.

Natural Features

- The ephemeral tributaries that form the headwaters of Pine Creek (located above the northern longwalls) and Kurrajong Creek (located above the southern longwalls). All tributaries of the two creeks drain the Mine Site generally in a northeasterly direction.
- Sandy alluvial deposits (up to 15m deep) are present along the creek channels with virtually no rock exposures evident.
- The silty sand and sandy clay surface soils present on the Mine Site display moderate erodibility and may be susceptible to erosion if exposed to concentrated runoff.
- Vegetation over the relatively undisturbed western half of the underground mine area consists of low mallee woodland with a dense shrub layer to open forest with sparse shrub layer. This vegetation merges with the cleared agricultural land to form partially cleared and disturbed woodland dominated by species adapted to, or tolerant of drier conditions, with occasional inundation due to flooding. Riparian zones along creeks within the predominantly cleared agricultural land over the eastern two thirds of the Mine Site provide partially cleared but relatively intact open forest to woodland dominated by casuarinas and species adapted to higher water availability. Section 4B.4 provides further detail on the vegetation of the Mine Site.
- Notably, there is a lack of significant rock outcropping or rock features such as caves or overhangs on the Mine Site.

Archaeological Features

- Aboriginal heritage features that are present across the Mine Site include open scatters of up to 100+ artefacts, isolated artefacts, axe grinding grooves and scarred trees. Section 4B.5.3 provides greater detail on the type and distribution of Aboriginal Sites across the Mine Site.



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Source: DGS (2009) - Figure 5

Figure 4B.1
MINE SITE SURFACE ELEVATIONS, SLOPES AND DRAINAGE FEATURES

Developed Features

Buildings, in particular residences, on the rural properties above the underground mine area. **Figure 4A.4** provides the locations of the three residences above the underground mine, all of which are owned by Narrabri Coal Pty Ltd.

- Soil conservation structures, eg. contour banks.
- Earth embankment dams for the watering of livestock.
- Unsealed gravel access roads and access tracks.
- Property boundary-line fences.
- Single-phase suspended power lines (for domestic power supply).
- Suspended Telstra telephone lines.

These features have all been considered in the assessment of subsidence-related impacts.

4B.1.2.2 Sub-Surface Conditions

Subsidence is influenced not only by the type and scale of longwall mining, but also by the type and condition of the geological strata above the area mined. The following considers the sub-surface conditions, specifically with respect to how these conditions may influence the prediction of subsidence.

As noted in Section 2.2.1, the Mine Site is situated within the Mullalley Sub-basin, which is in the northern part of the Gunnedah Basin. The sub-basin contains Permian to Jurassic Age sedimentary and igneous strata overlying the Hoskissons Coal Seam, which generally dips westwards at approximately 2^o. Several northwest to southwest and northeast to northwest trending normal and reverse faults, which have throws ranging from 1m to 5m, ie. less than half the coal seam thickness, have been identified within the mining area. A typical profile of the Mine Site stratigraphy is provided by **Figure 2.3**.

Typically, the geological strata above the Hoskissons Coal Seam comprises thin to medium bedded siltstone / sandstone laminite with minor claystone (Pilliga Sandstone, Purlawaugh Formation and Napperby Formation) between several massive 15m to 40m thick units of conglomerate (Digby Formation), basalt sills and lava flows (Garrawilla Volcanics). The depth of cover above the Hoskissons Coal Seam ranges from 160m to 380m with the depth of weathering typically varying from about 15m to 35m from the surface. Through a review of the available exploration data, DGS (2009) determined that the potential subsidence reducing 'massive' units in the overburden are the conglomerate of the Digby Formation, the intrusive basalt sill in the Napperby Formation and basalt lava flows of the Garrawilla Volcanics.

A summary of the thickness of the massive units in descending order from surface is presented in **Table 4B.1**.

Table 4B.1
Summary of Massive Strata Units of the Mining Area

Lithological Unit	Massive Unit Thickness (m)	Unit Distance Above the Mining Area (m)	Laboratory UCS Strength Range (Mean) (MPa)
Garrawilla Volcanics*	1 to 62	110 to 250	65 to 252 (140)
Basalt Sill of the Napperby Formation	7 to 27	44 to 80	91 to 189 (140)
Digby Conglomerate	13 to 25	0 to 34	21 to 42 (28)
Note *: The top 1m to 3m may be affected by weathering. Unit may have a maximum thickness of 20m			
Source: Modified after DGS (2009) – Table 1			

Each of the three geological units above the Hoskissons Coal Seam has been assessed for their potential for bridging behaviour. DGS (2009) determined (based on strength testing, empirical data base and an analytical Voussoir Beam model) that only the Garrawilla Volcanics has the potential to bridge the longwall panels and therefore reduce subsidence.

4B.1.3 Subsidence Development Mechanism

After the extraction of coal within a longwall panel, the immediate mine roof usually collapses into the void left by the removal of the coal. The overlying strata or overburden then sags down onto the collapsed material, resulting in settlement of the land surface. **Figure 4B.2** provides an illustration of this mechanism which is discussed in more detail, as follows.

As illustrated on **Figure 4B.2**, the maximum subsidence would occur in the middle of the extracted panel and would be dependent on the following.

- The height of the longwall panel which determines the height of the initial collapse. The longwall panels would be 4.2m high while the gate road headings and chain pillars between the panels would be 3.5m in height.
- The cover depth above each longwall panel influences rock fracture, swelling and bridging, all of which reduce the effect of the initial collapse with height. As noted in Section 4B.1.2.2, cover depths range from 160m in the east up to 380m in the west with a single row of chain pillars to be left between the extracted longwall blocks. The widths of the chain pillars would increase with cover depth from 24.6m in the east to 37.6m in the west.
- The geological properties of the strata above the collapsed section of mine including any massive structures above the longwall panel would influence the bulking characteristics of the collapsed strata, as well as any 'bridging' by the massive units over collapsed rock beneath it. As noted in Section 4B.1.2.2, only the Garrawilla Volcanics are likely to bridge over collapsed strata lower in the sequence.
- Features of surface geology and topography may exacerbate the impacts of surface subsidence through cracking or impacts on structurally vulnerable features such as creeks, caves, overhangs etc.

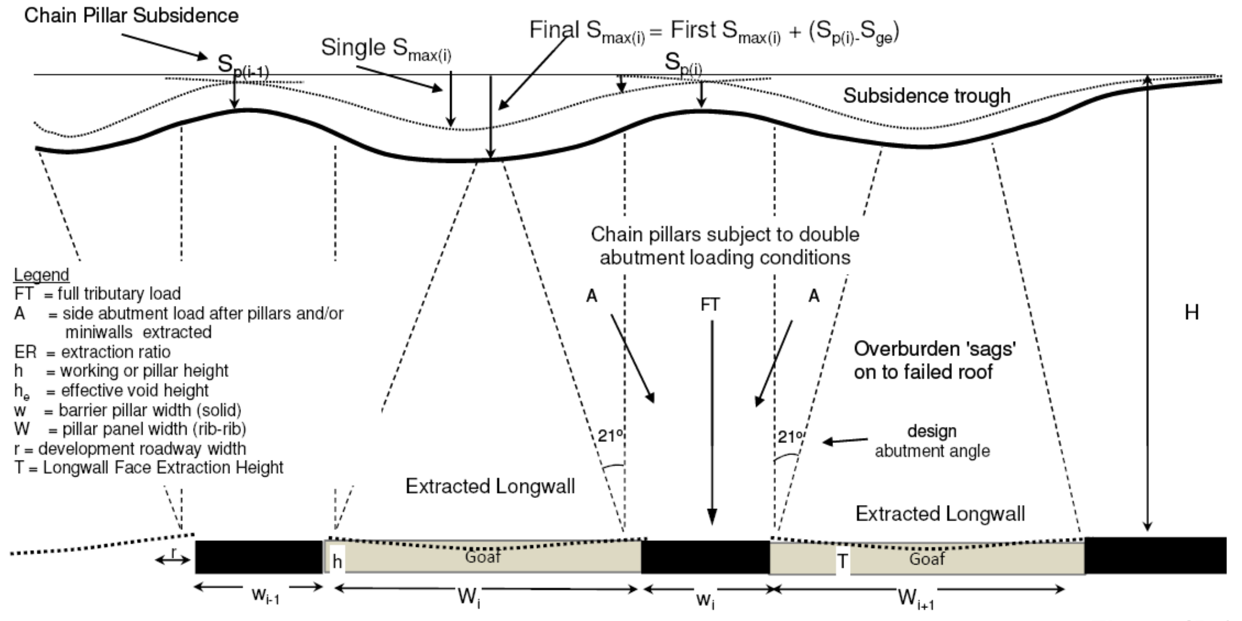

Figure 4B.2
LONGWALL PANEL SUBSIDENCE MECHANISM

Source: DGS (2009) – Figure 13

The combination of the above factors determines whether a single longwall panel would be sub-critical, critical or supercritical in terms of maximum subsidence. The terms sub-critical, critical or supercritical are defined as follows.

- Sub-critical subsidence refers to panels that are narrow and deep enough for the overburden to bridge or ‘arch’ across the extracted panel regardless of geology. It is also termed ‘geometrical’ or ‘deep beam arching’.
- Critical subsidence refers to panels that are unable to arch without the presence of massive, competent strata, ie. the strata above the panel sags down onto the collapsed or caved roof strata immediately above the extracted seam. If relatively thick and strong massive strata exist, then ‘critical arching’ or ‘shallow Voussoir beam’ behaviour can occur for panel W/H ratios up to1.8.
- Supercritical panels refer to panels with widths that cause complete collapse of the overburden.

In Australian coalfields, sub-critical or (geometrical arching) behaviour generally occurs when the panel width (W) is <0.6 times the cover depth (H) and supercritical when W:H > 1.4. Critical behaviour usually occurs between W/H ratios of 0.6 and 1.4 and represents the transition between ‘geometrical arching’ to ‘shallow beam bending’ to ‘complete failure’ of the overburden. The maximum subsidence for sub-critical and critical panel widths is < 60% of the longwall extraction height and could range between 10% and 40% (of the extraction height).

With an ultimate panel width of 305m (including the gate road heading either side) and cover depth of between 160m and 380m, the W/H ratio varies from 0.8 in the west to 1.9 in the east and falls outside the sub-critical range. However, it is possible that the Garrawilla Volcanics may bridge over the collapsed lower strata creating sub-critical behaviour in some or all of the longwall panels. This assessment has considered both sub-critical and critical longwall behaviour.

The surface effect of extracting several adjacent longwall panels is dependent on the stiffness of the overburden and the dimensions of the chain pillars left between the panels. Invariably, 'extra' subsidence occurs above a previously extracted panel and is caused primarily by the compression of the chain pillars and adjacent strata between the extracted longwall panels.

A longwall chain pillar undergoes the majority of life-cycle compression when subject to double abutment loading, ie. the formation of goaf on both sides of it, after two adjacent panels have been extracted. Surface survey data indicates that an extracted panel can affect the chain pillars between three or four previously extracted panels. The stiffness of the overburden and chain pillar system would determine the extent of load transfer to the preceding chain pillars. If the chain pillars go into yield, the load on the pillars would be mitigated to some extent by load transfer to adjacent fallen roof material or goaf.

The surface subsidence would extend beyond the limit of underground mining for a certain distance (i.e. the angle of draw). The angle of draw distance is usually less than or equal to 0.5 to 0.7 times the depth of cover (or angles of draw to the vertical of 26.5^o to 35^o) in the NSW and Queensland Coalfields.

4B.1.4 Potential Impacts and Management Issues

As a result of subsidence, the following impacts could be expected. Each of these is considered in relation to the subsidence predictions of DGS (2009) in Section 4B.1.6.

Surface Cracking

The development of surface cracking above a longwall panel is caused by the bending of the overburden strata as it sags down into the newly created void in the coal seam. The sagging strata is initially supported by previously collapsed roof material (goaf), which then slowly compresses to a maximum subsidence.

The tensile fractures generally occur between the chain pillars and the point of inflexion, which is where convex curvatures and tensile strains would develop. Compressive shear fractures or shoving zones would generally also develop in the area above the longwall panel and inside the inflexion points.

Sub-surface Cracking

The caving and subsidence development processes above a longwall panel usually results in sub-surface fracturing and shearing of sedimentary strata in the overburden (see **Figure 4B.2**). The extent of fracturing and shearing is dependent on mining geometry and overburden geology. As illustrated on **Figure 4B.2**, sub-surface fracturing may be defined as either 'continuous' or 'discontinuous' hydraulic fracturing.

Continuous sub-surface fracturing refers to cracking above a longwall panel that would provide a direct flow-path or hydraulic connection to the workings if a sub-surface aquifer (or surface) were intersected. The presence of sub-surface aquifers above the workings and within the continuous fracture zone could therefore result in increased water inflow into the seam level during longwall extraction.

Discontinuous fracturing refers to the additional extent above a longwall to which there could be a general increase in horizontal and vertical permeability, due to bending or curvature deformation of the rock mass. This type of fracturing does not usually provide a direct flow path or connection to the workings, however, it is possible that they would interact with surface cracks, joints, or faults. This type of fracturing can also result in an adjustment of:

- surface and sub-surface flow paths; and
- rock mass conductivity and storage magnitudes, but may not result in a significant change to the groundwater or surface water resource in the long-term.

Slope Stability and Erosion

As a consequence of changes in surface slopes and drainage paths, erosion may be accelerated leading to possible en-masse sliding, ie. a landslip, of the ridges or hills of the Mine Site. The occurrence or scale of erosion and/or landslip is likely to be influenced by soil type and pre-subsidence slopes with dispersive soils and slopes >10º more susceptible to these impacts.

Valley Closure and Uplift

'Valley closure' (or opening) movements can be expected along cliffs and sides of deep valleys wherever longwalls are mined beneath them. Valley closure can also occur across broader drainage gullies where shallow surface rock is present.

When creeks and river valleys are subsided, the observed subsidence in the base of the creek or river is generally less than would normally be expected in flat terrain. This reduced subsidence is due to the floor rocks of a valley buckling upwards when subject to compressive stresses generated by surface deformation. This phenomenon is termed as 'valley uplift'. In most cases in the Newcastle and Southern NSW Coalfields, the observed uplift has extended outside steep sided valleys and included the immediate cliff lines and the ground beyond them.

Ponding and Other Impacts on Local Drainage

Surface slopes in the elevated areas of the Mine Site range between 1° and 18° and are unlikely to be affected by ponding caused by closed form depressions from subsidence trough development, ie. the net fall across the area would therefore be sufficient to allow surface drainage to continue unimpeded after mining is completed.

Some watercourses present within the Mine Site, however, occur where the surface slope is considerably less than 1º and these could be susceptible to potential ponding depths of between 0.5m and 1.5m. The actual ponding depths would depend upon several other factors, such as rain duration, surface cracking and effective percolation rates of the surface soils and fractured rock bars/outcrops along the creeks.

In some instances, the ponding effect could result in a change to the alignment of the creek or tributary. This could impact on local erosion processes and impact on the vegetation along the pre-subsidence and altered drainage line.

Far-Field Horizontal Displacements

Horizontal movements due to longwall mining have been recorded at distances well outside of the angle of draw in the Newcastle, Southern and Western Coalfields. Horizontal movements recorded beyond the angle of draw are referred to as far-field horizontal displacements.

This phenomenon is strongly dependent on:

- cover depth;
- distance from the goaf edges;
- the maximum subsidence over the extracted area;
- topographic relief; and
- the horizontal stress field characteristics.

An empirical model for predicting Far-field displacement (FFDs) indicates that measurable FFD movements, ie. 20mm, generally occur in relatively flat terrain for distances up to three to four times the cover depth. The direction of the movement is generally towards the extracted area, but can vary due to the degree of regional horizontal stress adjustment around extracted area and the surface topography.

Aboriginal Artefacts

As a consequence of the potential impacts identified above, in particular surface cracking, Aboriginal artefacts may be damaged or vertically or laterally displaced.

Surface Infrastructure

As a consequence of the changing elevation caused by subsidence, or the potential impacts such as surface cracking and erosion resultant from erosion, surface infrastructure such as houses and other buildings, roads, pipelines, services (eg. power / telephone) and water management structures such as dams and contour banks may be damaged.

4B.1.5 Subsidence Modelling

4B.1.5.1 Subsidence Prediction Methodology

Subsidence Models

DGS (2009) used two empirically based prediction models (ACARP, 2003 and SDPS®, 2007) to generate subsidence contours above the proposed longwall panels after mining is complete. A summary of these two models is as follows.

- **ACARP, 2003.** An empirical model originally developed for predicting maximum single and multiple longwall panel subsidence, tilt, curvature and strain in the Newcastle Coalfield. The model database included measured subsidence parameters and overburden geology data which have been back analysed to predict the subsidence reduction potential (SRP) of massive lithology in terms of ‘Low’, ‘Moderate’ and ‘High’ SRP categories.

- The model database also includes chain pillar subsidence, inflexion point distance / subsidence, goaf edge subsidence and angle of draw prediction models, which allow subsidence profiles to be generated for any number of panels and a range of appropriate confidence limits. The Upper 95% Confidence Limit (U95%CL) has been adopted in this study for predictions of the Credible Worst-Case values.
- The model has been recently updated by Ditton Geotechnical Services Pty Ltd to allow the original model to be applied to other Australian Coalfields (including the Gunnedah Basin) due to its generic nature. DGS (2009) provides the detail of the model modification undertaken to improve compatibility between the ACARP, 2003 prediction model and the SDPS®, 2007 model.
- **SDPS®, 2007.** Developed as an influence function model for subsidence predictions above longwalls or pillar extraction panels. The model requires calibration to measured subsidence profiles to reliably predict the subsidence and differential subsidence profiles required to assess impacts on surface features.
- The value of this model is that it includes a database of percentage of hard rock, ie. massive sandstone / conglomerate, that effectively reduces subsidence above super-critical and sub-critical panels due to either bridging or bulking of collapsed material.
- Subsidence, tilt, horizontal displacement, and strain contours were ultimately produced using the modelled results of the SDPS®, 2007 model.

Further detail on the use of both models for the proposed Longwall Project is provided by DGS (2009).

Modelling Methodology

Using the two empirical prediction models, DGS (2009) produced total and differential subsidence predictions across the Mine Site at the following time sequence intervals:

- after each longwall block has been extracted, and
- after mining of all of the proposed longwall panels is complete.

Without prior experience longwall mining the Hoskissons Coal Seam, the following parameters influencing subsidence were considered.

- The subsidence reduction potential (SRP) of the overburden and the influence of proposed mining geometry on single panel subsidence development, ie. whether the panels are likely to be sub-critical, critical or supercritical. As noted in Section 4B.1.2.2, the Garrawilla Volcanics displays spanning potential that may influence the development of subsidence impacts, although the level of this influence is not known.
- The behaviour of the chain pillars and immediate roof and floor system under double-abutment loading conditions when longwall panels have been extracted along both sides of the pillars.

- The combined effects of single panel and chain pillar subsidence to estimate final subsidence profiles and subsidence contours for subsequent environmental impact assessment.
- In order to account for these uncertainties in model parameters and subsidence development, DGS (2009) considered the modelling predictions of the following three cases.
  - Case 1: Non-spanning Garrawilla Volcanics and maximum chain pillar subsidence.
  - Case 2: Spanning Garrawilla Volcanics (where thick enough) and maximum chain pillar subsidence.
  - Case 3: Non-spanning Garrawilla Volcanics and minimum chain pillar subsidence.

DGS (2009) based maximum panel and chain pillar subsidence predictions for the three cases on ‘Credible Worst Case’ values derived from ACARP (2003). The term ‘Credible Worst Case’ infers that the predictions would be exceeded by 5% of panels mined with similar geometry and geology etc., and is identified as the Upper 95% Confidence Limit (U95%CL) value.

Minimum values have been based on the ‘mean’ values derived from the ACARP (2003). The term ‘mean’ infers that the predictions would be exceeded by 50% of panels mined with similar geometry and geology etc., and is identified as the 50% Confidence Limit value.

4B.1.5.2 Results of Subsidence Modelling

DGS (2009) predicts single panel, chain pillar, goaf edge and multi-panel subsidence values for each of the three modelled cases.

Single Panel Subsidence

Based on an assumed SRP of ‘Low’, ‘Moderate’ and ‘High’, and a longwall extraction height (T) of 4.2m, DGS (2009) provides the predicted single panel subsidence for each longwall panel. **Table 4B.2** provides the mean and U95%CL subsidence for Cases 1 and 2 predicted by DGS (2009).

Table 4B.2
Predicted Maximum Single Panel Subsidence

Page 1 of 2

Longwall Panel No.	Cover Depth (m)	W/H	Unit (m)	SRP	Case 1		Case 2	
					Mean	U95%CL	Mean	U95%CL
1	165	1.85	30	H	2.40	2.44	1.93	2.14
2	175	1.75	30	H	2.44	2.44	1.81	2.02
3	195	1.57	20	M	2.41	2.44	2.19	2.40
4	210	1.45	15	L	2.33	2.44	2.33	2.44
5	230	1.33	20	H	2.24	2.44	1.93	2.14
6	250	1.22	35	H	2.18	2.39	1.75	1.96
7	275	1.11	40	M	2.12	2.33	1.96	2.33
8	290	1.05	40	M	2.06	2.27	1.87	2.27
9	290	1.05	40	M	2.06	2.27	1.87	2.27
10	300	1.02	40	M	2.02	2.23	1.81	2.23

Table 4B.2 (Cont'd)
Predicted Maximum Single Panel Subsidence

Page 2 of 2

Longwall Panel No.	Cover Depth (m)	W/H	Unit (m)	SRP	Case 1		Case 2	
					Mean	U95%CL	Mean	U95%CL
11	310	0.99	40	L	1.99	2.20	1.99	2.20
12	330	0.93	35	L	1.92	2.13	1.92	2.13
13	360	0.85	30	L	1.80	2.01	1.80	2.01
14	365	0.84	35	L	1.77	1.98	1.77	1.98
15	345	0.89	38	L	1.88	2.09	1.88	2.09
16	335	0.91	42	M	1.91	2.12	1.64	1.85
17	310	0.99	42	M	1.99	2.20	1.76	1.97
18	290	1.05	42	M	2.06	2.27	1.87	2.08
19	265	1.15	41	M	2.14	2.35	1.96	2.17
20	251	1.22	30	L	2.19	2.40	2.18	2.39
21	230	1.33	25	M	2.24	2.44	1.93	2.14
22	215	1.42	20	M	2.31	2.44	2.01	2.22
23	200	1.53	20	M	2.38	2.44	2.14	2.35
24	200	1.53	20	M	2.38	2.44	2.14	2.35
25	195	1.57	20	M	2.41	2.44	2.19	2.40
26	185	1.65	25	M	1.77	1.98	2.25	2.44

Source: Modified after DGS (2009) – Table 3

Chain Pillar Subsidence

The predicted mean and maximum subsidence values above the proposed chain pillars (under double abutment loading conditions and a mining height of 4.2m) predicted by the empirical modelling of DGS is summarised in **Table 4B.3**.

Table 4B.3
Predicted Chain Pillar Subsidence

Page 1 of 2

Longwall Panel No.	Cover Depth (m)	Chain Pillar Width (m)	Chain Pillar Stress (MPa)	Pillar FoS under DA^1 Loading Conditions	Subsidence			
					Cases 1 and 2		Case 3	
					Initial Subsidence (U95%CL)	Final Subsidence (U95%CL)	Initial Subsidence (mean)	Final Subsidence (mean)
1	165	24.6	17.3	1.51	0.46	0.51	0.26	0.31
2	175	24.6	19.8	1.32	0.53	0.59	0.33	0.39
3	195	24.6	23.3	1.13	0.63	0.72	0.43	0.51
4	210	29.6	23.2	1.42	0.63	0.71	0.43	0.51
5	230	29.6	27.0	1.22	0.75	0.86	0.55	0.66
6	250	29.6	31.5	1.05	0.89	1.03	0.69	0.82
7	275	29.6	36.0	0.92	1.00	1.16	0.80	0.96
8	290	34.6	33.6	1.24	0.94	1.09	0.74	0.89
9	290	34.6	34.4	1.21	0.96	1.12	0.76	0.91
10	300	34.6	36.5	1.14	1.01	1.17	0.81	0.97
11	310	37.6	37.1	1.28	1.02	1.18	0.82	0.98
12	330	37.6	42.2	1.13	1.10	1.28	0.90	1.08
14	365	37.6	45.1	1.05	1.13	1.32	0.93	1.11
15	345	37.6	41.7	1.14	1.09	1.27	0.89	1.07
16	335	34.6	40.8	1.02	1.08	1.26	0.88	1.06
17	310	34.6	35.9	1.16	1.00	1.16	0.80	0.95
18	290	34.6	31.5	1.32	0.89	1.03	0.69	0.82
19	265	29.6	30.7	1.08	0.86	1.00	0.66	0.79
20	245	29.6	27.1	1.22	0.75	0.86	0.55	0.66
21	230	29.6	24.2	1.37	0.66	0.75	0.46	0.55

Table 4B.3 (Cont'd)
Predicted Chain Pillar Subsidence

Page 2 of 2

Longwall Panel No.	Cover Depth (m)	Chain Pillar Width (m)	Chain Pillar Stress (MPa)	Pillar FoS under DA[1] Loading Conditions	Subsidence			
					Cases 1 and 2		Cases 1 and 2	
					Initial Subsidence (U95%CL)	Initial Subsidence (U95%CL)	Initial Subsidence (U95%CL)	Initial Subsidence (U95%CL)
22	215	29.6	21.5	1.54	0.58	0.65	0.37	0.45
23	200	24.6	23.0	1.14	0.62	0.71	0.42	0.50
24	200	24.6	22.6	1.16	0.61	0.69	0.41	0.49
25	180	24.6	21.2	1.23	0.57	0.64	0.37	0.44

Notes:
1. DA = Double abutment loading conditions.
2. The chain pillars referred to in the above table are on the Maingate side. As LW13 and LW26 are the last panels mined in the northern and southern panel series, they would not be subject to double abutment loading conditions, because they are adjacent to solid coal

Source: Modified after DGS (2009) – Table 4

The predicted initial subsidence over the chain pillars between the extracted panels is estimated to range from 0.26m to 1.32m for the range of pillar sizes and geometries proposed. The final subsidence over the chain pillars (after mining is completed) is estimated to range from 0.31m to 1.58m (an overall increase of 20%).

Goaf Edge Subsidence

DGS (2009) reports the mean and maximum goaf edge subsidence to be 0.07m to 0.58m respectively.

Multiple Panel Subsidence

Based on the single panel, chain pillar and goaf edge subsidence predictions, **Tables 4B.4** and **4B.5** present the maximum (Credible Worst Case) first and final maximum multi-panel subsidence predictions (and associated impact parameters) for Cases 1 and 2.

Table 4B.4
Predicted Credible Worst-Case First and Final Maximum Panel Subsidence Parameters (Case 1)

Page 1 of 2

Longwall Panel No.	Cover Depth (m)	Panel Width: Cover Depth Ratio	Predicted Subsidence					Max Tilt T_{max} (mm/m)	Max Curvature, C_{max} (km^{-1})		Maximum Strain, E_{max} (mm/m)*	
			Final Goaf Edge (m)	Single Panel S_{max} (m)	First Pillar S_p (m)	First Panel S_{max} (m)	Final Panel S_{max} (m)		Convex	Concave	Tensile	Compressive
1	165	1.85	0.22	2.44	0.46	2.44	2.44	45	1.05	1.36	11	14
2	175	1.75	0.22	2.44	0.53	2.44	2.44	41	0.95	1.20	9	12
3	195	1.57	0.22	2.44	0.63	2.44	2.44	35	0.76	0.97	8	10
4	210	1.45	0.22	2.44	0.63	2.44	2.44	32	0.63	0.84	6	8
5	230	1.33	0.24	2.44	0.75	2.44	2.44	30	0.56	0.78	6	8
6	250	1.22	0.28	2.39	0.89	2.44	2.44	30	0.55	0.78	5	8
7	275	1.11	0.34	2.33	1.00	2.44	2.44	30	0.53	0.78	5	8
8	290	1.05	0.38	2.27	0.94	2.44	2.44	30	0.52	0.78	5	8
9	290	1.05	0.38	2.27	0.96	2.44	2.44	30	0.52	0.78	5	8
10	300	1.02	0.40	2.23	1.01	2.44	2.44	30	0.51	0.78	5	8
11	310	0.99	0.43	2.20	1.02	2.44	2.44	30	0.50	0.78	5	8
12	330	0.93	0.49	2.13	1.10	2.44	2.44	30	0.48	0.78	5	8
13	360	0.85	0.58	2.01	-	2.40	2.44	30	0.45	0.78	5	8

Table 4B.4 (Cont'd)
Predicted Credible Worst-Case First and Final Maximum Panel Subsidence Parameters (Case 1)

Page 2 of 2

Longwall Panel No.	Cover Depth (m)	Panel Width: Cover Depth Ratio	Predicted Subsidence					Max Tilt T_{max} (mm/m)	Max Curvature, C_{max} (km^{-1})		Maximum Strain, E_{max} (mm/m)*	
			Final Goaf Edge (m)	Single Panel S_{max} (m)	First Pillar S_p (m)	First Panel S_{max} (m)	Final Panel S_{max} (m)		Convex	Concave	Tensile	Compressive
14	365	0.84	0.59	1.98	1.13	2.04	2.44	30	0.44	0.78	4	8
15	345	0.89	0.53	2.09	1.09	2.44	2.44	30	0.47	0.78	5	8
16	335	0.91	0.50	2.12	1.08	2.44	2.44	30	0.48	0.78	5	8
17	310	0.99	0.43	2.20	1.00	2.44	2.44	30	0.50	0.78	5	8
18	290	1.05	0.38	2.27	0.89	2.44	2.44	30	0.52	0.78	5	8
19	265	1.15	0.32	2.35	0.86	2.44	2.44	30	0.54	0.78	5	8
20	245	1.25	0.27	2.40	0.75	2.44	2.44	30	0.55	0.78	6	8
21	230	1.33	0.24	2.44	0.66	2.44	2.44	30	0.56	0.78	6	8
22	215	1.42	0.22	2.44	0.58	2.44	2.44	31	0.60	0.80	6	8
23	200	1.53	0.22	2.44	0.62	2.44	2.44	34	0.71	0.92	7	9
24	200	1.53	0.22	2.44	0.61	2.44	2.44	34	0.71	0.92	7	9
25	195	1.57	0.22	2.44	0.57	2.44	2.44	35	0.76	0.97	8	10
26	185	1.65	0.22	2.44	-	2.44	2.44	38	0.85	1.08	8	11

Notes:

Single Panel S_{max}: Maximum surface subsidence predicted for a single, isolated longwall panel.

Final Panel S_{max}: Estimated final subsidence for a given panel (including chain pillar compression effects) after all longwall panels have been extracted.

*: Predicted strains are for a surface with a deep soil cover and likely to have 'smooth' profile strains. A surface with rock exposures is likely to cause strain concentrations which are 2 x 'smooth' profile strains.

Source: Modified after DGS (2009) – Tables 6A and 6B

Table 4B.5
Predicted Credible Worst-Case First and Final Maximum Panel Subsidence Parameters with Spanning Garrawilla Volcanics (Case 2)

Page 1 of 2

Longwall Panel No.	Cover Depth (m)	Panel Width: Cover Depth Ratio	Predicted Subsidence					Max Tilt T_{max} (mm/m)	Max Curvature, C_{max} (km^{-1})		Maximum Strain, E_{max} (mm/m)*	
			Final Goaf Edge (m)	Single Panel S_{max} (m)	First Pillar S_p (m)	First Panel S_{max} (m)	Final Panel S_{max} (m)		Convex	Concave	Tensile	Compressive
1	165	0.02	0.41	0.26	0.41	0.70	0.70	6	0.21	0.26	2	3
2	175	0.03	0.44	0.33	0.56	0.93	0.93	8	0.24	0.31	2	3
3	195	0.07	2.19	0.43	2.32	2.44	2.44	25	0.51	0.65	5	6
4	210	0.07	2.33	0.43	2.44	2.44	2.44	23	0.44	0.56	4	6
5	230	0.09	1.93	0.55	2.11	2.44	2.44	22	0.41	0.52	4	5
6	250	0.07	0.53	0.69	0.79	1.58	1.58	12	0.26	0.34	3	3
7	275	0.10	0.55	0.80	0.88	1.78	1.78	14	0.30	0.38	3	4
8	290	0.11	0.52	0.74	0.90	1.73	1.73	13	0.29	0.37	3	4
9	290	0.11	0.48	0.76	0.83	1.70	1.70	13	0.28	0.36	3	4
10	300	0.12	0.44	0.81	0.80	1.72	1.72	13	0.29	0.36	3	4
11	310	0.13	0.37	0.82	0.76	1.68	1.68	13	0.28	0.36	3	4
12	330	0.16	0.47	0.90	0.86	1.86	1.86	15	0.31	0.39	3	4
13	360	0.18	0.62	-	1.04	1.64	1.64	12	0.27	0.35	3	3
14	365	0.17	0.46	0.93	0.46	1.52	1.52	11	0.26	0.32	3	3
15	345	0.18	0.35	0.89	0.80	1.79	1.79	14	0.30	0.38	3	4
16	335	0.16	0.30	0.88	0.73	1.72	1.72	13	0.29	0.37	3	4
17	310	0.12	0.30	0.80	0.72	1.62	1.62	12	0.27	0.34	3	3
18	290	0.10	0.36	0.69	0.74	1.52	1.52	11	0.25	0.32	3	3
19	265	0.08	0.40	0.68	0.73	1.51	1.51	11	0.25	0.32	3	3
20	245	0.11	1.49	0.57	1.79	2.40	2.40	21	0.40	0.51	4	5
21	230	0.08	1.46	0.46	1.72	2.22	2.22	19	0.37	0.47	4	5
22	215	0.07	2.01	0.37	2.20	2.44	2.44	22	0.42	0.53	4	5

Table 4B.5 (Cont'd)
Predicted Credible Worst-Case First and Final Maximum Panel Subsidence Parameters with Spanning Garrawilla Volcanics (Case 2)

Page 2 of 2

Longwall Panel No.	Cover Depth (m)	Panel Width: Cover Depth Ratio	Predicted Subsidence					Max Tilt T_{max} (mm/m)	Max Curvature, C_{max} (km^{-1})		Maximum Strain, E_{max} (mm/m)*	
			Final Goaf Edge (m)	Single Panel S_{max} (m)	First Pillar S_p (m)	First Panel S_{max} (m)	Final Panel S_{max} (m)		Convex	Concave	Tensile	Compressive
23	200	0.07	2.14	0.42	2.29	2.44	2.44	24	0.48	0.61	5	6
24	200	0.07	2.14	0.41	2.31	2.44	2.44	24	0.48	0.61	5	6
25	195	0.07	2.19	0.37	2.36	2.44	2.44	25	0.51	0.65	5	6
26	185	0.03	0.67	-	0.85	1.02	1.02	8	0.24	0.30	2	3

Notes:
Single Panel S_{max}: Maximum surface subsidence predicted for a single, isolated longwall panel.
Final Panel S_{max}: Estimated final subsidence for a given panel (including chain pillar compression effects) after all longwall panels have been extracted.
*: Predicted strains are for a surface with a deep soil cover and likely to have 'smooth' profile strains. A surface with rock exposures is likely to cause strain concentrations which are 2 x 'smooth' profile strains.

Source: Modified after DGS (2009) – Tables 7A and 7B

The predicted multi-panel subsidence impacts are illustrated on **Figures 4B.3** and **4B.4** for Cases 1 and 2. Derived from the mean goaf edge subsidence predictions, DGS (2009) estimates the angel of draw to range from 10° to 26.5°, where the angle of draw (AoD) is the angle from the vertical of the line drawn between the tailgate edge of the longwall panel to the 20mm subsidence contour[1] at the surface. Based on these AoDs, DGS (2009) anticipates that subsidence would extend the following distances beyond the limit of mining.

- 150m to 220m beyond the western boundary (23° to 31° draw angle).
- 35m to 70m beyond the eastern boundary (12° to 21° draw angle).
- 130m to 200m beyond the northern and southern boundaries at the western end, reducing to 35m to 70m in the east (12° to 31° draw angle).

Section 4B.1.6 provides an assessment of these results.

Reliance would be placed upon the monitoring to confirm the angle of draw well ahead of the commencement of Panels LW9 to LW13 to ensure that subsidence exceeding 20mm is confined within the northern boundary of ML1609.

4B.1.6 Assessment of Impacts and Management

4B.1.6.1 Surface Cracking

Predicted Impacts

Surface cracks caused by tensile fractures generally occur between the chain pillars and the point of inflexion, which is where convex curvatures and tensile strains would develop. Based on the predicted panel subsidence and tilt (see **Tables 4B.4** and **4B.5**), the point of inflexion is assessed to be located 20m to 60m from the panel ribs for the range of mining geometries proposed. Tensile fractures can also develop above chain pillars that are located between extracted panels.

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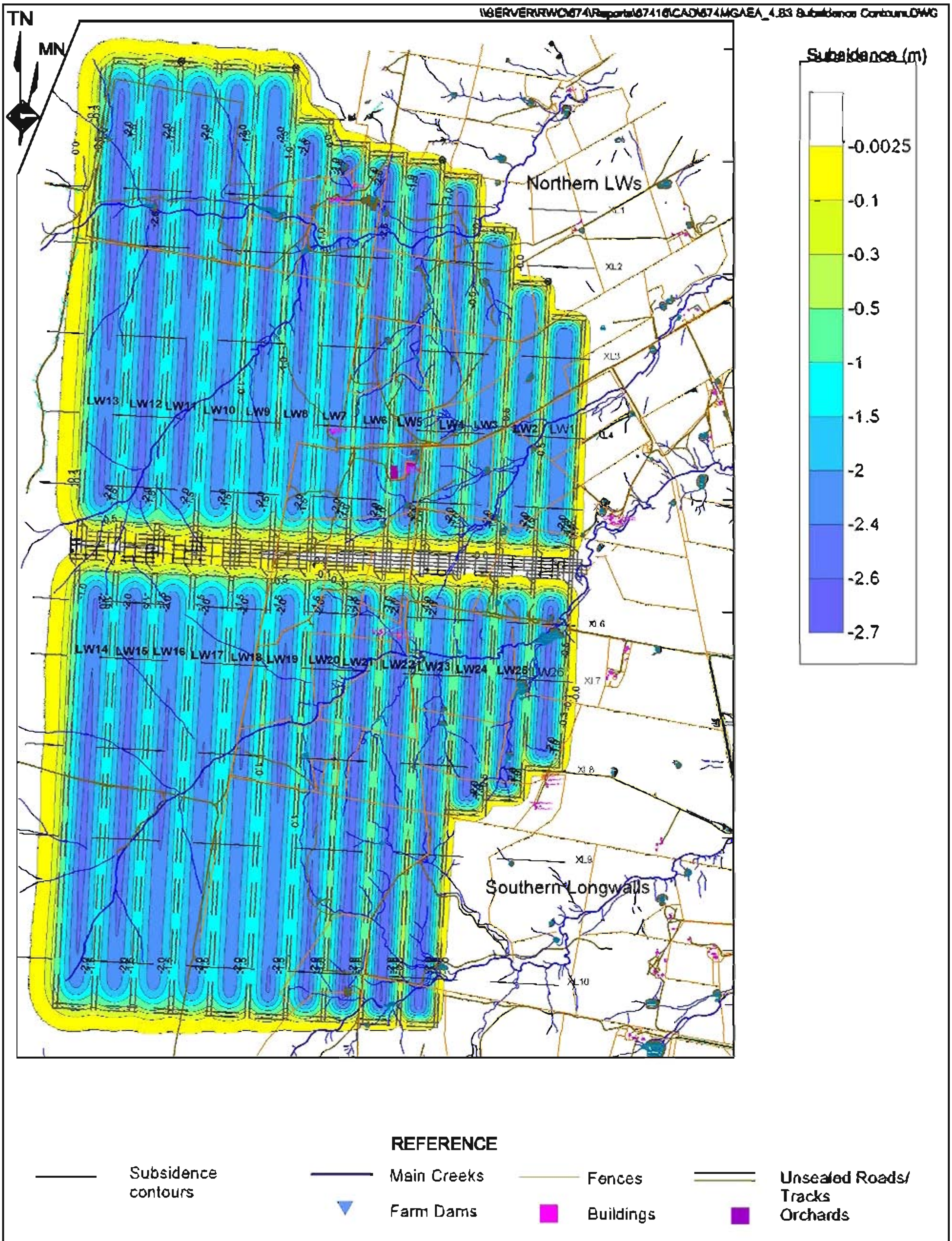
[1] The 20 mm subsidence contour is an industry defined limit and represents the practical measurable limit of subsidence.

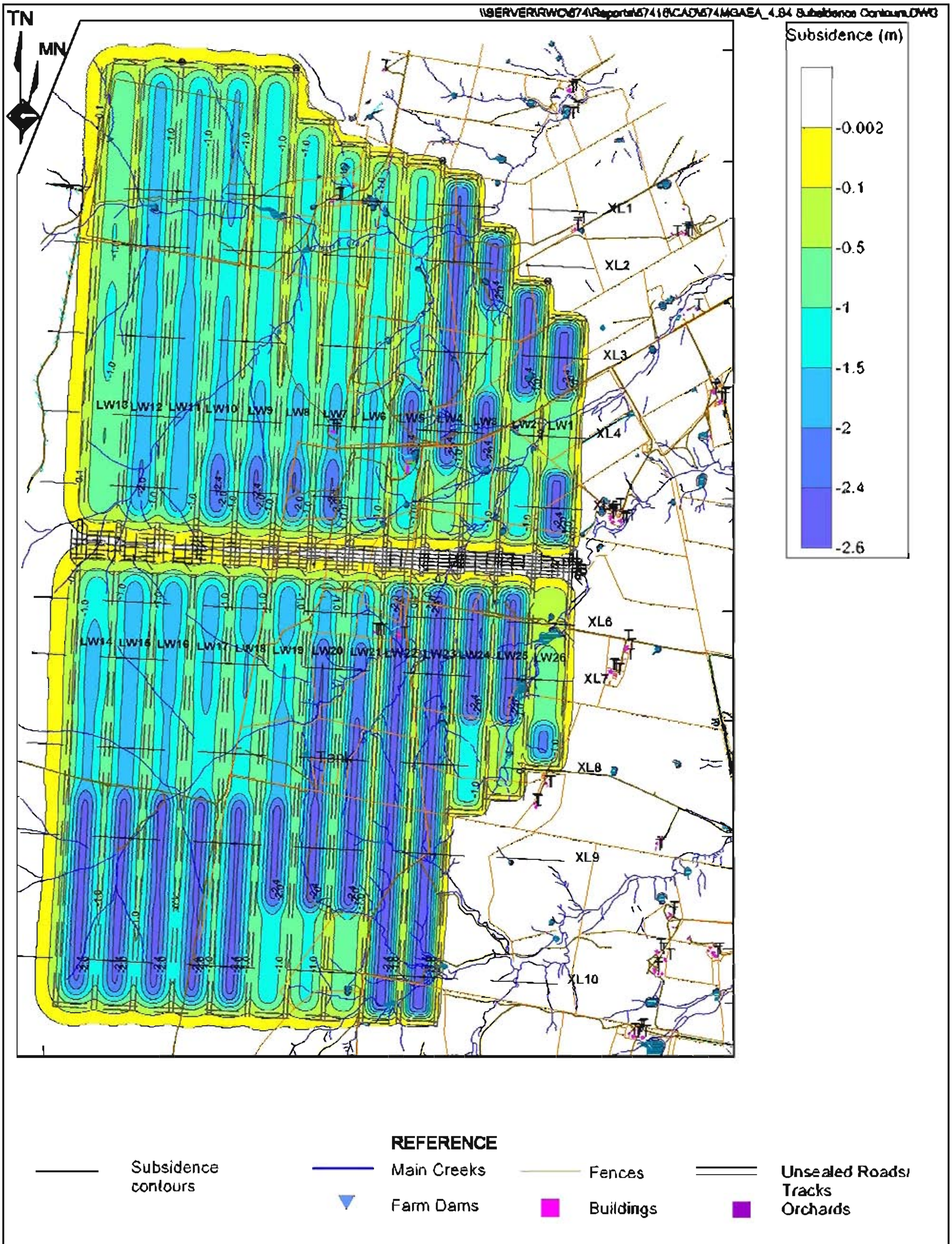


SCALE 1:50 000

0.5 0 0.5 1.0 1.5 2.0 2.5 km

Source: DGS (2009) - Figure 35

Figure 4B.3
PREDICTED MINE SUBSIDENCE CONTOURS (CASE 1)



Source: DGS (2009) - Figure 38

Figure 4B.4
PREDICTED MINE SUBSIDENCE CONTOURS (CASE 2)

The compressive shear fractures or shoving zones would generally develop in the area above the longwall panel and inside the inflexion points.

Surface crack widths (in mm) have been estimated by multiplying the predicted strains by 10 (and assuming a 10m distance between survey pegs). Therefore, based on the predicted range of maximum transverse tensile and compressive strains predicted by DGS (2009), ie. 19mm/m to 2mm/m, maximum surface cracking widths of between 20mm and 190mm may occur above the panels. It is acknowledged by both DGS (2009) and in the peer review by Dr Bruce Hebblewhite (see Volume 1, Part 1 of the *Specialist Consultant Studies Compendium*) that the crack widths could be greater than 190mm.

It is noted that the wider cracks would appear in the eastern side of the mining area and the narrower cracks would appear in the western side of the mining area. Strain concentrations in near surface rock, could also double the above crack widths to 40mm and 380mm respectively. The above crack width estimation method assumes all of the strain would concentrate at a single crack between the survey pegs. This could occur where near surface bedrock exists, but is more likely to develop as two or three smaller width cracks, over a tensile zone of 20m in width, in deep alluvial soil profiles. Therefore, the crack widths are expected to be wider on ridges than along sandy-bottomed creek beds.

The cracks in the tensile strain zones would probably be tapered and extend to depths ranging from 5m to 15m, and possibly deeper in near surface rock exposures and ridges. Cracks within compressive strain zones are generally low-angle shear cracks caused by failure and shoving of near surface strata. The cracks would probably have developed by the time the longwall face has retreated past a given location for a distance equal to 1 to 2 times the cover depth.

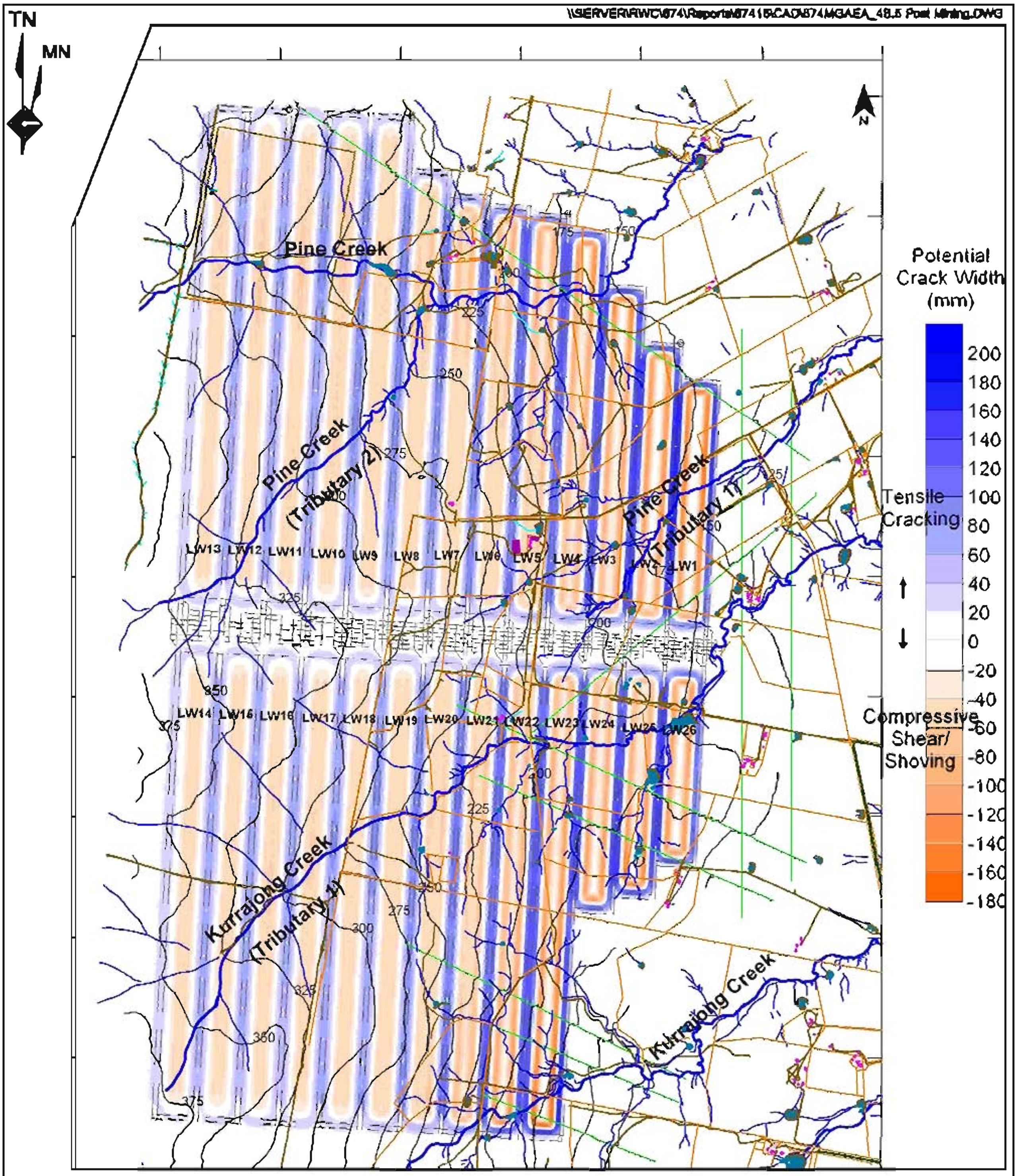
Figure 4B.5 presents the predicted subsidence crack width location zones associated with post-mining tensile and compressive strains for the worst-case scenario (Case 1 – Maximum chain pillar subsidence and non-spanning Garrawilla Volcanics). It is expected that the cracks would be orientated sub-parallel to the sides and ends of each panel, with diagonal cracking at the corners.

Undermining ridges can also result in surface cracks migrating up-slope and outside the limits of extraction for significant distances due to rigid block rotations. This phenomenon depends upon the slope angle, vertical jointing and the subsidence at the toe of the slope. There are few if any ridges within the Mine Site likely to enable upslope migration of cracking.

Proposed Management

The Proponent would regularly monitor areas of the Mine Site likely to be affected by surface cracking (see **Figure 4B.5**). This would involve inspection of the areas on foot, or where access is available by vehicle.

On identification of cracking, the location would be noted but no further action taken at that time as with many smaller width cracks, natural erosive forces are likely to result in these being in-filled naturally. For larger cracks (>100mm) or those persisting without being naturally in-filled, the Proponent would undertake remedial works involve the scarification or light ripping of surface over and both sides of the crack.



* Assuming Non-spanning Garrawilla Volcanics and minimum Chain Pillar Subsidence

SCALE 1:50 000

0.5 0 0.5 1.0 1.5 2.0 2.5 km

Source: DGS (2009) - Figure 41

Figure 4B.5
POST-MINING SURFACE CRACK WIDTH *

In the unlikely event that ripping alone is insufficient to fill in a deeper or wider crack, the Proponent would excavate the required volume of subsoil from stockpiles located at nearby gas drainage or ventilation sites or footprint of the Reject Emplacement Area, transfer it to the crack site and fill it in.

4B.1.6.2 Sub-Surface Cracking

Predicted Impacts

Two heights of fracturing models (A and B) were used by DGS (2009) to:

- ascertain the sensitivity of the predictions; and
- demonstrate which model is more conservative.

The predicted mean and U95%CL values for the continuous and discontinuous sub-surface cracking heights above longwall panels are summarised in **Table 4B.6**.

Table 4B.6
Summary of Predicted Sub-Surface Fracturing Heights

Longwall Panel No.*	**Cover Depth (m)**	**Mining Height, T (m)**	**Single Panel S_{max} (mean) (m)**	**Predicted Fracture Heights (m)**		
				Continuous (A Horizon)		**Discontinuous (B Horizon)** (mean - U95%CL)
				Model A (mean - U95%CL)	**Model B** 21T - 33T	
Northern Longwalls						
1	165	4.2	2.40	69 - 114	**88 - 139**	141 - *170*
2	175	4.2	2.44	69 - 116	**88 - 139**	147 - *177*
3	195	4.2	2.41	67 - 120	**88 - 139**	156 - *190*
4	210	4.2	2.33	64 - 120	**88 - 139**	161 - *198*
5	230	4.2	2.24	63 - 125	**88 - 139**	172 - *212*
6	250	4.2	2.18	68 - 135	**88 - 139**	186 - 230
7	275	4.2	2.12	**73 - 146**	88 - 139	204 - 252
8	290	4.2	2.06	**75 - 152**	88 - 139	213 - 264
9	290	4.2	2.06	**75 - 152**	88 - 139	213 - 264
10	300	4.2	2.02	**76 - 156**	88 - 139	220 - 272
11	310	4.2	1.99	**77 - 160**	88 - 139	226 - 280
12	330	4.2	1.92	**80 - 168**	88 - 139	239 - 296
13	360	4.2	1.80	**81 - 178**	88 - 139	256 - 319
Southern Longwalls						
14	365	4.2	1.77	**81 - 179**	88 - 139	259 - 323
15	345	4.2	1.88	**81 - 174**	88 - 139	248 - 308
16	335	4.2	1.91	**80 - 170**	88 - 139	242 - 300
17	310	4.2	1.99	**77 - 160**	88 - 139	226 - 280
18	290	4.2	2.06	**75 - 152**	88 - 139	213 - 264
19	265	4.2	2.14	**71 - 142**	88 - 139	197 - 243
20	245	4.2	2.19	67 - 132	**88 - 139**	183 - 226
21	230	4.2	2.24	63 - 125	**88 - 139**	172 - 212
22	215	4.2	2.31	62 - 120	**88 - 139**	163 - *201*
23	200	4.2	2.38	66 - 120	**88 - 139**	158 - *193*
24	200	4.2	2.38	66 - 120	**88 - 139**	158 - *193*
25	195	4.2	2.41	67 - 120	**88 - 139**	156 - *190*
26	185	4.2	2.44	69 - 118	**88 - 139**	152 - *184*

Notes:
*: Predictions determined along XL 4 and XL 7 (see **Figure 1** for cross line location)
T: Mining Height
Italics: Discontinuous fracturing may interact with surface cracks if B-Horizon within 15m of surface, resulting in surface flow re-routing.
Bold: Conservative modelling result
Source: Modified after DGS (2009) – Table 10

The results indicate that Model A is generally the more conservative model for cover depths >260m and less conservative for cover depths <260m. Model B predicts direct surface to seam fracturing could occur for cover depths between 88m and 139m.

The results indicate that continuous fracturing from seam to surface would not occur (given the predicted depth of continuous fracturing does not exceed the cover depth of any of the longwall panels). Subsurface aquifers within 110m to 180m above the proposed panels, ie. 50% to 70% of the cover depth, may however, be affected by direct hydraulic connection to the workings, with significant long-term increases to vertical permeability. DGS (2009) notes that the continuous fracture would not extend above the Garrawilla Volcanics, ie. not result in direct hydraulic connection between the groundwater of the Great Artesian Basin Intake Beds and the underground mine.

Table 4B.6 indicates that discontinuous sub-surface fracturing could interact with surface cracks where cover depths are <215m. This accounts for approximately 28% of the mining area. As a result, creek flows could be re-routed to below-surface pathways and re-surfacing downstream of the mining extraction limits in these areas. DGS (2009) notes, however, that this phenomenon would normally only occur where shallow surface rock is present and is unlikely where deep soil profiles exist. Deep soil profiles occur over that area of the Mine Site where cover depth <215m (LW1 to LW4 and LW 23 to 26) and it is therefore considered unlikely that there would be any interaction between discontinuous sub-surface cracks and local creeks or their tributaries.

The potential impacts of the predicted sub-surface fracturing has been included in groundwater modelling undertaken by Aquaterra (2009), which is summarised in Section 4B.2.5.

Proposed Management

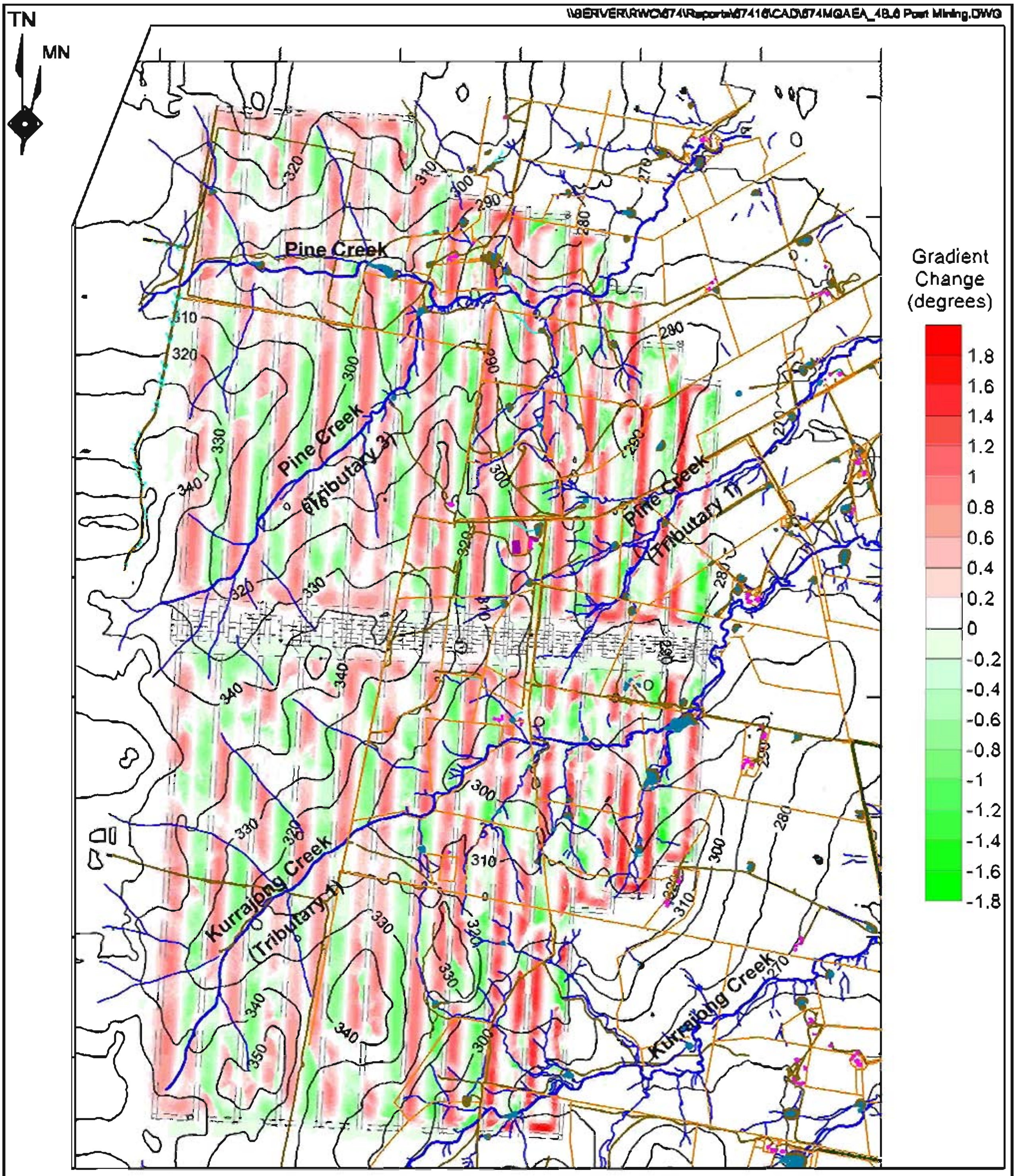
The management of sub-surface cracking impacts on local groundwater is considered as part of the Longwall Project groundwater assessment (see Section 4B.2.5).

4B.1.6.3 Slope Stability and Erosion

Predicted Impacts

The likelihood of en-masse sliding, ie. a landslip, of the ridges or hills over basal siltstone beds tilted by subsidence has been assessed based on landslide risk assessment terminology. The predicted post mining surface slope elevations and gradients for the proposed mining layout are presented in **Figure 4B.6**.

Based on the predictions presented in **Tables 4B.4** and **4B.5**, DGS (2009) indicates that the predicted tilts for the longwall panels are expected to change existing slopes by between 10mm/m and 45mm/m, ie. approximately 1° to 2° (see **Figure 4B.6**). This would indicate that any near surface creek beds might have their dip increased from about 3° to 5° to a range of 4° to 7° on east and west facing slopes within the Mine Site.



* Assuming Non-spanning Garrawilla Volcanics and minimum Chain Pillar Subsidence

SCALE 1:50 000

0.5 0 0.5 1.0 1.5 2.0 2.5 km

Source: DGS (2009) - Figure 47

Figure 4B.6
POST-MINING SURFACE LEVELS AND GRADIENT CHANGES *

Referring to Factors of Safety (FoS) against en-masse sliding of a natural slope, DGS (2009) calculated that the probability of the minimum recommended FoS for slopes with lower bound material strengths (1.2 to 1.3) being exceeded was 1% to 5%. That is, it is 'very unlikely' that a large scale instability or landslip would occur in the long-term due to the proposed longwall mining. Further, studies in terrain above the NSW coalfields to-date indicate longwall mining in undulating terrain with ground slopes up to 25^o has not resulted in any large scale, en-masse sliding instability due to mine subsidence (or other natural weathering processes etc.)

The predicted impacts of the tilts predicted by DGS (2009) and presented in **Table 4B.4** are also considered 'unlikely' (<10% probability) to cause localised surface slope instability unless mining-induced cracking and increased erosion rates also develop. The areas most susceptible to surface slope instability include any steeply eroded banks of Kurrajong and Pine Creeks and their tributaries on the Mine Site. These may slump or topple if cracks develop through them.

The rate of soil erosion is expected to increase in areas with exposed dispersive/reactive soils and slopes >10°. The topsoil layer of all soil types encountered on the Mine Site do not display significant dispersive tendencies and are therefore unlikely to be at significant risk of soil erosion (directly attributable to subsidence) (GCNRC, 2009). The subsoil layers of all soil types generally tend to display higher dispersion than the topsoil, with this especially evident in the soils derived from the Purlawaugh Formation (which represents less approximately 25% of the soils likely to be affected by subsidence – see **Figure 2.11**). However, as the subsoil layers are unlikely to be disturbed the erosion risk associated with the soils of the Purlawaugh Formation is likely to be minimal.

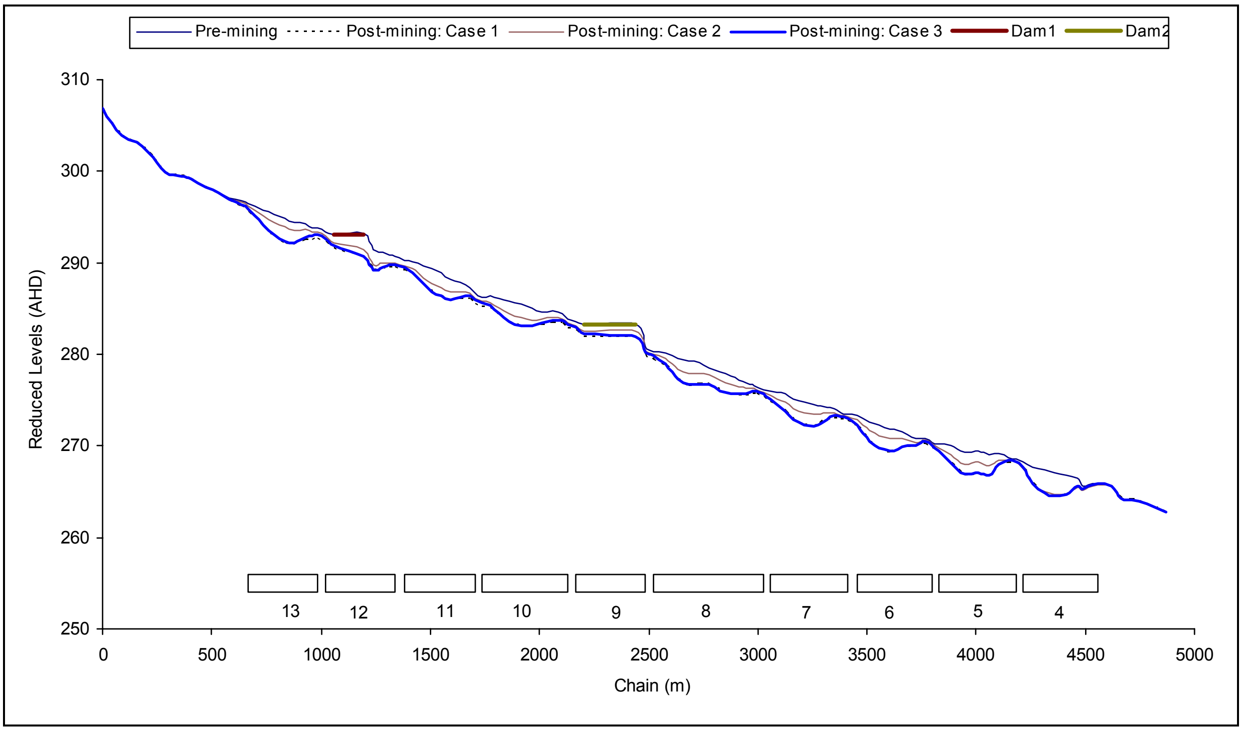
Areas with slopes <10° (see **Figure 4B.1**) are expected to have low erosion rate increases, except for the creek channels, which would be expected to re-adjust to any changes in gradient. **Figure 4B.7** provides a cross-section along Kurrajong and Pine Creeks illustrating the predicted gradient changes along these watercourses.

Proposed Management

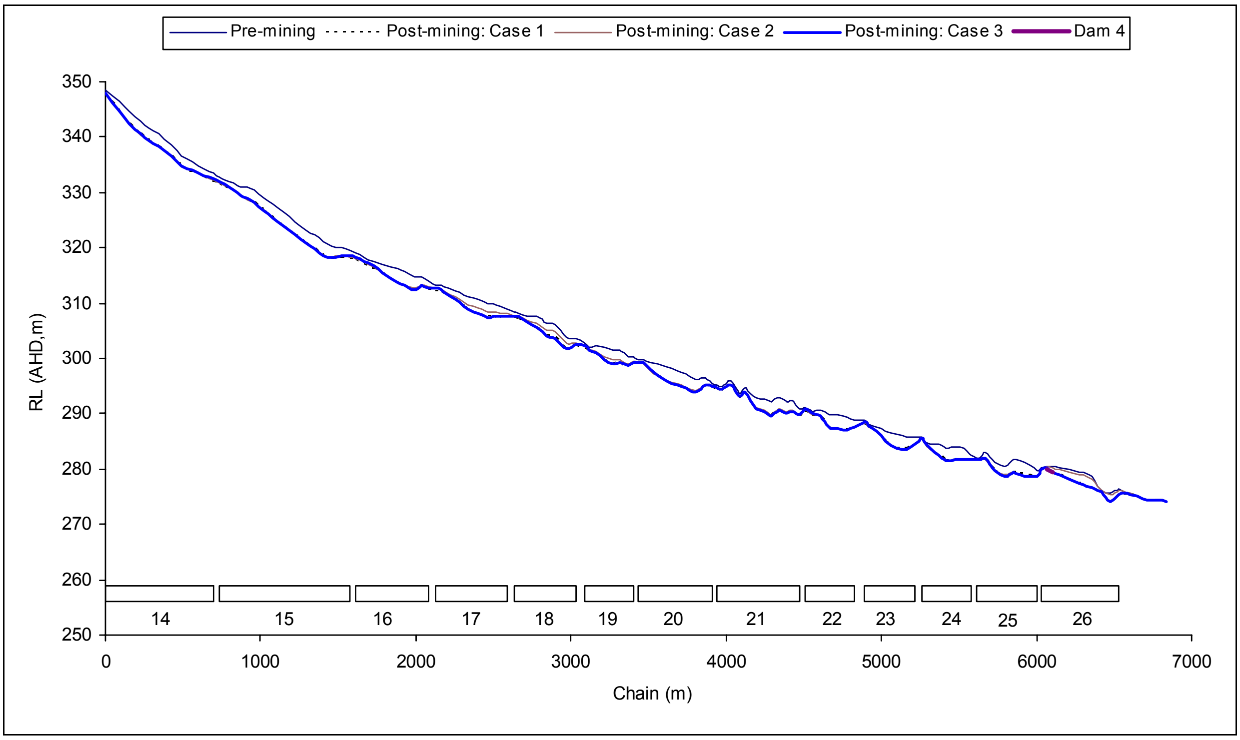
The Proponent would regularly inspect areas of the Mine Site susceptible to landslip of accelerated erosion, eg. drainage lines and steeply sloped areas of exposed Purlwaugh Formation derived subsoils.

While considered unlikely, should large-scale slope instability after mining be identified, the Proponent would undertake stabilisation works, such as the installation of deep sub-surface drainage trenches (to reduce pore pressures) and construct strategic catch drains along slope crests to improve surface run-off.

In the event erosion is identified, in particular along Kurrajong and Pine Creeks and their tributaries, the sections of damaged or steeply eroded banks would be stabilised. Any stabilisation works would be undertaken in accordance with an Erosion and Sediment Control Plan (ESCP) which would be prepared for the Mine Site. It is proposed that the ESCP be prepared in consultation with Narrabri Shire Council and relevant government agencies.



Pine Creek



Kurrajong Creek

Figure 4B.7
PRE-MINING AND PREDICTED POST-MINING SURFACE PROFILES ALONG PINE AND KURRAJONG CREEKS

Source: DGS (2009) – Figures 49 and 51

4B.1.6.4 Valley Closure and Uplift

Predicted Impacts

Valley closure and uplift movements are strongly dependent on the level of 'locked-in' horizontal stress immediately below the floor of the gullies and more importantly the bedding thickness of the floor strata, ie. thin to medium bedded sandstone is more likely to buckle than thicker beds. The influence of the aspect ratio, ie. valley width/depth, is also recognised as an important factor, with deep, narrow valleys having greater ‘upsidence’ than broad, rounded ones, due to higher stress concentrations.

As the valleys across the Mine Site are broad and there is a lack of thick, massive beds of conglomerate and/or sandstone units along the creeks / valleys, DGS (2009) concludes that the probability of ‘upsidence’ development and/or valley closure is likely to be negligible.

If 'upsidence' does occur, it may cause some minor, localised deviation of surface flows along ephemeral creek beds into sub-surface routes above the longwall panels. Failure and cracking of the near surface rocks due to tensile bending or compressive/shear strains would also contribute to the re-routing of surface flows. Re-routed surface flows would be expected to re-surface down stream of the damaged area.

Proposed Management

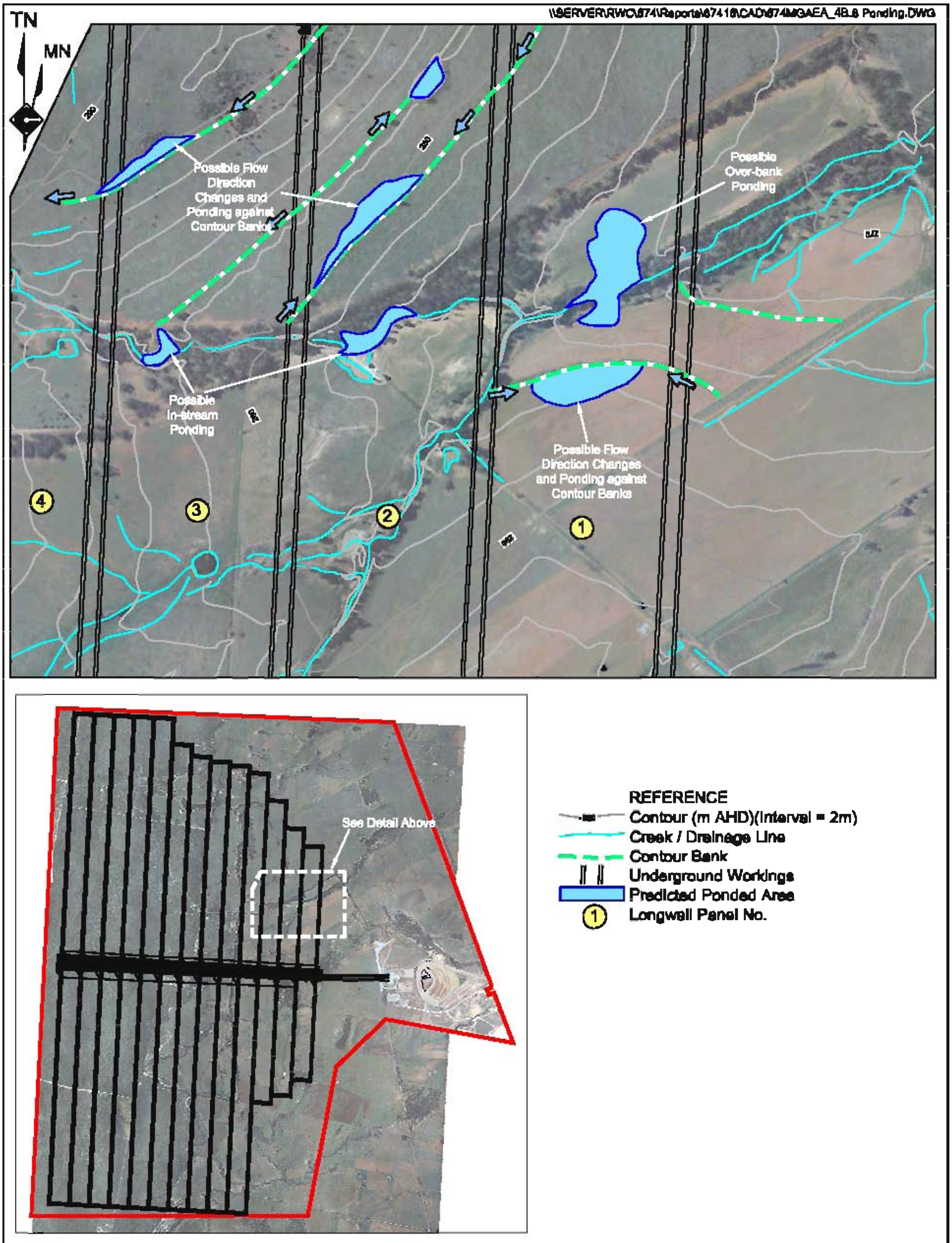
While the potential for ‘upsidence’ is considered negligible, the Proponent would undertake the following to manage the resultant impacts.

- Survey lines along ephemeral drainage gullies and along gully crests would be installed and monitored during and after longwall mining. This monitoring would be combined with visual inspections to identify any signs of cracking or ‘upsidence’.
- The predictions of ‘upsidence’ and valley crest movements would be reviewed after each longwall is completed.
- In the event that ‘upsidence’ results in the appearance of large cracks, remedial works such as those identified for surface cracking (see Section 4B.1.6.1) and erosion (see Section 4B.1.6.3) would be implemented.

4B.1.6.5 Ponding on Tributaries of Kurrajong and Pine Creeks

Predicted Impacts

DGS (2009) suggests that some of the watercourses present within the Mine Site could be susceptible to potential ponding depths of between 0.5m and 1.5m, based on the predicted final surface level profiles of Pine and Kurrajong Creeks (see **Figures 4B.7**). Surface gradients may subsequently increase or decrease by up to 6% (3^o) along creeks. The actual ponding depths would depend upon several other factors, such as rain duration, surface cracking and effective percolation rates of the surface soils and fractured rock bars/outcrops along the creeks. An assessment of the possible ponding that may occur on and adjacent to Pine Creek Tributary 1 during the initial years of mining has been completed by WRM Water and Environment Pty Ltd (WRM, 2009) (see **Figure 4B.8**). Additional predictions of ponding within the creeks and their tributaries on the Mine Site is provided by WRM (2009 – *Figures 7.1 to 7.4*). Notably, the predicted ponding would generally be restricted to within the existing channel banks (in-stream), with only one additional area of possible overbank ponding identified on a tributary to Kurrajong Creek near the southeastern corner of the Mining Area (over LW22).



SCALE 1:10 000

100 0 100 200 300 400 500 m

Source: Modified after WRM (2009) - Figure 7.1

Figure 4B.8
PREDICTED PONDING ON PINE CREEK TRIBUTARY 1 OVER LONGWALL PANELS LW1 to LW3

The impacts within this area are likely to include the following.

- In-stream and over bank ponding over LW1 and in-stream ponding (limited to within the channel of Pine Creek Tributary 1) over LW2 and LW3. Ponding is most likely to occur when the tributary channel is perpendicular to the longwall panels (as the change in channel slope is more significant).
- Over bank ponding and possible flow re-direction along the contour banks north of Pine Creek Tributary 1 over LW2 and LW3. This would occur as the variable subsidence across the retained chain pillars would result in the contour banks no longer run along contour.
- The bed slope of the channels would increase on the downstream (eastern) side of the chain pillars, which may increase channel erosion along these areas.
- Increased in-stream sedimentation would occur on the downstream (eastern) side of the longwall panels in the areas of in-stream ponding. The source of the increased sediment would be due to the channel erosion on the upstream (western) side of the same long wall panel draining from the chain pillars.

Additional impacts associated with the ponding illustrated on **Figure 4B.8** may be as follows.

- The short term loss of riparian vegetation.
- Inundation of identified (and unidentified) Aboriginal sites.
- Increased salinity of downstream flows as a result of ponding over saline soils. Notably, some sub-soils derived from the Purlawaugh Formation have been identified as slightly to moderately saline (GCNRC, 2009) and if exposed as a result of subsidence could increase the salinity of the water discharged from the Mine Site.

Following inspection of the post mine subsidence contours predicted along the tributaries of Kurrajong and Pine Creeks, WRM (2009) determines that the impacts illustrated on **Figure 4B.8** are likely to be typical and repeated across all watercourses within the subsidence zone of the Mine Site. WRM (2009) concludes that major changes in channel geomorphology due to changes in channel location (avulsions) are unlikely.

In considering the impacts of ponding, it is worthy of note that the ponded water would also be likely to provide an additional source of drinking water for local fauna.

Proposed Management

WRM (2009) suggests that the continual action of erosion and sedimentation without mitigation measures is likely to ‘self correct’ the geomorphic characteristics of the waterways over time. Water would be regularly sampled (in accordance with a Surface Water Monitoring Procedure – see Section 4B.3.8) to confirm no increase in the salinity of water which may be attributable to ponding over saline soils.

The above notwithstanding, the Proponent would regularly inspect the watercourses over the subsidence zone of the Mine Site and implement the following mitigation strategy.

- If little vegetation of significance is impacted and water quality analysis confirms no increase in salinity, the ponding would be left to self correct over time.

- If significant areas of vegetation (or vegetation of conservation significance) occur within the ponded area, the channel across the chain pillars would be excavated to reduce the gradient change which causes the pond to form. If this occurs, appropriate management measures (in accordance with an Aboriginal Cultural Heritage Management Plan – see Section 4B.5.5 and vegetation clearing procedures – see Section 4B.4.5.1) would be followed to ensure that Aboriginal sites or significant vegetation is not impacted by the excavation.
- In the event that an increase in salinity is observed, the channel across the chain pillars would be excavated to reduce the gradient change which causes the pond to form (thereby reducing the time over which the salts can leach from the soil and enter the water).

4B.1.6.6 Far-field Horizontal Displacements

Predicted Impacts

DGS (2009) reports that Far-field Displacements (FFDs) generally only have the potential to damage long, linear features such as pipelines, bridges, railway and dam walls. Therefore, any surface features such as bridges or culverts within three or four times the cover depth, ie. approximately 600m from the proposed LW1 and LW26 on the eastern side would be monitored for FFD movements during mining. The deeper western side of the proposed Stage 2 Longwall Project mining area may affect a larger area of up to 1.5km away.

Notably, FFDs outside a distance equal to one cover depth from the longwall extraction limits are unlikely to generate significant strains or movement to cause cracking or damage to the surface (DGS, 2009).

DGS (2009) concludes that the closest linear structures to the mining area (the Main Western Branch Railway Line and the Kamilaroi Highway) would be beyond the area likely to be affected by far-field movements. Hence, no management strategies would need to be adopted.

4B.1.6.7 Aboriginal Artefacts

Section 4B.5.6.2 presents the results of the assessment of potential impact(s) upon the predicted subsidence on Aboriginal sites and artefacts.

4B.1.6.8 Other Surface Features and Infrastructure

4B.1.6.8.1 Unsealed Gravel Access Roads and Tracks

Predicted Impacts

The unsealed gravel access public and private roads and tracks above the proposed longwall panels are likely to be damaged by cracking and ‘shoving’ at tensile and compressive strain zones.

Proposed Management

Given the maximum crack width is unlikely to exceed 380mm in the eastern side of the mining area (see Section 4B.1.6.1), this could be effectively managed through regular inspection and maintenance of the roads and access tracks undertaken after each longwall block is mined or as required when the impacts occur. Particular attention would be paid to public roads maintained by Narrabri Shire Council.

4B.1.6.8.2 Water Storage Dams

Predicted Impacts

Non-engineered farm dams and water storages would be susceptible to surface cracking and tilting due to mine subsidence. The tolerable tilt and strain values for the dams would depend upon the materials used, construction techniques, foundation type and likely repair costs to re-establish the dam's function and pre-mining storage capacity.

The expected phases of tensile and compressive strain development may result in breaching of contour banks or dam walls or water losses through the floor of the dam storage area. Loss or increase of storage areas may also occur due to the predicted tilting. Damage to windmills and fences around the dams may also occur and require repair.

Proposed Management

Notably, the damage to water management structures on the Mine Site would be largely on properties owned by the Proponent. It is also highly likely that any damage caused to these structures could be remediated, or the structure replaced with a comparable one in an appropriate location. For impacts on dams, contour banks, or windmills on the limited number of properties not owned by the Proponent, the Proponent would re-instate or replace the damaged structure in a timely manner and in the case of dams or windmills provide an alternative supply of water during the interim period. DGS (2009) notes that dams similar to those across the Mine Site have been undermined by longwall mining elsewhere in Australia with any damage effectively managed in the manner proposed.

4B.1.6.8.3 Property Fences and Livestock

The impact of subsidence on the grazing of livestock would primarily require the management and repair of surface cracking and fences. Ponding is not expected to affect grazing or pasture areas.

4B.1.6.8.4 Residential Dwellings and Machinery Sheds

Predicted Impacts

It is estimated that there are seven buildings, two orchards and two water tanks present above longwall panels LW5, LW7, LW21 and LW22. These structures and features may be subject to subsidence of up to 2.44m. DGS (2009) considers that the predicted level of subsidence, and the associated tilts and strains, is likely to significantly damage these features. The ultimate impact cannot be predicted, however, it may result in the structures becoming structurally unstable and therefore uninhabitable. The only residential dwellings above the underground Mining Area are on land owned by the Proponent and only two are occupied. The Proponent has already made provision for these dwellings to be vacated well ahead of the predicted subsidence occurring.

Mine subsidence impacts on surface structures are expected to develop soon after a longwall retreats beneath each structure and would be expected to continue until the longwall face is one to two times the cover depth past the structure. Subsidence movements would also be expected to commence again as the subsequent longwall panel(s) pass, albeit at decreasing rates and magnitudes. It is considered likely that subsidence movements would affect undermined properties for periods of at least 2 years after mining.

Structures located outside the Mining Area, but within the angle of draw, may be subject to subsidence movements <200 mm, tilts <4mm/m and strains <1mm/m. Within this zone, and regardless of the type of structure, DGS (2009) predicts damage to these structures to be minor.

Structures that are further than distances of 0.5 to 0.7 times the cover depth (ie. at angles of draw of 26.5^{o} and 35^{o}) from the limits of longwall extraction are likely to be subsided < 20mm with negligible tilts (<1mm/m) and strains (<0.5mm/m). It is very unlikely that mining would cause any damage to these buildings. There are several structures (ie. residences, machinery sheds and tanks) on the "Kurrajong" property which are 80 to 350m south of LW26 and 135m to 155m southeast of the starting position of LW25. The cover depth of 170m gives an effective angle of draw of 25.5 to 64^{o} for these structures.

A detailed assessment of all structures would be undertaken during the development of the Subsidence Management Plan for the Longwall Project.

Proposed Management

A dilapidation survey and inspection of all structures not owned by NCOPL would be made by a qualified building consultant within the proposed angle of draw (+200m) before and after mine subsidence. The report could then be referred to in individual property subsidence management plans (IPSMP) to provide fair and reasonable outcomes between the land owner and the Proponent. The IPSMPs should address the following issues in consultation between the stakeholders (ie. land owners, mine, Council and Utilities).

- When mining impacts would occur and the predicted damage to property structures.
- The monitoring plan for the property during mining and safety/hazard management plan.
- The timing of disconnection of power supply etc.
- The post-mining inspection and reporting of property damage and repair works options.

Any repair works to internal/externals cracking or re-levelling of damaged structures on non-project related properties would be implemented to ensure the properties are safe and serviceable before allowing re-entry to the property.

4B.1.6.8.5 Narrabri Coal Mine Site and Other Infrastructure

No damage or impacts are expected to the proposed Mine Site infrastructure given it is located east of the subsidence zone or along the West Mains, which would cause negligible subsidence.

DGS (2009) reports that the Kamilaroi Highway and North Western Branch Railway Line are well outside the limits of subsidence impact, including impacts from far-field displacements. Notwithstanding this, DGS (2009) recommends, as a precaution, that risk management zones are defined around the mine site infrastructure, highway and railway line.

4B.1.7 Monitoring Program

DGS (2009) notes that measurable subsidence at a given location above the longwall panel centreline is likely to commence at a distance of approximately 50m to 100m ahead of the retreating longwall face and may develop at rates of 50mm/day to 300mm/day. The Proponent would undertake a subsidence and strain-monitoring program in order to provide adequate information to enable the design and implementation of appropriate subsidence impact management plans, as well as to provide pillar stability data for the gate road and main headings. A Subsidence Monitoring Program would be prepared as part of a Subsidence Management Plan for the Longwall Project, which would allow a comparison between predicted and measured subsidence parameters for a given feature. The Subsidence Monitoring Program would include the following elements.

- A transverse subsidence line across the northern and southern panels. The lines would be installed to at least the middle of the next adjacent longwall before undermining occurs.
- A longitudinal line extending in-bye and out-bye from the starting and finishing point of each panel, for a minimum distance equal to the cover depth.
- A survey line along the riparian management zone of Kurrajong and Pine Creeks and their tributaries over the Mine Site.
- A minimum of three monitoring pegs spaced 10m apart in a line or triangle at any feature of interest, eg. dam walls, archaeological sites, to measure subsidence, tilt and strain.
- Visual inspections and mapping of damage before, during and after mining.

In each case, monitoring survey pegs would be spaced between 10m and 20m apart with a minimum of two baseline surveys of subsidence and strain completed before mine subsidence effects occur. Survey frequency would be determined by mine management and be dependent upon requirements for subsidence development data in order to implement subsidence and mine operation management plans.

An alternative method of subsidence monitoring that may be undertaken is Aerial Laser Scanning (ALS). This technique allows a reduction in ground monitoring to key baseline monuments and provide subsidence data to within +/- 0.15m. ALS scans also provide a more thorough picture of the subsidence development along creeks and surface terrain generally and without the need for intrusive surveys or monitoring pegs (which can be a hazard to livestock and be lost by farming activities). The Proponent has already acquired ALS data across the entire mining area to enable comparisons to be made with post-mining data.

4B.2 GROUNDWATER

The groundwater assessment was undertaken by Aquaterra Consulting Pty Ltd (Aquaterra, 2009). The full assessment is presented as Part 2 of the Specialist Consultant Studies Compendium, with the relevant information from the assessment summarised in the following subsections. A peer review of the groundwater modelling was undertaken by Professor Noel Merrick. A copy of Professor Merrick's review is behind the groundwater assessment in the compendium.

4B.2.1 Introduction

Based on the risk analysis undertaken for the Longwall Project (see Section 3.3 and **Table 3.5**), the potential groundwater impacts requiring assessment and their unmitigated risk rating are as follows.

- Groundwater pollution as a result of leakage or spillage (low to moderate risk).
- Drawdown of groundwater resulting in:
  - reduced water levels within the aquifers of the Intake Beds to the Great Artesian Basin Groundwater Source (high risk);
  - reduced water levels within the aquifers of the Lower and Upper Namoi Alluvial Groundwater Source (moderate risk); and
  - reduced water levels within the aquifers of the Gunnedah Basin Groundwater Source (high risk).
- Reduction in the yield / saturated thickness of groundwater bores:
  - on the Mine Site or Proponent-owned land (high risk);
  - by <15% on non-project related properties (moderate risk); and
  - by >15% on non-project related properties (high risk).
- Impacts on groundwater-dependent ecosystems (high risk).

In addition, the Director-General's Requirements identify "soil and water" as a key issue for assessment and require the *Environmental Assessment* to pay particular attention to:

- any potential impacts on the Great Artesian Basin intake beds;
- the requirements of the *NSW Great Artesian Basin Groundwater Sources Water Sharing Plan* and the *Upper and Lower Namoi Groundwater Water Sharing Plan*;
- demonstrating how the Proponent would manage mine water, especially any mine water brought to the surface; and
- any potential subsidence-induced soil and stream erosion.

This section commences with a review of the existing regional and local hydrogeology, local availability and use of groundwater resources and current statutory framework for the management of groundwater. Potential sources of groundwater contamination are then identified and the operational safeguards, controls and mitigation measures described. The section concludes with an assessment of the residual impacts following the implementation of these safeguards, controls and mitigation measures.

4B.2.2 The Existing Environment

4B.2.2.1 Regional and Local Hydrogeology

4B.2.2.1.1 Regional Hydrogeology

Section 2.2.1 records the Mine Site is located within the Mullaley Sub-basin, which is part of the Gunnedah Basin. In the western part of the Mine Site, the Gunnedah Basin sequence is unconformably overlain by the Jurassic age Surat Basin sequence. The Jurassic and Triassic sequences are overlain in northern and western parts of the Mine Site by Quaternary sand and talus material. These alluvial channel and overbank deposits of gravels, sand, silt and clay are associated with the Namoi River and can reach a thickness of up to 120m.

Regional Aquifers and Groundwater Management Areas (GWMAs)

The Triassic, Jurassic and Quaternary sequences contain differentiated aquifers which have been defined by the former Department of Water and Energy (DWE) as groundwater management areas (GWMAs). These are described as follows, with reference to the relevant geological units within the Mine Site.

- The Intake Beds of the Great Artesian Basin (GAB) GWMA (601) which are defined by the easterly extent of the Surat Basin sequence. The Surat Basin is a large intra-cratonic basin covering approximately 270 000km^2 with the southern third of the basin occupying a large part of northern New South Wales. The Surat Basin sequence of the Mine Site includes the following formations.
    - The Pilliga Sandstone: which is a Jurassic age braided stream deposit consisting of very well sorted medium to very coarse grained, quartzose sandstone with very minor interbeds of mudstone and siltstone. This formation constitutes the major intake beds and aquifers for the Great Artesian Basin groundwater system and sub-crops across the western part of the Mining Area (see **Figure 4B.9**). Aquaterra (2009) concurs with GHD (2007) which reported that the Pilliga Sandstone is not saturated within the Mine Site. Aquaterra (2009) notes, however, that the Pilliga Formation becomes partly saturated to the west of (down-dip from) the Mine Site, as the formation dips below the regional water table level.
    - The Purlawaugh Formation: which consists of thinly bedded, lithic, fine to medium grained sandstone interbedded with siltstone and mudstone. Soils derived from the readily weatherable argillaceous sediments of this formation occur over the eastern half of the Mining Area (see **Figure 4B.9**). The sandstone of this formation is noted as having low porosity and permeability and are rarely considered as aquifers with bore yields generally less than 0.5 L/s.

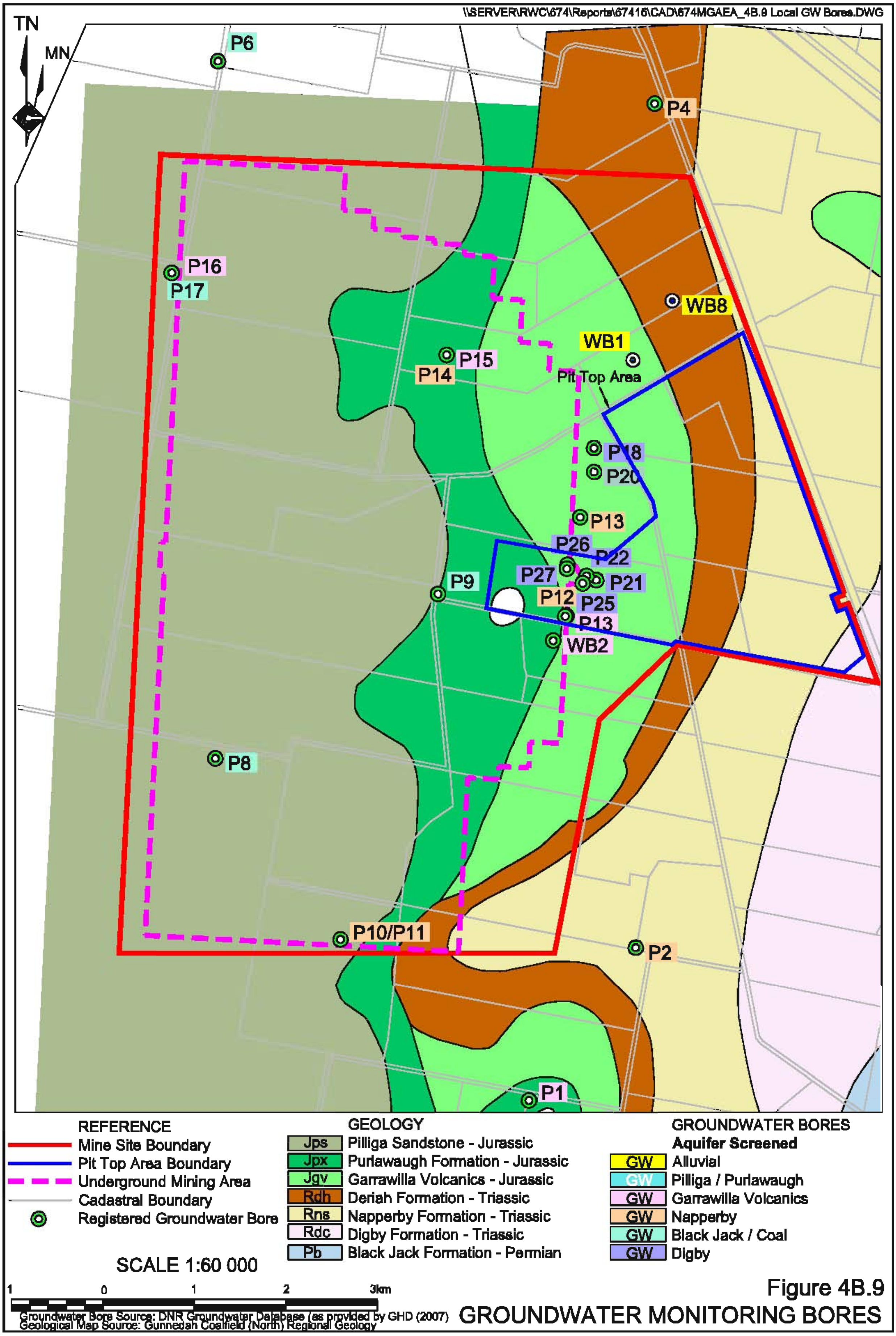


Figure 4B.9

GROUNDWATER MONITORING BORES

Groundwater Bore Source: DNR Groundwater Database (as provided by GHD (2007)
Geological Map Source: Gunnedah Coalfield (North) Regional Geology

  - The Garrawilla Volcanics: which consists of flows of basalt and trachyte and interbedded pyroclastics. Individual flows range in thickness from 1m to 8m and range from extremely vesicular to non-vesicular. The volcanics are found sub-cropping under alluvium generally to the east of the Mining Area (see **Figure 4B.9**) and represent the north-south trending boundary between the Surat Basin and Gunnedah Basin Sequence.

  Aquaterra (2009) reports that no groundwater flows have previously been recorded from these units within the Mine Site, however, during construction of the box cut for the Stage 1 Narrabri Coal Mine, groundwater inflows were observed emanating from the base of the weathered profile. The groundwater observed was restricted to small amounts of perched water accumulating between the more permeable weathered profile and relatively impermeable fresh rock below and while in this instance was restricted to the box cut area, could occur elsewhere across the Mine Site. Aquaterra (2009) notes that as the Mine Site is located above younger geological units that are topographically higher than the Namoi River floodplain, the groundwater of the intake beds of the GAB is not hydraulically connected with alluvial groundwater associated with the Namoi River.

- Gunnedah GWMA (604) which comprises the Permo-Triassic Gunnedah Basin sequence and is found in the eastern part of the Mine Site. The Gunnedah Basin sequence of the Mine Site includes the following formations.
  - The Mid Triassic Napperby Formation which is a thick sequence of siltstone/sandstone laminite overlain by sandstone. This formation sub-crops under alluvium/talus material in the eastern part of the Mine Site (see **Figure 4B.9**).
  - The Early Triassic Digby Formation which is a poorly sorted lithic conglomerate alluvial fan deposit and has not been mapped as sub-cropping on the Mine Site.
  - The Late Permian Black Jack Group which includes the Hoskissons Coal Seam with subordinate layers of fine grained sandstone, carbonaceous siltstone and claystone. These layers have been classified as follows.
    - Arkarula Formation – Quartzose sandstone and siltstone, typically the upper 10m of the Black Jack Formation throughout the Mine Site.
    - Brigalow Formation – Coarse sandstone and conglomerate interbedded within the coal seam and grades laterally into the Arkarula Formation, thickening to the west across the Mine Site from 2m to 10m.
    - Pamboola Formation – Lithic sandstone, siltstone, claystone and coals. Continuous over the Mine Site below the Arkarula Formation and Brigalow Formation with a thickness of between 55m to 75m.
  - The Late Permian Millie Group, Early Permian Bellata Group and Gunnedah Basin sequence basement lie beneath the Black Jack Group but would not be intersected by the proposed underground workings.

- Aquaterra notes that the Gunnedah Basin sequence contains local groundwater flow systems in fractured rock. Bore yields within the Gunnedah GWMA on and surrounding the Mine Site are generally low and similar to the Purlawaugh Formation.

- The Upper Namoi GWMA (004) which is contained in the unconsolidated sediments of the Namoi River and its tributaries. The Upper Namoi GWMA is divided into 11 zones of which Zone 5 is found to the east of the Mine Site. The alluvium associated with the Namoi River valley can exist to depths in excess of 100m, as is seen in the palaeochannels to the north of Narrabri. The aquifer is considered to be stressed due to large over-allocations of groundwater extraction.

Elsewhere, alluvial / colluvial sediments form surface cover over the sub-cropping geological units (see **Figure 4B.9**), with thicknesses that can extend up to 30m.

4B.2.2.1.2 Local Hydrogeology

Local hydrogeological conditions have been identified based on the following investigations.

Groundwater Modelling of the Saturated Aquifer System of the Upper and Lower Namoi Valley Alluvium

Identified as a narrow palaeochannel 3km to 10km in width, the Namoi Valley contains a sequence of non-marine alluvial deposits (up to 120m thick) of Tertiary and Quaternary age. A numerical groundwater flow model (using MODFLOW), periodically revised since 1982, has been developed to simulate the behaviour of this aquifer system and has been incorporated into the model developed for the Mine Site and surrounds.

Groundwater Investigations Undertaken by GHD (2007) for the Stage 1 Narrabri Coal Mine

Through a review of the available literature and mapping of the hydrogeological properties of the various formations below the Mine Site, and site investigations which involved the construction and permeability testing of eight groundwater bores, GHD (2007) reported that the groundwater at the Mine Site is typically associated with fractures encountered in the consolidated sedimentary rocks and volcanics. In consolidated sandstones and shales, groundwater can occur both in the pore space in the rock matrix and within fractures and joints, whereas in the volcanics groundwater is generally only associated with fractures and joints. In the absence of fracturing, the inter-bedded and laminated nature of the Napperby and Purlawaugh Formations is likely to restrict vertical groundwater flow in these formations.

Shallow groundwater intersections at depths of 15m to 30m below surface are associated with the weathered and fractured strata of the Garrawilla Volcanics. Between 35m and 75m below surface, groundwater intersections within a confined to semi-confined fractured rock aquifer occur within the Purlawaugh, Napperby and Garrawilla Volcanics formations. Deeper groundwater intersections, typically associated with the fractures in the Basalt Sill and Napperby Formation, are encountered from 74m to 144m below surface. The pump testing of piezometers within the Hoskissons Coal Seam, Arkarula Formation and Pamboola Formation encountered groundwater, however, low permeability values and slow recharge rates suggest the three formations are unlikely to provide significant groundwater intersections.

Groundwater Investigations Undertaken by Aquaterra (2009) for the Stage 2 Longwall Project

Additional monitoring bores have been installed within and surrounding the Mine Site since the completion of the Stage 1 groundwater assessment. These additional installations bring the total dedicated groundwater monitoring bores within the monitoring network to 26. **Figure 4B.9** presents the location of the groundwater monitoring bores, targeting the principal hydrogeological units of the Mining Area, on the Mine Site[2]. Monitoring of groundwater levels in 20 of the 26 piezometers (P1 to P20) and 12 existing registered bores (WB1 to WB12) indicates that groundwater levels in most bores have generally been very stable and are not influenced greatly by direct rainfall recharge.

Permeability testing undertaken by Aquaterra (2009) (by falling head slug tests) were conducted on the new monitoring bores (constructed since the Stage 1 testing) and a selection of Stage 1 monitoring bores. The test results for both the Stage 1 and Stage 2 Longwall Project tests are summarised in **Table 4B.7**.

Table 4B.7
Permeability Testing Results for Selected Monitoring Bores

Monitoring Bore ID[1]	Screen Interval (m bgl)	Hydraulic Conductivity(K) (m/day)			Target Formation
		Stage 1 Test Results[2]	Stage 2 Test Result[3]		
			Method		
P1	44 – 50	NT	Slug	0.11	Garrawilla Volcanics
P2	44 – 50	NT	Slug	0.057	Napperby Formation
P3	34 – 40	NT	Slug	0.03	Pamboola Formation
P4	24 – 30	NT	Slug	0.004	Napperby Formation
P5	24 – 30	NT	Slug	0.002	Pamboola Formation
P6	78 – 90	NT	Slug	0.029	Pilliga Sandstone
P7	78 – 90	NT	Slug	0.19	Pilliga Sandstone
P8	57 – 63	NT	Slug	0.017	Purlawaugh Formation
P9	24 – 30	0.41	NT	0.032	Purlawaugh Formation
P10	118 – 130	NT	Slug	0.049	Napperby Formation (no sill)
P11	44 – 50/ 24 – 40	0.0007	Slug	0.00055	Napperby Formation
P12	84 - 90	0.0016	Slug	0.09	Napperby Formation above sill
P13	24 - 30	0.068	Constant Rate -DD	0.44	Garrawilla Volcanics / Napperby Formation
			Constant Rate - Recovery	0.016	
			Slug	0.13	
P15	24 – 30	0.047	NT		Garrawilla Volcanics
P16	137 - 146	NT	Slug	0.003	Garrawilla Volcanics
P17	47 - 56	NT	Slug	0.0028	Purlawaugh Formation
P18	143 - 146	0.0086	Slug	0.013	Hoskissons Coal Seam
P19	184 - 187	0.0028	Slug	0.023	Pamboola Formation
P20	159 - 162	0.012	Slug	0.013	Arkarula Formation
GWB4S	57 – 63	0.0011	NT		Purlawaugh Formation
Claremont Bore	?	NT	Constant Rate - Recovery	2.0[4]	Garrawilla Volcanics

NT = No Test
Note 1: See **Figure 4B.9** Note 2: Recorded by GHD (2006) or RCA (2007) Note 3: Recorded by Aquaterra (2009)
Note 4: The calculated hydraulic conductivity was assessed to be approximately 2m/day based on a measure transmissivity of $75m^2$/d and an aquifer thickness of 37m. This result indicates a higher permeability for the volcanic unit than normally encountered and is probably related to localised fracturing.

Source: Modified after Aquaterra (2009) – Table 3.2

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[2] It is noted that several monitoring bores located to the west (P7), north (P5) and east (P3) of the Mine Site are beyond the coverage of **Figure 4B.9**.

On the basis of the hydraulic conductivity results presented in **Table 4B.7** the hydraulic conductivity within the geological units of the Mine Site has been summarised as follows.

- Several zones of elevated hydraulic conductivity occur within various formations (up to 0.44m/d in the Garrawilla Volcanics and the Pilliga Formation). Moderately high conductivity (0.09m/day) was also found in the Napperby Formation (above the basalt sill).
- Other units show a wide range of conductivities (0.0005m/d to 0.03m/d), with the higher conductivities generally in sub-crop areas. The mean conductivity of the Purlawaugh Formation and Basalt Sill is an order of magnitude lower (0.01m/d to 0.02m/d). All formations are assumed to be fractured and range from unconfined to semi-confined.
- The geological units underlying the Basalt Sill are characterised as being of low inherent permeability. The mean permeability of the Napperby Formation (below the sill) and the Digby Formation range from 1 x 10-4 m/d to 8 x 10-5 m/d.
- The mean permeabilities of the Black Jack Group, comprising the Hoskissons Coal Seam, Arkarula Formation/Brigalow Formation and the Pamboola Formation, ranged from 2 x 10^{-3} m/d to 3 x 10^{-2} m/d.

4B.2.2.1.3 Groundwater Systems and Flow Patterns

By reviewing the information gathered on local hydrogeology (see Section 4B.2.2.1.2), Aquaterra (2009) identifies two groundwater flow systems occur below the Mine Site, namely a shallow aquifer system and a deep aquifer system.

The shallow groundwater system occurs in the upper part of the Permo-Triassic sequence where it is weathered and locally fractured. This shallow aquifer effectively occurs within a range of geological units, due to the westerly dip on the strata. Groundwater in this aquifer is localised and influenced primarily by topography and local surface drainage, ie. flow is north to northeast towards the Namoi River. Recharge to the shallow aquifer system is believed to occur by infiltration of rainfall through the surficial alluvium and regolith (weathered material of the Surat Basin), with discharge occurring at the lower regional drainage lines.

The deeper aquifer system is influenced by regional features such as basin structure and regional recharge and discharge processes, and groundwater flow occurs primarily in fractures. Visual inspection of drill core suggests that the stratigraphic units are heterogeneous with aquifer properties varying depending on the nature and continuity of fractures and joints. The limited number of formation-specific monitoring points over the Mine Site makes it difficult to accurately map groundwater flow patterns. An analysis of temperature variations within the monitored bores indicates an increase in temperature at depths which correspond to the Hoskissons Coal Seam. This has been interpreted to correspond to increased groundwater flow within the coal seam.

4B.2.2.2 Surface Water – Groundwater Interaction

Groundwater Recharge

The main recharge mechanism for the groundwater within the Mine Site is local infiltration of rainfall with recharge rates a function of rainfall intensity, evaporation, vegetation coverage and density, topography and soil properties of the surficial aquifer material. Recharge occurs by direct infiltration of rainfall and local runoff into the unconsolidated surficial material, comprising alluvium/colluvium in low-lying areas, and the weathered zone of the bedrock (regolith layer) in more elevated areas. Water percolates downwards until reaching a zone of reduced permeability (top of fresh bedrock beneath the alluvium/colluvium, or the base of weathering), and then flows laterally above the less permeable aquitard layer.

The Permian and Triassic aquifers of the Mine Site are also recharged at the outcrop or sub-crop of the Surat Basin units (beneath the Quaternary alluvium or weathered ‘regolith’ layer). Where permeable areas of the Jurassic, Triassic and/or Permian formations sub-crop beneath alluvium, colluvium or highly weathered bedrock, recharge can also occur to these hard rock formations by downward percolation through the unconsolidated materials.

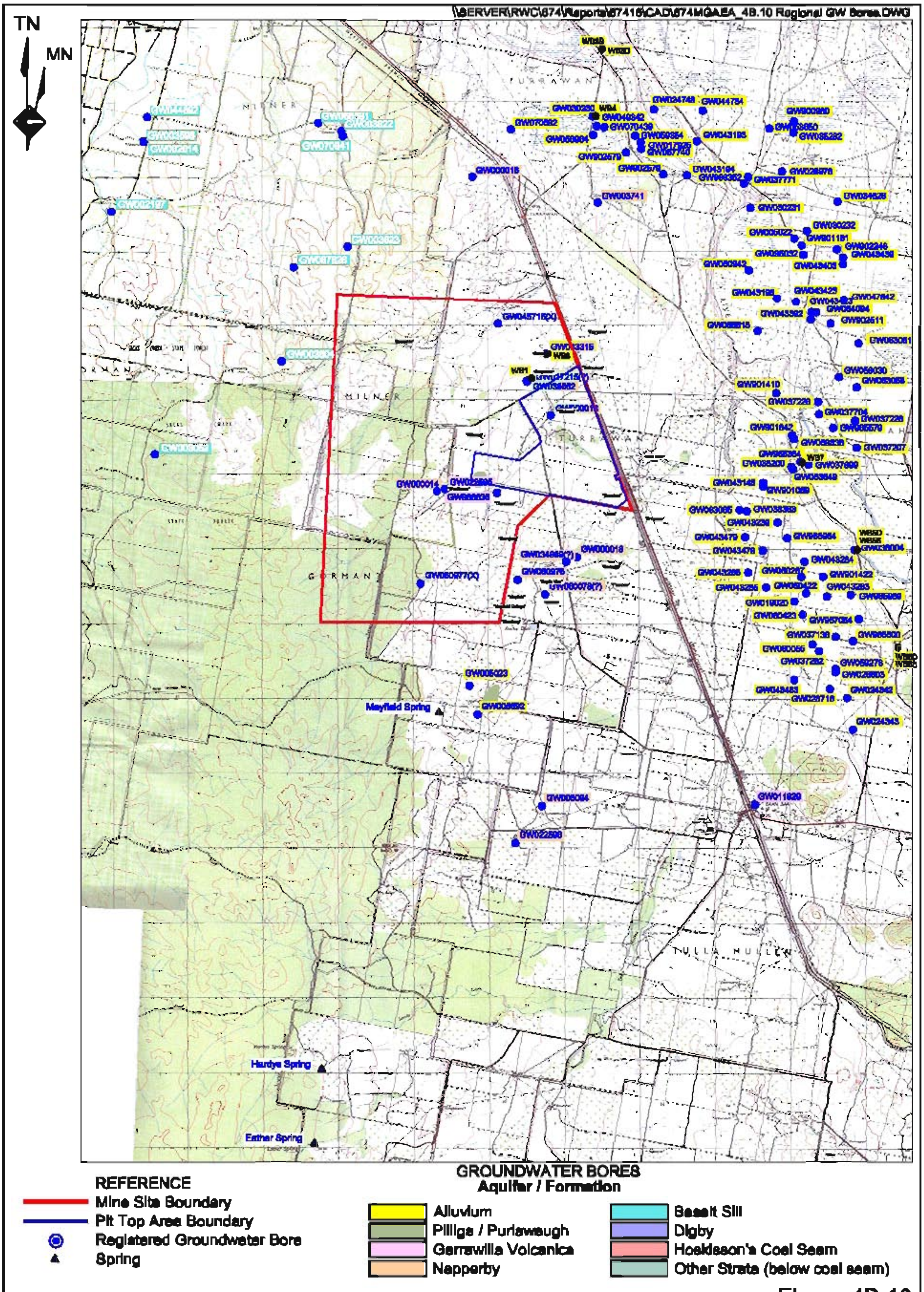
Natural groundwater discharge occurs through evapotranspiration, seepage and spring flow where the watertable intersects the ground surface, and through base flow contributions to creeks and rivers, including possible discharge to the alluvium in some locations. Local spring or seepage discharges may also occur wherever a permeable fractured zone within a hard rock unit crops out, such as on hillsides or the flanks of creeks and gullies, if the water level in that unit is higher than the ground surface.

Groundwater Discharge

With the possible exception of the area of the Mine Site around P13, where a perched groundwater aquifer was measured at 5m below surface (formed by the sub-crop zone of the Garrawilla Volcanics in a low lying area adjacent to a local drainage channel), Aquaterra (2009) reports that as groundwater generally occurs >15m below surface across the Mine Site, there is a very low likelihood for groundwater discharge to surface water systems.

To the south of the Mine Site, a spring discharging to surface (referred to as the “Mayfield Spring”) has been identified and is utilised for stock watering (**Figure 4B.10**). It is believed to be derived from the Purlawaugh Formation with a flow rate not exceeding 0.1L/s. The Department of Environment, Climate Change and Water – NSW Office of Water (NOW) has also recorded the occurrence of an additional two groundwater derived springs further south of the Mine Site. **Figure 4B.10** identifies the locations of these groundwater dependent ecosystems to the south of the Mine Site referred to locally as Hardys Spring and Eather Spring.

More regionally, Aquaterra (2009) report that there is probably some discharge from the Jurassic-Permian formations to the Namoi Valley alluvium to the east of the Mine Site.



SCALE 1:150 000

2.5 0 2.5 5.0 7.5 km

Groundwater Bore Source: DNR Groundwater Database (as provided by GHD (2007))

Figure 4B.10

REGIONAL REGISTERED GROUNDWATER BORES AND IDENTIFIED SPRINGS

4B.2.2.3 Groundwater Quality

Groundwater monitoring undertaken since the approval of the Stage 1 Narrabri Coal Mine has been analysed and compared to the groundwater quality analysis of GHD (2007) by Aquaterra (2009) to gain an understanding of the groundwater contained within the various geological units above the Hoskissons Coal Seam. Aquaterra (2009) reports that groundwater quality is variable, both in terms of key field parameters such as salinity and pH, and also in terms of major and minor hydrochemical constituents. The analytical testing of groundwater data collected from the geological units that would potentially be affected by the Longwall Project indicates the following.

- Groundwater pH is in the neutral to slightly alkaline range of 6.7 to 8.2.
- **Figure 4B.11** presents the distribution of salinity (as mg/L TDS) measured at various boreholes over the Mine Site. Groundwater salinity varies considerably, with recorded values of total dissolved solids (TDS) ranging from less than 100mg/L in the Garrawilla Volcanics and less than 500 mg/L within the Pilliga and Purlawaugh formations, to more than 16,000 mg/L in the Napperby Formation and the Basalt Sill.
- Limited sampling from the Hoskissons Coal Seam suggests that salinity within the coal seam would be around 2000mg/L (TDS), which is lower than overlying Triassic and Permian strata where salinities ranging from 6000mg/L to 8000mg/L TDS are typical. Aquaterra (2009) notes, however, that recent groundwater sampling and analysis from the SIS drilling program suggests that the TDS concentration within the Hoskissons Coal Seam may be up to 8000mg/L. Aquaterra (2009) suggests that the lower salinity determined from earlier monitoring may be limited to areas close to outcrop/subcrop.
- Laboratory analyses of groundwater samples indicate moderately elevated dissolved metals concentrations in groundwater. Notably, most sampled groundwater exceeded the ANZECC (2000) dissolved metal concentration guideline values for Cu, Pb, Ni and Zn. A number of groundwater samples (from bores P1, P2, P4, P5, P10 and P11) exceed the ANZECC (2000) guidelines for Mn as well.
- An analysis of major ions contained within the sampled groundwater identified that all groundwater was low in sulphate, but there is a broad distribution from bicarbonate to chloride dominance among the other anions. Chloride dominance occurs in the higher salinity waters from deeper intersections, particularly in the Pamboola Formation and the Napperby Formation. Bicarbonate dominance is normally associated with low salinity, and is typically an indicator of recent recharge or proximity to recharge in the flow system. An exception to this is found in the groundwater of the Hoskissons Coal Seam and Arkarula Formation where bicarbonate dominates despite relatively high salinity. In this case, the high bicarbonate is believed to be derived from some mineralisation source in the Permian sequence.

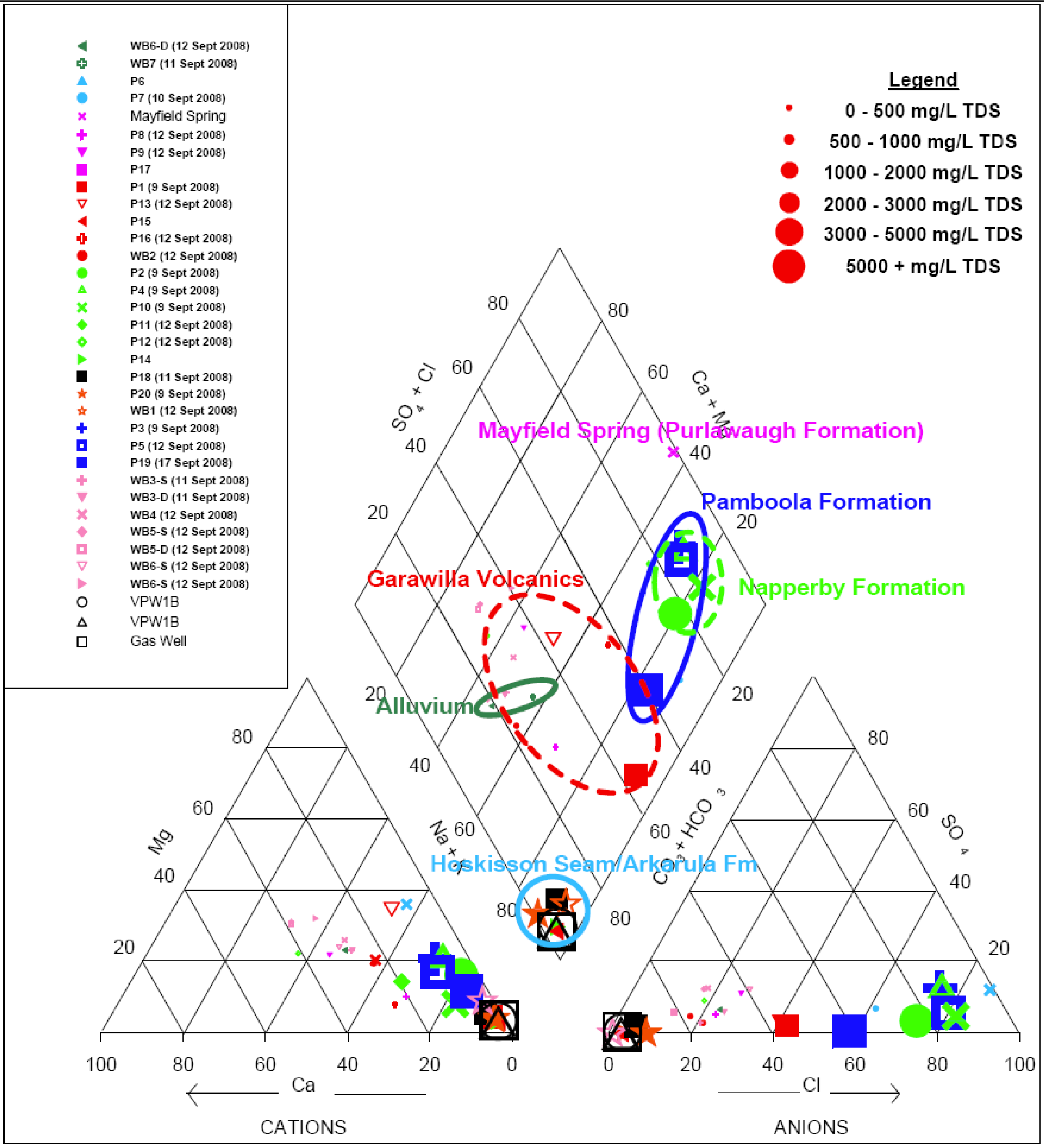


FIGURE 4B.11
GROUNDWATER QUALITY

Source: Aquaterra (2009) – Figure 4.9

4B.2.2.4 Water Use and Availability

Groundwater use within the boundaries of the Mine Site is restricted to a number of low yielding groundwater bores used for stock and domestic purposes. Surrounding the Mine Site, ie. within 5km of the Mine Site, groundwater is also used predominantly for domestic or agricultural purposes, with the extent of use invariably dependent on the quality of water and/or yield available from the bore. A summary of groundwater use, based on consideration of the former DWE groundwater bore database and general liaison between the Proponent and local landholders, is as follows.

- Numerous bores are registered in the Quaternary alluvium of the Namoi River Valley (Lower and Upper Namoi Alluvial Groundwater Source) (see **Figure 4B.10**). These bores are typically shallow bores screened within the Quaternary alluvium and the pumped water used for domestic, stock and irrigation purposes. Some of the deeper irrigation bores are up to 80m deep and have yields of up to 90L/s.
- To the south, north and west of the Mine Site, some groundwater bores screen the Pilliga Sandstone and possibly other deeper Jurassic sediments. The groundwater of these bores is generally non-saline with bore yields of between 0.1L/s and 0.8L/s. The standing water levels vary between 50m to 80m below surface level close to the Mine Site to typically between 30m to 40m depth further to the northeast. Other groundwater bores on or surrounding the Mine Site with better quality water screen the Garrawilla Volcanics.
- A limited number of groundwater bores within 5km of the Mine Site are identified as screening the deeper formations of the Gunnedah Basin Groundwater Source. This water is generally more saline than water drawn from the geological units of the intake beds of the GAB, with yields less than 2L/s.

As noted in Section 4B.2.2.2, GDEs to the south of the Mine Site, occurring as groundwater derived springs, draw water from the Purlawaugh Formation.

It is noted that Narrabri Shire Council sources the town water supplies for both Narrabri and Boggabri from groundwater bores within the Upper Namoi Alluvial Groundwater Source. Discussions held with Narrabri Shire Council personnel indicate that while in recent times recovery times within these bores has increased slightly, groundwater draw from these bores remains well below their licenced and operational capacity.

4B.2.2.5 Regulatory Framework

Water sharing plans (WSPs), ie. statutory instruments under the *Water Management Act 2000*, have been prepared for the Great Artesian Basin Groundwater Sources (with the Mine Site located within the Southern Recharge (non-artesian) zone of the GAB) and the Upper and Lower Namoi Groundwater Sources (the Mine Site is located within the Upper Namoi Groundwater Source). These WSPs are designed to provide long term environmental protection and achieve a level of sustainability of the groundwater resources as well as directing how water would be allocated and shared among the different water users and apply the goals and principles of the State Groundwater Policy at the regional and local level.

The NSW EPA 2003 State of the Environment Report identified groundwater use in the Great Artesian Basin (GAB) Groundwater Sources exceeded 100% of the sustainable yield. In the Upper Namoi GWMA, groundwater use is 70% to 100% of sustainable yield (DEC, 2003). As a consequence, the Upper Namoi and GAB Groundwater Sources have been identified by the former Department of Water and Energy as high risk aquifers (DLWC, 1998).

4B.2.3 Potential Impacts on Groundwater Quality and Availability

4B.2.3.1 Potential Sources of Groundwater Contamination

The potential sources of groundwater contamination include:

- fuel, oil or other hydrocarbon spills or leaks;
- recharge of saline water and/or concentrated brine to fresh water aquifers; and
- explosives residues.

Based on experience elsewhere, explosives residues would be unlikely to have any measurable effect on the chemistry of the groundwater. In any event, negligible quantities of explosives would be used throughout the life of the mine. Potential contamination by fuel, oil or other hydrocarbons, and/or localised increases in the salinity of currently non-saline aquifers, are therefore the main issue that needs to be managed across the Mine Site.

4B.2.3.2 Potential Impacts on Groundwater Availability

Longwall mining would create a pressure gradient between the aquifers surrounding the underground mine (high pressure) and void (low pressure) resulting in the movement of groundwater flow into the underground void. This groundwater would be pumped from the underground mine resulting in the continuance of these mine in-flows. As water is drawn from the aquifers of the underground mine (Hoskissons Coal Seam) and immediately above, the vertical movement of groundwater from aquifers higher in the geological sequence downwards (from higher to lower pressure) may be accelerated. Ultimately, this movement of groundwater into the underground mine or accelerated vertical movement of groundwater would lead to a lowering of the water levels within the intercepted aquifers, which may subsequently impact on the yield of the groundwater bores on landholdings surrounding the Mine Site (see **Figure 4B.10**).

Continuous sub-surface fracturing resultant from mine subsidence may increase vertical movement of groundwater from the strata higher in the geological sequence by creating higher permeability flow paths along the cracks. This may increase the lowering of groundwater levels within affected geological units, thereby increasing the impact on groundwater availability and yield. Flow between geological units higher in the sequence, not directly connected to the underground mine, may also occur as a result of discontinuous sub-surface fracturing. The impact of this discontinuous fracturing would be less influential on groundwater levels and yields as the pressure gradient between the units linked by cracking would not be as great as that created by continuous cracking into the underground mine. The results of subsidence modelling provided in Section 4B.1.6 have been used to assess the impact of mine subsidence on mine in-flows and movement of groundwater between geological units, and subsequently groundwater levels and availability.

The potential lowering of shallow and non-saline aquifers which recharge the GAB and Upper Namoi Groundwater Sources also has the potential to affect groundwater dependent ecosystems (GDEs) which may be dependent to varying degrees on this water supply.

4B.2.4 Management Measures and Mitigation Measures

4B.2.4.1 Groundwater Contamination

Although it is not anticipated that the Longwall Project would have a significant or long-term impact on the level or quality of groundwater beneath landholdings surrounding the Mine Site, specific controls and mitigation measures have been proposed by the Proponent for surface hydrocarbon and saline water management. These measures are described in relation to the overall surface water management system in Section 4B.3.4.2.5.

It is currently proposed to re-inject concentrated brine solution into the completed underground workings following the cessation of mining. Transfer of the brine from the Brine Storage Area to the injection points (goaf gas drainage holes likely to be located over the western-most longwall panels) would be managed to minimise the risk of pipeline leakage or break. A HDPE pipe would be placed within an excavated channel such that should a leak occur, the discharged brine would remain within the channel. The length of the pipe would be regularly inspected to ensure no breaks or leaks. At the time of installation, additional monitoring controls would be considered, eg. flow meters linked by telemetry. In the event of a large spill or leak, the spill control measures outlined in Section 4B.3.4.2.5 would be implemented.

Based on modelling of the injection process, the brine would be re-injected over a 2 year period. This would ensure that groundwater levels do not rise to elevations which would have allowed saline water to enter the Garrawilla Volcanics via the subsidence zone. With a 2 year re-injection period, Aquaterra (2009) established that water levels in the goaf area would not rise above the top of the Napperby Formation during the re-injection period.

Finally, the Proponent is committed to continuing its ongoing investigations into alternative uses for the brine (see Section 2.14.4). Feasible and cost effective alternatives to brine re-injection will continue to be considered throughout the life of the mine.

4B.2.4.2 Groundwater Availability

Given the bulk of the groundwater in-flows would originate from the Gunnedah Basin Groundwater Source geological units which are saline and, with the possible exception of fractured zones, low in permeability, the likely impact on groundwater levels, bore yields and groundwater availability generally is predicted not to be significant. As such, emphasis in the management of groundwater availability (and groundwater quality) would be placed on the implementation of a groundwater monitoring program, as recommended by Aquaterra (2009). Section 4B.2.6.1 presents further detail on the preparation of the groundwater monitoring program while Parts 6 and 16 of **Table 5.1** present the details of commitments made in relation to this groundwater monitoring program.

4B.2.5 Assessment of Impacts

4B.2.5.1 Impact Assessment Criteria

Water Quality

Table 4B.8 presents the National Environment Protection Measure (NEPM) groundwater quality criteria (NEPC, 1999). Groundwater quality would be assessed predominantly against the NEPM livestock guideline levels, given this is the predominant use of groundwater in the vicinity of the Mine Site.

Impacts on the water quality parameters of pH, TDS, other anions and heavy metals (not considered by the NEPM criteria) would be based on comparisons to baseline monitoring of groundwater quality taken from all groundwater bores within the Mine Site.

Groundwater Levels and Water Availability

Groundwater levels and the saturated thickness within bores on neighbouring landholdings would be monitored with any variations over 15% considered a significant impact given these levels would be expected to naturally vary by this much. The criteria for groundwater level and saturated thickness has therefore been determined to be a >15% decrease in water level or saturated thickness.

Table 4B.8
Groundwater Quality Criteria

Analyte	Agricultural Irrigation (mg/L)	Livestock (mg/L)
Arsenic (total)	0.1	0.5
Cadmium	0.01	0.01
Chromium (Total)	1.0	-
Chromium (VI)	0.1	1.0
Copper	0.2	0.5
Lead	0.2	0.1
Manganese	2.0	-
Mercury (total)	0.002	0.002
Nickel	0.02	1.0
Zinc	2.0	20.0
Calcium	-	1 000
- No published values		
Source: Modified after NEPC (1999)		

4B.2.5.2 Assessment Methodology

4B.2.5.2.1 Groundwater Model Construction

The extent of mine in-flows into the underground workings and the effect the Longwall Project would have on groundwater levels, borehole yields, groundwater level re-establishment and availability of groundwater from existing surrounding bores has been predicted using the United States Geological Survey (USGS) finite-difference groundwater flow modelling code MODFLOW 2000 (Harbaugh et al., 2000) in conjunction with the SURFACT module (SURFACT Version 3, HydroGeoLogic, 2006 – cited in Aquaterra, 2009).

The MODFLOW package is the industry-leading groundwater modelling software, and has advanced modules for simulating surface water and groundwater interaction which allows for the assessment of impacts on creeks and rivers. Aquaterra (2009) has identified that MODFLOW has two notable limitations when simulating longwall mining.

- MODFLOW does not allow aquifer properties to change with time as mining progresses. In order to overcome this potential limitation, the model simulation has been run in a series of consecutive time slice models, with model hydraulic parameters changed from one time slice to the next to reflect the mining advance and associated subsidence.

- Standard MODFLOW cannot routinely simulate free draining conditions in rock layers above a longwall panel. By using the SURFACT module, saturated and unsaturated flow conditions can be simulated allowing for more stable drying and re-wetting of cells in thin model layers (such as coal seams and thin aquitards).

Aquaterra (2009) reports that the modelling and hydrogeological assessment generally was undertaken in accordance within the '*Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region*' (DNR, 2005), and the modelling was undertaken in accordance with the best practice guideline on groundwater flow modelling (MDBC, 2001).

The extent of the model used for the Longwall Project extends that constructed by GHD (2007) to cover an area which includes the Boggabri Ridge extending west of the Mullaley Sub-basin and parts of the Gunnedah Basin, Upper Namoi and intake beds for the GAB Groundwater Sources. The model domain was also extended to capture the Namoi River alluvial aquifer system.

Similar to the GHD (2007) model, the Longwall Project groundwater model contains 11 active layers representing the major hydrogeological units of the Mine Site (see **Table 4B.9**) and differentiates between the Gunnedah Basin sequence (Gunnedah Basin GWMA), the Jurassic formations which comprise the Great Artesian Basin GWMA and Upper Namoi Alluvium GWMA.

A significant change made to the model of GHD (2007) was the direct physical disconnection of basal units, ie. Digby Formation and Blackjack Formation, from any direct connection with shallow alluvial sediments associated with the Namoi River. Aquaterra (2009) notes that this is in keeping with the geological model for the local stratigraphy, and in recognition that the Digby Formation and the Black Jack Formation have been partly truncated by the overlying Napperby Formation.

Table 4B.9
Conceptual Model Structure

Model Layer	Formation	Groundwater Source
1	Alluvium	Upper Namoi Alluvium
2	Pilliga Sandstone	Great Artesian Basin
3	Purlawaugh Formation	
4	Garrawilla Volcanics	
5	Napperby (above Sill)	Gunnedah Basin
6	Basalt Sill	
7	Napperby (below Sill)	
8	Digby Formation	
9	Hoskissons Coal Seam	
10	Arkarula Formation	
	Brigalow Formation	
11	Pamboola Formation	

Source: Modified after Aquaterra (2009) – Table 4.3

Values for the initial input parameters of the model were generated through a review of GHD (2007), historic literature and mapping available for the region and local area, as well as additional on-site testing conducted since the approval of the Stage 1 Narrabri Coal Mine. Aquaterra (2009) provides a detailed description of the on-site testing completed and historic literature reviewed.

The Aquaterra (2009) model was then calibrated, firstly in steady state mode to simulate long term average aquifer conditions and then in transient mode to improve the model calibration by means of a historic match to the observed groundwater levels during the period November 2007 to August 2008. The calibrated aquifer hydraulic parameters resulting from the steady and transient model calibration are summarised in **Table 4B.10**.

Table 4B.10
Calibrated Aquaterra (2009) Model Aquifer Parameters

Model Layer	Formation	Hydraulic Conductivity (m/day)		Storativity	
		Horizontal (Kh)	Vertical (Kv)	Unconfined Sy (-)	Confined S (-)
1	Alluvium	0.5-5.0	0.0005-0.005	0.1	5x10^{-6}
2	Pilliga Sandstone	0.001-0.5	0.000005-0.0005	0.1	
3	Purlawaugh Formation	0.001-0.3	0.000005-0.0003	0.1-0.2	5x10^{-6}
4	Garrawilla Volcanics	0.001-0.3	0.000002-0.0003	0.1	
5	Napperby Formation (above Sill)	0.001-0.05	0.000002-0.0001	0.1	5x10^{-6}
6	Basalt Sill	0.001-0.01	0.000002-0.00005	0.1	
7	Napperby Formation (below Sill)	0.001-0.01	0.000002-0.000008	0.1	5x10^{-6}
8	Digby Formation	0.001-0.01	0.000002-0.000005	0.1-0.15	
9	Hoskissons Coal	0.005-0.01	0.000002	0.1-0.15	5x10^{-6}
10	Arkarula Formation	0.001-0.01	0.000001	0.1	5x10^{-6}
11	Pamboola Formation	0.01	0.001	0.1	5x10^{-6}

Source: Modified after Aquaterra (2009) – Table 6.7

In general, overall simulated transient hydrograph results coincided very well with the actual hydrographs, confirming the model as a good predictive tool to simulate the complex multi-layer Narrabri aquifer system.

Further detail on the design and calibration and running of the model is provided in Aquaterra (2009) (*Sections 6.2 to 6.5*).

4B.2.5.2.2 Predictive Modelling (Base Case)

Using the calibrated set of boundary and hydraulic properties identified in Section 4B.2.5.2.1 (and **Table 4B.10**), the impact of the Longwall Project on the hydrogeological conditions of the Mine Site was simulated. Specific impacts of the longwall mining on the following parameters were then measured.

- Mine in-flow rates.
- Regional changes in groundwater levels, both during mining and after mine closure.
- Changes in base flow contributions to surface watercourses, particularly the Namoi River system.

- Impacts of re-injecting concentrated brine into the underground void at the completion of longwall mining. Potential impacts on groundwater quality and local groundwater table recovery were considered.

The "Base Case" simulation of potential mining impacts involved a simulation comprising 14 time slices, with the first time slice representing 3 years (from commencement of the Longwall Project) and then at 2 yearly intervals for the remaining life of the mine. The Base Case model also provides for hydrogeological conditions 100 years post-completion of the Longwall Project.

The hydraulic properties of the model cells within the region above the progressively collapsed goaf of the completed longwall panels was changed progressively to reflect progressive effects of subsidence fracturing. As the longwall mine progresses, it is expected that mine in-flows would increase (as the total void space created increases). However, to simulate the fact that once longwall mining commences in the southern longwall panels (LW14 to LW26), in-flowing groundwater could be retained in the down-dip (western) section of the underground mine (and would not need to be dewatered), the drain cells of the model associated with the down-dip section of the mine were turned off.

Post-mining recovery was simulated for a period of 100 years from the completion of mining. The recovery modelling simulated the re-injection of brine stored within the Brine Storage Area over a two year period into 20 large diameter goaf gas drainage bores screened within the goaf zone of the Hoskissons Coal Seam. Based on a water balance for the Mine Site prepared by WRM (2009) (see Section 4B.3.5), approximately 2 000ML of brine would be re-injected. In order to ensure that groundwater levels would not rise to elevations which could allow saline water to enter the Garrawilla Volcanics (via the subsidence zone), a 2 year re-injection period was used modelled. The results from the end of re-injection were used as the initial conditions for modelling the remaining 98 year recovery period.

Further detail on the simulation of the changing model conditions associated with the progressive gate road headings, longwall mining and goaf collapse is provided in Aquaterra (2009) (*Section 6.5*).

4B.2.5.2.3 Predictive Modelling (Sensitivity and Uncertainty Analysis)

Sensitivity Analysis

In order to assess the sensitivity of the model calibration to the assumed input parameters and boundary conditions, Aquaterra (2009) has undertaken a sensitivity analysis by sequentially changing key input parameters or boundary conditions, and evaluating the impacts of the changes on the calibration statistics. Any parameter change that resulted in a significant change to the scaled root mean square (SRMS) value of the model was identified as a sensitive parameter in the model.

Sensitivity analyses were undertaken on the horizontal conductivity, vertical conductivity and recharge parameters of the model to determine the impact on the SRMS value of the model. Aquaterra (2009) found the model was not highly sensitive to either horizontal or vertical hydraulic conductivity of the in-situ rock strata. However, it was assessed that the model would likely be sensitive to the hydraulic properties that were assumed for the subsidence fracture zone extending from the goaf.

Uncertainty Analysis

Uncertainty analysis is an assessment of the impact that uncertainty in the assumed values of the input hydraulic parameters has on model predictions and model reliability. While the sensitivity analyses conducted by Aquaterra (2009) suggests that the model is not sensitive to changes in hydraulic parameter values, in the absence of prior experience with longwall mining in the Gunnedah Basin, Aquaterra (2009) undertook the following uncertainty analyses.

1. Accounting for the possibility that continuous fracturing could extend higher into the Garrawilla Volcanics.
2. Assuming higher and lower vertical hydraulic conductivities for the portions of Layers 5 to 8 within the longwall footprint.
3. Assuming the changed hydraulic parameters (of uncertainty analyses 2) within the fracture zone may reduce over time (lag factor of 1 to 2 years) to model the settling and/or redistribution of fines within the affected strata.

Detail on the parameter values incorporated into each uncertainty analysis model run are provided by Aquaterra (2009 – see *Table 6.14*).

4B.2.5.3 Predicted Impacts on Mine In-flows

Figure 4B.12 presents the predicted groundwater in-flow to the underground workings, for the base case and three uncertainty analyses of Aquaterra (2009), over the life of the Longwall Project. It is predicted that groundwater would initially in-flow at a moderate rate of 0.21ML/day (78ML/year), steadily increase to a peak rate of 3.89ML/day (1419ML/year) in about Year 18 before declining as water is allowed to recover into the goaf areas of completed longwall panels in areas down dip of the active mining.

When considering the uncertainty analyses, the modelling of Aquaterra (2009) indicates the following.

- If connected fracturing extends up into the Garrawilla Volcanics, a slight increase in the peak inflow rate to 3.85ML/day (1 409ML/year) may occur.
- In the unlikely event that vertical permeabilities are increased by a significantly greater amount than anticipated in the subsidence zones above the longwall goafs, inflow rates peaking at up to 5.23ML/day (1 914ML/year) may occur.

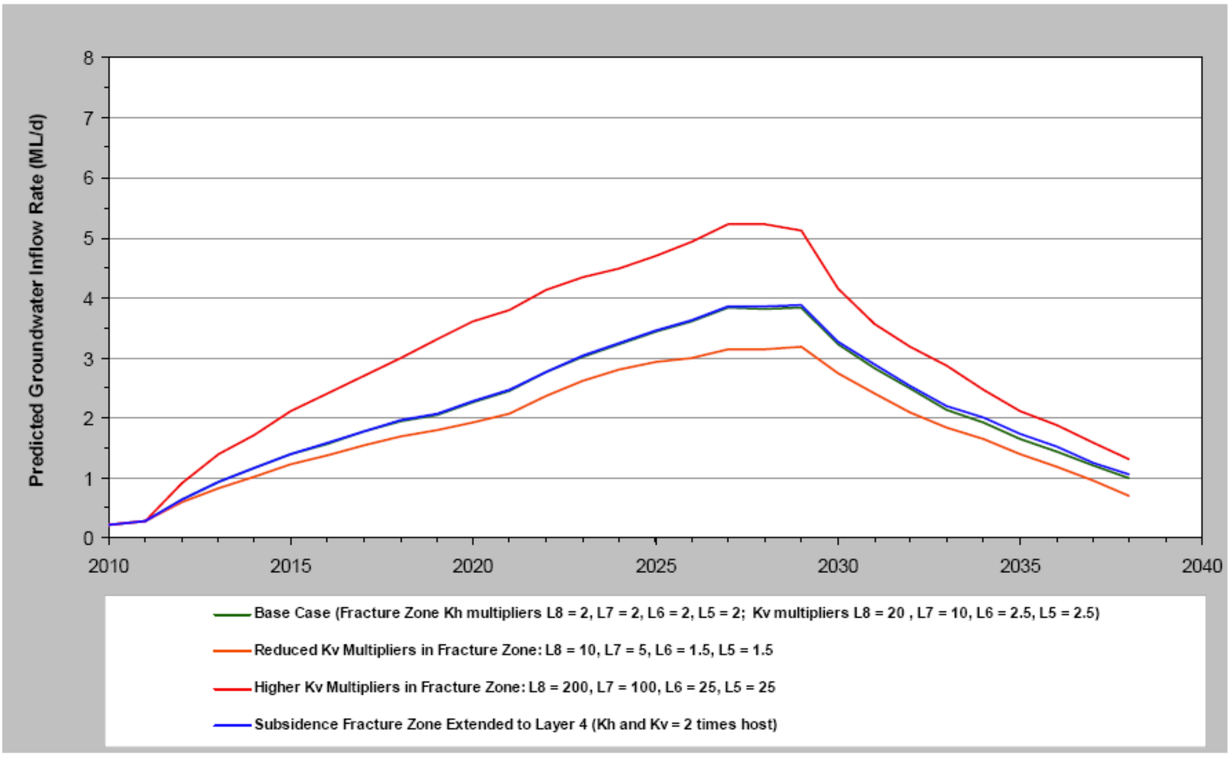


FIGURE 4B.12
PREDICTED MINE IN-FLOWS

Source: Modified after Aquaterra (2009) – Figure 6.27

Acknowledging the lack of prior experience of longwall mining in the Gunnedah Basin, the base case and uncertainty analyses 1 and 2 represent a conservative approach to parameter estimation, and therefore the prediction of possible in-flow rates. Elements of conservatism that have been built into the assessment of mine in-flows (and subsequently groundwater drawdown – see Section 4B.2.5.5) for the base case and uncertainty analyses 1 and 2 are as follows.

- The representative hydraulic properties assumed for each model layer may be too high. The values used have been influenced principally by the results of hydraulic testing, which is carried out preferentially on bores that intersected measurable groundwater inflows, ie. those bore holes which have no or very low in-flows are not included in the calculation of average hydraulic properties. Hence the dataset is skewed towards the more permeable locations, and ignores the numerous locations that are essentially impermeable.
- All model layers have been assumed to be regionally hydraulically continuous. It is likely that hydraulic barrier boundaries would be found to exist within the vicinity of the mine that would at least partly reduce the regional extent of drawdown and therefore groundwater in-flow. Aquaterra (2009) report that these hydraulic barriers are common in practice, but can only be identified under extended pumping or dewatering conditions. It is likely that some partial hydraulic barriers would be found to exist in the area of predicted impact that would lead to a reduction in actual in-flow rates.

- No allowance has been made for reduction in permeability or lateral flows of the subsidence affected strata over time. Aquaterra (2009) reports that some locations in the central Hunter Valley have shown signs of apparent "healing" or in-filling of subsidence fractures reasonably soon after subsidence occurs which leads to a reduction in ongoing drawdown and mine in-flow.

Based on the above, it is assessed that the predicted mine in-flows presented for the base case and uncertainty analyses 1 and 2 in **Figure 4B.12** (in particular that representing the higher vertical permeabilities in Layers 5, 6, 7 and 8 of uncertainty analysis 2 - see **Table 4B.10**), are likely to over-estimate actual mine in-flows. The third uncertainty analysis, which accounts for some reduction in vertical conductivity and lateral flows, provides for a reduction in the predicted mine in-flow rate, peaking at up to 3.17ML/day (1 157ML/year) may occur. This may be the more likely of the four scenarios modelled, however, in the interest of conservatism, the Proponent has provided for water management of groundwater up to and exceeding that predicted by uncertainty analysis 2.

The Proponent has committed to monitoring mine in-flows throughout the life of the Longwall Project, to obtain the necessary operational experience such that the groundwater model can be refined and recalibrated to allow for greater confidence to be placed on forward predictions of inflow rates (and other impacts).

4B.2.5.4 Predicted Impacts on Groundwater Levels

Figures 4B.13 to **4B.15** present the groundwater drawdown predicted by Aquaterra (2009) in the Alluvium (Layer 1), Garawilla Volcanics (Layer 4) and Hoskissons Coal Seam (Layer 9) after Year 15, the completion of mining (Year 29) and at the end of the recovery period (Year 129).

The most significant impacts on groundwater levels are predicted to occur within the Hoskissons Coal Seam (Layer 9). Groundwater in-flows would be induced laterally and from adjacent hydrogeological units, and subsidence fracturing above the goaf would allow increased drainage from the units above the longwall panels, extending up to the Napperby Formation, and possibly above into the Garrawilla Volcanics. Although the mine is not overlain by any significant aquifer, potential impacts on the aquifers that do exist are as follows:

- A cone of depression centred on the Mining Area is evident in the Hoskissons Coal Seam, with a less pronounced cone of depression in the units above. A review of **Figures 4B.13** to **4B.15** indicates the following.
  - Within the Hoskissons Coal Seam, drawdowns of 5m or more extend to 15km from the Mine Site at the end of mining. Drawdowns of 1m or more are predicted to extend to a maximum of approximately 20km from the Mine Site to the southwest and northwest and 10km from the mined areas to the south. Drawdown to the east is limited by the truncation of the Hoskissons Coal Seam in sub-crop.

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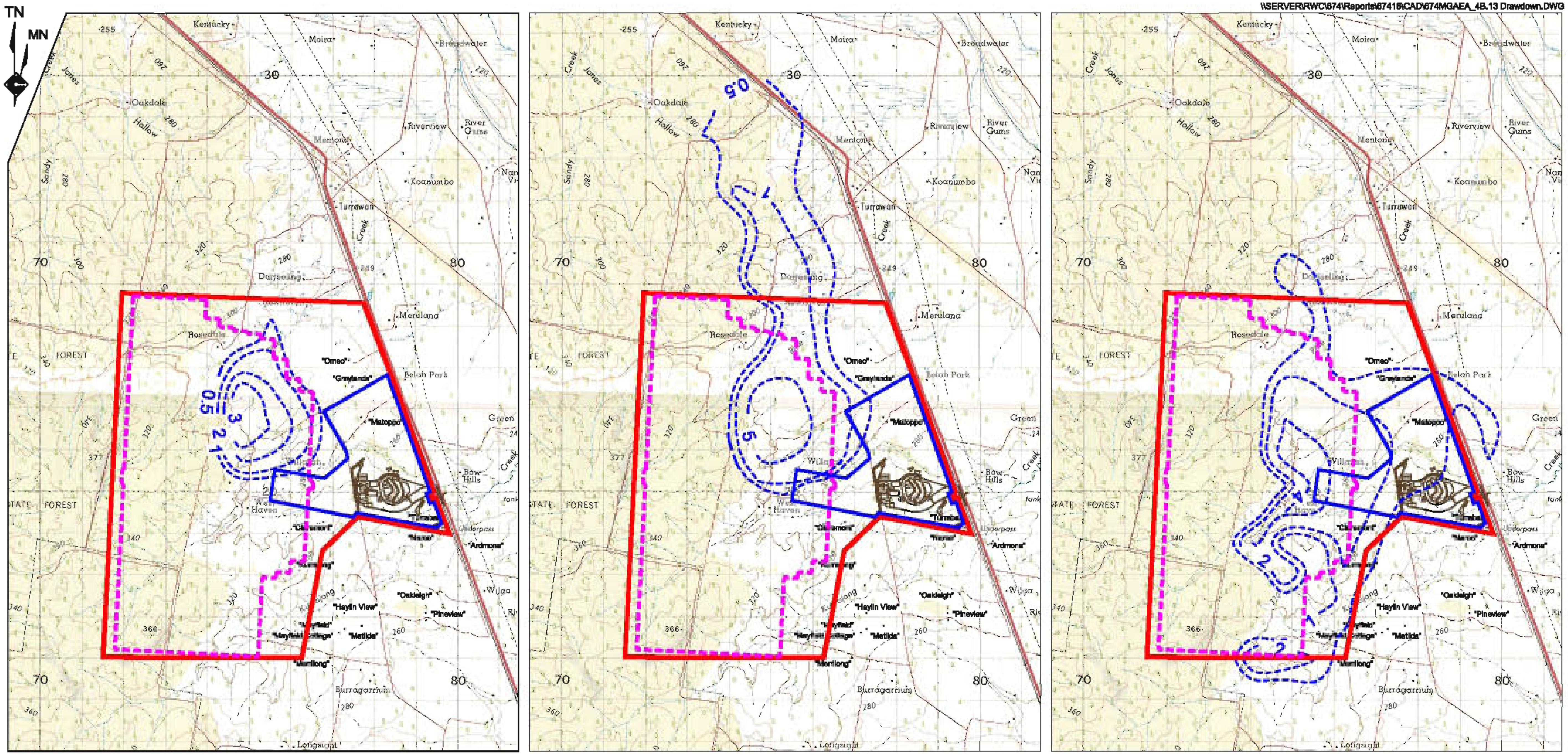

Year 15

Year 29

Year 130

REFERENCE

🟥	Mine Site Boundary
- - -	Indicative Limit of Underground Workings
—	Pit Top Area Boundary
- - 3 - -	Groundwater Drawdown Contour (m AHD)

SCALE 1:100 000

1 0 1 2 3 4 5 km

Source: Aquaterra (2009) - Figures 6.13, 6.14 & 6.21

Figure 4B.13

PREDICTED GROUNDWATER DRAWDOWN IN ALLUVIUM, COLLUVIUM AND REGOLITH

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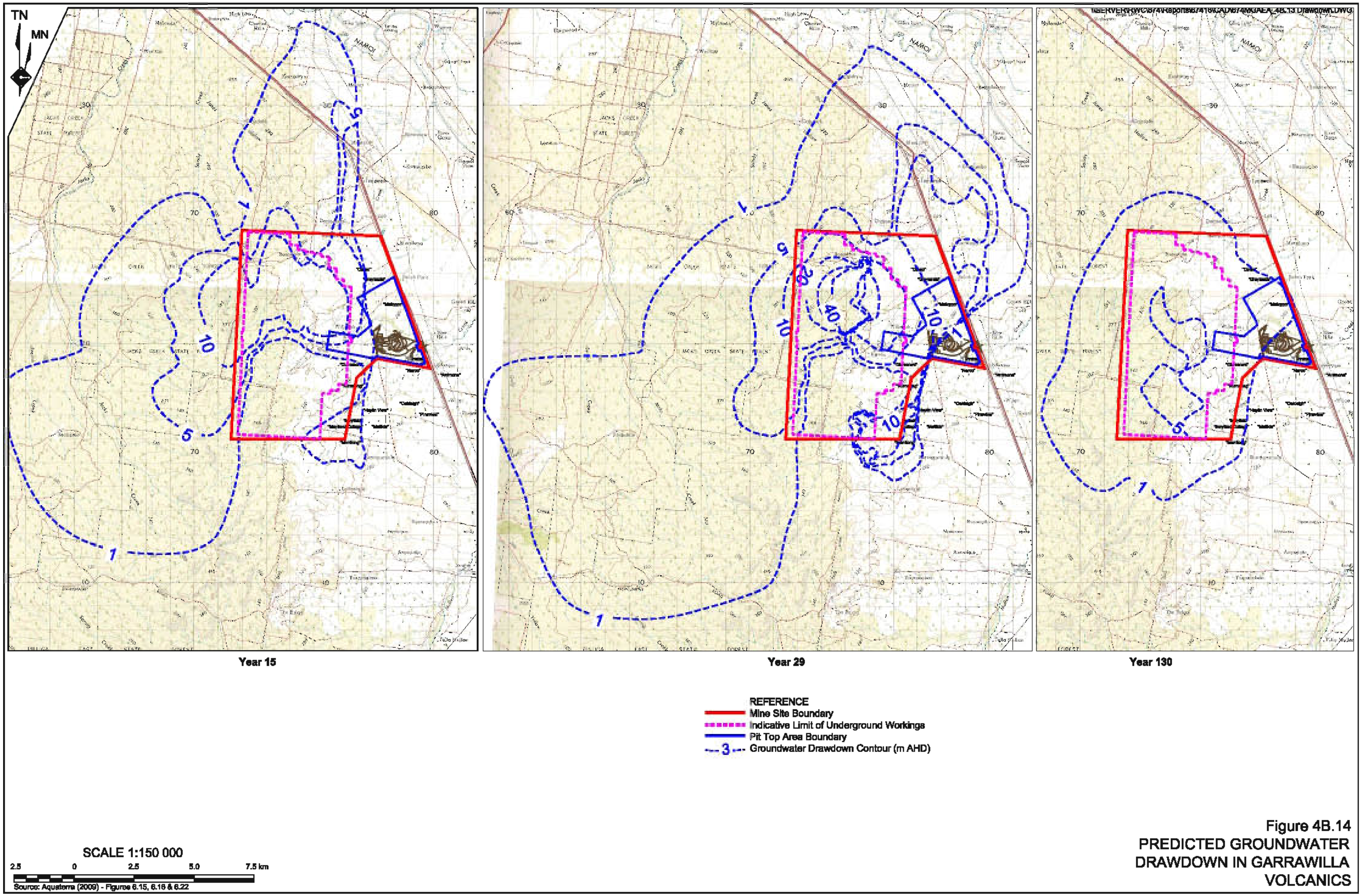


Year 15

Year 29

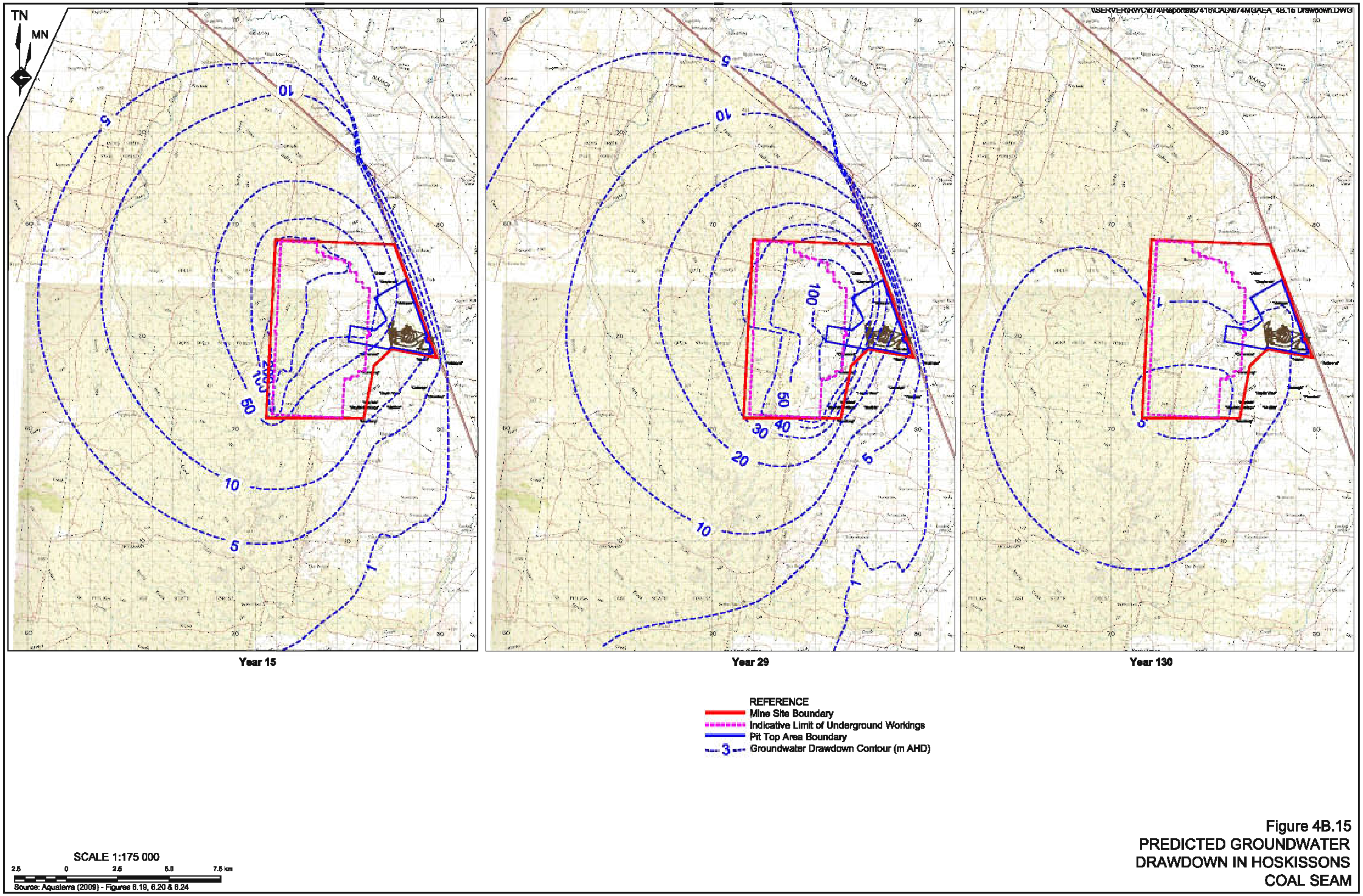
Year 130

REFERENCE
🟥 Mine Site Boundary
Indicative Limit of Underground Workings
Pit Top Area Boundary
--3-- Groundwater Drawdown Contour (m AHD)

SCALE 1:150 000
2.5 0 2.5 5.0 7.5 km

Source: Aquaterra (2009) - Figures 6.15, 6.16 & 6.22

Figure 4B.14
PREDICTED GROUNDWATER DRAWDOWN IN GARRAWILLA VOLCANICS



Source: Aquaterra (2009) - Figures 6.19, 6.20 & 6.24

Figure 4B.15
PREDICTED GROUNDWATER DRAWDOWN IN HOSKISSONS COAL SEAM

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  - Within the Garrawilla Volcanics, a drawdown of generally less than 5m is predicted adjacent to the mine at the end of mining. A 1m drawdown is predicted to extend between 5km and 8km to the west of the Mine Site.
  - Drawdown in the water table within the regolith (Layer 1) at the end of mining is predicted to be less than 1m outside the Mining Area and limited to areas close to the mine. Maximum drawdown is limited to around 5m, and these only occur in the immediate vicinity of the Mining Area.
  - Drawdown in the Namoi Valley alluvium (Layer 1) is predicted to be less than 0.1m.
- Aquaterra (2009) reports no drawdown in the Jurassic sediments of the Great Artesian Basin, ie. Purlawaugh Formation and Pilliga Sandstone.
- At the end of the 100 year recovery period, water levels in all the main hydrogeological units are predicted to have recovered to levels almost equivalent to those recorded at the start of mining.

The impact associated with the predicted drawdowns is further considered in the following sub-sections.

- Section 4B.2.5.6 considers the impact of the predicted drawdown on the three GWMAs which occur within the Mine Site.
- Section 4B.2.5.7 considers the impacts associated with the predicted drawdown on local groundwater availability and use.
- Section 4B.2.5.8 considers the impacts associated with the predicted drawdown on base flows to the Namoi River.
- Section 4B.2.5.9 considers the impacts associated with the predicted drawdown on groundwater dependent ecosystems.

4B.2.5.5 Predicted Impacts on Groundwater Quality

4B.2.5.5.1 Mine Dewatering

The average water quality of mine inflows would be a composite blend of the water qualities from all groundwater sources contributing to inflows. Aquaterra (2009) notes, however, that groundwater quality would initially be dominated by the groundwater from the Hoskissons Coal Seam and the underlying Arkarula Formation. Over time, as proportionally more groundwater flows from the higher units and from more distant parts of the area of predicted drawdown impact, the groundwater quality would change to reflect an increased contribution from those areas.

Aquaterra (2009) calculates the contribution from each unit by identifying the change in groundwater storage within each layer for each 1 year time step in the base case model, and multiplying this volume change by the average salinity for that layer, summing the totals and dividing by the total mine inflow volume for that time step to determine an average salinity value. This method gives equal weight to both close and distant changes in storage in the model, and hence may underestimate the proportional effect of salinity in the Hoskissons Coal Seam and the other Permian units close to the workings.

Aquaterra (2009) modelled the change in water quality within the underground void based on an initial groundwater salinity (TDS) of 6 000mg/L (which provides an average of all salinity measurements for the Hoskissons Coal Seam, ie. including one low salinity measurement of 2000mg/L) and 8 000mg/L (which weights the average in favour of the higher salinity measurements). Aquaterra (2009) suggests that the actual average salinity of inflows is likely to be between these two calculations.

Figure 4B.16 presents the results of this modelling which predicts that an initial average inflow salinity of between 6 500mg/L to 8 000mg/L, decreasing to around 4 500mg/L (Year 20) before steadily rising again to around 6000mg/L by the end of mining. Aquaterra (2009) notes that while some variation in the salinity of water flowing into the underground mine is expected each year due to periodic short-term inflows of higher or lower salinities, the salinity of day to day in-flows is not expected to vary dramatically.

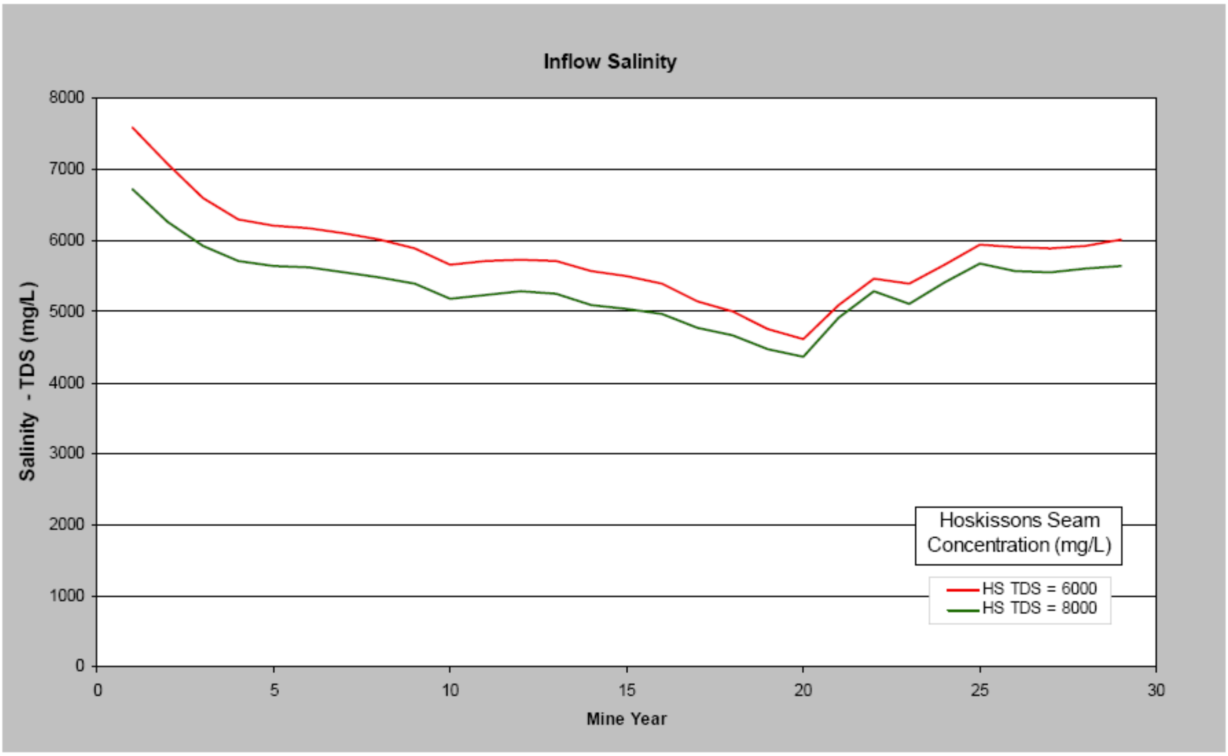


FIGURE 4B.16
PREDICTED CHANGES IN GROUNDWATER SALINITY

Source: Modified after Aquaterra (2009) – Figure 7.1

Further review of **Figure 4B.16** suggests that the groundwater quality of the Mining Area would be generally improved as lower salinity water is drawn from the units higher in the geological sequence into the void space of the underground mine.

4B.2.5.5.2 Brine Re-injection

Aquaterra (2009) undertook a particle tracking exercise on the recovery model to assess the potential for re-injected brine to migrate from the goaf to hydrogeological units of the Gunnedah Basin, Great Artesian Basin and/or Namoi Alluvium Ground Water Management Areas. The particle tracking considers that at the completion of mining and dewatering ceases, groundwater will start to flow back into the drawdown zone created by the 29 years of dewatering. Hence, groundwater will flow radially towards the mine area from the outer edges of the drawdown "cone". However, as the groundwater levels become elevated within the goaf area during the 2 year brine re-injection period, there will also be an inner region where groundwater will have the potential to initially flow outwards from the goaf area into the drawdown zone. The particle tracking concentrated on this inner region, looking at the distances travelled by particles, and also whether there is any upward migration to higher model layers. (Further detail on the particle tracking methodology and modelling is provided by Aquaterra (2009) – *Section 6.5.9*).

The results of the particle tracking indicate the following.

- Groundwater flow directions within the Jurassic strata will generally trend away from the Mining Area. The distance predicted to be travelled by particles in the simulated 100 year recovery period is limited to less than 1km from the Mining Area in all directions.
- Groundwater flow directions within the Permian – Triassic strata, initially trend away from the goaf area. The distance predicted to be travelled by particles in the simulated 100 year recovery period is limited to less than 2km from the Mining Area to the north and less than 1km elsewhere.
- In most cases, the particle tracking shows that particles stay within the layer from which they started. Where interchange between geological units does occur, the movement is downward to the underlying layer. No upward migration to a higher layer occurs.

On the basis of the above, it is predicted that the migration of brine would be restricted to less than 2km, and in most cases less than 1km from the Mining Area, in 100 years after cessation of mining. Importantly, there would be no upward migration to the higher quality aquifers of the formations of the Great Artesian Basin GWMA.

4B.2.5.6 Predicted Impacts on Groundwater Management Areas

Potential Impacts on the Upper Namoi Alluvium GWMA

As discussed in Section 4B.2.5.4, the Longwall Project would result in negligible drawdown in the Quaternary Alluvium due to the presence of a significant barrier of low permeability strata between the Namoi River alluvium and the proposed mine footprint. There would be no measurable impact in the volume of water held within the Upper Namoi Alluvium GWMA.

Section 4B.2.5.8 considers the impacts of the Longwall Project on base flows to the Namoi River.

Potential Impacts on Intake Beds of the Great Artesian Basin GWMA

The groundwater modelling of Aquaterra (2009) predicts minimal change (<0.03ML/day) in outflow to the GAB. Furthermore, the Pilliga Sandstone, recognised as a major intake bed to the GAB, is believed to be dry within the Mine Site and therefore, even in the highly unlikely event that continuous sub-surface cracking from longwall mining does extend beyond the floor of the underlying Purlawaugh Formation, which is recognised as a major regional aquitard, the intake beds would be insulated from groundwater depressurisation occurring within the underlying Permian coal measures.

On the basis of the above, the Longwall Project would have no measurable impact on the volume of water held within the intake beds of the Great Artesian Basin GWMA. In order to account for any theoretical loss in water availability within the geological units which make up the intake beds of the GAB (0.03ML/day), as a result of the minor drawdown predicted within the Jurassic sediments, and in accordance with the Water Sharing Plan which requires any removal of water to be licensed, the Proponent holds WAL AL811436 for 248MLpa within this GWMA.

Particle tracking has confirmed that saline water (brine) would not migrate from the goaf upward into the GAB formations following brine re-injection.

Potential Impacts on Intake Beds of the Gunnedah Basin GWMA

The groundwater modelling of Aquaterra (2009) predicts that impacts associated with the Longwall Project would be largely restricted to the hydrogeological units of the Gunnedah Basin GWMA. As illustrated by **Figure 4B.15**, the most significant impact on groundwater levels would be observed within the Hoskissons Coal Seam (measurable drawdown predicted up to 20km from the Mine Site at the completion of mining). Aquaterra (2009) also predicts that there would be measurable drawdown in the overlying hydrogeological units of the Gunnedah Basin (as changing hydraulic gradients draw water vertically and horizontally towards the void space of the underground workings). The drawdown in the Triassic units of the Gunnedah Basin GWMA are less pronounced than those within the coal seam and are typified by those predicted within the Napperby Formation. A measurable drawdown (of ≥1m) is predicted to extend to approximately 10km from the Mining Area, however, the level of drawdown quickly reduces from a maximum of 20m immediately adjacent to the Mining Area.

As a consequence of drawdown impacts being predominantly restricted to the hydrogeological units of the Gunnedah Basin GWMA, and the negligible impact of the predicted drawdowns on the volume of water held within the Upper Namoi Alluvium, and intake beds of the Great Artesian Basin GWMAs, it is concluded that the vast majority of mine in-flows would originate from the Gunnedah Basin GWMA. Therefore, the Longwall Project is predicted to reduce the volume of water held within the Gunnedah Basin GWMA each year.

To account for the predicted annual reduction in the volume of groundwater held within the Gunnedah Basin GWMA, the Proponent is currently finalising the acquisition of an Aquifer Interference Licence No. 90BL254679 under the *Water Act 1912* with an allocation of 818MLpa. Based on the groundwater modelling of Aquaterra (2009), this allocation would be sufficient for the predicted mine in-flows up to Year 11 of the Longwall Project (see **Figure 4B.12**). Prior to Year 11, the Proponent would have had opportunity to validate the measured actual mine in-flows and compare these to the predicted in-flow rates. In the event that the actual in-flow rate equals or exceeds that predicted, the Proponent would obtain additional allocation or an additional water access licence for the extraction of the groundwater as mine in-flow.

4B.2.5.7 Predicted Impacts on Water Use and Availability

Drawdown associated with the Longwall Project is predicted in the fractured rock aquifers above the mine up to the base of the Garrawilla Volcanics, with greatest impacts in geological units close to the Hoskissons Coal Seam, and less impact on higher units. Yields and available drawdown may therefore be affected at any existing groundwater bores close to the mine which are screened in the formations predicted to be affected by groundwater drawdowns.

A search of the database of registered groundwater bores revealed a number of registered bores within the predicted impact zone, however a field inspection undertaken by Aquaterra (2009) identified that many are either non-existent, abandoned or destroyed. As there would be no drawdown within the Namoi Alluvium, within which the majority of the bores of the region are screened, the potential for impact on groundwater users would be limited to the small number of bores screening the lower units of the geological sequence, eg. Napperby Formation, Digby Formation and Hoskissons Coal Seam.

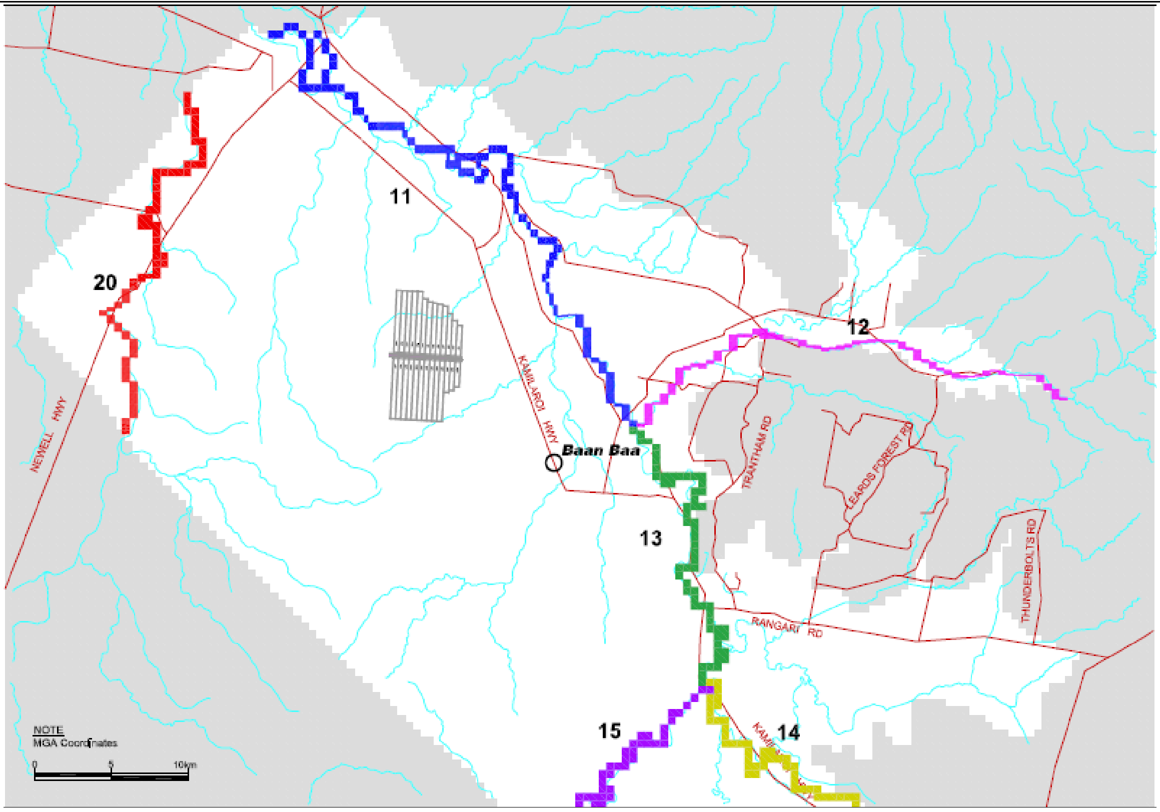
The potential for impact on the small number of bores screening the aquifers of these lower geological units has to a large degree been mitigated by the Proponent's acquisition of properties within the anticipated zone of impact. However, in the event that drawdown associated with the Longwall Project is determined to impact on the yield of a non-project related bore, the Proponent has committed to mitigating these impacts (or compensating the bore holder). Assessment of potential impacts would be undertaken on a case by case basis, with possible mitigating measures discussed with each affected bore holder.

4B.2.5.8 Predicted Impacts on Namoi River Base Flows

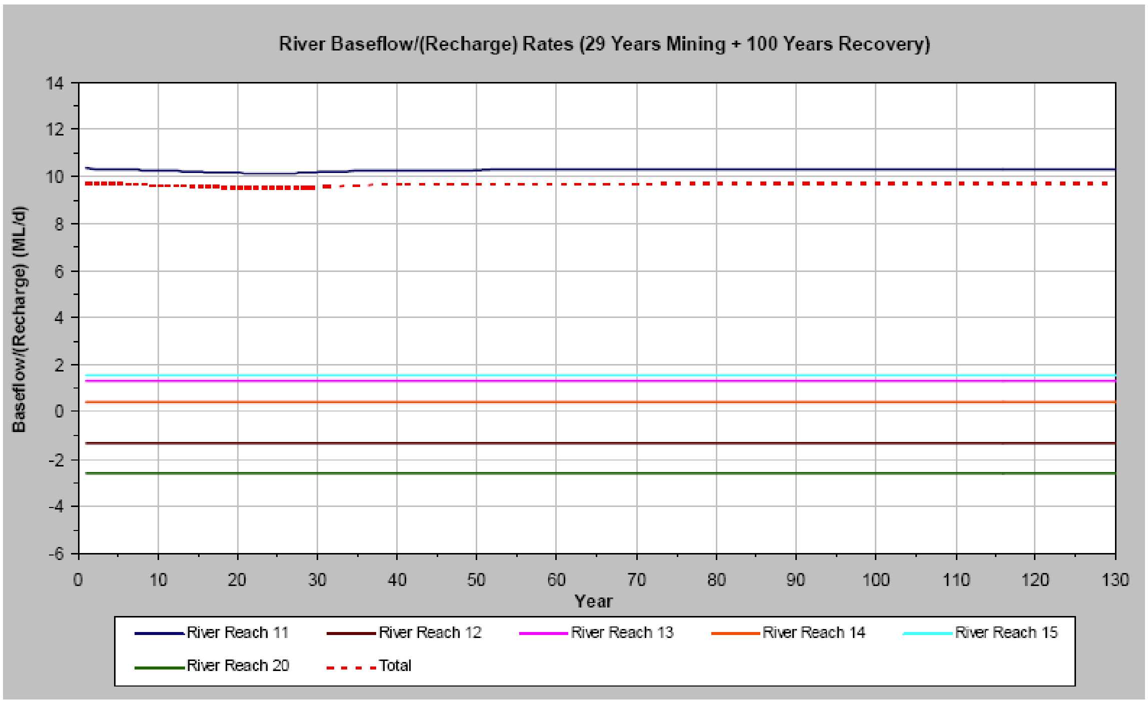
The impacts of the Longwall Project on the groundwater base flow discharges to Namoi River (Reaches 11, 13 and 14), Maules Creek (Reach 12) and Jacks Creek (Reach 20) have been assessed by Aquaterra (2009) for each of six river reaches designated on **Figure 4B.17**. Most of the river reach base flows remain stable during the mining period with a very minor reduction predicted in Reach 11 of the Namoi River (increasing to a maximum of 0.22ML/day at the completion of mining). The maximum predicted base flow impact during mining represents about a 2% reduction in the pre-mining base flow in Reach 11, but an insignificant percentage of total stream flow in the Namoi River (Aquaterra, 2009).

4B.2.5.9 Predicted Impacts on Groundwater Dependent Ecosystems

It is anticipated that the Purlawaugh Formation would insulate shallow groundwater from any mining-induced groundwater depressurisation of the underlying Permian coal measures. Therefore it is not anticipated that there would be significant impact to groundwater dependent ecosystems due to the Longwall Project.



Defined Reaches of the Namoi River



Modelled Impacts on Base Flows

FIGURE 4B.17
PREDICTED CHANGES TO NAMOI RIVER BASE FLOWS

Source: Modified after Aquaterra (2009) – Figures 6.7 & 6.25

It is acknowledged that shallow surface cracking may impact locally upon shallow groundwater such as the sporadic perched systems that exist at the base of the weathered zone, eg. "Mayfield Spring". It is likely, however, that these effects would not be permanent as the surface cracking would not be continuous to the underground workings. Any storage that is drained would be rapidly restored by recharge from rainfall, as the discontinuous fractures close up or become in-filled with fine sediment.

4B.2.5.10 Regulatory Compliance

An embargo currently exists on the issuing of new industrial bore licences within the intake beds of the Great Artesian Basin GWMA. In compliance with the Water Sharing Plan for this GWMA, the Proponent holds a Water Access Licence (WAL AL811436 for 248MLpa) for any incidental draw of groundwater. The licenced quantity of 248MLpa far exceeds the predicted incidental drawdown in the intake beds of the GAB.

An embargo also currently exists on the issuing of new industrial bore licences within the Upper Namoi Alluvium GWMA. However, the predictive modelling of Aquaterra (2009) has shown that there would be a negligible impact on the alluvium associated with the Namoi River and therefore the purchase of a Water Access Licence is not considered necessary.

Mining activities would be undertaken beneath the existing groundwater table in the Permian Coal Measures. An Aquifer Interference Licence has been obtained by the Proponent for 818MLpa for the incidental groundwater make of the underground mine which would be dewatered over the life of the Longwall project. The mine inflows are predicted to be below the 818MLpa level for at least 11 years. The Proponent would monitor flows and would purchase additional licences to cover the then predicted upper quantity of groundwater inflow.

4B.2.6 Groundwater Monitoring and Contingency Plans

4B.2.6.1 Groundwater Monitoring

The current baseline monitoring program of groundwater quality and standing water level would be continued, with a modified network of monitoring points finalised prior to commencement of mining.

An updated groundwater monitoring program would be prepared following the receipt of project approval. Monitoring to be included in this updated program would include.

- The volume of groundwater pumped to surface from all extraction bores, sumps within the underground workings and the box cut sump would be measured/recorded at least weekly.
- The volumes of water introduced to the mine for longwall mining operations would be measured/recorded at least weekly.
- Dewatered groundwater quality. The EC and pH of samples collected from each groundwater extraction point would be measured on a monthly basis.

- In-situ groundwater quality. More detailed chemical analyses would be undertaken of the groundwater of each extraction point measuring the following parameters:
  - Physical parameters: EC, TDS, TSS and pH;
  - Major cations: calcium, magnesium, sodium and potassium;
  - Major anions: carbonate, bicarbonate, sulphate and chloride;
  - Dissolved metals: aluminium, arsenic, boron, cobalt, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, selenium, zinc;
  - Nutrients: ammonia, nitrate, phosphorus, reactive phosphorus; and
  - Other: fluoride, cyanide.
- Quarterly manual monitoring, or continuous automated monitoring, of water levels from the network of monitoring bores.
- Quarterly monitoring of the spring discharges.

All monitoring results would be reviewed annually and summarised/evaluated in each Annual Environmental Management Report together with an assessment of the need to modify the parameters measured or monitoring frequency. It is fundamental that only meaningful data is collected.

In addition to the above, which is designed to assess general impacts of drawdown, the Proponent would implement a comprehensive monitoring program to investigate the subsidence impacts as they develop above longwall panels LW1 to LW3. Several multi-level vibrating wire piezometers are already in place, strategically placed within proposed chain pillars between LW1 and LW2 and just outside LW1, to enable ongoing monitoring. Additional multi-level vibrating wire piezometers and extensometers are proposed and monitoring of these would be conducted in conjunction with the subsidence monitoring recommended by DGS (2009).

4B.2.6.2 Contingency Plans

The Proponent is committed to addressing and mitigating impacts on groundwater as they occur. The following contingency plans, which build on those already in place for the Stage 1 Narrabri Coal Mine, would be implemented.

Water Levels

In the event that groundwater level drawdown in any bore in the alluvium, regolith or the Garrawilla Volcanics exceed predicted drawdown by 15% or more for any consecutive three month period, the monitoring data would immediately be referred to an approved hydrogeologist for review. The reviewer would then assess the data to establish the nature of the exceedance and the reasons for it, and recommend an appropriate response action plan for implementation in consultation with the relevant government agency.

In the event that an existing water supply is deemed by the hydrogeologist to be adversely affected drawdown generated by the Longwall Project, the Proponent would mitigate, or compensate for this impact through the provision of a replacement water supply.

The exact nature of impact mitigation or compensation would be developed on a case by case basis and would be referred to the relevant government agency in the event that mitigation or compensatory measures are unable to be negotiated.

Groundwater Quality

Should the water quality of the mine inflows or dewatering discharge indicate an inflow salinity of more than 20% above that predicted by the Aquaterra (2009) modelling (see **Figure 4B.16**), all relevant monitoring data would be provided to an approved experienced hydrogeologist for review and assessment of the impact on other users or the environment. If remedial action is recommended by the reviewer on the basis of the water quality, the recommended action would be implemented in consultation with the relevant government agency(ies) as appropriate.

4B.3 SURFACE WATER

The surface water assessment was undertaken by WRM Water & Environment Pty Ltd. The full surface water assessment is presented as Part 3 of the Specialist Consultant Studies Compendium, with the relevant information from the assessment summarised in the following subsections. The assessment is referred to as WRM (2009) throughout this document. A peer review of the water balance modelling component was undertaken by Mr Lindsay Gilbert, Director of Gilbert and Associates Pty Ltd. A copy of Mr Gilbert's review is included behind the surface water assessment in this compendium.

4B.3.1 Introduction

Based on the risk analysis undertaken for the project (see Section 3.3 and **Table 3.5**), the potential surface water impacts requiring assessment and their unmitigated risk rating are as follows.

- Discharge of sediment-laden or turbid water from the Mine Site (high risk).
- Temporary degradation of downstream water quality through discharge/spill of saline or contaminated water (high risk).
- Long term contamination of downstream water quality through major or repeated discharge/spill of saline or contaminated water (extreme risk).
- Altered flooding patterns and indirect impacts on native vegetation communities and ecosystems (moderate risk).
- Erosion of natural drainage lines (moderate risk).
- Erosion of rehabilitated final landform (moderate risk).
- Reduced flows to downstream agricultural land (low risk) and native vegetation (low risk).

In addition, the Director-General's Requirements issued by the DoP require that the assessment of surface water demonstrate "*how the company would manage mine water, especially any mine water brought to the surface*" and refer to the following policies, guidelines and plans:

- *Australian Guidelines for Fresh and Marine Water Quality (ANZECC/ ARMCANZ);*
- *Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ ARMCANZ);*
- *Namoi Catchment Action Plan (DPI);*
- *Managing Urban Stormwater: Soils & Construction (Landcom);*
- *Technical Guidelines: Bunding and Spill Management (DECC); and*
- *Environmental Guidelines: Use of Effluent by Irrigation (DECC).*

The following sub-sections describe and assess the existing drainage and surface water environment, identify the surface water management issues, proposed surface water controls, safeguards and mitigation measures and an assessment of the residual impacts following the implementation of these safeguards and mitigation measures.

4B.3.2 The Existing Environment

4B.3.2.1 Regional Drainage

The Mine Site is located in the Namoi River catchment and within the catchments of its tributaries, namely Kurrajong Creek, Pine Creek and Tulla Mullen Creek. The Namoi River flows in a northwesterly direction approximately 3km to 5km to the east of the eastern boundary of the Mine Site.

The Namoi River catchment has been used extensively for agricultural activities for over 100 years and is one of Australia's most developed irrigation areas, supporting significant cotton and broadacre cropping (mainly sorghum, sunflower and wheat) as well as other crops, and some sheep and cattle grazing. There are a number of major storages in the Namoi River catchment, namely the Keepit, Chaffey and Split Rock Dams located on the Namoi, Peel and Manilla Rivers, to provide water for the licensed water users in the region (**Figure 4B.18**).

The Mine Site is located within the catchments of Kurrajong and Pine Creeks. Pine Creek and its tributaries traverse the northern part of the Mine Site, before entering the Namoi River, while Kurrajong Creek and its tributaries originate in the southwestern corner of the Mine Site and traverse the southern part of the Mine Site, draining to Tulla Mullen Creek, which in turn drains into the Namoi River. The total catchments areas of Pine and Kurrajong Creeks are 76km^2 and 62km^2 respectively. The local catchment boundaries and drainage paths draining the Mine Site are shown in **Figure 4B.19**.

Pine and Kurrajong Creeks are ephemeral, generally flowing for short periods after significant rainfall events or protracted wet periods. Base flows in these creeks are insignificant. Sections of the local creeks are quite 'active' and are susceptible to high levels of erosion. The drainage paths of the smaller tributaries are poorly defined along some reaches through the Mine Site. Further detail on the structure and hydrological properties of these streams is provided by WRM (2009) – Section 2.2.

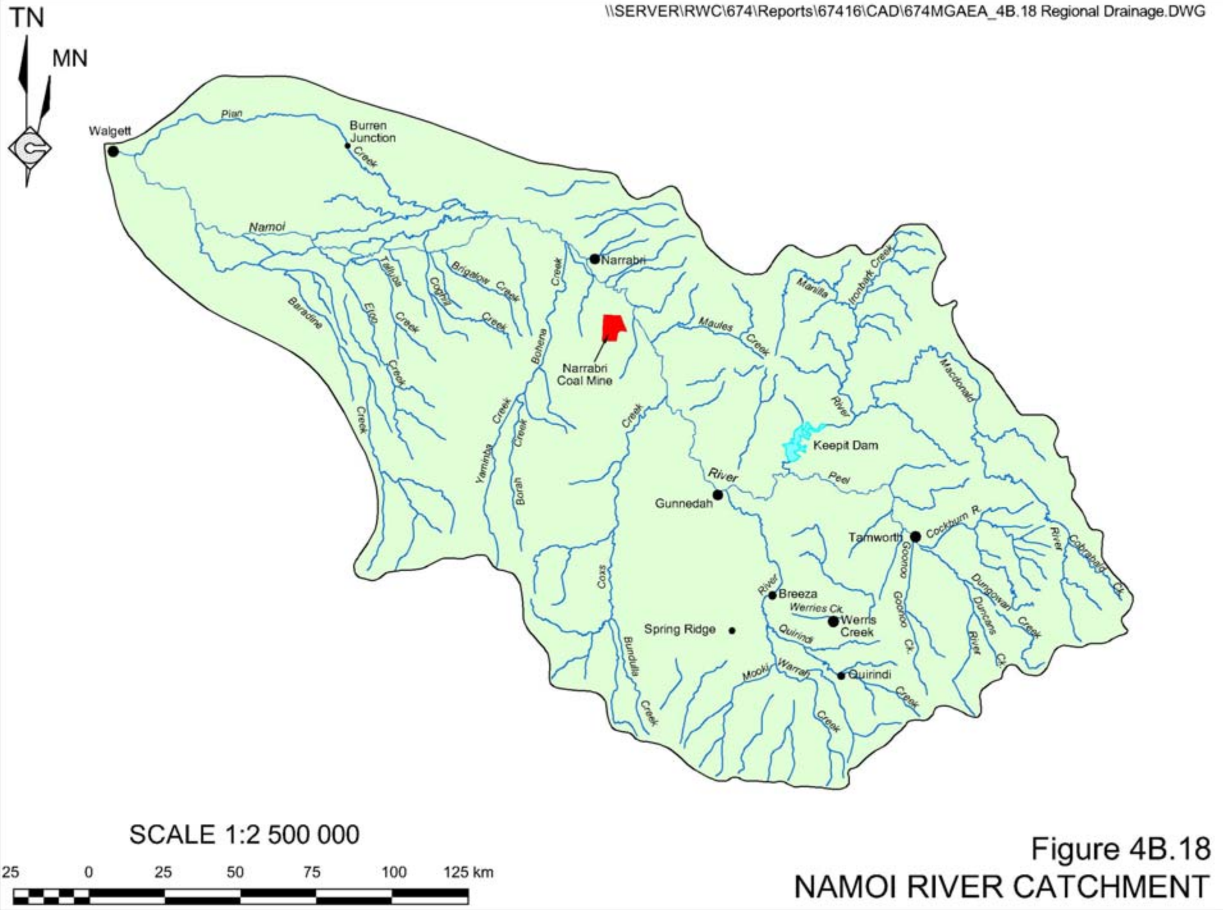


Figure 4B.18
NAMOI RIVER CATCHMENT

4B.3.2.2 Mine Site Drainage

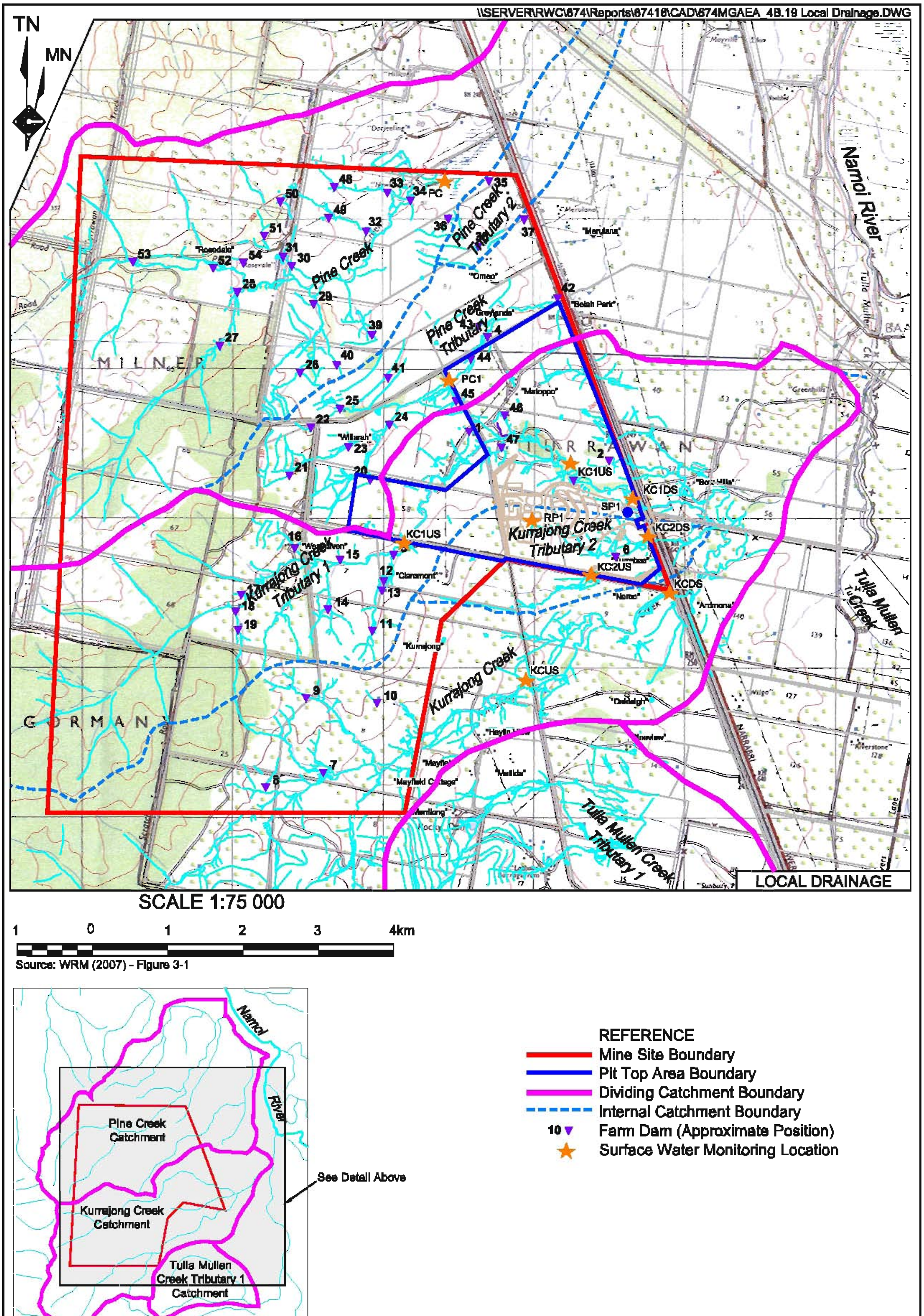
Figure 4B.19 depicts the Mine Site, the location of the Pit Top Area and the local catchment boundaries whilst **Figure 4B.20** presents greater detail of the Pit Top Area and the local drainage paths and catchments within that area.

Table 4B.11 lists the proportions of the Mine Site and Pit Top Area that currently drain to each of the local sub-catchments. **Table 4B.12** lists the existing cleared and forested areas within the Project Site in each of the local sub-catchments.

Table 4B.11
Mine Site and Pit Top Areas Draining to Local Sub-Catchments

Sub-Catchment	Mine Site Area Within Catchment	
	Area (ha)	Area (%)
Pine Creek	1743	33.5
Pine Creek Trib 1	761	14.6
Pine Creek Trib 2	80	1.5
Kurrajong Creek	830	15.9
Kurrajong Creek Trib 1	1562	30.0
Kurrajong Creek Trib 2	234	4.5
Total	5210	100

Source: Modified after WRM (2009) – Table 2.1



Source: WRM (2007) - Figure 3-1

Figure 4B.19
LOCAL DRAINAGE

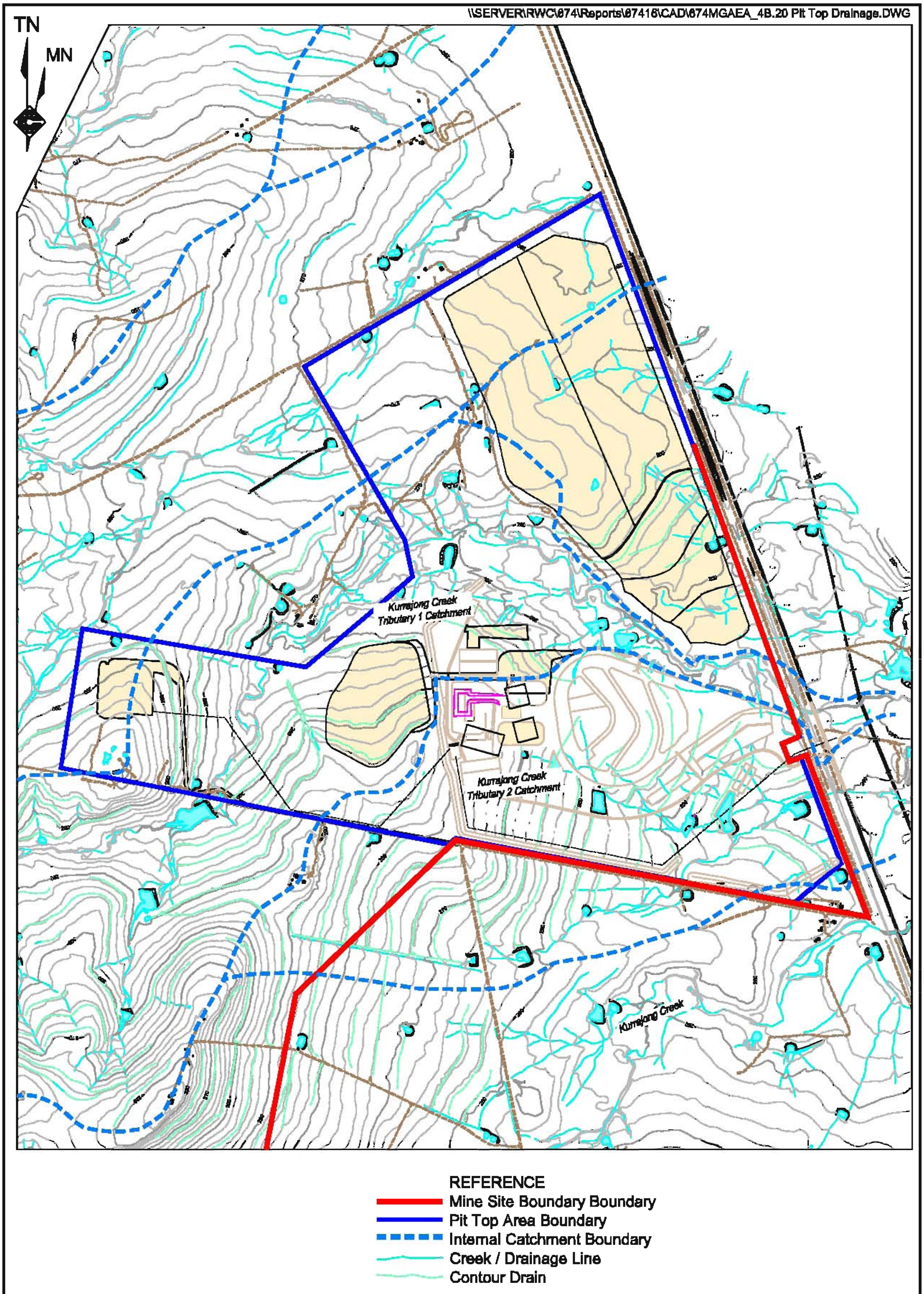


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Figure 4B.20
PIT TOP AREA DRAINAGE

Table 4B.12
Cleared and Forested Areas within the Project Site in Each Local Sub-Catchment

Sub-Catchment	Cleared Area		Forested Area	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Pine Creek	655	12.6	1088	20.9
Pine Creek Trib 1	708	13.6	53	1
Pine Creek Trib 2	80	1.5	-	-
Kurrajong Creek	592	11.4	238	4.6
Kurrajong Creek Trib 1	846	16.2	716	13.7
Kurrajong Creek Trib 2	234	4.5	-	-
Total	3115	59.8	2095	40.2

Source: WRM (2009) – Table 2.2

4B.3.2.3 Existing Local Water Storages

There are 54 farm dams within the Mine Site, the locations of which are shown on **Figure 4B.19**. 34 of these dams, with a total capacity of 60.7ML, are located within Pine Creek catchments and the remaining 20, with a total capacity of 60.5ML, within Kurrajong Creek catchments. A total of 35 farm dams, with a combined capacity of 88.7ML, are located within the Proponent’s landholdings. The individual storage capacities of these dams vary from approximately 0.5ML to 22.5ML.

4B.3.2.4 Existing Local Water Use

Existing (pre-mining) surface water use on the Mine Site and in the local area is primarily stock watering. There is no large scale irrigation infrastructure on the Mine Site to suggest that crops on the Mine Site were ever irrigated from the existing dams. There are two small dams on Pine Creek downstream of the Mine Site from which water is used for stock watering. There are also no farm dams on Kurrajong Creek and its tributaries or Pine Creek Tributary 1 downstream of the Mine Site.

The major towns of the Narrabri Shire all draw town water supply from groundwater bores within the Upper Namoi Alluvial Groundwater Source, ie. there is no reliance on surface water flows within the Namoi River Catchment. The small village of Baan Baa has no town water supply with rainwater and water captured within a dam to the south of the village the only source of water to residents of the town. Notably, the catchment for this dam would not be affected by activities on the Mine Site, nor dependent on runoff from the Mine Site catchments.

4B.3.2.5 Surface Water Quality

Regional Water Quality Data

Water quality data is available for the Namoi River at the Turrawan gauging station (Station No. 419023), located between the Kurrajong Creek and Pine Creek confluences with the Namoi River (see **Figure 4B.19**), for the period 1976 to 1986. **Table 4B.13** presents a summary of available water quality data for the Namoi River at Turrawan gauging station.

Table 4B.13
Water Quality Data, Namoi River at Turrawan

Parameter	**Years of Data**	**Mean**	**Median**	**Min**	**Max**	**10th %ile**	**80th %ile**	**ANZECC (2000) Trigger Value**	
								Upland	**Lowland**
Electrical Conductivity (µS/cm)	10	545	538	275	1 720	330	716	30 - 350	125 – 2 200
pH	10	8.0	8.0	7.4	8.8	7.6	8.4	6.5 – 8.0	6.5 – 8.0
Temperature (°C)	10	19.6	20.5	10	30	11.0	26.5	NA	NA
Turbidity (NTU)	9	15.6	5.4	2	130	2.0	40.4	NA	NA

Source: Modified after WRM (2009) – Tables 3.3 and 3.5

Over the 10 year monitoring period, the ANZECC (2000) default trigger values were exceeded 87% of the time for electrical conductivity (EC), 50% of the time for pH and 17% of the time for turbidity. Similar results in relation to the ANZECC (2000) default trigger values were recorded following monitoring undertaken at 22 sites throughout the Namoi River catchment during 2000 and 2001 (DLWC, 2002b) (WRM, 2009).

Continuous water quality data, measuring electrical conductivity, was collected between 1995 and 2005 at the Gunnedah Station (63km upstream of the Mine Site). WRM (2009) reviewed this data and identified the following relationship between river flow and electrical conductivity.

- Electrical conductivity varies between 200µS/cm and 1 200µS/cm with the majority of elevated values occurring when flows are lower than 1 000ML/day.
- There is a strong relationship between flow rate and electrical conductivity with high flows, associated with floods, measuring lower electrical conductivity values.
- Higher electrical conductivity tends to occur when there are limited releases from Keepit Dam to supply the downstream irrigation demand and the majority of the flow is being generated from the downstream catchments of the Peel and Mooki Rivers (generally during the winter months).
- Elevated electrical conductivity values can occur for many months during low flow periods.

Local Catchment Water Quality Data

Water quality data has been obtained from locations upstream and downstream of the Pit Top Area on the tributaries of Kurrajong Creek following four storm events in July 2006, September 2008, December 2008 and February 2009. **Figure 4B.19** identifies the sites sampled in August 2006 (following sustained rainfall in the area at this time) which have not been affected by the construction activities on the Mine Site and are therefore representative of background data. **Table 4B.14** presents a summary of the water quality results.

Table 4B.14
Water Quality Data for the Local Catchments of the Mine Site

Parameter	No. Samples	Mean	Median	Min	Max	10th %ile	80th %ile	ANZECC (2000) Trigger Value	
								Upland	**Lowland**
Electrical Conductivity (µS/cm)	23	227	125	55	1300	65	301	30 - 350	125 – 2 200
pH	23	7.2	7.1	6.5	8.2	6.7	7.6	6.5 – 8.0	6.5 – 8.0
Total Suspended Solids (mg/l)	23	76	38	6	320	14.2	139	NA	NA
Oil & Grease (mg/l)	<2	<2	<2	<2	<2	<2	<2	NA	NA

Source: Modified after WRM (2009) – Tables 3.4 and 3.5

The results presented in **Table 4B.14** suggest that local surface water is of generally neutral pH, fresh with a relatively high suspended sediment level reflecting the ephemeral nature of these drainage lines. When compared to the ANZECC (2000) Trigger Values, WRM (2009) concludes the following in relation to water quality.

- Electrical conductivity in the local creeks is lower than in the receiving waters of the Namoi River and generally lower than the default ANZECC (2000) trigger values. The upland rivers electrical conductivity trigger value of 350µS/cm was exceeded in the local creeks four times over the monitoring period.
- pH is generally within the bounds of the ANZECC (2000) trigger values.
- ANZECC (2000) does not specify trigger values for oils and greases or Total Suspended Solids and no data is currently available for turbidity (which can be used to indicate likely acceptable TSS values).

4B.3.2.6 Flooding Potential

WRM (2007) completed a flood study of Kurrajong Creek Tributary 1 to the north of the Pit Top Area for the approved Stage 1 Narrabri Coal Mine. The infrastructure developed for Stage 1 was generally outside the 100 year Average Recurrence Interval (ARI) flood extent for Kurrajong Creek Tributary 1 except for a small section of the rail adjacent to the Kamilaroi Highway. The impact of the constriction caused by the rail loop was not significant.

The additional Pit Top Area infrastructure required for the Longwall Project, including the Brine Storage Area is also outside the modelled 100 year ARI flood extent. The Mine Site is not susceptible to flooding from the Namoi River as it is located some 20m in elevation above the Namoi River floodplain.

On the basis of the above, the potential impacts of flooding are not considered further in the *Environmental Assessment*.

4B.3.2.7 General Sensitivity of the Namoi River Catchment

The surface water flows on and around the Mine Site provide a very minor contribution to the overall flows within the Namoi River catchment. This water is important to local landowners that use the water from local creeks for stock watering and/or crop irrigation purposes, with any changes in water availability potentially detrimental to the existing land uses. The impact on

Namoi River catchment flows during periods of floods and low flows would be negligible given the level of regulation and the size of the upper catchment in relation to the Project Site. The surface water flows are also important to the ecological health of the Namoi River, ie. the fauna and flora which rely on good quality water. A release of contaminated water from the Mine Site could significantly impact on the health of flora and fauna, as well as downstream water users.

In assessing the potential impacts of the Longwall Project on the Namoi River catchment, the management targets for surface and ground water ecosystems of the Catchment Action Plan for the Namoi River (NCMA, 2007) are considered.

1. From 2006, there would be an improvement in riverine structural stability, and the condition and extent of native riverine vegetation in priority riverine areas.
2. From 2006, maintain or improve surface and ground water quality suitable for irrigation, raw drinking water and aquatic ecosystem protection at Gunnedah, Narrabri and Goangra (near Walgett). Target values are as determined by:
   a) ANZECC (2000) guidelines for:
      - Irrigation Water - Electrical conductivity range of 650 –1300µS/cm; and
      - Aquatic Ecosystem Protection - mean values of Total Endosulphan <0.03µS/L and Atrazine <0.7µS/L.
   b) MDBC; River Salinity of 550µS/cm 50% of the time and <1 000µS/cm 80% of the time at Goangra (at time of writing the CAP).
3. From 2006, protect and assist the recovery of threatened or priority native aquatic species in identified priority areas.
4. From 2006, oversee and review water management planning and other processes under the *Water Management Act 2000*, so that Water Management Plans, including Water Sharing Plans (WSPs), result in fair and reasonable access to surface and ground water sources for the environment (water dependant ecosystems), economic uses (agricultural, industrial, town water supply) and social values (recreation, cultural).

The Longwall Project has been designed to operate within the framework outlined in NCMA (2007) to achieve these targets on the Mine Site and thereby assist in the achievement of these across the catchment.

4B.3.3 Surface Water Management Issues

4B.3.3.1 Introduction

The Longwall Project has the potential to impact upon both the quality, quantity and hydrology of surface water flowing from the Mine Site. The following sub-sections identify the potential impacts that have been considered in the design of surface water management controls and measures for the Mine Site. Section 4B.3.4 then addresses the controls to be implemented to avoid or maintain these impacts at an acceptable level.

4B.3.3.2 Potential Sources of Water Pollution

The potential sources of water pollution from the proposed activities within the Mine Site are as follows.

- Runoff from areas disturbed during construction within the Pit Top Area and progressive development of gas drainage and ventilation infrastructure.
- Runoff from stockpiles of topsoil, subsoil and mined rock.
- Surface runoff from ROM coal and coal product stockpiles.
- Runoff from hardstand areas including roads, coal crushing/sizing area and surface buildings.
- Surface runoff from rehabilitated areas prior to full stabilisation.
- Sedimentation generated by increased or accelerated erosion within the Mine Site.
- Uncontrolled discharge of dewatered mine in-flows (which are anticipated to be of elevated salinity).
- Leakage or spillage of saline groundwater stored within Dam A1.
- Leakage or spillage of brine stored within Dams A2, A3, B or BR1 to BR5.
- Leakage or spillage of hydrocarbons.

Based on the potential sources of pollution, suspended solids, ie. sand, silt, clay or coal particles in water, saline water and hydrocarbons are likely to be the major sources of surface water pollution.

i) The Longwall Project also has the potential to pollute the Namoi River as a result of the discharge of raffinate. Based on the proposed treatment of mine in-flows pumped to the surface and treated in the Water Conditioning Plant, the most likely source of pollution would be elevated salinity (measured by electrical conductivity).

4B.3.3.3 Potential Changes to Surface Water Quantity

Development of the Longwall Project would necessitate the clearing of some areas, mainly agricultural in nature and construction of hardstand areas which would potentially result in increased surface water run-off within the affected catchment and subsequently from the Mine Site. It is more likely, however, that the volume of water leaving the Mine Site would decrease marginally as a result of surface water being captured within water storages constructed on the Mine Site to provide for operational water requirements.

4B.3.3.4 Potential Impacts of Subsidence

As illustrated on **Figure 4B.7**, mine subsidence would result in a variable change in the gradient of the watercourses that traverse the Mine Site. Those likely to be affected are:

- Pine Creek;
- Pine Creek Tributary 1;
- Kurrajong Creek; and
- Kurrajong Creek Tributary 1.

These creeks and their tributaries range from first order water courses at the upstream (western end) of the mine subsidence zone to third order watercourses at the downstream (eastern end) under the Strahler stream ordering system (Strahler, 1957). All four have little to no capacity, are ephemeral and are therefore likely to be Schedule 1 streams in accordance with DIPNR (2005). Further detail on the structure and hydrological properties of these streams is provided by WRM (2009 – Section 2.2). The altered channel gradients within these creeks and their tributaries may result in the following impacts (which have previously been discussed in the Section 4B.1.6.5).

- Ponding, which may or may not be confined to the creek channel (in-stream or over bank ponding). **Figure 4B.8** illustrates the predicted ponding resultant following mining of LW1 to LW3.
- Ponding and possible flow direction changes against contour banks.
- Increased or accelerated in-stream erosion and sedimentation generated by the altered channel gradients.
- Increased water salinity as a result of increased storage time over saline soils.
- Degradation of riparian vegetation as a consequence of inundation.

Riparian Risk Management Zones have been defined through consideration of existing channel slopes and location in relation to the retained chain pillars of the underlying longwall panels (where the change in channel gradient is likely to be most affected – see **Figure 4B.7**).

- High Risk Management Zones, ie. those areas highly likely to be affected by one or more of the above impacts, are generally those higher order watercourses at the downstream (eastern) end of the mine site that are highly likely to be affected by one or more of the above impacts outlined.
- Moderate Risk Management Zones are those sections of the Mine Site creeks and tributaries which cross the retained chain pillars of the underlying longwall panels but have steeper existing channel slopes (≥5º) (the steeper the channel is, the less the area of potential ponding).
- Low Risk Management Zones are those sections of the Mine Site creeks and tributaries which are located off the Mining Area.

Based on the existing drainage patterns of the Mine Site and the longwall panel design, **Figure 4B.21** provides the locations of the expected Riparian High Risk Management Zones across the Mine Site. The moderate risk management zones are defined as those sections upstream of the high risk management zones. The low risk management zones are downstream of the Mining Area.

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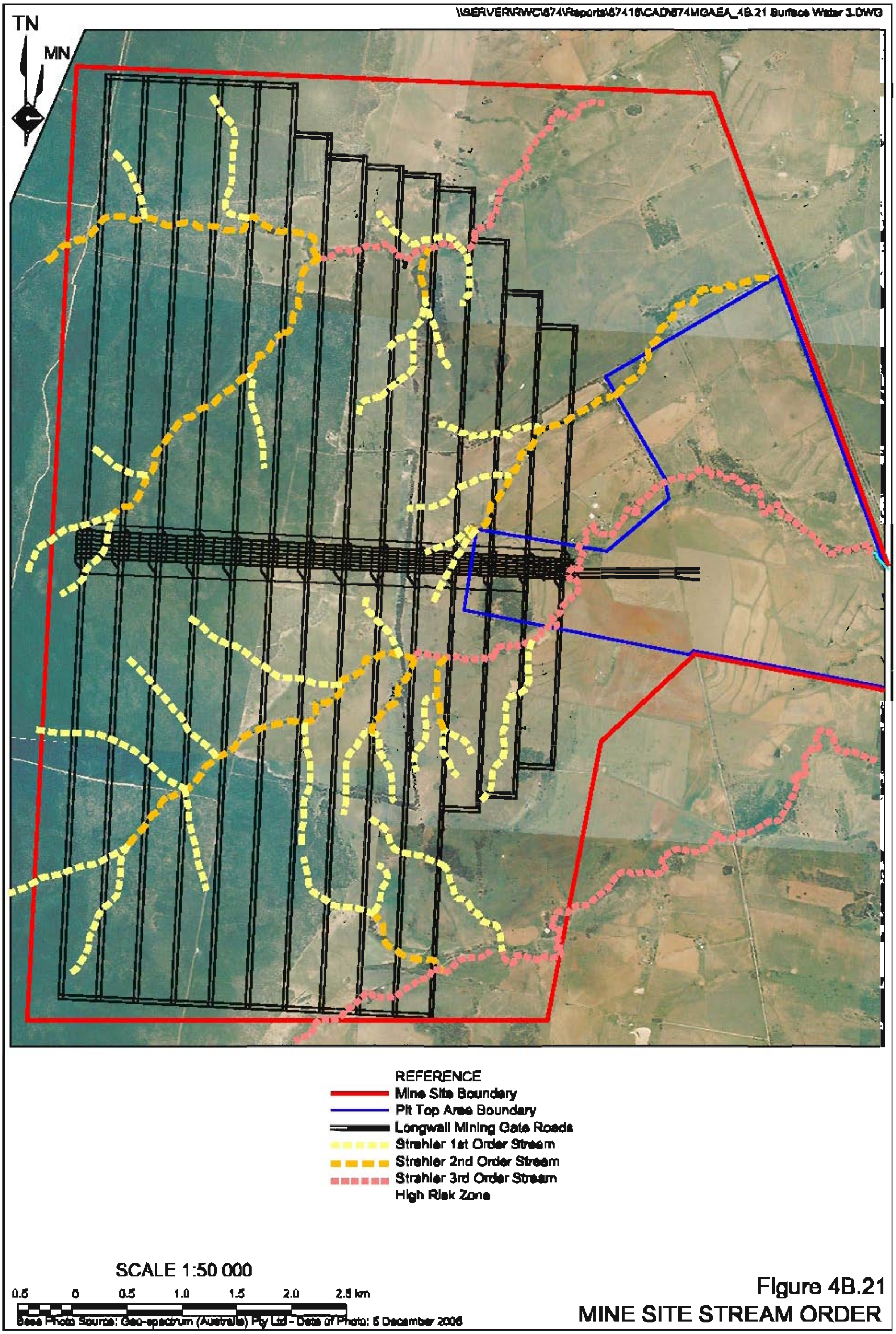


Base Photo Source: Geo-spectrum (Australia) Pty Ltd - Date of Photo: 5 December 2006

Figure 4B.21
MINE SITE STREAM ORDER

4B.3.3.5 Potential Impacts on Aquatic Habitat

Changes to water quantity and quality within the creeks and tributaries of the Mine Site could potentially affect aquatic habitat and species (should these occur on the Mine Site). Ecotone (2009) completed a comprehensive field survey of the ecology of the Mine Site and did not identify aquatic habitat or species (as distinct from Riparian vegetation). No further assessment of potential impacts on aquatic habitat has been undertaken, although it is noted that future ecological surveys to be undertaken on the Mine Site as mining progresses beyond LW7 would consider the potential for aquatic habitat or species.

4B.3.3.6 Dryland Salinity

Dryland salinity which is the accumulation of salts within the soil profile has been recognised as an issue of concern within the Namoi Valley for some time. The potential of the Longwall Project to increase dryland salinity has been considered given the necessity to store dewatered groundwater and brine within the Pit Top Area. However, as the ponds would be constructed with an impermeable liner (permeability $< 1 \times 10^{-14}$m/sec), and recognising the bulk of the deep rooted vegetation of the Mine Site is located outside of the proposed area of disturbance, the potential for dryland salinity is considered minimal.

4B.3.3.7 Regional Drainage

As noted in Section 2.4.8.3, raffinate surplus to the storage capacity of Dams C and D would be discharged to the Namoi River. Whilst the volume of water discharged would represent a very minor contribution to the total flow within the river, the potential for this to impact on water quantity and quality more regionally requires consideration. In particular, the impact on the salt load within the river requires consideration (especially in relation to the management objectives of the Namoi River CAP).

4B.3.4 Water Management Measures and Operational Safeguards

4B.3.4.1 Introduction

For management purposes, the surface water within the proposed areas of disturbance has been divided into four categories, namely:

- **"Clean"** - surface runoff from rehabilitated catchments and catchments undisturbed or relatively undisturbed by construction, mining or related activities;
- **"Dirty"** - surface runoff from areas disturbed by construction or activities such as soil, overburden and coal stockpiling, and rehabilitation (until stabilised), all of which could contribute suspended solids to the surface water;
- **"Saline"** - water containing concentrations of total dissolved solids (TDS) greater than the ANZECC (2000) trigger level (see **Table 4B.22** Section 4B.3.7.6); or
- **"Contaminated"** - surface water containing hydrocarbons or any other contaminant other than suspended solids.

The key principles in managing surface water within and around the Mine Site would be to:

- divert clean water away from disturbed areas;
- capture dirty water and treat it so that it could be discharged in accordance with relevant criteria;
- prevent the leakage or spillage of groundwater dewatered from the underground workings and brine generated by the Water Conditioning Plant;
- capture and treat contaminated water prior to discharge from and/or re-use on the Mine Site;
- maintain as much vegetation cover (particularly grass) as possible; and
- manage the direct and indirect affects of mine subsidence on the hydrology of the Mine Site.

The water management controls identified for both the management of impacts associated with the surface operations of the Longwall Project and mine subsidence related changes to local hydrology have been drawn from WRM (2009) (see Part 3 of the *Specialist Consultant Studies Compendium*).

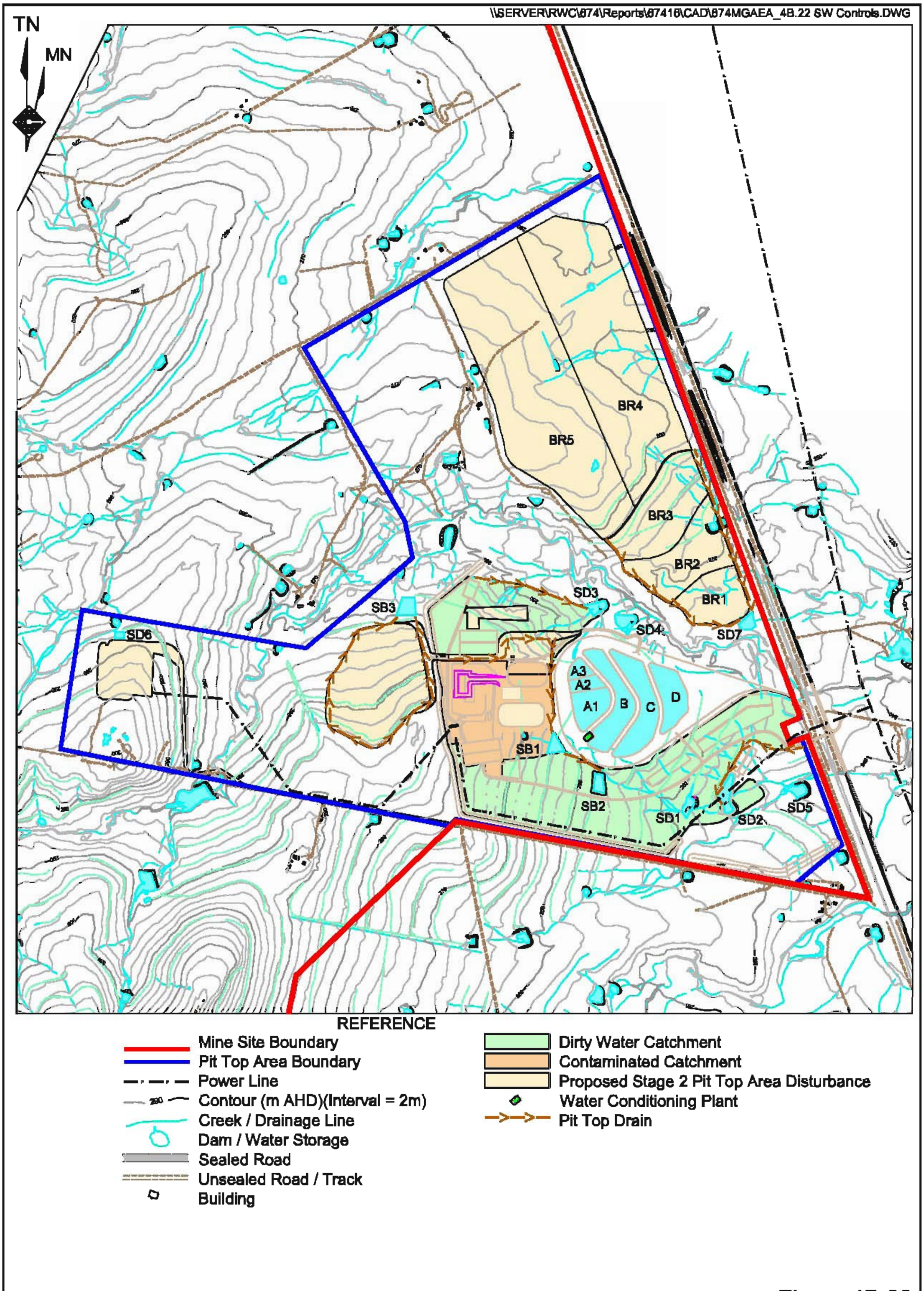
It should be noted that, whilst comprehensive in its assessment of Mine Site surface water flow and the design of water management structures, the proposed water management remains conceptual in terms of the positioning and number of structures. As the development and operation of the Longwall Project progresses, some variation to the structures may be required. The design of any variations would reflect, however, the overall objectives and principles included in the Site Water Management Plan for the Longwall Project.

4B.3.4.2 Water Quality

4B.3.4.2.1 Pit Top Area Surface Water Management Infrastructure

The locations of the existing and proposed water management control structures on the Pit Top Area are presented in **Figure 4B.22**. The general features of the surface water management infrastructure for the Pit Top Area remain consistent with those constructed and currently operating for the Stage 1 Narrabri Coal Mine and are as follows.

- A sediment basin (SB1) to collect dirty and contaminated runoff from the stockpiling and crushing/sizing area.
- A sump in the box cut to collect rainfall/runoff and seepage from the walls of the box cut.
- A series of sediment basins (SD1, SD2, SD3, SD4 and SD5) to collect and treat runoff from the southern part of the Pit Top Area, disturbed during Pit Top Area construction.
- A series of drains to collect runoff from the Pit Top Area and divert it to the various water management dams.



Source: Modified after WRM (2009) - Figure 5.1

Figure 4B.22
PIT TOP AREA
SURFACE WATER CONTROLS

- A series of ponds within the rail loop for the storage of dewatered groundwater (Dam A1), treated raffinate (Pond D) and waste brine (Ponds A2, A3, B and C). Water would continue to be drawn from Dam A1, Dam C or D for operational purposes (depending on the quality requirements of the operation[3]).
- A Water Conditioning Plant to treat dewatered groundwater to a sufficient quality for Mine Site use (in underground, coal washing etc), increasing environmental flows in the Namoi River and potentially for use off site**.**

The following additional (or modification to existing) controls is proposed as part of the Longwall Project (see **Figure 4B.22**).

- The capacity of SB1 would be increased and an additional sediment basin (SB2) would be constructed immediately downstream of SB1 to provide additional capacity for the collection and storage of dirty runoff from the coal processing area.
- A new sediment basin (SB3) would be constructed to collect potentially dirty runoff from the proposed Reject Emplacement Area.
- A new storage dam (SD6) would be constructed to collect potentially dirty runoff from the initial ventilation shaft area.
- Additional brine storage ponds (identified as BR1 to BR5 on **Figure 4B.22**) would be progressively constructed within the Brine Storage Area to the north of Kurrajong Creek Tributary 2 to contain the brine generated by the Water Conditioning Plant. A description of the design, construction and operation of these brine storage ponds is provided in Sections 2.4.8.4 and 2.4.9.14.
- A new sediment dam (SD7) would be constructed to collect potentially dirty runoff from the construction of the proposed Brine Storage Area
- An underground pipe would be constructed from Dam C to the Namoi River to enable the extraction of additional water from the Namoi River or discharge of surplus raffinate to the Namoi River.

4B.3.4.2.2 Pit Top Area Sediment Basins and Dams

Storage Basins (SB1, SB2 and SB3)

SB1 would accept the dirty and potentially contaminated runoff from the coal processing area with any overflow, as well as runoff from the small area downstream of SB1, flowing to SB2. The water collected in SB1 and SB2 would be regularly pumped to Dam A1 to be used for dust suppression and other activities within the Pit Top Area that does not require clean water.

SB3 would collect runoff from the proposed Reject Emplacement Area. Only direct rainfall on the Reject Emplacement Area would flow to SB3 as a paired diversion bank / catchment bank arrangement would be constructed to the east and south of the structure to capture runoff from the slopes of the structure, as well as divert clean runoff from the east and south around the structure and into Kurrajong Creek Tributary 2.

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[3] Water for underground dust suppression in the vicinity of the longwall unit is required to have a TDS of ≤500mg/L, whereas saline water is able to be used for most activities on the surface.

There would be no discharge from SB2 or SB3 (effectively there would be discharge from SB1 as any overflow from this storage basin would be captured by SB2) with the water collected in SB1, SB2 and SB3 periodically pumped to Dam A1 to supplement the Longwall Project water supply.

Table 4B.15 provides the proposed design capacities of the four storage basins on the Pit Top Area.

Table 4B.15
Storage Basin (SB) Design Capacities

Structure*	Catchment Area (ha)	Storage Volume (ML)
SB1	29.7	20.0
SB2	0.0	30.0
SB3	25.0	15.0

* See **Figure 4B.22**
Source: Modified after WRM (2009) – Tables 6.3 and 6.4

Sediment Dams (SD1 to SD7)

SD1, SD2, SD3, SD4 and SD5 are all currently active and contained within the Site Water Management Plan for the Stage 1 Narrabri Coal Mine. SD1 and SD2 collect runoff from the disturbed catchment of the Pit Top Area downstream of SB2, as well as any runoff from SB2 should this overflow. SD3 collects runoff from the disturbed catchment to the north of the coal processing area and box cut (which would include the longwall assembly laydown area), while SD4 collects any overflow from SD3. SD5 collects clean runoff from Kurrajong Creek Tributary 1.

SD6 would accept the dirty runoff from the initial ventilation shaft area (similar sediment basins would be constructed within the additional ventilation shaft areas and gas drainage sites to be constructed over the life of the Longwall Project). SD7 would accept the dirty runoff from the construction zone of the Brine Storage Area.

The Pit Top Area sediment dams have been designed to store runoff received from rainfall up to the 5 day 95th %ile rainfall event for the region (in accordance with the recommended design standards of *Soils and Construction – Managing Urban Stormwater, Volumes 1 and 2,* [Landcom, 2004, and DECC, 2008]). To maintain capacity within the sediment dams, and in accordance with DECC (2008), the settled water would be released to the downstream creeks within 5 days of the runoff event. During the initial years of the Longwall Project, water captured within the sediment dams would be pumped to Dam D to supplement the Mine Site water supply, however, as dewatering rates increase, this practice would cease and water would be released downstream after settlement in the structure.

Table 4B.16 provides the minimum design capacity of SD1 to SD7 (to provide sufficient water settlement and sediment storage zones to contain the 5 day 95%ile storm event (DECC, 2008)) and the proposed design capacity. The minimum design capacity has been calculated by WRM (2009) assuming a 5 day 95%ile storm event of 52mm and runoff coefficient of 0.74.

Table 4B.16
Sediment Dam (SD) Design Capacities

Structure*	Dirty Water Catchment Area (ha)	Minimum Storage Volume (ML)	Storage Volume (ML)
SD1	32.3	12.4	5.9
SD2	31.5	12.1	55.2
SD3	25.2	9.7	4.7
SD4	4.5	1.7	35.0
SD5	0	0	11.2
SD6	7.2	2.8	4
SD7	38.2	TBC	TBC

TBC: The design capacity would be determined prior to construction following confirmation of the individual brine storage pond specifications.
* See **Figure 4B.22**

Source: Modified after WRM (2009) – Tables 6.3 and 6.4

When comparing the nominated minimum design capacity and proposed design capacity, the following is noted.

- SD1 overflows to SD2. Excess storage is provided in SD2 to contain the minimum storage requirements for SD1.
- SD5 is not strictly a sediment dam because it primarily collects clean runoff from Kurrajong Creek Tributary 2.
- SD3 overflows to SD4. Excess storage is provided in SD4 to contain the minimum storage requirements for SD3.
- The design capacity of SD7 would be determined prior to construction of the first brine storage pond, at which point the Proponent will have a better understanding of the ultimate storage volume required of the Brine Storage Area to accommodate groundwater dewatering and brine generation.
- The spillway of each sediment dam would have sufficient capacity to pass the 100 Year ARI critical duration design flood.

4B.3.4.2.3 Management of Groundwater, Raffinate and Brine Storages

Figure 4B.22 identifies the locations of the existing water storages constructed to manage the dewatered groundwater, treated raffinate and brine. Each pond is approximately 5m deep, has 1:3 (V:H) side slopes and 5m wide crests. The storage volumes and surface areas of the evaporation ponds at full supply level are given in **Table 4B.17.**

As described in Sections 2.4.8.4 and 2.4.9.14, a series of additional storages to contain the additional brine generated by the treatment of dewatered groundwater would be constructed within the Brine Storage Area as required (see **Figure 4B.22**). Based on the results of the groundwater modelling (base case), and the anticipated water demand of the Longwall Project, WRM (2009) have calculated that between 2 200ML and 2 730ML of additional brine storage would be required. Brine storage ponds BR1 to BR3 would provide storage capacity for this volume of brine with **Table 4B.17** providing the surface area and storage volumes of these ponds. Brine storage ponds BR4 and BR5 would provide for contingency storage areas in the event that groundwater in-flows are much higher than predicted by the groundwater modelling of Aquaterra (2009).

Table 4B.17
Groundwater, Raffinate and Brine Storages

Pond*	Storage	Surface Area (ha)	Storage Volume (ML)
Existing Storages			
A1	Dewatered groundwater and dirty water from Pit Top Area storage basins	3.17	129.8
A2	Brine	0.98	30.6
A3	Brine	0.93	30.8
B1	Treated Raffinate	1.0	40.0
B2	Brine	4.85	165.0
C	Treated Raffinate or Water harvested from Pit Top Area SB's and SD's	6.63	218.3
D	Water harvested from Pit Top Area SB's and SD's	4.15	128.4
	Total	**21.71**	**742.9**
Additional Storages			
BR1	Brine	8.5	470
BR2	Brine	13.7	748
BR3	Brine	16.2	898
BR4	Brine (if required)	~55.0	>2 500
BR5	Brine (if required)	~65.0	>3 000
	Total	**158.4**	**>8 350**
* See **Figure 4B.22**			

The storages identified in **Table 4B.18** would be managed as follows.

- Groundwater pumped from the underground mine, along with all potentially contaminated runoff from the storage dams SB1, SB2 and SB3, would be discharged into Dam A1. Dam A1 is lined with HDPE with a maximum permeability of 1 x 10^{-14}m/sec.
- Concentrated brine produced by the Water Conditioning Plant would be discharged into Dam A2 and Dam A3, which are lined with HDPE. Overflow from Dam A3 would spill to Dam A2.
- Overflow from Dam A2 would spill to Dam B2, via a pipe. Dam C would be lined with HDPE (permeability <1 x 10^{-14}m/sec), if and when it is required to store the excess concentrated brine from the Water Conditioning Plant.
- BR1, BR2 and BR3 would be constructed if and when required to store the excess concentrated brine from the Water Conditioning Plant. These would be lined with HDPE and receive brine pumped from the Water Conditioning Plant.
- Dam B1 is clay lined and would be the primary storage for treated raffinate from the Water Conditioning Plant. This water would be used preferentially for underground operational requirements and as potable water after further treatment. Water may also be 'shandied' with water in Pond A1 or from Pond D for use in surface coal handling and site dust suppression.
- The clay lined Dams C and D would be the primary storage for clean or potentially dirty water harvested from the sediment dams of the Pit Top Area. The maximum permeability of the clay would be <1 x 10^{-9}m/sec. Ponds C and D could also store the excess raffinate from the Water Conditioning Plant in preference to discharge of this water.

- Water in excess of the storage capacity of Dams B1, C and D would be released to the Namoi River via the water pipeline described in Section 2.4.9.15. Section 4B.3.4.2.7 provides further detail of the proposed discharge of raffinate from the Pit Top Area.
- To prevent any of the brine storage dams from overflowing, each dam would maintain a 0.5m freeboard, which would be sufficient to contain the 100 year 72 hour storm event (0.26m) and any wave run up.
- The spillway for each brine storage dam or pond would be sufficient to convey the 10,000 year ARI critical duration storm event without overtopping the dam wall.

Section 4B.3.5.3 considers the operational behaviour of these storages over the life of the Longwall Project.

4B.3.4.2.4 Management of Progressive Surface Disturbance over the Mining Area

Surface water flows within each gas drainage or ventilation shaft area would be managed in accordance with a general Erosion and Sediment Control Plan (ESCP) (in accordance with the requirements of Landcom, 2004). The ESCP would provide for the following management.

- Prior to disturbance, the area would be marked out and ‘no-go’ zones identified.
- If located on or adjacent to a natural drainage line, a diversion bank would be constructed up-slope of the area to be disturbed and in accordance with Standard Drawing (SD) 6-4 of Landcom (2004).
- Based on the area to be disturbed, soil type and local topography, the requirement for a sediment basin would be determined, using the Revised Universal Soil Loss Equation (RUSLE).
- If a sediment basin is required, ie. soil loss >200t/ha/year, the sediment basin design capacity would be calculated.
- Vegetation and soil would be cleared and stripped and stockpiled away from natural drainage lines for future use in rehabilitation of the site.
- Sediment fencing would be installed along the down-slope boundaries of the disturbed areas.
- The function of the sediment fencing (and diversion bank or sediment basin if constructed) would be regularly inspected and remedial works undertaken immediately if not performing at optimum capacity.

4B.3.4.2.5 Contaminated Water Management

Runoff containing hydrocarbon contamination may be generated by:

- washdown area(s);
- workshop(s);
- fuel, oil and grease storages; and
- refuelling pads.

These areas would be managed as follows.

- Runoff would be drained to a triple interceptor (or similar) to reduce hydrocarbon concentration to acceptable levels before draining to SB1. The oily fraction would enter a containment system for removal as necessary.
- All oil, grease, fuel and hydrocarbon products would be securely stored on an impermeable surface within a bund capable of containing 110% of the largest tank's capacity.
- Refuelling, oiling and greasing would be restricted to designated areas, away from drainage and where spill kits are readily available.

In the event of a major hydrocarbon spill, the following actions would be undertaken.

- The contaminated soil at the site of the spill would be collected and transported to an approved waste depot or remediated safely on the Mine Site.
- Pits would be constructed around the spill with sufficient hydraulic gradient to capture seepage water and contaminated material, enabling the pits to be pumped out.
- The local groundwater would be monitored for signs of further contamination.

4B.3.4.2.6 Maintenance of Vegetation

The maintenance of vegetation, particularly ground cover, would be an important factor in reducing the velocity of surface water flows and maintaining acceptable surface water quality. By reducing flow velocity, the potential for soil erosion is reduced as would be the potential for further sediment to be entrained by the runoff. The vegetation itself would also act to filter any suspended solids contained within the water. As a general rule, all groundcover would be maintained on the Mine Site beyond the planned areas of disturbance. Importantly, the Proponent would undertake progressive revegetation of all completed landforms in order to maintain a ground cover of vegetation at 70% or better, although this value may fluctuate with seasonal conditions.

The areas where the retention and management of vegetation is of highest priority would be those subjected to large quantities of diverted water. This water is likely to be sediment-laden or potentially dirty.

Vegetation, particularly trees, also reduce the risk of dryland salinity by reducing the depth of the water table relative to the root zone of plants. By maintaining and/or enhancing as much vegetation on the Mine Site as possible, particularly trees, the potential for dryland salinity would be reduced.

4B.3.4.2.7 Water Discharge

No saline water would be discharged from the Mine Site. Dams A1, A2, A3, C and BR1 to BR5 would be lined with a impermeable HDPE (or equivalent) liner with a permeability of $\leq 1 \times 10^{-14}$m/sec and have been designed to have sufficient capacity to accept and store the predicted groundwater and brine make of the Longwall Project.

Within the Pit Top Area, water collected within SB1 to SB3 would not be discharged from the Mine Site. As these structures fill, the water contained would be pumped to Dam A1, from where it would be processed through the Water Conditioning Plant.

The discharge points from the Pit Top Area would be from SD2, SD4, SD5, SD6 and SD7. Based on the design of the sediment dams meeting the requirements of Landcom (2004) and DECC (2008) for a 5 day 90th %ile rainfall event, any release would achieve the water quality compliance criteria provided in Section 4B.3.6.

Discharged water would be sampled within 24 hours of a discharge event and assessed against DECCW water quality criteria. Contingency measures in the event of an exceedance of water quality criteria have been prepared and are discussed in Section 4B.3.5.

Finally, it is proposed to discharge raffinate from Dam D to the Namoi River. **Table 4B.18** presents the predicted annual discharge volumes based on the base case (most likely) groundwater modelling results.

Table 4B.18
Predicted Life of Mine Raffinate Discharge

Year	Predicted Discharge	
	ML/day	ML/year
8	0.3	98.1
9	0.6	209.3
10	0.7	241.4
11	0.8	301.6
12	1.0	355.3
13	1.2	445.8
14	1.4	521.7
15	1.6	588.6
16	1.8	647.3
17	1.9	696.9
18	2.1	761.2
19	2.1	758.4
20	2.1	758.3
21	1.6	583.1
22	1.3	466.3
23	1.0	371.9
24	0.7	261.9
25	0.6	203.5
26	0.3	118.8
27	0.2	64.5
28	-	-
29	-	-

Source: Modified after WRM (2009) – Table 8.6

The pipeline would be fitted with a leak detection system such that any leak is able to be immediately detected, pumping ceased and the leak repaired before any significant impact on the surrounding soil and/or vegetation occurs.

4B.3.4.3 Water Quantity

The goals of the Proponent in relation to managing the quantity of water captured/discharged within the Mine Site are as follows.

- To ensure that sufficient water is available for operational requirements.
- To minimise the volume of clean water captured from natural (undisturbed) catchment on the Mine Site.
- To minimise the volume of treated raffinate discharged to the Namoi River.

Measures to Ensure Certainty of Water Supply

Transfer of surface water captured within the storage basins and sediment dams of the Mine Site has now been included in the water balance for the Mine Site. However, in the event that the commencement of the Longwall Project coincides with several years of low or average rainfall, the water captured on the Mine Site would be supplemented by water extracted from the Namoi River and pumped to the Mine Site via the proposed pipeline. It remains the Proponent's intent to only pump water to the Mine Site from the Namoi River when there are insufficient/reliable supplies on site.

Measures to Minimise Clean Water Capture

Only Dam SD5 captures clean water on the Mine Site for a combined dam capacity of 54.2ML (see **Figure 4B.22**). This is well within the maximum harvestable right dam capacity (MHRDC) for the Proponent's landholding which is calculated as follows.

MHRDC = Catchment Area of Proponent-owned land x Multiplier Value
= 3 825ha x 0.07
= 267.75ML

The above MHRDC calculation is based on guidelines provided by the former Department of Water and Energy (DWE) using the folder supplied by Department of Land and Water Conservation (DLWC) titled *Rural Production and Water Sharing Landholders Information Package*. It is noted that the maximum harvestable right does not include storages that are used on a Mine Site for environmental management purposes, eg. capture of 'dirty', saline or sediment-laden water.

Measures to Minimise Raffinate Discharge

In order to minimise the volume of groundwater treated, and therefore raffinate generated by the Water Conditioning Plant, raw groundwater (stored in Dam A1) would be used for all on-site dust suppression and coal processing operations within the Pit Top Area. Where the use of saline water will not adversely impact on equipment, this water would also be used for underground operations, eg. cooling, dust suppression away from the longwall unit.

Considering these management measures, the anticipated water requirements of the Mine Site and the predicted dewatering requirements of the underground mine a Site Water Balance has been prepared for the Longwall Project by WRM (2009). A summary of this water balance, which assesses the availability of water to supply the Longwall Project as well as capability of the nominated structures to store all water on the Mine Site is presented n Section 4B.3.5.

4B.3.4.4 Subsidence-related Impacts

The general principles involved in managing the impact of mine subsidence of the various watercourses that cross the Mine Site are as follows.

- Maintain stream stability where subsidence occurs.
- Minimise stream fracture where possible.
- Maintain stream channels with minimal incision from bed grade change.
- Minimise stream bed grade change to provide stable stream length.
- Maintain stream stability through soft controls, such as vegetation, where possible.

Figure 4B.8 illustrated that the potential impacts of mine subsidence may be significantly different at each creek crossing of each longwall panel. Based on the variable nature of impact, mitigation strategies would be tailored to each individual location, considering the geomorphic characteristics, vegetation and soil types of each individual location. The Proponent would inspect the creek channels of the Mine Site within 6 months of being crossed by a longwall panel. The inspection would consider, local ponding, erosion impacts on vegetation, with a water sample taken from ponded areas to assess water salinity and pH. In the event that significant erosion, ponding which inundates significant areas of vegetation, increased salinity or water pH outside the target range of ANZECC (2000) is identified, the Proponent would develop an impact mitigation strategy. The impact mitigation strategy may include the following strategies.

- Visible cracks in the bed of the creek will be in-filled.
- Contour banks that cross chain pillars would be removed and reconstructed if appropriate for the ongoing land use (noting that the Proponent owns the majority of the land over the mine subsidence zone which would have lower stocking rates and higher vegetation cover).
- If significant ponded areas are identified, the following assessment and mitigation would be made.
  - If little vegetation is impacted and minimal salt producing soils are evident, the ponding would be retained.
  - If larger areas or more significant vegetation is affected or salt producing soils are evident within the ponded area, the channel across the chain pillars may be excavated to reduce the extent of ponding.

Further to the above, the creek channels draining into the mine subsidence zone and on the downstream side of the chain pillars would be monitored for erosion following each runoff-producing storm event. Specific attention would be paid to those within the Riparian Risk Management Zones identified on **Figure 4B.21**. Any erosion would be repaired and remedial measures, such as check dams or drop structures, would be constructed, if necessary.

4B.3.4.5 Post-Mining Management

With the exception of the established perimeter bund wall, the rail loop and Mine Access Road which are intended to be retained, the final landform would be constructed to effectively recreate the landform disturbed by the surface facilities activities. Contour banks would be reconstructed along appropriate contour lines to allow for erosion protection of the land.

It is anticipated that over time, the process of erosion and sedimentation would re-instate the pre-subsidence channel gradients of the creeks and their tributaries that traverse the Mining Area. In accordance with the proposed approach to managing the affects of subsidence on local hydrology, channel excavation would be undertaken to mitigate larger ponds, or those which affect local vegetation and/or water quality. The Mine Site hydrology of the final landform would therefore be equivalent to that of the pre-mining landform.

Monitoring of the final landform and surface water flows on the Mine Site would be included in post project monitoring until such time as a stable landform could be demonstrated.

4B.3.5 Site Water Balance

4B.3.5.1 Introduction

Based on the proposed water management system described in Section 4B.3.3, WRM (2009) prepared a daily and annual water balance for the various water management dams on the Mine Site.

The daily water balance model was used to determine:

- the reliability of the various storages to supply the Mine Site water requirements during the initial years of the Longwall Project; and
- the frequency and volume of potential discharges from the storage basins and sediment dams under two scenarios:
  - during the second year (Year 2) of the Longwall Project when water is being pumped from the storage basins and sediment dams to Dam D;
  - during that period of the Longwall Project when the maximum volume of groundwater is predicted to be dewatered from the underground mine and therefore the maximum volume of raffinate is being produced for on-site consumption, ie., no water from the storage basins and sediment dams would be pumped back to Dam D (Year 18).

The Mine Site water demands for Year 2 and Year 18, with the dewatering rates of 0.28ML/day and 3.83ML/day respectively, are given in **Table 4B.19**.

Table 4B.19
Annual Operational Water Demand

Activity	**Annual Demand (ML)**	
	Year 2	**Year 18**
Supply		
Underground Dust Suppression and Other Uses	337	465
Coal Processing (Surface)	56	100
Pit Top Area Dust Suppression	27	27
Potable Water Supply	20	20
Recycle		
Underground Capture and Storage	-89	-284
Pit Top Area Capture and Storage	-5	-5
Total	**346**	**323**

Source: Narrabri Coal Operations Pty Ltd

The annual water balance of the major Pit Top Area water storages was used to determine:

- the frequency and volume of clean water releases from the Pit Top Area to the Namoi River; and
- the design requirements and behaviour of the brine storage ponds.

4B.3.5.2 Daily Water Balance Model

WRM (2009) used the AWBM rainfall runoff model (Boughton, 2003 [cited in WRM, 2009]) to determine the runoff volume from the various catchments on the Mine Site. Catchment parameters were based on the recommendations of Boughton (2003). WRM (2009) then used the IQQM water balance model (NSW DWE, 2007 [cited in WRM, 2009]) to assess the behaviour of the various storages on the Pit Top Area. The model was run over the 105 year period of daily rainfall data collected from 1900 to 2004 (inclusive). The use of such a long period of continual data provides a good indication of the behaviour of the various storages over extended dry and wet periods.

WRM (2009) provides further detail on the assumptions used in the development of water balance models and calibration of the water balance models. The following provides a summary of the water balance model results for Pit Top Area water storage behaviour during periods of low groundwater in-flow (potential surface water supply deficit) and high groundwater inflow (potential surface water supply surplus).

Reliability of Supply During Year 2 (potential surface water supply deficit)

The water balance model results for the Year 2 scenario were considered by WRM (2009) for a range of wet and dry years representing:

- 10th%ile wet year (1 year in 10 are expected to produce more runoff);
- median (50th%ile) year (1 year in 2 are expected to produce more runoff);
- 90th%ile dry year (9 years in 10 are expected to produce more runoff); and
- 99th%ile driest year (99 years in 100 are expected to produce more runoff).

Table 4B.20 summarises the results of the water balance model under the above rainfall conditions.

Table 4B.20
Annual Operational Water Demand

Rainfall Year	Water Supply from Pit Top Area Water Storages (ML)	Percentage of Demand Supplied by Pit Top Area Water Storages (%)
10th%ile wet year	438	99
Median (50th%ile) year	302	68.6
90th%ile dry year	205	46.6
99th%ile driest year	142	38.4
Source: Modified after WRM (2009) – Table 8.4		

The results show that the Pit Top Area water storages would be sufficient to supplement the groundwater inflows only during the wettest (10%ile) years. Therefore, during the majority of years, when rainfall is less than the 10th%ile year, there is an elevated potential for the water contained in the Pit Top Area water storages to be insufficient to supplement the groundwater in-flows. Based on the results presented in **Table 4B.20**, the Proponent would be required to source additional water from either licensed groundwater or river water supplies.

Potential Water Storage Discharges During Year 2 and 18 (potential surface water supply surplus)

Table 4B.21 presents the predicted probability and volume of discharges from the Pit Top Area water storages for Year 2 and Year 18 of the Longwall Project.

The following is of note with respect to the water balance modelling results.

- There are no uncontrolled spills from any of the dams constructed to store saline groundwater, brine or treated raffinate. This indicates that the proposed operating strategy is adequate for groundwater inflows up to 3.84ML/day.
- There are no uncontrolled spills from the four potentially contaminated storage basins of the Pit Top Area. Therefore, the proposed storage volume and operating strategy is deemed to be appropriate.
- Uncontrolled spills from SD1 to SD4 occur only once or twice when low groundwater in-flows (Year 2) are simulated, ie. when water is being harvested to supplement water supplies for the Longwall Project .
- WRM (2009) predicts no uncontrolled spills during Year 18 as all water would be released to the downstream creeks within 5 days of the rainfall event. At this stage, the water quality collected within the sediment dams is expected to achieve the water quality compliance criteria.
- Sediment Dam SD6 at the Vent Shaft spills on average of 1 year in 3. This satisfies the average annual sediment basin overflow frequency criteria given in DECC (2008).
- For the Year 18 scenario, controlled releases of the raffinate water are made from Dam D at a rate of 2.1ML/day to prevent uncontrolled spills. When less groundwater is dewatered to the surface, the volume of releases made to the Namoi River will be less.

Table 4B.21
Mine Site Water Storage Overflows and Uncontrolled Releases

Water Storage	**Groundwater In-flow (ML/day)**	
	0.28 (Year 2)	**3.83 (Year 18)**
Dam A1		
Years of Uncontrolled Spills (%)	0	0
Median Volume of Spill (ML)	0	0
Brine Storage Ponds		
Years of Uncontrolled Spills (%)	0	0
Median Volume of Spill (ML)	0	0
Raffinate Storages (B&D)		
Years of Uncontrolled Spills (%)	0	0
Median Volume of Spill (ML)	0	0
Years Controlled Release (%)	0	100
Median Volume of Release (ML)	0	763[1]
Storage Basins SB1& SB2		
Years of Uncontrolled Spills (%)	0	0
Median Volume of Spill (ML)	0	0
Storage Basin SB3		
Years of Uncontrolled Spills (%)	0	0
Median Volume of Spill (ML)	0	0
Sediment Dams SD1 & SD2		
Years of Uncontrolled Spills (%)	2	0
Median Volume of Spill (ML)	2	0
Sediment Basin SD3 & SD4		
Years of Uncontrolled Spills (%)	1	0
Median Volume of Spill (ML)	1	0
Sediment Basin SD6		
Years of Uncontrolled Spills (%)	31.5	31.5
Median Volume of Spill (ML)	2	2

Note 1: Includes constant Namoi River release of 2.1 ML/day
Source: Modified after WRM (2009) – Table 8.5

4B.3.5.3 Annual Water Balance Model

An annual spreadsheet water balance was developed by WRM (2009) to consider the behaviour and performance of:

- Dam A1 (saline groundwater storage);
- Brine storage ponds A2, A3, B2and BR1 to BR3; and
- Raffinate storage dams B1, C and D.

The annual water balance model provides an indication of the annual volume of clean water that would be released from Dam D to the Namoi River each year of operation. It also provides an approximate timeframe as to when BR1 to BR3 would be required and an estimation of the volume of brine that may need to be re-injected back into the underground void at the end of the Longwall Project. WRM (2009) provides additional detail on the assumptions made in the development and operation of the annual water balance model, which was run both for the predicted base case and upper bound groundwater in-flows of Aquaterra (2009).

The results of the annual water balance are summarised in Tables 8.6 and 8.7 of WRM (2009). The results show the following.

- For both the base case and upper bound groundwater in-flow scenarios, BR1, BR2 and BR3 would be required. BR4 would be required if groundwater in-flows are equivalent to those predicted by the high in-flow uncertainty analysis of Aquaterra (2009), however, BR5 is unlikely to be required unless in-flows are significantly higher than predicted by Aquaterra (2009) or the Proponent reduces the depth of each brine storage pond (to increase evaporation from these).
- For both cases, Dam B2 would be required for brine storage by Year 2 and would therefore be lined with HDPE prior to Year 2.
- BR1 would be required in Year 4 for both the base case and upper bound groundwater in-flow scenario.
- BR2 would be required by Year 7 to Year 9 and BR3 by Year 13 to Year 16.
- Pumping would cease from the sediment dams to augment Mine Site supplies in Year 3 or Year 5. The rehabilitation program from these catchments would be completed by this stage and the runoff quality would therefore be acceptable.
- Releases of raffinate water are expected to commence in Year 8 for the base case groundwater in-flow scenario or Year 6 for the upper bound groundwater in-flow scenario.
- Release of raffinate water is expected to peak in Year 18 at 761ML/yr for the base case groundwater in-flow scenario and in Year 19 at 1 171ML/yr for the upper bound groundwater in-flow scenario. Notably, the off site releases estimated in the base case scenario are very similar to the peak off site release estimated using the daily water balance model (see Section 4B.3.5.2).
- At the end of mine life, there would be 1 989 ML to 2 237 ML of brine left in storage that would be re-injected back into the underground void.

4B.3.6 Impact Assessment Criteria

The current environmental protection licence for the Stage 1 Narrabri Coal Mine (EPL 12789) requires the Proponent to comply with Section 120 of the *Protection of the Environment Operations Act 1997*, ie. the Proponent must not discharge water which contains concentrations of potentially polluting material greater than that of the accepting environment. It is proposed that this condition be retained for the Longwall Project. Alternatively, water quality criteria in line with the ANZECC (2000) trigger levels for lowland rivers apply.

The Proponent also proposes measurable water targets for the release of treated raffinate water to the Namoi River as presented in **Table 4B.22** (see Section 4B.3.7.5).

4B.3.7 Assessment of Impacts

4B.3.7.1 Introduction

Following the adoption of the water management controls and mitigation measures identified in Section 4B.3.4, the impacts on surface water within and beyond the Mine Site have been assessed as follows.

4B.3.7.2 Surface Water Catchments

The final landform created following the completion of the Longwall Project and rehabilitation of the Mine Site would be equivalent in topography and vegetation to that of the pre-mining landform (see **Figure 2.18**). There may be minor changes to the total catchment areas to the creeks and tributaries traversing the Mine Site, however, any change would be minimal and have no impact on the total catchments of Kurrajong and Pine Creeks.

No other catchment would be significantly effected by the Longwall Project.

4B.3.7.3 Subsidence Related Impacts on Local Drainage

Impacts associated with mine subsidence on local drainage is provided in Section 4B.1.6.5 and **Figure 4B.8**.

4B.3.7.4 Surface Water Quantity

The water balance modelling undertaken by WRM (2009) illustrates that during the initial years of the Longwall Project, additional water would have to be sourced from either groundwater or river sources. Supply from these sources would have to be licensed in accordance with either the *Water Act 1912* or *Water Management Act 2000*.

Importantly, the capture of clean water would not exceed the harvestable right of the Mine Site and as such it is assessed that the minor reduction in environmental flows to the Kurrajong Creek catchment is acceptable. As discussed in Section 4B.3.7.5, the Longwall Project would actually provide for a net increase in flows to the wider Namoi River catchment.

4B.3.7.5 Surface Water Quality

Pit Top Area

The proposed operating strategy for water management on the Pit Top Area has been designed to capture all “dirty” and “contaminated” water and direct it to sediment dams and storage basins, via a number of diversion banks and culverts. The design of these storage structures was reviewed by WRM (2009) with each determined to meet the requirements of Landcom (2004) and DECC (2008).

Notably, those structures constructed to accept runoff from the potentially contaminated catchments have been designed to contain all water with these structures, with the stored water ultimately processed through a Water Conditioning Plant to remove any contaminants before either used on the Mine Site or discharged to the Namoi River.

All storages constructed to contain saline water would be lined with HDPE plastic, which is effectively impermeable (permeability of < 1 x 10^{-14}m/sec). The dam and liner would be inspected by an appropriately qualified person prior to the inflow of any saline water or brine. Shallow piezometers would be installed and monitored to identify if any leakage from these storages occurs and appropriate remedial measures completed as required and in consultation with the relevant government agency.

Impacts on water quality of the Namoi River (as a result of discharged raffinate) is considered in Section 4B.3.7.6.

Based on the above, it is concluded that the Longwall Project would not result in any unacceptable impact on local water quality. A surface water monitoring program (see Section 4B.3.8.1) would be updated and implemented to ensure impacts on the water quality of local catchments are as predicted and acceptable.

4B.3.7.6 Raffinate Discharge to the Namoi River

The water balance modelling, see Section 4B.3.5.3, indicates that discharge to the Namoi River is likely to be required after about 7 to 10 years. Considering the impact of the proposed volume of the discharge on the overall flow rate of the Namoi River, flow rate historic daily recorded flows in the Namoi River at Boggabri over the period 1990 to 2009 were reviewed by WRM (2009). The 1990 to 2009 period of record was selected because the majority of the irrigation infrastructure in the catchment would have been constructed by then and the Murray Darling Basin Commission cap on diversions had been imposed.

The ‘base line’ flow rates and the flow rate including the addition of up to 3ML/day from the Longwall Project was considered by WRM (2009) and the following conclusions made.

- Over 70% of daily ‘base line’ flows exceed 100ML/day and therefore the minor increase in flow resulting from the mine discharge is insignificant.
- The mine discharges could potentially increase the frequency of low flows, which could increase the reliability of stock and domestic users and improve environmental flows in the catchment.

Considering water salinity specifically, a plot of salinity levels against flow rate within the Namoi River at Gunnedah was prepared by WRM (2009) and is reproduced as **Figure 4B.23**.

Notwithstanding the varied and at times elevated salinity levels within the Namoi River, the Proponent would treat any water to be released sufficiently to comply with the water quality criteria provided by **Table 4B.22**.

Notably, at flow rates exceeding 100ML/day, background salinity levels in the Namoi River vary between 250µS/cm and 650µS/cm, with the salinity of the discharged raffinate (<250µS/cm) at the lower end of this range. It is also notable that during lower flow periods (flow < 100ML/day), salinity levels generally exceed the nominated water quality compliance requirement (see **Table 4B.15**). Therefore, the releases are expected to reduce the salinity concentrations during periods of low flows.

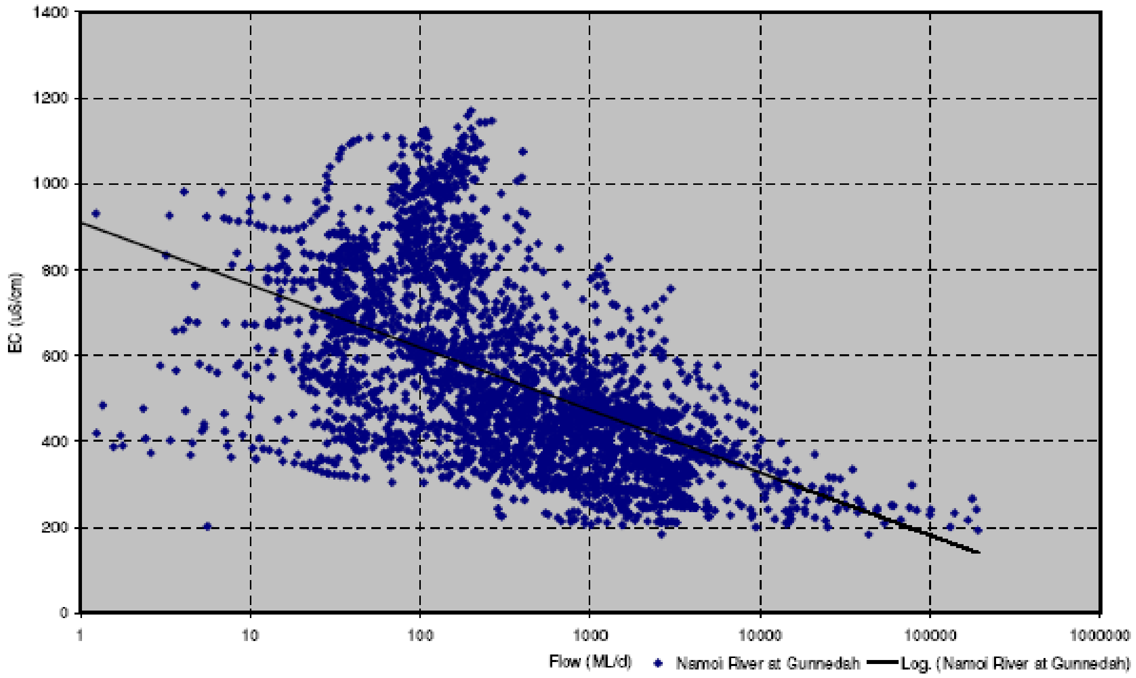


Figure 4B.23
Daily Flow and Electrical Conductivity Comparison, Namoi River at Gunnedah

Source: WRM (2009)

Table 4B.22
Water Quality Compliance Targets

Parameter	**Unit**	**Target**
pH		5.5 - 8
TDS	mg/L	350
Aluminium[1]	µg/L	55
Ammonia (as N)	µg/L	900
Antimony	µg/L	9
Arsenic[1]	µg/L	13
Boron[1]	µg/L	370
Beryllium[1]	µg/L	0.13
Cadmium[1]	µg/L	0.2
Chromium[1]	µg/L	1
Cobalt[1]	µg/L	1.4
Copper[1]	µg/L	1.4
Fluoride[1]	µg/L	2000
Iron[1]	µg/L	300
Lead[1]	µg/L	3.4
Manganese[1]	µg/L	1900
Mercury[1]	µg/L	0.1
Molybdenum[1]	µg/L	34
Nickel[1]	µg/L	11
Selenium[1]	µg/L	5
Uranium[1]	µg/L	0.5
Vanadium	µg/L	6
Zinc[1]	µg/L	8

Note 1: ANZECC (2000) default trigger values for slightly-moderately disturbed catchments

4B.3.8 Monitoring Program and Contingency Planning

4B.3.8.1 Monitoring Program

A comprehensive monitoring program is already in place across the Mine Site that incorporates:

- the collection of rainfall and meteorological data;
- the collection of water quality and water level data in the water storages and creeks.

Table 4B.23 summarises the proposed surface water monitoring program for the Longwall Project. All samples would be collected in a manner consistent with the "*Approved Method for Sampling and Analysis of Water Pollutants in NSW*" (DEC, 2004).

Table 4B.23
Surface Water Monitoring Program

Location [1]	Parameters	Frequency
Site (Meteorological Monitoring)	- Rainfall - Wind speed and direction - Temperature - Relative humidity - Solar Radiation	Recording every 15 minutes
Rail Loop Water Storages and Brine Storages Ponds	- Water Level - EC - pH - Turbidity - TDS - TSS - Metals - Anion and Cations	Monthly (until baseline is established) and then quarterly
Sediment Dams and Storage Dams	- Water Level - EC - pH - TSS - TDS - Turbidity - NFR - Total Organic Carbon - Grease and Oil - Nutrients	Daily during runoff events
PC, PC1, KC1US, KC1DS, KC2US, KC2DS, KCUS, KCDS[1]	- Water Level - EC - pH - TSS - TDS - Turbidity - NFR - Total Organic Carbon - Grease and Oil - Nutrients	Daily during runoff events
Note 1: see **Figure 1.4**		
Source: Modified after WRM (2009) – Table 10.1		

The existing monitoring program would also be extended to include the monitoring of the impact of mine subsidence on the various watercourses that cross the mine subsidence zone. The monitoring would include the following components.

- Each creek traversing a longwall panel would be surveyed at regular intervals to determine the ultimate level of the area.
- Photographs of the creek would be taken prior to mine subsidence and after mine subsidence following significant rainfall events to assess whether erosion has occurred.
- A log of when inspections occur (and photographs taken) would be kept together with an assessment of the changes in erosion.

The Proponent proposes to review the frequency of monitoring and range of parameters analysed after the first two years of the Longwall Project.

4B.3.8.2 Contingency Planning

Polluting Discharge from Pit Top Area Water Storages

Whilst the water management structures of the Mine Site have been designed to collect and store runoff generated by rainfall events up to the 5 day 95th %ile, it is still possible that rainfall events of greater magnitude may occur which result in water with elevated levels of sediment discharging from the designed water storages (SB4, SD2 or SD4). The Proponent would sample water discharging from the final discharge structures as licenced in EPL 12789 by DECCW (Currently SD2, SD4 and SD5) within 24 hours of discharge and analyse the water for suspended solids, turbidity, electrical conductivity, oil and grease, and pH. In the event that monitoring confirms elevated concentrations of any of these parameters (in comparison to Environment Protection Licence criteria or ANZECC, 2000 trigger levels), one or more of the following measures would be adopted.

- The relevant government agencies would be advised. Salient preceding weather information would also be provided.
- Additional flocculants would be used to expedite settlement of sediments.
- The sediment basins would be enlarged or additional sediment basins constructed.
- An additional storage dam would be constructed downstream which would become the new site discharge point and monitoring location. DECCW would be advised to enable amendment to any Environment Protection Licence.

Polluting Discharge from Groundwater or Brine Storage Ponds

In the event that one of the groundwater or brine storage ponds or other saline water transfer or storage structure is breached, one or a combination of the following measures would be implemented.

- Dewatering from the underground workings would be transferred to an intact and lined storage structure along with any water remaining in the breached pond. As a last resort and in the event no suitable storage facility is available, the underground workings would be evacuated and dewatering ceased until a suitable storage area is identified.

- The breached pond or pipe would be repaired immediately and inspected by a suitably qualified person prior to re-integration into the saline water management system.
- The water cart would be used to transfer non-saline water to the area of the spill to flush and dilute the water discharged. As far as practical, at least four times the volume of the spilled water would be used to flush the downstream environment.
- Downstream vegetation would be monitored for any impacts of increased salinity and treated appropriately.

4B.4 ECOLOGY

The ecological assessment was undertaken by Ecotone Ecological Consultants Pty Ltd. The full assessment is presented as Volume 1, Part 4 of the Specialist Consultant Studies Compendium, with the relevant information from the assessment summarised in the following subsections. The full assessment is referred to as Ecotone (2009) throughout this document.

4B.4.1 Introduction

Based on the risk analysis undertaken for the project (see Section 3.3 and **Table 3.5**), the potential ecological impacts requiring assessment and their **unmitigated** risk rating are as follows.

- Disturbance to native vegetation / habitat within nominated areas (high risk).
- Disturbance to native vegetation / habitat outside nominated areas (moderate risk).
- Disturbance to threatened flora / fauna and endangered ecological communities (high risk).
- Disturbance leading to local population reduction (high risk).
- Disturbance leading to local extinction(s) (high risk).
- Reduced local biodiversity (moderate risk).
- Reduced regional biodiversity (high risk).

In addition, the Director-General's Requirements issued by the DoP identified "Biodiversity" as one of the key issues requiring assessment. The assessment of biodiversity is required to include:

- accurate estimates of any vegetation clearing associated with the Longwall Project;
- a detailed assessment of the potential impacts of the Longwall Project particularly from subsidence impacts on threatened species, populations, ecological communities or their habitat; and
- a description of any measures that would be implemented to maintain or improve biodiversity values in the region.

In accordance with the DGRs, the assessment of Ecotone (2009) was undertaken in accordance with the draft *Guidelines for Threatened Species Assessment under Part 3A of the Environmental Planning and Assessment Act 1979* (DEC, 2005) and has considered the following guideline documents and planning policies.

- "The NSW State Groundwater Dependent Ecosystem Policy" (DLWC, 2002).
- "Policy and Guidelines – Fish Friendly Waterway Crossings" (NSW Fisheries, undated).
- State Environmental Planning Policy No. 44 – Koala Habitat Protection.

The following subsections describe and assess the existing threatened species and their habitat, identify the ecological management issues, proposed controls, safeguards and mitigation measures for the threatened species and their habitat.

4B.4.2 Study Methodology and Outcomes

4B.4.2.1 Desktop Assessment

The desktop component of the ecological assessment, completed in satisfaction of Step 1 of the *Draft Guidelines for Threatened Species Assessment* (for projects assessed under Part 3A of the *Environmental Planning and Assessment Act 1979*) (DEC / DPI, 2005) (hereafter referred to as the Part 3A Guidelines), involved a review of flora and fauna surveys and assessments that have previously been conducted in the vicinity of the Mine Site and a web-based search of the documented records held on the Department of Environment and Climate Change, Atlas of NSW Wildlife Database and the Rare or Threatened Australian Plants (ROTAP) database (Briggs & Leigh 1996). In particular, Threatened flora and fauna species recorded within the Baan Baa, Narrabri, Boggabri and Horton 1: 100 000 map sheets were identified (hereafter referred to as "the region").

Subsequently, the records of the region were considered over a reduced area within a 20km radius from the centre of the Mine Site (hereafter referred to as "the locality").

Lists of threatened species known or predicted to occur within the Liverpool Plains (Part B), Pilliga (Part A) and Pilliga Outwash Catchment Management Authority (CMA) subregions of the BIOCLIM model were also reviewed (Busby, 1991). This modelling is based on areas of suitable climate for a species, although this does not mean that its required habitat would necessarily be present within the study locality.

4B.4.2.2 Field Surveys

4B.4.2.2.1 Introduction

In satisfaction of Step 2 of the Part 3A Guidelines, field surveys were completed by Ecotone across the Mine Site on 19 January 2009 and between 20 and 23 January 2009.

4B.4.2.2.2 Flora Surveys

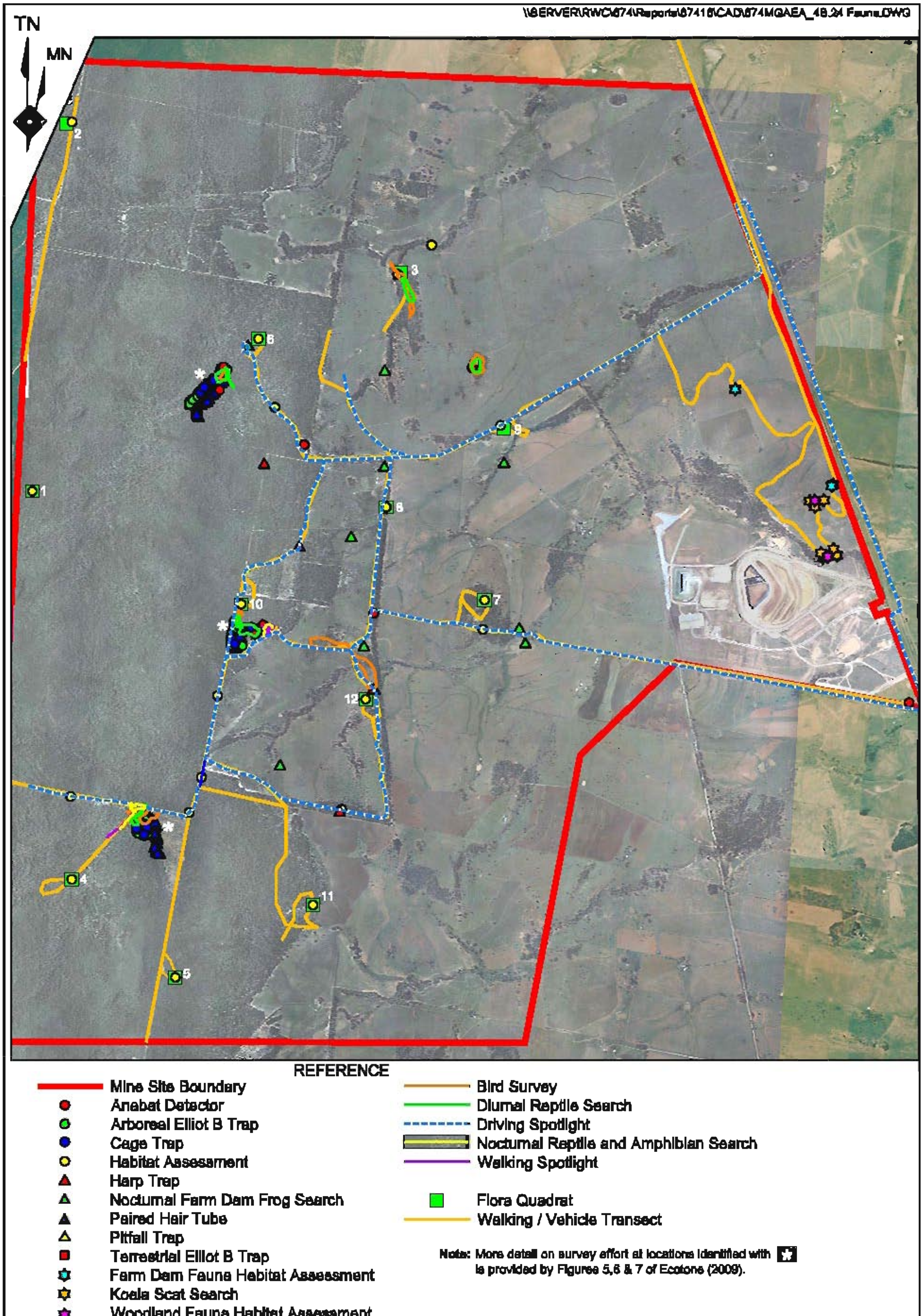
An initial and general site inspection of the Mine Site was undertaken on 19 January 2009, followed by four full days of field survey between the 20 to 23 January 2009 to document the flora and vegetation communities of the Mine Site. A total of 12 survey sites were selected, chosen to ensure that representative vegetation communities were sampled, for detailed survey and sampling. **Figure 4B.24** identifies the locations of the 12 vegetation survey sites. The methodology at each survey site involved the following components.

- A 'loop' transect on foot ranging in length from approximately 600m to 1km within which all vascular flora species were recorded and the variation in the structure and condition of the vegetation generally was noted.
- One 20m x 20m flora quadrat at a representative point along the loop transect within which vegetation structure (strata, heights and cover), soil type, topography, extent of modification, disturbance, weed invasion and condition of the vegetation generally was recorded. All vascular flora species were recorded within the quadrat.
- A targeted search, using the random meander method (Cropper, 1993), for any Threatened flora species listed under the *Threatened Species Conservation Act 1995* (TSC Act) or *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for which potential habitat was available and which were considered to have at least a moderate likelihood of occurring and being detected at the time of the survey.

The survey sites were supplemented by general traverses over the entire Mine Site, mainly by vehicle, with some short random meanders on foot to assess the general vegetation type and condition throughout the study area in locations other than the survey sites.

A supplementary flora survey was undertaken over the Brine Storage Area (not included in the original field surveys) and proposed Water Pipeline Route between the Mine Site and Namoi River on 6 and 7 August 2009. A total of five survey sites were selected, chosen to ensure that representative vegetation communities were sampled, for detailed survey and sampling. The methodology at each survey site involved the same components as described for the 12 sites of the January 2009 field survey. **Figure 4B.25** identifies the locations of the five additional vegetation survey sites.

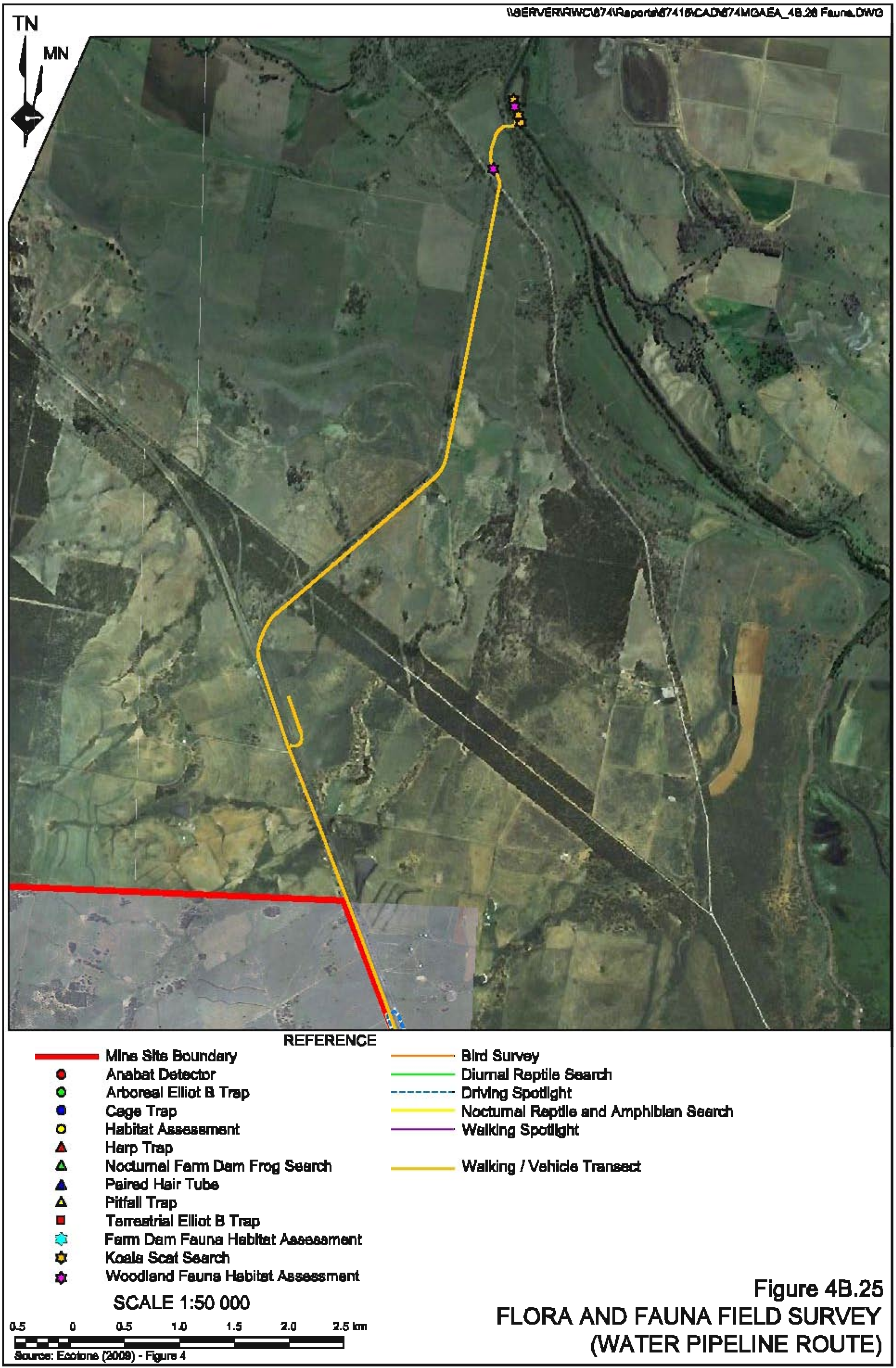
The survey methodology broadly complied with current best practice flora survey guidelines for a full impact assessment where practically possible, such as the *Draft Threatened Biodiversity Survey and Assessment Guidelines* (DEC, 2004). **Table 4B.24** outlines the level of compliance with the DEC (2004) recommended level of survey effort, based on the area covered by each vegetation community identified on the Mine Site (Stratification Unity).



Note: More detail on survey effort at locations identified with * is provided by Figures 5,6 & 7 of Ecotone (2009).

Source: Ecotone (2009) - Figure 4

Figure 4B.24
FLORA AND FAUNA FIELD SURVEY
(MINE SITE)



Source: Ecotone (2009) - Figure 4

Figure 4B.25
FLORA AND FAUNA FIELD SURVEY
(WATER PIPELINE ROUTE)

Table 4B.24
Compliance with Suggested Flora Survey Effort

Method	Suggested Minimum Effort[1]		As Carried Out
Transects (or Traverse)	Community 1[2]	20 traverses of 100m each = 2200m total traverse length	6 traverses of average 800m each = 4800m total traverse length
	Community 2[2]	3 traverses of 100m each = 300m total traverse length	3 traverses of average 800m each = 2400m total traverse length.
	Community 3[2]	2 traverses of 100m each = 200m total traverse length	2 traverses of average 800m each = 1600m total traverse length.
	Community 4[2]	1 traverse of 100m	1 traverse of approx. 800m
Random Meander	30 minutes for each quadrat sampled within the same stratification unit as the quadrat		Done
Plot-based (Quadrat) Survey	Community 1[2]	20 quadrats	6 quadrats[3]
	Community 2[2]	3 quadrats	3 quadrats
	Community 3[2]	2 quadrats	2 quadrats
	Community 4[2]	1 quadrat	1 quadrat

Note 1: Community = Stratification Unit
Note 2: Distribution of identified Community types are presented on **Figures 4B.26** and **27**
Note 3: Due to uniformity of stratification, greater survey effort was allocated to transect length than quadrat number

Source: Modified after Ecotone (2009) – Table 5

4B.4.2.2.3 Fauna Surveys

Mine Site

Field surveys for fauna were undertaken between 19 and 23 of January 2009. A summary of the survey methods and strategies is provided as follows.

Habitat Assessment

The type and condition of potential habitat for fauna species was investigated and recorded. Habitat features identified included:

- topographic features;
- the dominant vegetation community composition, structure and condition at all strata levels, ie. from ground to canopy cover;
- groundcover type and percentage cover;
- presence, location and quality of water sources;
- type and size of tree hollows;
- presence, number and condition of unique habitat features (such as caves, crevices, loose tree bark, rocks on rock and mistletoe); and
- level of disturbance.

During the habitat assessment, all opportunistic observations of fauna or faunal activity were recorded, including visual and auditory recognition of fauna species and identification of evidence of faunal activity (eg. nests, diggings, scratch marks, droppings).

Trapping Sites

Three trapping sites were established in the woodland areas of the western half of the Mine Site (see **Figure 4B.24**). The trapping sites were selected to sample the representative woodland vegetation types present and to cover the area of the Mine Site.

At each of the three trapping sites, the following trapping effort was undertaken.

- 25 terrestrial Elliott A and 10 arboreal Elliott B traps.
- Five terrestrial cage traps.
- One 30m pitfall fence with three buckets.
- 20 terrestrial medium, 20 terrestrial small and 10 arboreal small hair tubes.

Bird Surveys

Each survey comprised one person hour of survey, ie. either by a single observer for one hour or by two observers for 30 minutes with birds identified either visually or by call. Where possible, bird surveys were undertaken during early morning or late afternoon. Two bird surveys were completed at each of the trapping sites and three additional bird surveys were completed at opportunistic habitat locations (see **Figure 4B.24**). Bird sightings were also recorded opportunistically during all other survey activities.

Reptile and Amphibian Searches

Each survey comprised one person hour of survey, ie. either by a single observer for one hour or by two observers for 30 minutes, both during the day and at night. The nocturnal searches included both terrestrial and aquatic habitats. Where possible, diurnal searches were undertaken during early to mid morning or mid to late afternoon and nocturnal searches between early and mid evening. Two diurnal and one nocturnal search were completed at each of the trapping sites and two additional diurnal searches were completed at opportunistic habitat locations (**Figure 4B.24**).

Spotlight Surveys

Both walking and driving spotlight surveys were undertaken between dusk and 1:00am over a single person hour (two observers) on each occasion. Both walking and driving spotlight surveys were undertaken at each of the three trapping sites, with driving spotlight surveys also undertaken across most of the Mine Site while travelling to and from trapping or other survey sites (**Figure 4B.24**).

Call Playback

Call playback for the following species was undertaken at dusk or during early evening at each of the trapping sites (see **Figure 4B.24**).

- Squirrel glider (*Petaurus norfolcensis*).
- Koala (*Phascolarctos cinereus*).
- Barking owl (*Ninox connivens*).
- Masked owl (*Ninox novaehollandiae*).
- Powerful owl (*Ninox strenua*).

Anabat Survey

Anabat detectors were used to record the echolocation calls of micro-bats at the three trapping sites for two nights and an additional opportunistic location for an additional night (see **Figure 4B.24**).

Brine Storage Area and Water Pipeline Route

A supplementary fauna survey was undertaken over the Brine Storage Area (not included in the original field surveys) and proposed water pipeline route between the Mine Site and Namoi River on 6 and 7 August 2009. The survey involved opportunistic fauna survey over the entire footprint of the proposed Brine Storage Area and water pipeline route including:

- recording of species sighted or heard;
- koala scat searches at the base of trees (1m radius);
- the opportunistic rolling of rocks and logs; and
- the identification of species presence from signs and traces such as scats and scratch marks.

Ecotone (2009) reports that the survey effort complied with that recommended by DEC (2004). The survey area for the supplementary survey is depicted on **Figure 4B.25**.

4B.4.3 Results of the Flora Surveys

4B.4.3.1 Regional Threatened Flora

Ecotone (2009) identified 17 threatened flora species as being known to occur within the region. Of these, only two have been recorded within the study locality (see **Table 4B.25**).

Table 4B.25
Rare or Threatened Flora Previously Recorded Within the Study Locality

Scientific Name	Status		Records (Region)	Records (Locality)
	TSC Act	EPBC Act		
Bertya opponens[1]	V	V	5	4
Boronia ruppii	E1	~	1	0
Bothriochloa biloba	U	V	3	0
Cadellia pentastylis	V	V	41	9
Cyperus conicus	E1	~	2	0
Dichanthium setosum	V	~	1	0
Digitaria porrecta	E1	E	3	0
Hakea pulvinifera	E1	E	9	0
Haloragis exalata	V	V	2	0
Homopholis belsonii	U	V	4	0
Lepidium aschersonii	V	V	28	0
Philotheca ericifolia	V	V	2	0
Polygala linariifolia	E1	~	1	0
Pomaderris queenslandica	E1	~	1	0
Pterostylis cobarensis	V	V	1	0
Rulingia procumbens	V	V	3	0
Swainsona murrayana	V	V	1	0

Note 1: *=Bertya sp. A Cobar-Coolabah*

Status (TSC Act): refers to the NSW *Threatened Species Conservation Act* 1995 (TSC)
E1 Schedule 1, Part 1: Endangered Species
V Schedule 2: Vulnerable Species
U Unprotected (not listed in Schedule 13 of the NPW Act 1974 or in the TSC Act 1995)

Status (EPBC Act): refers to the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC)
E Endangered Species
V Vulnerable Species

Source: Modified after Ecotone (2009) – Table 2

One NSW Wildlife Atlas record of *Bertya opponens* occurs within the Mine Site, although it is noted that its position was only given to an accuracy of 1 000m. In recognition of this record, the noted location was used as the basis for the location of Flora Quadrat 1 (see **Figure 4B.24**), and this species was particularly targeted during the survey at this site.

A total of 27 additional species previously recorded in the region are listed on the ROTAP database but are not protected under either the TSC Act or EPBC Act.

Two additional known or predicted flora species were identified following a review of the BIOCLIM database, namely:

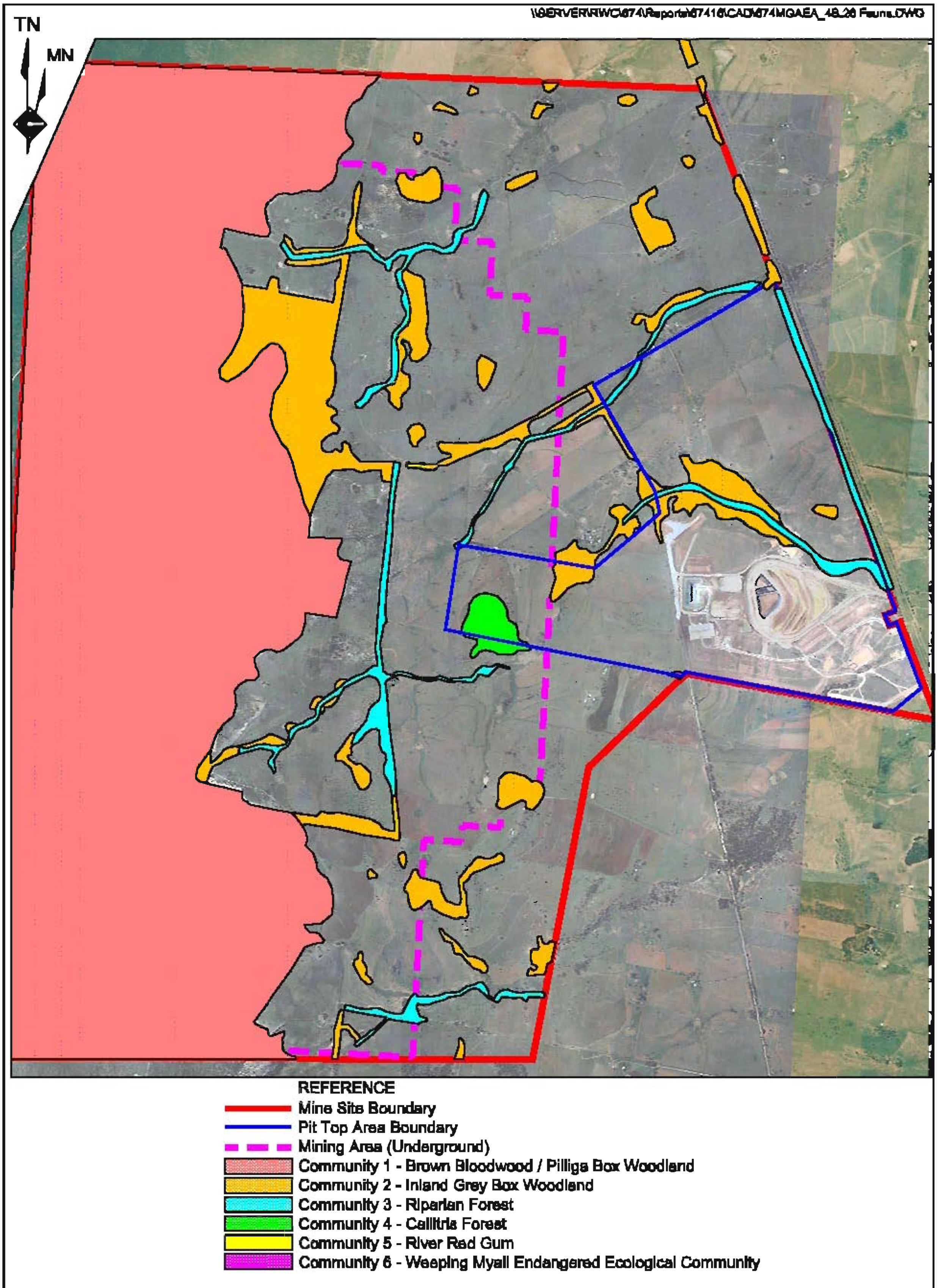
- *Thesium australe* (Austral Toadflax): known from Liverpool Plains (Part B) subregion; and
- *Tylophora linearis:* Predicted to occur in Pilliga (Part A) and Pilliga Outwash subregions

4B.4.3.2 Existing Vegetation

4B.4.3.2.1 Vegetation Communities of the Mine Site

Six broad natural or predominantly native vegetation community types occur within the Mine Site and water pipeline route (see **Figures 4B.25** and **4B.26**). These communities also reflect types of faunal habitat, with both listed as follows.

- Community 1 - Brown Bloodwood / Pilliga Grey Box / Red Ironbark Woodland (Sandstone Slopes Woodland).
  Occurring on the undulating sandstone slopes and ridgetops of the Mine Site on sandy / sandy loam or rocky soil, this community ranges from low mallee woodland with dense shrub layer to open forest with sparse shrub layer. The tree layer is mostly sparse and dominated by Brown Bloodwood, Pilliga Grey Box and Red Ironbark. A dense shrub layer of tall wattles is often present.
- Community 2 – Inland Grey Box / Bimble Box / Blakely's Red Gum Woodland (Lower Flats and Floodplain Woodland).
  This modified, partially cleared and disturbed woodland community is dominated by adapted to or tolerant of drier conditions, with occasional inundation due to flooding. Tree species include Bimble Box, Western Grey Box and Blakely's Red Gum. Most areas of this community have been modified by agricultural activities with partial clearing of the shrub layer and at least occasional grazing of the groundcover.
- Community 3 – River She Oak / Belah / Inland Grey Box Forest (Riparian Forest).
  This community has been partially cleared but remains a relatively intact open forest to woodland dominated by casuarinas and species adapted to higher water availability including River She Oak, Belah, Blakely's Red Gum, Spiny Mat Rush over very dense shrub and sparse ground cover.

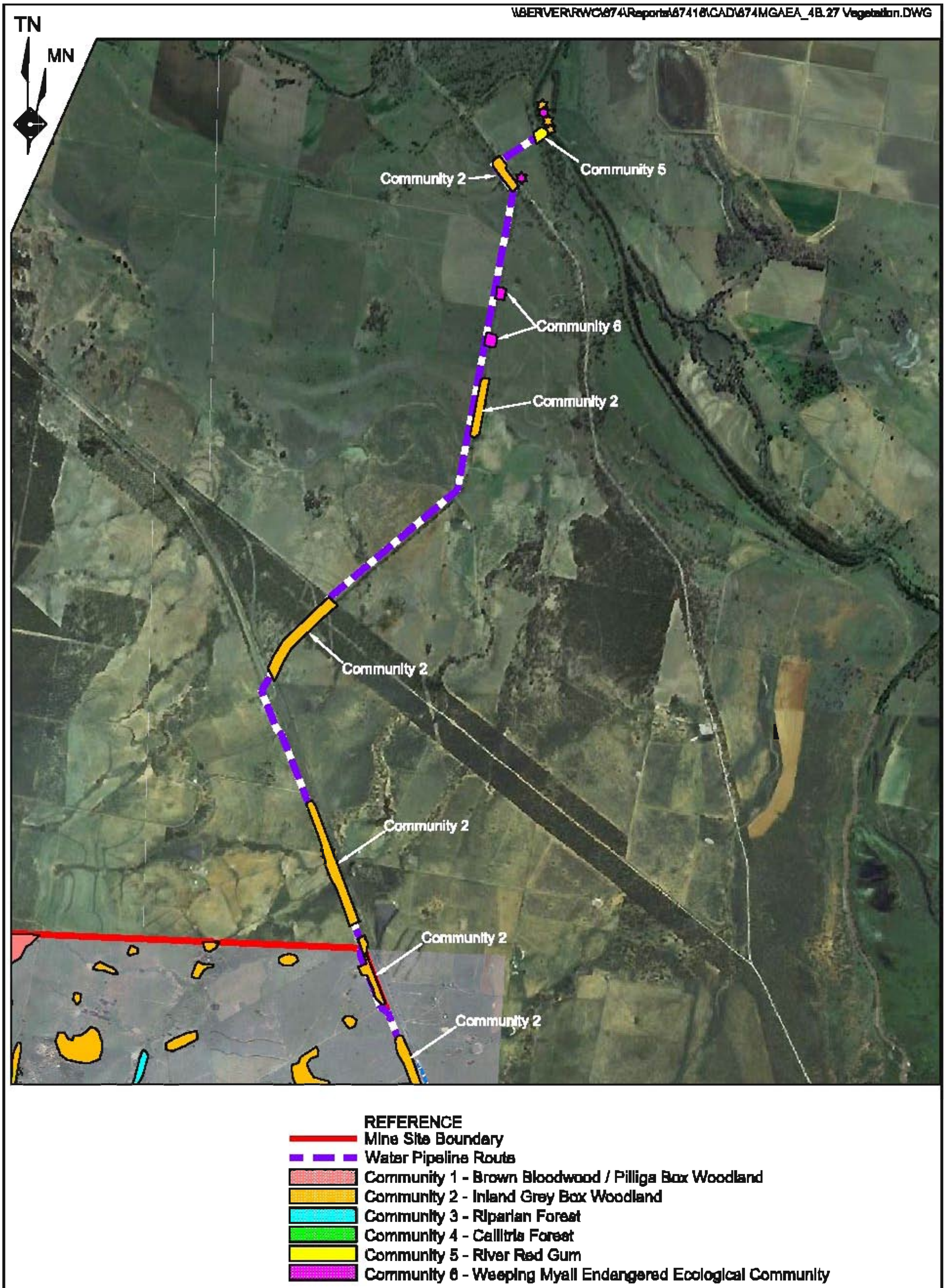


SCALE 1:50 000

0.5 0 0.5 1.0 1.5 2.0 2.5 km

Source: Ecotone (2009) - Figure 4

Figure 4B.26
VEGETATION COMMUNITIES OF THE MINE SITE



Source: Ecotone (2008) - Figure 4

Figure 4B.27
VEGETATION COMMUNITIES OF THE WATER PIPELINE ROUTE

- Community 4 – White Cypress Forest.
  This simplified community consists almost entirely of White Cypress Pine, *Callitris glaucophylla*, with no shrub layer and a sparse, grazed ground layer.
- Community 5 – River Red Gum Riparian Open Forest / Woodland.
  This community was identified on the banks of the Namoi River and has been partially cleared. While modified it remains a relatively intact open forest to woodland dominated by river red gum and species adapted to wetter areas or permanently available water. Shrub and ground layers are variable in density.
- Community 6 – Weeping Myall Woodland.
  Identified as remnant patches of woodland on an existing farm track along the southern edge of the Pit Top Area and within the road reserve of Old Narrabri Road of the water pipeline route. Modified by clearing, the remnant patches of this community contain weeping myalls (*Acacia pendula*) but lack a native understorey.

A seventh artificial (cleared/semi-cleared or cultivated) community makes up the balance of the surface facilities, namely:

- Community 7 – Cleared Open Grassland / Cropland / Weedy areas / Cultivated Gardens.
  This community occupies the majority of the eastern two-thirds of the Mine Site. It is composed predominantly of cleared open pasture without trees, or isolated paddock trees with groundcover generally to a height of less than 50cm. Cropped fields and artificially planted gardens around homesteads are also included in this artificial community. The community is regularly grazed and/or ploughed and cultivated. The community has no flora conservation significance.

As illustrated on **Figure 4B.26**, Community 1 generally occupies the western third of the Mine Site, whilst Communities 2, 3 and 4 are spread over small areas of the eastern two thirds of the Mine Site. Community 5 occurs along the Namoi River at the proposed discharge point of the water pipeline. One small patch of Community 6 was identified along a farm track on the Mine Site (on the southern boundary of the Pit Top Area) with additional patches identified within the road reserve of the water pipeline route. Community 7 is the largest single community in area, and make up the balance of the eastern two thirds of the Mine Site.

The flora species diversity across the entire Mine Site was observed to be high with 209 flora species from 60 families identified. A total of 22 species of introduced flora were identified, representing approximately 11% of the total species identified.

No threatened flora species listed under either the TSC Act or EPBC Act or rare species on the ROTAP database were detected on the Mine Site during the flora survey.

The condition of the vegetation varied significantly across the Mine Site. The natural vegetation of Community 1 over the western portion of the Mine Site was reported by Ecotone (2009) to be often close to pristine, with few or no exotic species (although some evidence of past logging and/or clearing was evident). Overall, the condition of the vegetation was considered good by Ecotone (2009), even in the grazed pasture areas with patches of remnant tree cover where there was moderate to high native species diversity and a low diversity and cover of weeds.

4B.4.3.2.2 Water Pipeline Route

Figure 4B.27 displays the presence of patches of four of the vegetation communities identified on the mine site, namely:

- Community 2: Inland Grey Box / Bimble Box / Blakely's Red Gum Woodland.
- Community 5: River Red Gum Riparian Open Forest / Woodland.
- Community 6: Weeping Myall Woodland.
- Community 7: Cleared Open Grassland / Cropland / Weedy areas / Cultivated Gardens.

Each of these communities within the water pipeline route contain similar tree, shrub and grass species to those on the Mine Site.

4B.4.3.3 Noxious Weeds

Weeds were recorded almost exclusively in the cleared areas of Communities 2 to 5 over the eastern two thirds of the Mine Site. Six of these species are declared Noxious Weeds in the Narrabri Shire Council control area, pursuant to the *Noxious Weeds Act 1993*, namely:

- Bathurst burr (*Xanthium spinosum*) – Class 4[4];
- Creeping oxalis (*Oxalis corniculata*) – Class 5[5];
- Mother of millions (*Bryophyllum delagoense*) – Class 4;
- Noogoora burr (*Xanthium occidentale*) – Class 4;
- Prickly pear (*Opuntia stricta*) – Class 4; and
- Spiny burrgrass (*Cenchrus longispinus*) – Class 4

4B.4.3.4 Flora of Conservation Significance

Endangered Ecological Communities

Of the vegetation communities identified on the Mine Site, Community 2, qualifies as the TSC Act listed Endangered Ecological Community (EEC) *Inland Grey Box Woodland in the Riverina, NSW Western Slopes, Cobar Peneplain, Nandewar and Brigalow Belt South Bioregions.*

Ecotone (2009) reports that a second EEC listed by the TSC Act, *Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions,* occurs in marginal form only in scattered parts of Community 1 over the western slopes of the Mine Site. A third EEC listed by the TSC Act, *Myall Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain, Murray-Darling Depression, Riverina and NSW South western Slopes bioregions*

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[4] Class 4: Locally Controlled Weeds: The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority.

[5] Class 5: Restricted Plants: The requirements in the *Noxious Weeds Act 1993* for a notifiable weed must be complied with.

was also identified by Ecotone (2009), both as a narrow patch of weeping myalls (*Acacia pendula*) along both sides of a dirt road on a more elevated part of the central plains area on the Mine Site and at isolated locations within the road reserve of the water pipeline route (see **Figure 4B.27**). On the basis of these occurrences, other remnant occurrence of the species could occur elsewhere on the Mine Site.

Threatened Species

As noted in Section 4B.4.3.2, no threatened or rare flora species were detected on the Mine Site during the flora survey. Based on the identified habitat of the vegetation communities of the Mine Site, Ecotone (2009) assessed the likelihood of those species previously identified within the locality, or predicted to occur within the locality by BIOCLIM or the Protected Matters Report of the EPBC Act.

Only one species, *Bertya opponens*, was assessed as having a high likelihood of occurring. One species, *Cadellia pentastylis*, is assessed as having a moderate likelihood of occurring and a further species, *Lepidium aschersonii*, a low to moderate likelihood of occurring. All remaining species are assessed as having a low or minimal likelihood of occurring.

General Significance of the Flora of the Mine Site

The flora of the Mine Site is significant in terms of threatened species legislation, as one threatened flora species (*Bertya opponens*) has been identified within the Mine Site, the presence of one EEC has been confirmed with two further EECs identified in marginal or very small remnant form.

More generally, the Sandstone Slopes Woodland (Community 1) is contiguous with the large area of natural vegetation in Jacks Creek State Forest beyond the western boundary of the Mine Site. This community is of a high quality and represents a large remnant of practically undisturbed, weed free natural vegetation. It has high species diversity, and is a sharply contrasting vegetation type to the community on the low-lying flats and floodplains. The natural vegetation on the low-lying flats and floodplains of Communities 2, 3 and 4 is much more disturbed by past and current clearing and grazing, however, retains a high native species diversity, particularly in the ground layer. These communities are disturbed remnants of the once extensive floodplain communities that would have occurred widely on the flat areas that are now largely cleared for grazing and agriculture.

All the remnant natural vegetation within the site has ecological value in that it facilitates movement of fauna and exchange of genetic material between native flora species locally, from one part of the Mine Site to another via remnant connections and riparian corridors (including scattered trees in some areas). Although loss or modification of this vegetation may not isolate any populations of flora or fauna, it could have local impacts on natural populations and compromise movements.

4B.4.4 Fauna

4B.4.4.1 Regional Threatened Fauna

A total of 27 threatened terrestrial fauna species have previously been recorded within the locality, comprising 19 bird, seven mammal and one reptile species (see **Table 4B.26**).

Table 4B.26
Threatened Fauna Previously Recorded Within the Study Locality

Scientific Name	**Common Name**	**Status**		**Records (Locality)**	**Records (within 10km)**
		TSC Act	**EPBC Act**		
Alectura lathami	Australian Brush-turkey	E2	~	8	2
Anseranas semipalmata	Magpie Goose	V	~	1	0
Ephippiorhynchus asiaticus	Black-necked stork	E1		2	2
Hamirostra melanosternon	Black-breasted Buzzard	V	~	2	1
Rostratula benghalensis australis	Painted Snipe (Australian subspecies)	E1	V, Mi	1	1
Calyptorhynchus lathami	Glossy Black-Cockatoo	V	~	7	6
Neophema pulchella	Turquoise Parrot	V	~	10	1
Polytelis swainsonii	Superb Parrot	V	V	1	1
Tyto novaehollandiae	Masked Owl	V	~	1	1
Ninox connivens	Barking Owl	V	~	7	5
Climacteris picumnus	Brown Treecreeper	V	~	19	12
Climacteris picumnus victoriae	Brown Treecreeper (eastern subspecies)	V	~	1	0
Pyrrholaemus saggitatus	Speckled Warbler	V	~	10	9
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	V	~	1	0
Xanthomyza phrygia	Regent Honeyeater	E1	E, Mi	1	1
Melanodryas cucullata	Hooded Robin	V	~	3	2
Pomatostomus temporalis temporalis	Grey-crowned Babbler (eastern subspecies)	V	~	5	5
Stagonopleura guttata	Diamond Firetail	V	~	4	0
Phascolarctos cinereus	Koala	V	~	17	6
Petaurus norfolcensis	Squirrel Glider	V	~	2	1
Macropus dorsalis	Black-striped Wallaby	E1	~	1	0
Petrogale penicillata	Brush-tailed Rock-wallaby	E1	V	8	0
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	V	~	5	3
Nyctophilus timoriensis	Eastern Long-eared Bat	V	V	3	2
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	2	1
Hoplocephalus bitorquatus	Pale-headed Snake	V	~	1	0

Status (TSC): refers to the NSW *Threatened Species Conservation Act* 1995 (TSC)
E1 Schedule 1, Part 1: Endangered species
CE Schedule 1A, Part 1: Critically endangered species
V Schedule 2: Vulnerable species

Status (EPBC): refers to the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC)
E Endangered Species
V Vulnerable Species
Mi Migratory Species

At the date of submission, the following preliminary determinations for listing under the TSC Act exist on the following species known to occur in the locality (recorded during surveys for this project or recorded on the Atlas of NSW Wildlife):

- Little lorikeet (*Glossopsitta pusilla*): proposed vulnerable species listing;
- Little eagle (*Hieraaetus morphnoides*): proposed vulnerable species listing; and
- Varied sittella (*Daphoenositta chrysoptera*): proposed vulnerable species listing.

An Australian Brush-turkey population in the Nandewar and Brigalow Belt South Bioregions is located within the locality.

4B.4.4.2 Mine Site Fauna

A habitat assessment of the various components of the Mine Site was undertaken by Ecotone (2009). The habitat assessment identified four primary fauna habitat types, all of which occurred on the Mine Site (see **Figure 4B.28**) and three of which occur along the water pipeline route.

- Woodland areas[6].
- Open areas comprised of pasture and/or cropping paddocks[6].
- Drainage lines[6].
- Farm dams.

A total of 156 fauna species were recorded within the study area during the field surveys, comprising 93 birds, 37 mammals, 16 reptiles and ten frogs. Nine introduced species (two birds and seven mammals) were recorded.

Notably, the drainage lines of the Mine Site (Kurrajong and Pine Creeks and their tributaries) were inspected by Ecotone (2009) who reported that these drainage features comprise little more than dry drainage lines lacking pools of semi-permanent or permanent water. No aquatic vegetation was recorded and no fish habitat was identified or considered likely to occur.

4B.4.4.3 Fauna of Conservation Significance

Fourteen Threatened fauna species listed on the TSC Act were recorded during field surveys across the Mine Site (see **Figure 4B.28**).

- Pale-headed snake.
- Glossy-black cockatoo.
- Turquoise parrot.
- Superb parrot.
- Speckled warbler.
- Grey-crowned babbler.
- Eastern pygmy possum.
- Diamond firetail.
- Koala.
- Delicate mouse.
- Black-striped wallaby.
- Eastern long-eared bat.
- Little pied bat.
- Yellow-bellied sheathtail-bat.

Of the fourteen threatened fauna species, the Delicate mouse and Black striped wallaby are the only endangered species (TSC Act) with the 12 remaining species listed as vulnerable on the TSC Act.

The Varied sittella, for which a preliminary determination under the TSC Act for vulnerable status has been completed, was also identified on the Mine Site. An additional two threatened species, the squirrel glider and spotted-tailed quoll, are likely to occur but were not recorded during field surveys.

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[6] Occurs along the water pipeline route.

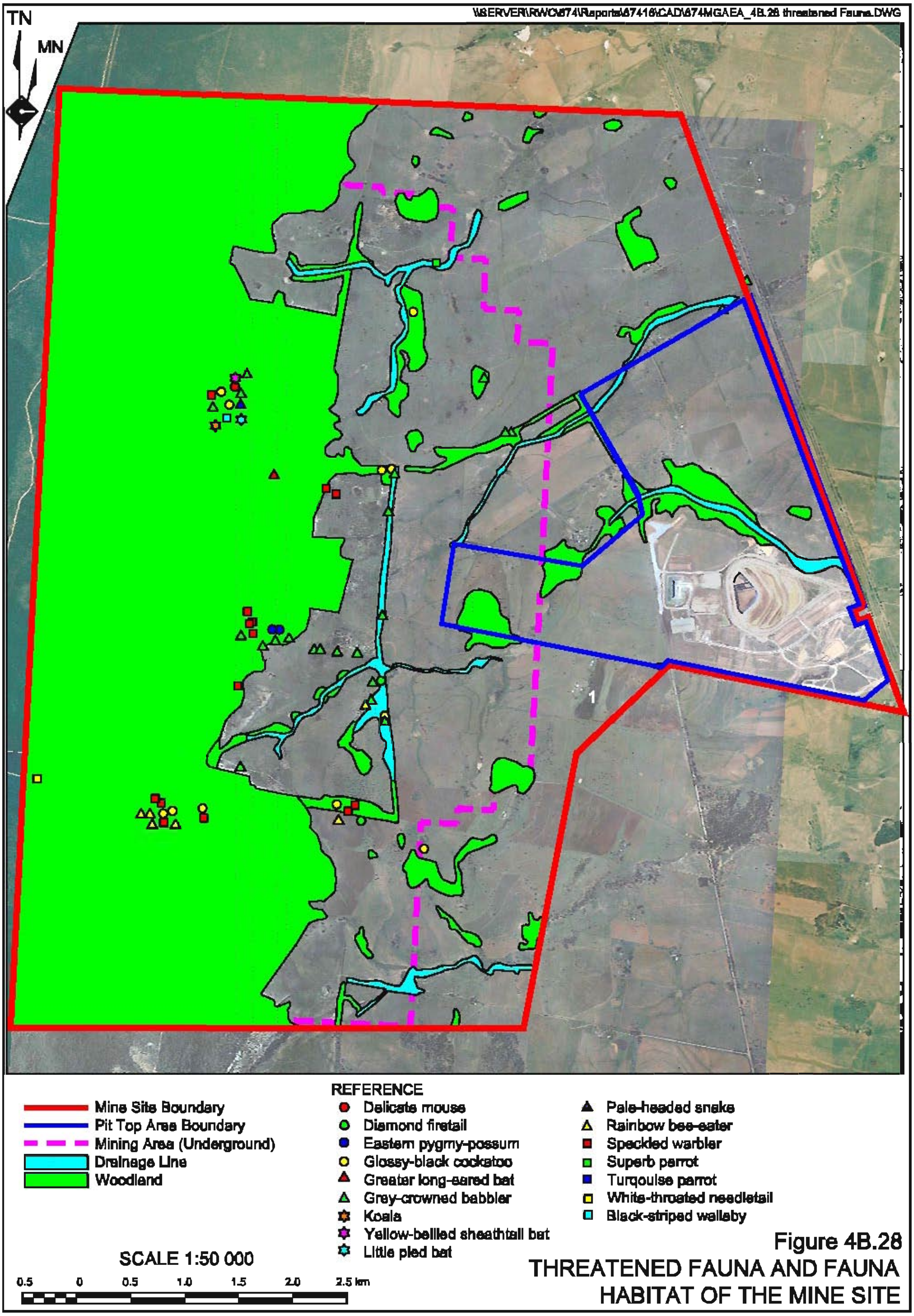

Figure 4B.28
THREATENED FAUNA AND FAUNA HABITAT OF THE MINE SITE

Six threatened or migratory species listed within the *Environment Protection and Biodiversity Conservation Act* (EPBC Act) were recorded during field surveys, namely:

- superb parrot[7];
- delicate mouse[7];
- white-throated needletail;
- eastern long-eared bat[7];
- rainbow bee-eater; and
- yellow-bellied sheathtail-bat[7].

Potentially suitable habitat exists across the Mine Site for a further 20 threatened or migratory species that were not identified during field surveys (Ecotone, 2009).

4B.4.5 Potential Impacts of the Longwall Project

4B.4.5.1 Vegetation Clearing and Habitat Loss

Section 2.4.9 provides a detailed summary of the surface disturbing activities associated with the proposed Longwall Project. It has been estimated that up to 705ha of the Mine Site would be disturbed by activities such as the construction of mine ventilation shafts, gas drainage, extension of the Pit Top Area, development of the Reject Emplacement Area, Brine Storage Area and construction of access tracks and power line corridor across the Mine Site.

Over the eastern two thirds of the Mine Site, where Community 7 is the dominant vegetation type, the majority of this disturbance would be able to be restricted to the cleared lands of Community 7. However, the Mining Area of LW7 to LW20 includes significant areas of remnant vegetation (predominantly Community 1) where it would not be possible to avoid the disturbance to native vegetation. While the exact location of surface disturbing activities such as ventilation shaft construction and gas drainage cannot be exactly plotted, as underground and mining conditions at the time would dictate the exact location of these activities, **Figure 4B.29** presents the estimated location of all surface disturbance over the life of the mine. **Table 4B.27** provides a summary of the areas of disturbance of each vegetation community based on this estimate.

Based on the results of the desktop and field surveys of the Mine Site, there are only three Threatened flora species that are considered as potentially occurring on the Mine Site which could be disturbed as a result of the proposed surface disturbing activities. Habitat for up to 37 fauna species, 15 of which were identified on the Mine Site, would be disturbed. Section 4B.4.6 describes the management measures to minimise the impact of the proposed clearing and habitat loss and Section 4B.4.7 evaluates the residual impact on the 40 threatened species potentially affected (in accordance with Step 3 of Part 3A Guidelines).

Table 4B.27
Estimated Disturbance to Native Vegetation Associated with the Longwall Project

Surface Disturbing Activity	Area of Disturbance (ha) of Communities					
	1	2	3	4	6	Total
Ventilation Fan Sites	13.0	1.0	0	0	0	17.0
Pre-drainage Sites	88.6	11.2	0.6	1.0	0	101.4
Goaf Gas Drainage Sites	62.0	8.0	3.0	1.0	0	74.0
Internal Access Roads, Power Lines and Service Corridors	15.3	2.7	0.5	0.2	0	18.7
Pit Top Area	0	1.9	0	0.5	0	2.4
Total	**178.9**	**24.8**	**4.1**	**2.7**	**0**	**210.5**

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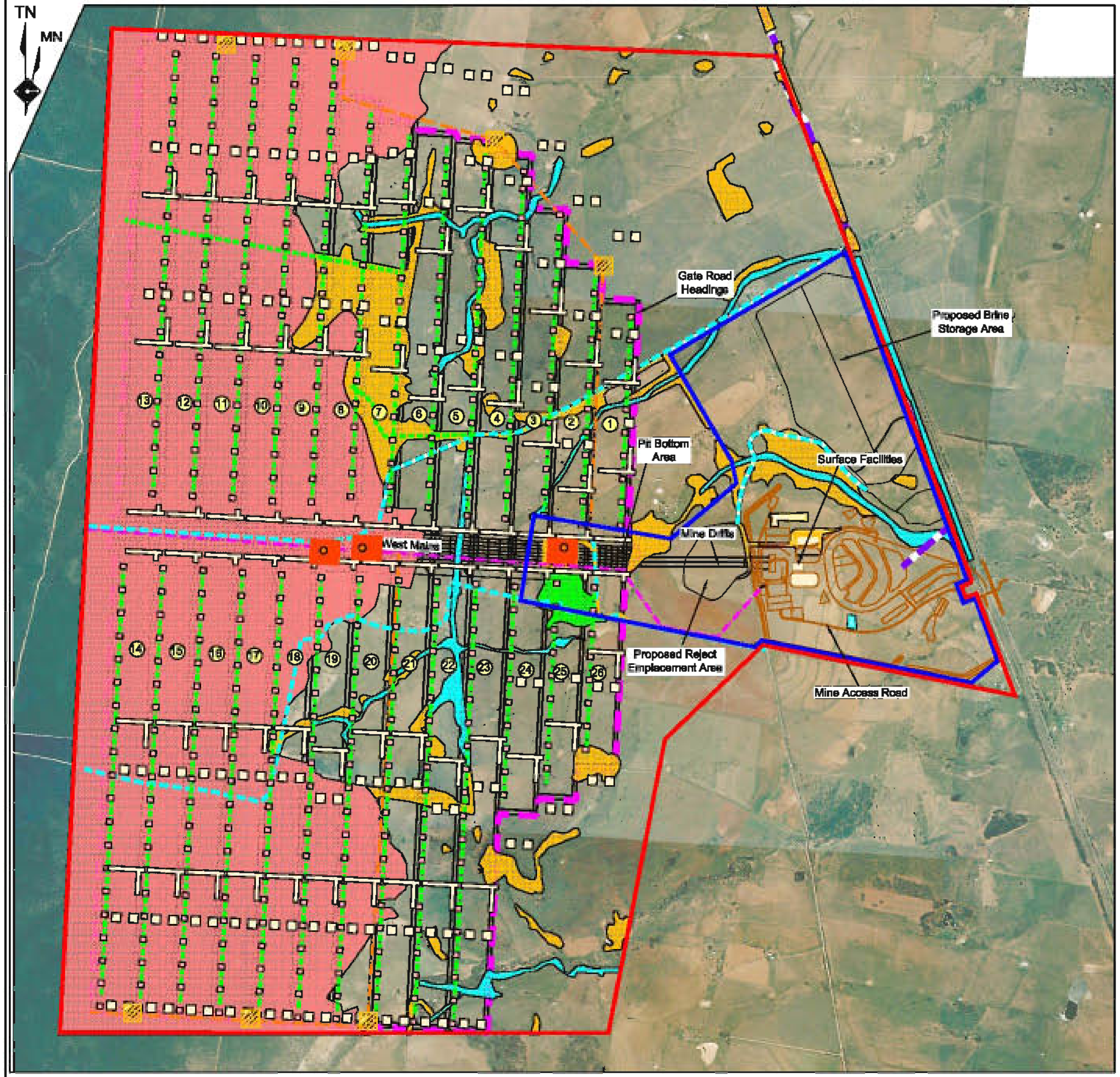
[7] Also listed under the TSC Act.

\\SERVER\RWC\674\Reports\67416\CAD\674MGAEA_4B.29 Surface Dist.DWG



REFERENCE
- 🟥 Mine Site Boundary
- 🟦 Pit Top Area Boundary
- Limit of Longwall Mining Area
- ① Longwall Panel No.
- Underground Gate Road
- Water Pipeline Route
- Cadastral Boundary
- Contour (m AHD)(Interval = 10m)
- Creek / Drainage Line
- Approved Disturbance within the Pit Top Area
- Area of Proposed Stage 2 Surface Disturbance
- Proposed All Weather Unsealed Access Road
- Proposed Stage 2 Access for Goaf Drainage
- Proposed Power Line
- Proposed Power Line Advancing with Mine
- 🟥 Ventilation Shaft Area
- ● Proposed Ventilation Shaft Location* [1]
- ⊙ Proposed Rear of Panel Ventilation Shaft
- ☐ Proposed Goaf Drainage Borehole Site
- Proposed Gas Production Site
- ☐ Proposed Pre-drainage Borehole Site
- ▨ Community 1 - Brown Bloodwood / Pilliga Box Woodland
- ▨ Community 2 - Inland Grey Box Woodland
- ▨ Community 3 - Riparian Forest
- 🟩 Community 4 - Callitris Forest
- 🟨 Community 5 - River Red Gum
- ▨ Community 6 - Weeping Myall Endangered Ecological Community

Note *[1] : The exact location of the additional ventilation shafts would be determined during mine operations and would be based on measured gas desorption rates, actual ventilation requirements and surface features

SCALE 1:40 000
0.5 0 0.5 1.0 1.5 2.0 km

Base Photo Source: Geo-spectrum (Australia) Pty Ltd - Date of Photo: 5 December 2005

Figure 4B.29
INDICATIVE SURFACE DISTURBANCE FOR THE LONGWALL PROJECT

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