APPENDIX A
HYDROGEOLOGICAL ASSESSMENT
FINAL
HYDROGEOLOGICAL ASSESSMENT
COWAL GOLD MINE
EXTENSION MODIFICATION

Barrick Australia Limited

GEOTLCOV21910AW-AI
9 September 2013
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1 INTRODUCTION

This report presents a hydrogeological assessment conducted by Coffey Geotechnics Pty Ltd (Coffey) for Barrick Australia Limited’s (Barrick) Cowal Gold Mine (CGM) Extension Modification (the Modification). The Modification includes the continuation of open cut mining operations at the CGM for an additional operational life of five years.

Barrick proposes to lodge an Environmental Assessment (EA) to facilitate approval of the Modification under section 75W of the New South Wales (NSW) Environmental Planning and Assessment Act, 1979. A groundwater assessment is required to support the EA.

This report presents the results of a hydrogeological study of open pit mining, abstraction from the Bland Creek Palaeochannel Borefield (BCPB) and Eastern Saline Borefield (ESB) operated by Barrick as water supplies for mine operations and was prepared to support the EA of the Extension Modification.

This report provides an assessment of potential impacts caused by open pit mining and future groundwater extraction from the BCPB and ESB, under the Modification, on groundwater quality, and groundwater drawdown, and surrounding bores, and potential associated subsidence. The performance of the borefield in supplying water based on drawdown constraints is also assessed.

1.1 Modification Background

CGM is located within Mining Lease (ML) 1535 approximately 38 kilometres (km) north-east of West Wyalong on the western side of Lake Cowal in central NSW. The location of the CGM is shown in Figure 1.

The Development Consent (DA 14/98) for CGM has been modified on several occasions, the most recent being the April 2011 Modification (MOD 10).

The main activities associated with the development of the Modification would include:

- Continued development of open pit mining operations at the CGM, including expansion of the extent and depth of the open pit.
- Extension of the operational life of the CGM by an additional five years.
- Ongoing exploration activities within ML 1535.
- Continued and expanded development of the existing mine waste rock emplacements within ML 1535 for placement of mined waste rock over the life of the CGM, including:
  - raising the maximum design height of the Northern Waste Rock emplacement to 308 metres (m) Australian Height Datum (AHD);
  - raising the maximum design height of the Southern Waste Rock emplacement to 283 m AHD; and
  - extension of the Northern Waste Rock emplacement to the west with an additional disturbance footprint of approximately 39 hectares (ha).
- Ongoing utilisation of the existing process plant at the installed capacity to continue ore processing at a rate up to 7.5 million tonnes per annum.
• An increase in total gold production to approximately 3.8 million ounces.

• Continued and expanded development of the existing Tailings Storage Facilities (TSF) within ML 1535 for deposition of tailings produced over the life of the CGM, including raising the maximum design height of:
  
  - the Northern TSF to 248 m AHD; and
  - the Southern TSF to 255 m AHD.

• Continued utilisation of cyanide destruction in tailings prior to deposition in TSF.

• Continued and expanded development of soil stockpiles as well as development of a new mineralised waste stockpile.

• Continued operation of the existing saline groundwater supply bores within ML 1535 during suitable lake conditions.

• Continued use of water supplied by other existing approved external water supply sources (e.g. BCPB (formerly known as the Jemalong Borefield Area), ESB and Lachlan River water entitlements via the Jemalong Irrigation Channel).

• Continued use of existing CGM water management infrastructure with some additional works including:
  
  - redesign of the existing contained water storage D5; and
  - construction of a new water supply storage D10.

• Construction of a new pump station on the eastern side of Lake Cowal to improve the capacity/flow to the existing mine water supply pipeline, and associated diesel generator and access track.

• Minor upgrade works to the mine water supply pipeline including construction of a new pump station on the eastern side of Lake Cowal.

• Ongoing environmental monitoring.

• Other associated minor infrastructure, plant, equipment and activities.

1.2 Scope of Work

The key tasks undertaken for this groundwater assessment comprised:

• Characterisation of the existing hydrogeological environment; including climate, topography, regional geology, mine geology, regional hydrology and hydrogeology.

• Characterisation of existing pit dewatering rates and groundwater drawdown monitoring results.

• Collation and review of bore census data to describe surrounding landholder bore use.

• Review of subsidence monitoring results.

• Identification of data gaps and recommendations for additional testwork/monitoring.

• Review of groundwater licensing information including required licenses, allocations and the influence of regulatory constraints on use.
• Update of an existing groundwater numerical model of the BCPB to incorporate conditions relevant to the Modification components, as well as groundwater data, water supply usage, and validation/calibration of that model against observation data.

• Assessment of the potential impact of the BCPB borefield and ESB use on trigger bores (GW036553 in the BCPB area, GW036597 in the Billabong area, and GW036611 in the Maslin Area) and groundwater level recovery in the region of the BCPB and ESB based on predictive numerical groundwater simulation.

• Qualitative assessment of potential groundwater quality impacts due to pumping from the BCPB and ESB.

• Update of an existing groundwater numerical model of the mine site (ML 1535) to incorporate conditions relevant to the Modification, including the extension (in area and depth) of the open pit (E42 pit) and the raising of the TSF, new groundwater monitoring data and dewatering volume records for the E42 pit, and calibration of that model against observation data (including the above average rainfall in 2010 and 2011, and the inundation of Lake Cowal).

• Predictive modelling to assess the following under the Modification:
  - potential changes to the hydrogeological regime as a result of the increased surface area and depth of the E42 open pit under the Modification;
  - potential groundwater drawdown associated with E42 open pit dewatering;
  - expected inflows rates to the E42 open pit;
  - potential seepage rates from the TSF;
  - groundwater drawdown and flow impacts on Lake Cowal after mine closure, over both the short-term (up to 20 years) and long-term (steady state, potentially hundreds of years into the future after mine closure); and
  - sensitivity analysis of modelling results to selected model parameters will be conducted, consistent with contemporary groundwater modelling guidelines.

• Prediction of potential contaminant migration from the TSF based on analytical modelling (adopting a particle tracking method).

• Discussion relating to the open pit and pit dewatering, including:
  - potential changes to the hydrogeological regime as a result of the increased surface area and depth of the E42 open pit under the Modification, based on the predictive modelling;
  - expected inflows rates to the E42 open pit, based on the predictive modelling;
  - potential groundwater drawdown associated with E42 open pit dewatering, based on the predictive modelling;
  - commentary relating to potential drawdown effects against criteria noted in the NSW Department of Primary Industries (DPI) *NSW Aquifer Interference Policy* (DPI, 2012) and, if published prior to issue of Coffey’s final report, against criteria relating to groundwater under the Strategic Regional Land Use Plan for the region;
- qualitative assessment of the expected groundwater quality of water seeping into the E42 open pit; and
- qualitative assessment of impacts on groundwater quality due to pit dewatering.

• Discussion relating to tailings and waste rock emplacement seepage, including:
  - assessment of predicted seepage rates from the TSF, based on the predictive modelling. Seepage rates appraised against current performance by comparing model-predicted groundwater levels against monitored groundwater levels in the vicinity of the TSF.
  - qualitative assessment of the potential groundwater quality impacts down gradient of the TSF due to seepage of stored water. Assessed groundwater quality impacts reviewed in the context of groundwater quality monitoring results.
  - review of the extended Northern Waste Rock Emplacement’s basal layer design for direction of seepage from the emplacement towards the open pit.

• Discussion relating to mine closure, based on the predictive modelling and including assessment of:
  - The potential groundwater flow impacts on Lake Cowal after mine closure, over both the short-term (up to 20 years) and long-term (steady state, potentially hundreds of years into the future after mine closure).
  - Groundwater level recovery in the vicinity of the BCPB and ESB and open pit. Recovery at the open pit assessed independently of recovery at the BCPB and ESB (cumulative impacts are not expected to be relevant and are not considered). Recovery in the BCPB and ESB is assessed for only one recovery scenario in which pumping by the mine has ceased (continued abstraction by other groundwater supply users is assumed post-mine closure – this provides a conservative estimate of recovery).


• Review of mine subsidence monitoring results.


• Discussion of potential measures to manage/mitigate/avoid the potential impacts of the Modification on groundwater levels in relation to the open pit, TSF, BCPB, ESB, and Lake Cowal.
2 LEGISLATION, POLICY AND GUIDELINES

This assessment has been prepared with consideration of the following policies, guidelines and plans:

- NSW State Groundwater Quantity Management Policy (DLWC).
- The NSW Groundwater Dependent Ecosystem Policy (DLWC, 2002).
- NSW Aquifer Interference Policy (NSW Office of Water [NOW], 2012).
3 DATA REVIEW

CGM is located within ML 1535 on the western side of Lake Cowal in central NSW. A regional location plan illustrating topographical contours and the location of regional groundwater extraction bores (both Barrick owned and privately owned) is presented in Figure 1.

3.1 Site Layout

The CGM site is shown in Figure 2.

The following infrastructure and features are present within ML 1535:

- open pit in the east of the site;
- perimeter waste rock emplacement and lake protection bund running beyond, and around, the open pit;
- northern and southern waste rock emplacements to the north-west and south-west of the open pit;
- processing plant located to the west of the open pit;
- a number of contained water storages at various locations across the eastern portion of the site; and
- TSF comprising two storage dams of approximate dimensions 1,300 m by 1,300 m in the west of ML 1535.

3.2 Information Sources

Coffey has a long involvement with the CGM development. This report has been prepared in consideration of the previous reports completed by Coffey and others. Information sources used in development of the hydrogeological conceptual model are listed in Section 13.

3.3 Topography

The region is characterised by a flat landscape with very low undulating hills and occasional rocky outcrops. The majority of vegetation in the area has been cleared, with most of the cleared areas used for agriculture. Remnant and secondary vegetation is restricted to elevated rocky areas (SNC-Lavalin Australia, 2003).

Figure 3 shows the topography and drainage of the area. Ground slopes fall from the north-east (Lachlan Floodplain) and south-east (upper Bland Creek Palaeochannel) towards Lake Cowal. Lake Cowal forms a local depression and fills with flood water every few years. It drains north-west towards Nerang Cowal, and eventually to the Lachlan River. Breakout flows from the Lachlan River at Jemalong Gap and drains towards Lake Cowal.

Ground elevations at the mine site range from around 225 m AHD on the western lease boundary to approximately 200 m AHD at the eastern lease boundary at Lake Cowal. The BCPB area has an elevation of just under 210 m AHD, with minimal variation. Hills formed by rock outcrops on the fringes of the Bland Creek floodplain reach to in excess of 300 m AHD.
CGM is located in the Lachlan River Valley, on the western margin of the Bland Creek Palaeochannel Plain, which is approximately 20 to 30 km wide, bounded by the following:

- Bland Creek Palaeochannel and Jemalong Range (Tullamore Syncline) to the east;
- Manna Anticline and its associated ridge, together with the regionally extensive Gilmore Suture/Gilmore Fault Zone (Figure 1), located to the west of Lake Cowal;
- Lachlan River to the north; and
- Bland Creek catchment to the south.

3.4 Climate

The closest rainfall station to the study area with long-term records is Station 73054 (Wyalong Post Office) operated by the Australian Bureau of Meteorology (BoM), located south of ML 1535, in the western part of the Bland Creek Palaeochannel. This station has no monitoring data between 1939 and 1948. Table 1 lists average and median (Decile 5) monthly rainfall for this station. The average annual rainfall is 480 millimetres (mm). Note that the median annual rainfall is not equivalent to the sum of the monthly median rainfalls.

The closest climate station within 100 km of the site with reasonable amounts of pan evaporation data is BoM Station 73038 (Temora Research Station), located about 60 km away. Table 1 lists the average monthly pan evaporation for the station.

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<th>Temora Research Station (73038)</th>
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<td>Mean rainfall (mm)</td>
<td>Decile 5 (median) rainfall (mm)</td>
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<tr>
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<tr>
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</table>

Table 1. Average Rainfall and Pan Evaporation in the Regional Area

Source: BoM (2013).
Average rainfall shows no obvious seasonal trend. Pan evaporation follows a simple sinusoidal trend which is a maximum in January and December. Using average rainfall, a rainfall deficit occurs for all months of the year except June and July. Average annual pan evaporation is more than three times higher than average annual rainfall (Table 1).

The region is semi-arid with an average annual rainfall of approximately 480 mm (mean rainfall recorded at BoM’s West Wyalong Station, Station Number 73054, for the period 1895 to 2012). Annual and monthly rainfall from the beginning of mine life (2005) to 2012 at that station is shown in Figure 4. Annual rainfall was significantly above mean annual rainfall for 2010 and 2011.

The regional annual evaporation totals from the nearest BoM pan evaporation stations as well as average annual open water or lake evaporation was calculated by Gilbert & Associates (2011) using the modified Penman method (Doorenbos and Pruitt, 1977) from CGM weather station records, are as follows:

- 1,972 mm (Condobolin Agricultural Research Station, Station No. 050052, 1973 to 2000).
- 1,571 mm (Condobolin Soil Conservation, Station No. 050102, 1971 to 1985).
- 1,388 mm (Cowra Research Station, Station No. 063023, 1965 to 2010).
- 1,919 mm (CGM, 2007 to 2010).

### 3.5 Surface Drainage

Lake Cowal is an ephemeral shallow freshwater lake that is predominantly dry with water influx during severe rainy seasons (SNC-Lavalin Australia, 2003). The pit envelope encroaches on the lake area and a pit protection bund and dewatering programme forms an integral part of the mine plan. The lake is filled by runoff from the Bland Creek catchment to the south and flood breakout from the Lachlan River to the north. Lake Cowal is located within the Black Creek Valley, a major tributary of the Lachlan River system. The lake overflows into Nerang Cowal, another ephemeral lake to the north, and then into Bogandillon Swamp before returning to the Lachlan River. Prior to drought conditions which occurred last decade, the lake was observed to be substantially full seven years out of ten. The lake was last full in 2011.

Water courses in the area (with the exception of the Lachlan River) are intermittent. Bland and Barmedman Creeks are the largest of the local creeks (Figure 3). They form ephemeral tributaries to Lake Cowal, flowing in from the south. An extensive irrigation canal system is present at the BCPB area and to the north (Figure 1). These canals deliver water from the Lachlan River to irrigators to sustain the agricultural industry in this area.

A search of the Government Pinneena database indicated two streamflow gauging stations for which reasonable amounts of data were available. These gauging stations are:

- 412103 (Bland Creek at Morangarell); and
- 412170 (Burragorang Creek at Bimbi).
Data for Station 412170 cover a short period however Station 412103 has been continually monitored since 1976. Data are available for the period 1976 to 2003. Station 412103 is located in the Burrarorang Palaeochannel and is approximately 10 km south of the southern boundary of the modelled area. Flow at this gauging station exhibits transient characteristics, having recorded nil daily flow for 60 percent (%) of the monitoring period however, in contrast, the station recorded an average daily flow over the period (including nil flow days) of 119 mega litres per day (ML/day). The maximum recorded flow was 17,854 ML/day on 27 July 1993.

3.6 Land Use

The Australian Natural Resources Atlas (2009) indicates land use over the region surrounding the CGM site includes livestock grazing, dryland and irrigation agriculture and unclassified water bodies.

Within the Lachlan River Valley, livestock grazing area comprises 69% of land use, followed by dryland agriculture area at 22% and nature conservation area at 4% (Australian Natural Resources Atlas, 2009).

3.7 Regional Hydrology

The Lachlan River is the major regional surface water system, forming part of the Murray-Darling Basin. CGM is located on the western side of Lake Cowal, a fresh water lake within the Bland Creek valley. Lake Cowal receives inflow from:

- Bland Creek, which drains into the lake at its southern end; and
- Lachlan-Lake Cowal floodway to the north-east; when breakout flows from the Lachlan River are directed (during floods) into the north-east section of Lake Cowal.

The lake covers an area of approximately 10,500 ha and holds 150,000 megalitres (ML) of water when full. The lake remained dry from the beginning of mine life (early 2005) to mid-2010, when the lake began to fill. Recorded lake water levels are shown in Figure 5.

The lake has a maximum depth of approximately 4 m when full and overflows into Nerang Cowal to the north-west, which ultimately drains to the Lachlan River.

3.8 Regional Groundwater Recharge

3.8.1 Stream Baseflow Analysis

To assess the recharge to the groundwater system in the area, a baseflow analysis was undertaken on the flow data for Station 412103 (located on Bland Creek). Baseflow response was separated from streamflow measurements using a deterministic procedure proposed by the British Institute of Hydrology (1980a; 1980b). The method combines a local minimum approach with a recession slope test, and a requirement to test the results over a range of time windows for testing of local minima. The software package BFI (Wahl and Wahl, 1988 and 1995), which incorporates this method, was used for the analysis. BFI estimates the annual baseflow volume of unregulated rivers and computes an annual baseflow index (the ratio of baseflow to total flow volume for a given year) for multiple years of data at one or more gauges. Although the method may not yield the true baseflow as might be determined by a more sophisticated analysis, the index has been found to be consistent with other methods, and is useful for analysis of long-term baseflow trends.
The analysis for Station 412103 is shown in Figure 6. For each year of data, the flow record is analysed for varying time windows used for selection of minima. The output is then visually examined on a graph to find the inflexion point in the baseflow response. In Figure 6, baseflow processes are evident over an interval between four and eight days, prior to which the streamflow is predominantly controlled by surface runoff. At Station 412103, the assessment indicates that baseflow to the creek (rainfall that infiltrates the ground and finds its way to the creek by groundwater flow) varied between 0.2% and 0.3% of rainfall between 1977 and 2000. This result will have a smaller irrigation component than the groundwater recharge at the location of the BCPB (where more significant irrigation takes place).

There are natural surface water sources in the BCPB area that are perennial, or that are highly connected to the Lachlan Formation. To the north, The Lachlan River channel is seated in the Upper Cowra formation however it has minimal hydraulic communication with the Lachlan Formation due to the depth of the Lachlan Formation and the vertical anisotropy of the sediments. Irrigation canals are present in the BCPB area however these also have minimal hydraulic communication with the Lachlan Formation due to the depth of pumping and the vertical anisotropy of the sediments. The irrigation canals are understood to lose water rather than accept baseflow from the surrounding medium, due to the typical water table depths (about 5m below ground).

3.8.2 Literature Review

The Warroo irrigation channel has been reported as suffering losses through seepage from the channel base (Van der Lely, 1993). Losses were estimated at around 2000 ML/year but potentially ranging between 500 and 6000 ML/year.

Studies of groundwater chemistry in the Bland Creek Palaeochannel (Carrara et al., 2004) indicate that the Thuddungra region is a recharge area for both aquifers (Carrara et al., undated). These studies also suggest that the Lachlan Formation shows a generalised preferential lateral groundwater flow system, without significant vertical recharge except in the Thuddungra region. By contrast, the studies suggest that the shallow parts of the Cowra Formation comprise a system where vertical infiltration (and recharge to groundwater) dominates, and lateral groundwater flow is limited and local.

Anderson et al. (1993) believed that recharge through the base of stream channels and over-bank flooding were the dominant recharge processes in the Lachlan Valley. The amount of recharge provided by this process in the Bland Creek Palaeochannel is difficult to assess due to impact of pumping on groundwater monitoring hydrographs. Minor flooding occurs intermittently in the Bland Creek Palaeochannel area however surface sediments in this area are less permeable than further north in the Jemalong and Wyldes Plains irrigation districts and the main Lachlan Valley, resulting in lower recharge from this source compared to the Lachlan Valley.

Hawkes (1998) suggested Lake Cowal has negligible hydraulic connection to deeper layers, but that it may provide low intermittent recharge to the Upper Cowra Formation after flood events.

Coffey (1994b) estimated a total accession rate (irrigation deep drainage and rainfall infiltration) to the groundwater system of between nil and 18 mm/year based on model calibration using hydrographs for the Upper Cowra Formation in the Jemalong / Wyldes Plains Irrigation District, with the higher infiltration rates restricted to a 10 km-wide zone south of the Lachlan River. The overall average calibrated recharge to the Upper Cowra Formation between Lake Cowal and the Lachlan River was around 10 mm/year or around 2% of average rainfall.
Studies conducted in the early 1980s (Ross, 1982) in the low salinity groundwater areas of the Upper Lachlan Valley indicated that only 1.25% of rainfall accedes to the groundwater system.

Williams (1993) estimated that long-term increases in groundwater storage in the Upper Cowra Formation in the Jemalong / Wyldes Plain Irrigation District amounted to a minimum net increase of 5.2 mm/year (about 1% of incident rainfall, assuming a value of 5% for the pore volume available for increased storage at the water table). However, that study was unable to determine the contribution made by flooding, rainfall, and irrigation. The estimate by Williams (1993) was considered a minimum.

Cook et al. (2001) provide results of a study of rainfall recharge over agricultural land of the Mallee region near the Murray River (average rainfall 300 mm/year to 400 mm/year). Results indicated deep drainage rates varying between 3 mm/year (0.9% of annual rainfall) and 30 mm/year (9% of annual rainfall) at crop rotation sites with average clay contents in the upper 2 m of the surface soil profile varying between 30% and 2% respectively.

Numerical modelling by Williams (1993) for the upper 20 m of the Cowra Formation indicated that evaporation from surface ponding caused by groundwater seeps was occurring in several locations in the more topographically depressed area in the vicinity of the Corinella Constriction.

The calibrated model developed in Bilge (2012) for the Upper Lachlan catchment area adopted a rainfall recharge rate of 0.1% and an evapotranspiration rate of 25% with an extinction depth of 9 m, in the vicinity of the CGM.

3.8.3 Hydrograph Analysis for the BCPB Area

Given the irrigation practices in the area, an assessment was conducted of the processes influencing recharge at the water table. This was done in the area east of Lake Cowal, the only area in the model domain where shallow water table bores (maintained by Jemalong Irrigation Limited) are available.

Figure 7a shows the hydrographs of water table bores whose water levels are assessed to be influenced mainly by rainfall, with minimal irrigation input. This is not to say that irrigation does not occur there, but that any irrigation mostly does not reach the water table. Recharge mainly by rainfall is identified by the similarity of a hydrograph to the rainfall residual cumulative mass curve.

Figure 7b shows the hydrographs of water table bores whose water levels are assessed to be significantly influenced by irrigation, in addition to rainfall. These bores are plotted on Figure 8 according to their main source of recharge. The pattern identifies the area where irrigation is affecting the water table. For modelling, this means that areas where irrigation does not occur may have lower groundwater recharge. The model adopts a single average rate which takes into account the irrigation process, however further south there are fewer tracts of land that are irrigated. This necessarily adds a degree of approximation to the recharge rate used in the model. Irrigation is also likely to be occurring in the Maslin and Billabong areas to the south.

3.9 Regional Geology

The Forbes Geological Map (SI55-7, 1:250,000) shows that the regional geological setting is dominated by the Gilmore Fault Zone, a structurally and lithologically complex feature that trends north-south through ML 1535, approximately 500 m west of the CGM open pit.
The fault separates a Late Ordovician volcanioclastic sequence (referred to as the Lake Cowal Volcanic Complex) from Siluro-Devonian sedimentary basement to the west. Siluro-Devonian sedimentary rocks also occur east of the Lake Cowal Volcanic Complex on the eastern side of Lake Cowal, where the basement has been deeply incised and hosts palaeochannel deposits of the Bland Creek unit.

The region is covered by varying thicknesses of Tertiary and Quaternary regolith deposits. The Bland Creek Palaeochannel Plain was formed by the infilling of the Lachlan and Bland Creek Palaeochannels, located to the north and east of Lake Cowal respectively, with sediments of the Lachlan and Cowra Formations. The depth of these sediments is over 100 m. Locally, Pleistocene Cowra alluvium overlies ML 1535 and thick Quaternary lacustrine sediments underlie Lake Cowal.

3.9.1 Alluvial Sequence

Williams (1988) subdivides the alluvial sequence in the study area into the Upper and Lower Zones which are now known as the Cowra and Lachlan Formations respectively. The Lachlan Formation is the main aquifer in the study area with the overlying Cowra Formation having lower permeability and higher salinity.

The Cowra Formation comprises predominantly stiff red/yellow/brown high plasticity clay (grading to grey at depth) with intermittent sand and silt horizons. The base of the Cowra Formation is generally marked by a conspicuous multicoloured clay layer. The Cowra Formation is underlain by the Lachlan Formation which comprises light grey fine to coarse grained sand and fine to medium grained gravel, consisting mostly of smoky quartz, chert, and wood fragments. The Lachlan Formation is underlain by bedrock. Between 2 m and 5 m of clay generally lies between the base of high permeability sediments in the Lachlan Formation and the top of bedrock, however in some places the clay is absent. The colour and consistency of the clay suggests that much of it is residual weathered product of underlying rocks. Additional information on the geology of the alluvial sequence is provided in Coffey (1995b).

The position of the top of the Lachlan Formation was assessed in detail by examining registered bore logs covering the study area. Logs for 213 bores were available for which the drilled depth was 70 m or more in the Bland and Burragorang Palaeochannels. These logs were reviewed to assess the depth to the top of the Lachlan Formation and the extent of high permeability sands and gravels in the Lachlan Formation. The logs have been compiled over a significant time period by various personnel and were analysed for the presence of light-grey to white sands and gravels below 70 m depth (potentially indicating the Lachlan Formation). In many instances the bore logs could not provide definitive information on the boundary between the Lachlan and Cowra Formations however in many cases a characteristic marker horizon of multicoloured clay, representing Cowra / Lachlan Formation contact, was recorded.

The assessed structure contour surface for the top of the Lachlan Formation was then intersected with the assessed bedrock structure contour surface to find the extents of the Lachlan Formation. The extent of the Cowra Formation was found by intersecting the bedrock structure contour surface with the digital elevation model obtained from Geoscience Australia. The extent of the Lachlan Formation includes lower permeability sediments surrounding the high permeability sands and minor gravels in the deeper parts of the palaeochannel. The high permeability sands and minor gravels appear to be located adjacent to steep bedrock surface gradients within the deeper parts of the palaeochannel. The spatial variation in high and low conductivity sediments in the Lachlan Formation indicates that the high conductivity part of the Lachlan Formation bifurcates just north of Marsden.
Geophysical (gamma) logs and hydraulic test data for bores in the vicinity of the BCPB suggest that the Cowra Formation can be divided into upper and lower sequences (Figure 9 and Sections 3.10 and 3.11). Based on these data, the base of the Upper Cowra sequence is assessed to be at about 47 m below ground level (bgl).

3.9.2 Top of Bedrock

The structure contour surface for the top of bedrock is a vital component of the numerical model and was developed from an assessment of the following data (not available at the time of the Cowal Gold Project, Environmental Impact Statement [EIS] [North Limited, 1998] in 1998):

- Digital depth to bedrock surface on a 250 m grid provided by Geoscience Australia for the Forbes 1:250,000 map sheet. These data are the result of an assessment of airborne geophysical surveys (mainly magnetic and gravity), known surface geology, and borelogs for mineral exploration and private bores.

- Registered bore records for private bores drilled since 1998 for the entire area, and all available private bore logs for the study area south of the area covered by the Geoscience Australia depth to bedrock surface.

A constriction in the bedrock surface occurs to the north of the BCPB, and is referred to as the Corinella Constriction. In assessing bedrock structure contours in this area, additional information from hydraulic testing was available. From results of pumping testing conducted in BLPR2 in 1994 and 1995 (Coffey, 1994a; 1995b) it was assessed that a hydraulic barrier boundary occurred to the north-west, west, or south-west of BLPR2 at an estimated distance of about 1.8 km. Pumping test results in Groundwater Consulting Services Pty Ltd (GCS) (2006) for BCPB bores were interpreted by GCS as indicating a palaeochannel boundary with a width of approximately 4.5 km in the vicinity of the borefield. BCPB Bore 4 was assessed to be in proximity to the palaeochannel boundary on its eastern, western, and southern sides (at distances of less than 500 m) with hydraulic connection to the rest of the borefield occurring in a northerly direction only (GCS, 2006).

3.10 Mine Geology

The CGM site lies within the Lake Cowal Volcanics, which comprise massive and stratified non-welded pyroclastic debris, overlying a partly brecciated lava sequence, overlying volcanic conglomerate interbedded with siltstone and mudstone. The host rock has a consistent strike of 215 degrees (°) and an approximate dip of 50° to the north-west.

Within the Lake Cowal Volcanic Complex are diorite and gabbro intrusions, one of which is intersected by the CGM open pit. Within the ore body there are several north-south oriented, near vertically dipping faults and fractured dykes.

Overlying the Ordovician host rock (Saprock and Primary) is a Tertiary age laterite (Saprolite), which averages approximately 20 m and varies in thickness across the CGM site from approximately 15 m to 55 m. Quaternary age sediments of predominantly lacustrine clay (Transported Alluvium) characteristically cover the Tertiary laterite. The depth of sediments across the CGM site and surrounds ranges from approximately 14 m to 55 m. This is consistent with thickness of the Transported Alluvium (Lower Cowra and Upper Cowra Formations) utilised in a calibrated groundwater model developed by NOW, in which values of over 20 m were adopted over the CGM site and surrounds.

The geology of the CGM site and surrounds is illustrated in Figure 10.
3.11 Regional Hydrogeology

Regionally, groundwater resources are present in the Bland Creek Palaeochannel, which include the following two geological formations:

- **Cowra Formation**: comprises isolated sand and gravel lenses in predominantly silt and clay alluvial deposits, with groundwater of generally higher salinity; and

- **Lachlan Formation**: comprises quartz gravel with groundwater of generally low salinity.

Figure 1 shows the interpreted extent of the Cowra and Lachlan Formations as assessed by Coffey (2006).

Three distinct alluvial sequences were interpreted to be present based on the distribution of hydraulic conductivity with depth assessed by Coffey (2006). These are as follows:

- **Upper Cowra Formation**: this sequence generally occurs from ground surface to an average depth of approximately 45 m to 50 m over most of the CGM site and surrounding area. The average depth to groundwater is approximately 7 m, giving an average saturated thickness of just over 40 m (Coffey, 2006). The data suggest the Upper Cowra sequence generally shows decreasing hydraulic conductivity with depth and greater stratification than deeper layers, providing for a lower average ratio of vertical hydraulic conductivity ($K_v$) to horizontal hydraulic conductivity ($K_h$).

- **Lower Cowra Formation**: this sequence generally occurs over an average depth interval of approximately 50 m to 90 m over most of the CGM site and surrounding area. This layer appears to have lower horizontal hydraulic conductivity values than the Upper Cowra Formation, and is likely to have a higher average value of $K_v/K_h$ than the overlying sequences.

- **Lachlan Formation**: this sequence generally occurs over an average depth interval of around 90 m to 120 m in the Bland Creek Palaeochannel. Within this formation there were assessed to be two distinct sequences, including:
  - High permeability sands and minor gravels close to and within the deeper parts of the palaeochannel.
  - Lower permeability sediments that generally occur further away from the deeper parts of the palaeochannel and surround the high permeability sands and minor gravels. The average hydraulic conductivity of this sequence appears similar to the Lower Cowra Formation.

Coffey (2006) interpreted that the western limit of the Cowra Formation extends within the eastern boundary of ML 1535, but that the Lachlan Formation did not extend into ML 1535. Pre-mining groundwater flow was generally from east to west under a hydraulic gradient of approximately 0.1%, increasing to 0.3% further west.

Geological data available from the BCPB (formerly known as the Jemalong Borefield) to the north-east and for the Bland Creek system to the south-east of the CGM site have also been used in characterising the regional hydrogeology. Figure 11 shows geological cross-sections at the location of the Nerang Cowal and Marsden sections marked on Figure 1, based on information presented in Coffey (2006) and Anderson *et al.* (1993).
Carrara et al. (2004) used multi-component geochemical tracers to identify groundwater flow regimes within the Bland Creek Catchment. Carrara et al. (2004) inferred from the results that historical groundwater flow directions in the Lachlan Formation were not consistent with present flow directions, and that groundwater flow from the Lachlan Valley to the Bland Creek Catchment was a natural process and not a direct effect of irrigation practises.

3.12 Mine Hydrogeology

Coffey (2009a) developed geological cross-sections through the western area of the CGM site. The locations of the cross-sections are shown on Figure 2 and the cross-sections are shown on Figure 12. The extent of the Saprolite and Saprock units outside the CGM site are not defined.

Figure 13 presents a simplified conceptual cross-section through approximately the centre of the CGM open pit (at Map Grid of Australia [MGA] N6,278,030).

Locally at the CGM site, four hydrogeological units have been identified:

- The Transported hydrogeological unit comprises alluvium (thick clay sequences and more permeable zones of gravel within a sandy clay matrix) of the Quaternary aged Cowra Formation. The Cowra Formation is laterally equivalent to the Transported unit (Barrick, 2010a). (In prior reports and literature, this unit is often termed the Transported Alluvial Aquifer.)
- The Saprolite hydrogeological unit underlies the Transported unit, and is of relatively low hydraulic conductivity.
- The Saprock hydrogeological unit underlies the Saprolite unit, and occurs in the weathered fractured surface of the Lake Cowal Volcanics.
- More massive and less permeable Bedrock/Primary Rock underlies the Saprock unit.

The Saprolite, Saprock and Bedrock/Primary Rock are considered to be within the fractured rock groundwater system. Surfaces of topographic (ground surface) elevations and the base elevations of the Transported, Saprolite and Saprock hydrogeological units were provided by Barrick for the ML 1535 area, and were updated by Coffey (2012) with additional drilling data provided by Barrick.

The surfaces of the hydrogeological units were linearly extrapolated from the boundaries of ML 1535 to regions outside ML 1535, with the following considerations:

- Interpolation between the geological cross-sectional data shown on Figures 12 and 13, based on Coffey (2009a), and data for the CGM open pit and surrounding area (Coffey, 2008a) (interpolation between approximately MGA E535500 and MGA E536800).
- Geological cross-sections at the Nerang Cowal and Marsden sections marked on Figure 1 and shown on Figure 11.
- The Cowra Formation is laterally equivalent to the Transported unit (Barrick, 2010).
- Data for the top of bedrock (equivalent to the top of Primary Rock), covering from the eastern side of the CGM site to the eastern boundary of the model domain. The bedrock (Primary Rock) outcrops at the surface along the Gilmore Suture and at Cowal West Hill (Coffey, 1995a).
- The Gilmore Suture marks a geological divide to the west of which the Primary Rock is the only unit underlying the Transported unit.
Figures 14 to 17 show the model adopted surface contours for ground surface level, and the base of the Transported, Saprolite and Saprock units, respectively, over the mine site area.

3.13 Regional Groundwater Levels and Flow Regimes

3.13.1 Groundwater Levels

3.13.2 Hydrographs

The study area hosts a large number of government groundwater monitoring piezometers, complemented by monitoring piezometers installed by Barrick at the BCPB area and on the mine site. In selecting monitoring piezometers for assessment of hydraulic heads, the following criteria were generally applied, to reduce the potential for unrepresentative measurements:

- Backfilling of 20 m or less from the base of the borehole to the bottom of the screen.
- Screens placed in separate boreholes.

Where multiple screens have been installed in a single borehole, only the lowermost standpipe has been selected for model calibration purposes, subject to the backfilling criterion and other factors. The selection process provided a database of 39 measurement points (screens) at 32 locations. Two screens monitor the water table in the Upper Cowra Formation, four screens monitor the Upper Cowra Formation below the water table, 10 screens monitor the Lower Cowra Formation, 20 screens monitor the Lachlan Formation, and three screens straddle the Upper Cowra Formation and Lower Cowra Formation. These piezometers are listed in Table 2, with locations shown in Figures 18a to 18c.

Groundwater levels in the area are characterised by falling water levels in the Lachlan Formation over the last decade, caused by the rise in groundwater extraction to supply significantly increased irrigation demands resulting from diminishing surface water allocations as a result of drought conditions during most of the last decade. Commencement of pumping from the BCPB has also contributed to this drawdown.

Figure 19a shows hydrographs for the Upper Cowra, Lower Cowra and Lachlan Formations in the BCPB area, using an approximately coincident set of monitoring piezometers throughout the vertical profile (refer to Figures 18a to 18c for locations). The effect of increased groundwater extraction from the Lachlan Formation is apparent. The vertical anisotropy of the alluvial sediments limits the upward propagation of depressurisation in the Lachlan Formation. The water table appears to remain unaffected over most of the record, however in this area, high volumes of irrigation are applied to the ground surface. The higher conductivity of the Lachlan Formation allows depressurisation from pumping to travel extensively in the lateral direction.

Figure 19b shows how the depressurisation in the Lachlan Formation evolves through the overburden. Observed drawdown between June 1998 and January 2010 at five locations (GW036523, GW036552, GW036611 / GW03700, GW090093 / GW702262, and GW036553 / GW036594) is shown as a percentage of the drawdown in the Lachlan Formation. For location GW090093 / GW702262 the drawdown is for the period January 2007 to January 2010. The attenuation of the depressurisation, moving up the profile, is apparent.
# Table 2. Observation Piezometers

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<th>MGA Northing</th>
<th>Stratum</th>
<th>Screen (m bgl)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW090093-Ln</td>
<td>210.12</td>
<td>549718</td>
<td>6294192</td>
<td>Ln</td>
<td>130</td>
<td>136 Piping in separate drillholes.</td>
</tr>
<tr>
<td>GW090093-UC</td>
<td>210.05</td>
<td>549718</td>
<td>6294192</td>
<td>UC</td>
<td>5</td>
<td>11 Piping in separate drillholes.</td>
</tr>
<tr>
<td>WT50-UC</td>
<td>208.56</td>
<td>551121</td>
<td>6281522</td>
<td>UC</td>
<td>Water table</td>
<td>JIL salinity monitoring bore. Screen interval unknown, but straddles water table.</td>
</tr>
<tr>
<td>PZ01-UC/LC</td>
<td>210.71</td>
<td>555703</td>
<td>6287188</td>
<td>UC/LC</td>
<td>20</td>
<td>80 ESB Monitoring. No monitoring from September 2012.</td>
</tr>
<tr>
<td>PZ02-UC/LC</td>
<td>210.69</td>
<td>556267</td>
<td>6288075</td>
<td>UC/LC</td>
<td>18</td>
<td>78 ESB Monitoring. No monitoring from September 2012.</td>
</tr>
<tr>
<td>PZ05-UC/LC</td>
<td>211.05</td>
<td>555984</td>
<td>6286935</td>
<td>UC/LC</td>
<td>18</td>
<td>78 ESB Monitoring. No monitoring from September 2012.</td>
</tr>
<tr>
<td>PZ09-UC</td>
<td>211.19</td>
<td>556580</td>
<td>6288433</td>
<td>UC</td>
<td>13</td>
<td>16 ESB Monitoring</td>
</tr>
<tr>
<td>PZ10-LC</td>
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<td>556584</td>
<td>6288435</td>
<td>UC/LC</td>
<td>48</td>
<td>51 ESB Monitoring</td>
</tr>
<tr>
<td>PZ11-LC</td>
<td>211.33</td>
<td>556588</td>
<td>6288437</td>
<td>LC</td>
<td>60</td>
<td>64 ESB Monitoring</td>
</tr>
<tr>
<td>Coles(GW701579)</td>
<td>209.20</td>
<td>553655</td>
<td>6269485</td>
<td>Ln</td>
<td>107</td>
<td>110 Private bore.</td>
</tr>
<tr>
<td>Koreela(GW702262)</td>
<td>212.80</td>
<td>549551</td>
<td>6293010</td>
<td>Ln</td>
<td>117</td>
<td>125 Private bore. Also in model as a pumping bore.</td>
</tr>
<tr>
<td>Muffet(GW701958)</td>
<td>209.00</td>
<td>556164</td>
<td>6270450</td>
<td>Ln</td>
<td>88</td>
<td>93 Private bore. Also in model as a pumping bore.</td>
</tr>
<tr>
<td>Trigalana(GW702286)</td>
<td>208.30</td>
<td>555791</td>
<td>6279759</td>
<td>Ln</td>
<td>102</td>
<td>113 Private bore. Also in model as a pumping bore.</td>
</tr>
<tr>
<td>Warrakimbo(GW701681)</td>
<td>208.00</td>
<td>552699</td>
<td>6266036</td>
<td>Ln</td>
<td></td>
<td>Private bore. Very close to Maslin Pumping Bore.</td>
</tr>
<tr>
<td><strong>Observation Bores Not Used in Modelling</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GW036597-LC</td>
<td>209.81</td>
<td>544390</td>
<td>6263522</td>
<td>LC</td>
<td>78</td>
<td>84 Piping in same drillhole. SWLs identical to 36597-Ln.</td>
</tr>
<tr>
<td>GW036603-LC</td>
<td>219.76</td>
<td>551670</td>
<td>6239550</td>
<td>LC</td>
<td>67</td>
<td>71 Outside Model Domain (bedrock at shallow depth).</td>
</tr>
<tr>
<td>GW036604-Ln</td>
<td>223.99</td>
<td>557145</td>
<td>6240264</td>
<td>LC</td>
<td>98</td>
<td>102 Directly coincident with 39379-Ln, and SWLs are virtually the same.</td>
</tr>
<tr>
<td>GW036825-LC</td>
<td>221.97</td>
<td>564360</td>
<td>6255194</td>
<td>LC</td>
<td>43</td>
<td>49 Data appear questionable. SWLs may be still recovering since installation.</td>
</tr>
<tr>
<td>PZ06</td>
<td>212.09</td>
<td>557239</td>
<td>6289189</td>
<td>-</td>
<td>-</td>
<td>- ESB Monitoring. Screen information unavailable.</td>
</tr>
<tr>
<td>PZ07</td>
<td>211.80</td>
<td>557343</td>
<td>6288365</td>
<td>-</td>
<td>-</td>
<td>- ESB Monitoring. Screen information unavailable.</td>
</tr>
<tr>
<td>PZ08</td>
<td>210.97</td>
<td>556465</td>
<td>6286840</td>
<td>-</td>
<td>-</td>
<td>- ESB Monitoring. Screen information unavailable.</td>
</tr>
</tbody>
</table>

**Glossary:**
- **JIL:** Jemalong Irrigation Limited.
- **m bgl:** metres below ground level.
- **UC:** Upper Cowra Formation.
- **LC:** Lower Cowra Formation.
- **Ln:** Lachlan Formation.
- **SWL:** static water level.
3.13.3 Hydraulic Head Surfaces

Monitoring data have been used to interpret water level surfaces for the Bland Creek Palaeochannel for the Upper Cowra, Lower Cowra, and Lachlan Formations for December 1997 (immediately prior to the model calibration period) and for September 2006. These surfaces are shown in Figures 20a to 20c for 1997 and Figures 21a to 21c for 2006. The main changes in water level surfaces between these times are:

- the disappearance of the groundwater mound in the Upper Cowra Formation underneath Lake Cowal (with the Lake Cowal water level probably having been at around 205 m AHD in mid-1998); and

- the appearance of the drawdown cone around the BCPB.

The 1997 surfaces indicate overall westward groundwater flow. Trends in the Lower Cowra and Lachlan Formations suggest north-south structural features on the western side of the palaeochannel may play a part in groundwater drainage. The 2006 surfaces show the effects of significant pumping from the Lachlan Formation at the BCPB and in the Billabong Area (see below).

Water levels in the Upper Cowra Formation, where data are available, are an average of 5 m bgl. Vegetation in the area is characterised by food crops and scrub plains, with root depths probably not deeper than 2 m below ground. Consumption of groundwater by evapotranspiration is therefore likely to be negligible, except at Lake Cowal, where water levels can rise to within the vicinity of the lake bottom during wet times. However, evapotranspiration of groundwater beneath Lake Cowal is likely to be limited by the low hydraulic conductivity of the lacustrine clay that forms a layer of between 3 m and 8 m thickness at the base of the lake.

Near the current mine pit, the Upper Cowra Formation shows some drawdown from drainage into the mine excavation, in conjunction with regional drawdown from drought conditions. This drawdown appears localised and is considered unlikely to significantly affect drawdown in the Upper Cowra, Lower Cowra, and Lachlan Formations further east (in the Bland Creek Palaeochannel). The Lower Cowra and Lachlan Formations in the palaeochannel appear to have been unaffected by mining.

Data were not available for groundwater levels at distance to the west of the mine site. However, levels are believed to be similar to those in the western region of the mine site (e.g. in the vicinity of the TSF). Groundwater flow in this region is likely to be in an easterly direction, from the Cowal West Hill ridge-line towards the mine site.

3.13.4 Hydraulic Head Cross-Sections

Figures 21d and 21e show interpreted hydraulic heads along a north-south cross-section running approximately through the middle of the model domain, for December 1997 and January 2010 respectively. Salinity corrections have not been applied to the water level measurements however the corrections are not considered necessary given the moderate salinity magnitude of the Upper Cowra Formation, and the inverted salinity profile for the sediments (that is, salinity decreases with depth, which acts to slightly amplify the downward hydraulic head gradient in the Upper Cowra Formation).
In December 1997 pumping from the Lachlan Formation was significantly lower than in subsequent years, since drought conditions had not as yet developed. Hydraulic heads in the Lachlan Formation were similar to those in overlying strata, with gentle vertical gradients. The effect of drainage to the west is subtle but noticeable. Minor inflow from the Corinella Constriction appeared to be occurring. The BCPB and ESB were not active at this time.

The lowest hydraulic heads observed in the Lachlan Formation since monitoring began were observed in January 2010, when the BCPB and private bores were pumping at high levels from the Lachlan Formation. Several bore screens are more than 500 m from the cross-section, but their positions have been projected onto the cross-section. However, hydraulic head contours are for the cross-section itself, therefore the shape of the contours do not closely align with the bore screens. Significant vertical gradients are apparent in the Lower Cowra Formation, in response to significant depressurisation in the Lachlan Formation. Hydraulic head gradients in the underlying rock are interpreted to be large, with negligible upward leakage. A low $K_v/K_h$ ratio is interpreted from the relatively greater insulation of the Upper Cowra Formation from the depressurisation occurring at depth.

### 3.14 Local Groundwater Levels and Flow Regimes

#### 3.14.1 Groundwater Monitoring

The installation details for active groundwater monitoring piezometers within the ML 1535 are shown in Table 3. Piezometers with the suffix ‘A’ are screened in the Saprolite/Saprock unit, while those with suffix ‘B’ are screened in the Transported unit. The location of these piezometers is shown in Figures 22 and 23.

Groundwater monitoring records for these piezometers are shown in Figures 24 to 25. Records for piezometers P555A, P555B and P412B show those piezometers have remained dry over the mine life and are therefore are not shown in the figures.

### Table 3. Mine Area Monitoring Bore Details

<table>
<thead>
<tr>
<th>Area</th>
<th>Piezometer Name</th>
<th>Screened Stratum</th>
<th>m AHD of Top of Casing</th>
<th>Depth (m bgl)</th>
<th>Screen Intervals (m bgl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pit Area</td>
<td>PDB1A</td>
<td>Saprock</td>
<td>208.26</td>
<td>88</td>
<td>82 to 88</td>
</tr>
<tr>
<td></td>
<td>PDB1B</td>
<td>Transported</td>
<td>208.23</td>
<td>20</td>
<td>14 to 20</td>
</tr>
<tr>
<td></td>
<td>PDB3A</td>
<td>Saprock</td>
<td>204.80</td>
<td>100.5</td>
<td>94.5 to 100.5</td>
</tr>
<tr>
<td></td>
<td>PDB3B</td>
<td>Transported</td>
<td>204.82</td>
<td>29.6</td>
<td>23.6 to 29.6</td>
</tr>
<tr>
<td></td>
<td>PDB4A</td>
<td>Saprock</td>
<td>204.84</td>
<td>80</td>
<td>74 to 80</td>
</tr>
<tr>
<td></td>
<td>PDB4B</td>
<td>Transported</td>
<td>204.84</td>
<td>30.5</td>
<td>24.5 to 30.5</td>
</tr>
<tr>
<td></td>
<td>PDB5A</td>
<td>Saprock</td>
<td>209.05</td>
<td>82.5</td>
<td>76.5 to 82.5</td>
</tr>
<tr>
<td></td>
<td>PDB5B</td>
<td>Saprolite</td>
<td>208.82</td>
<td>29.8</td>
<td>23.8 to 29.8</td>
</tr>
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<td>Processing Area</td>
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<td>212.58</td>
<td>No data</td>
<td>No data</td>
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<td></td>
<td>PP01</td>
<td>Transported</td>
<td>215.61</td>
<td>25</td>
<td>13 to 25</td>
</tr>
<tr>
<td></td>
<td>PP02</td>
<td>Transported</td>
<td>213.00</td>
<td>18.5</td>
<td>8.5 to 18.5</td>
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<tr>
<td></td>
<td>PP03</td>
<td>Saprolite</td>
<td>213.52</td>
<td>51</td>
<td>31 to 51</td>
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<td>PP04</td>
<td>Transported</td>
<td>213.89</td>
<td>19.5</td>
<td>10.5 to 19.5</td>
</tr>
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<td>PP05</td>
<td>Transported</td>
<td>214.18</td>
<td>20</td>
<td>11 to 20</td>
</tr>
<tr>
<td></td>
<td>PP06</td>
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<td>214.03</td>
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<td>11 to 20</td>
</tr>
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</table>
Table 3 (Continued). Mine Area Monitoring Bore Details

<table>
<thead>
<tr>
<th>Area</th>
<th>Piezometer Name</th>
<th>Screened Stratum</th>
<th>m AHD of Top of Casing</th>
<th>Depth (m bgl)</th>
<th>Screen Intervals (m bgl)</th>
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<tr>
<td>Tailings Areas</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P555A</td>
<td>Saprolite</td>
<td>227.41</td>
<td>19.8</td>
<td>17.8 to 19.8</td>
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</tr>
<tr>
<td>P555A-R</td>
<td>Saprock</td>
<td>227.35</td>
<td>36</td>
<td>27 to 36</td>
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<tr>
<td>P555B</td>
<td>Saprolite</td>
<td>227.41</td>
<td>10</td>
<td>8 to 10</td>
<td></td>
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<tr>
<td>P558A-R</td>
<td>Saprolite</td>
<td>224.29</td>
<td>42.6</td>
<td>30.6 to 42.6</td>
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</tr>
<tr>
<td>P412A</td>
<td>Saprolite</td>
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<td>30</td>
<td>18 to 30</td>
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</tr>
<tr>
<td>P412A-R</td>
<td>Saprolite</td>
<td>216.12</td>
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<td>55 to 61</td>
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<tr>
<td>P412B</td>
<td>Transported</td>
<td>216.09</td>
<td>16</td>
<td>10 to 16</td>
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</tr>
<tr>
<td>P414A</td>
<td>Saprolite</td>
<td>217.05</td>
<td>34</td>
<td>22 to 34</td>
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<td>P414B</td>
<td>Transported</td>
<td>217.07</td>
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<td>10 to 16</td>
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<td>P417A</td>
<td>Saprolite</td>
<td>216.49</td>
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<td>8 to 14</td>
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<td>214.23</td>
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<td>20 to 32</td>
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</tr>
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<td>P418B</td>
<td>Transported</td>
<td>214.22</td>
<td>16</td>
<td>10 to 16</td>
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<tr>
<td>TSFNA</td>
<td>Saprock</td>
<td>215.28</td>
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<td>92 to 98</td>
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<td>TSFNB</td>
<td>Transported</td>
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<td>30.1</td>
<td>24.1 to 30.1</td>
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</tr>
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<td>TSFNC</td>
<td>Transported</td>
<td>215.27</td>
<td>18</td>
<td>12 to 18</td>
<td></td>
</tr>
<tr>
<td>MON01A</td>
<td>Saprock</td>
<td>215.26</td>
<td>69</td>
<td>63 to 69</td>
<td></td>
</tr>
<tr>
<td>MON01B</td>
<td>Transported</td>
<td>215.29</td>
<td>15</td>
<td>9 to 15</td>
<td></td>
</tr>
<tr>
<td>MON02A</td>
<td>Saprock</td>
<td>222.48</td>
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<td>63 to 69</td>
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<td>MON02B</td>
<td>Saprolite</td>
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<tr>
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<td>21 to 23</td>
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</tr>
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<td>Transported</td>
<td>215.05</td>
<td>10</td>
<td>8 to 10</td>
<td></td>
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<tr>
<td>Lake Protection Bund</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>PBP1</td>
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<td>~12 to 13</td>
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<td>PBP2</td>
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<td>11.7</td>
<td>Assumed 6 to 12</td>
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<tr>
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<td>~12 to 13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PBP5</td>
<td>Transported</td>
<td>209.62</td>
<td>~12 to 13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.14.2 Groundwater Inflows and Levels within ML 1535

Over the life of the mine, Lake Cowal remained dry until June 2010 when significant rainfall caused the lake to begin to fill with water. It has since remained inundated (to mid-2013). Since the commencement of the CGM, the underlying aquifers surrounding and intercepting the open pit have been depressurised as a result of the inflows to the open pit and active pit dewatering. Despite Lake Cowal becoming inundated, groundwater inflows to the open pit are assessed (considering rainfall runoff) to have remained below (or consistent with) historical records and relatively stable. This is most likely because the lacustrine sediments that form the lake bed have a very low vertical permeability and act as an aquitard (low permeability layer) between lake water and underlying aquifers (Coffey, 1997).

The open pit groundwater inflow observations confirm the finding of Coffey (1997) that the long term leakage from the lake (when containing water) to underlying aquifers would be minuscule and impossible to measure.
Notwithstanding, monitoring piezometers show an increase in groundwater levels since filling of the lake commenced, as shown on Figures 5 and 24. This may partially be as a result of the additional pressure placed on the underlying aquifers due to the weight of the lake water. It is also possible that changes in dewatering practises since the start of the inundated lake period have influenced those groundwater levels (i.e., a greater proportion of sump dewatering rather than bore dewatering has occurred compared to before the inundation of the lake).

It is relevant to note that the groundwater level in piezometer PDB3A fell significantly in March 2011. This corresponds to the date of installation of horizontal drains W911 (passing within 30 m of PDB3A) and W912 (passing within 110 m of PDB3A), both of which reported significant groundwater flows immediately following installation (600 cubic metres per day [m$^3$/d] and 170 m$^3$/d, respectively). It is likely that the groundwater level in piezometer PDB3A has been significantly impacted by pit dewatering since March 2011.

Piezometers PDB4A and PDB4B were decommissioned in September 2009.

### 3.14.3 Groundwater Response to Tailings Storage Facilities

Groundwater monitoring records for piezometers in the vicinity of the TSF are shown in Figure 25.

Groundwater levels in the Transported, Saprolite and Saprock units in the vicinity of the TSF show a progressive rise since CGM began operating. Generally, the magnitude of the groundwater rise correlates with the distance of the monitoring bore from the TSF. For example, in the Transported unit, the groundwater level rise at bore P414B, which is relatively close to the TSF, is greater than that at bore TSFN1B, located further away. Similarly, in the Saprock unit, bore MON02A has displayed a significant rise since late 2006, whilst the magnitude of groundwater level rise at bore MON01A (located at greater distance from the TSF) is lower.

Groundwater levels in piezometers MON02A and MON02B (screened in the Saprock and Saprolite, respectively) have displayed a significant rise since late 2006. Groundwater level variation around the TSF was investigated by Coffey (2009a). Rises were assessed to be related to the percolation and the movement of seepage from the TSFs.

Note that modelling carried out for the EIS showed groundwater level rise around the tailings impoundments to near the ground surface under some assumptions in relation to hydraulic properties of the soil profile and tailings dam materials (EIS Appendix N – Attachment N2-A of the EIS). The results at MON02A and MON02B are consistent with this possibility. Well established measures can be used to control groundwater levels approaching the surface; these are discussed in Section 9.3.

### 3.15 Surface Water Bodies

Records of Lake Cowal water levels available from August 1990 to November 2001 indicated levels varied between 202.9 m AHD and 206.2 m AHD over this period. Hawkes (1998) reported that the full storage Lake Cowal water level was 205.65 m AHD. North Limited (1998) reported that the full storage Lake Cowal water level was 205.7 m AHD and the bed level was 201.5 m AHD.

The lake is understood to have been dry over the years 2005 to 2009. Observations made at Lake Cowal indicate that the lake began to fill with water from June 2010. Figure 26 presents lake water level monitoring from October 2010 to December 2012, as well as a forward prediction for lake water levels.
The forward prediction estimates the lake will become dry in mid-February 2016, with the water level falling at a rate of some 3 mm per day. Assuming the lake water is lost to evaporation and considering the annual pan evaporation rate of 1,919 mm, this rate of decline in lake water levels is equivalent to a pan evaporation factor of 0.8 (i.e., an annual open water evaporation rate of 1,535 mm), a factor within the range of expected values for a lake in this regional setting.

When Lake Cowal is full it overflows into Lake Nerang Cowal (North Limited, 1998). Data were not available for historical water levels within Lake Nerang Cowal during wet periods, with the exception that as at August 2010 it was reported by CGM staff that the water within Lake Cowal had not overflowed into Lake Nerang Cowal. Lake Nerang Cowal is likely to have been dry during the years 2005 to 2012.

3.16 Groundwater Quality

3.16.1 Groundwater Quality in ML 1535

Electrical Conductivity (EC) concentrations and pH levels in groundwater within ML1535 have generally remained stable between 2004 and 2012. Monitored pH levels have been slightly acidic to neutral, and have been similar to baseline levels. Monitored pH levels near to the Tailings Storage Facilities have generally ranged between 6.5 and 7, with the exception of MON01B (to the east of the northern TSF), with a lower pH generally ranging between 4.5 and 6, and TSFNC with a pH of around 6. Results from MON01B may reflect a response to increased rainfall recharge during 2012. While open pit dewatering is causing a localised reduction in groundwater levels, pH and EC appear to be unaffected by this drawdown.

3.16.2 Groundwater Contamination in ML 1535

Cyanide (CN) is used in the gold extraction process and is measured by Barrick as both total cyanide and weak acid dissociable (WAD) cyanide (CN). The ANZECC (2000) trigger value of 0.007 milligrams per litre (mg/L) is for un-ionised hydrogen cyanide (HCN) which may be converted to free cyanide (HCN + CN-) using ANZECC Table 8.3.8 from ANZECC (2000) and corresponding pH and temperature values (ANZECC, 2000). The total cyanide is free cyanide plus the measurable cyanide from breakdown of metallo-cyanide and organic complexes.

Monitoring results for cyanide in groundwater were reviewed for the mine life history (September 2004 to December 2012). Within the available data, concentrations over this period have remained below the Limit of Reporting concentration of four micrograms per litre (µg/L) at all monitoring locations, with the exception of those listed in Table 4.

Generally, cyanide has not been observed at significant concentrations in groundwater over the site. Where monitoring has shown total cyanide to be present, its concentration at individual monitoring locations has not been consistent over time, and its observed presence has not always been supported by WAD analysis.

The groundwater monitoring results suggest that, as of December 2012, there is no consistent trend to suggest that significant concentrations of cyanide have leached from the TSF into the surrounding groundwater.
Dissolved arsenic concentrations were less than or close to the laboratory limit of reporting over the 2012 calendar year. Variations in metal concentrations are assessed to reflect the natural heterogeneity in ground conditions, rather than direct impacts from mining, since the regional groundwater system is located in a naturally metalliferous geological terrain.

### 3.16.3 Groundwater Salinity in the BCPB Area

To assess potential water quality impacts from pumping from the Lachlan Formation, an assessment of groundwater salinity was conducted for the BCPB area. A significant database is available in Anderson et al. (1993). This information has been augmented by monitoring of EC and total dissolved solids (TDS) at the monitoring bores in the BCPB. From these sources a database of 60 measurements has been compiled. The measurements were taken at 48 bores with measurement points over the interval from the near surface to the Lachlan Formation. These data is listed in Appendix A.
The measurements of the database have been plotted in Figure 27a, showing the trend of decreasing salinity with depth. The Cowra Formation is conspicuous above 80 m depth with a greater range in salinities than the deeper Lachlan Formation. Near Lake Cowal, salinities in the Upper Cowra Formation are generally high (as are those in the Corinella Constriction and Lake Cowal cross-sections in NSW Department of Water Resources, 1993).

Ignoring the group of low salinities at shallow depth in Figure 27a, it is assessed that in the vicinity of the BCPB the Upper Cowra Formation has a geometric mean salinity of around 25,000 microSiemens per centimetre (µS/cm). The Lower Cowra Formation has a geometric mean salinity of around 8,000 µS/cm, and the Lachlan Formation a geometric mean salinity of around 2,000 µS/cm.

Anderson et al. (1993) identified that higher salinities are generally associated with increasing distance from recharge sources, and with proximity to basement rocks. Water table maps show convergence of contours from the north and south on the area east of Lake Cowal, suggesting it is a discharge zone. Numerical modelling conducted in 1993 (Williams, 1993) for the upper 20 m of the Upper Cowra Formation indicated that evaporation from surface ponding caused by groundwater seeps was occurring in several locations in the more topographically depressed area in the vicinity of the Corinella Constriction (north-east of Lake Cowal).

The monitoring bores at the BCPB (BLPR1 to BLPR7) have been monitored for water quality since 2004. Figure 27b shows the database of EC measurements made in the field at the monitoring bores, as a graph. Figure 27c shows the data with spikes and other interpreted anomalous values removed. Spikes may be associated with leakage of more saline water down the outside of the casing. The data show an average salinity of around 2000 µS/cm, except for BLPR 3 (about 5,000 µS/cm). BLPR3 has a higher salinity because it is screened higher in the profile, in the Lower Cowra Formation.

Based on the groundwater data, EC has remained relatively stable at all monitoring locations within the BCPB since the commencement of the CGM.

### 3.17 Aquifer Parameters (Regional)

#### 3.17.1 Hydraulic Conductivity

A review of available government bore records and hydraulic test results conducted within the palaeochannel and within ML 1535 was undertaken to incorporate data from additional tests conducted since 2006, and review older records in more detail. A database of 94 hydraulic tests conducted in the Bland Creek and Burragarorang Palaeochannels has been compiled from the following sources:

- 26 single rate pumping tests conducted on ML 1535;
- three packer tests in volcanic rocks conducted on ML1535;
- two long-term single rate pumping tests conducted at the two saline borefields (one at each borefield);
- six long-term single rate tests conducted at the BCPB; and
- 102 pumping tests on private bores recorded as specific capacities in government records and converted to equivalent transmissivities (45 tests are from the Lachlan Floodplain [north of the Corinella Constriction]).
Table 5 lists results from several long-duration pumping tests (of which two utilised multiple monitoring piezometers), with transmissivities interpreted from an analysis of transient drawdown measurements. The results from 13 of these tests are relevant to alluvial sediments of the Bland Creek Palaeochannel.

Specific capacities were calculated from government bore records where all the following parameters were available for each bore:

- pumping test duration;
- discharge rate;
- bore / casing diameter;
- pre-test water level and test drawdown level (at the end of pumping); and
- screen interval.

To obtain an equivalent transmissivity from each specific capacity measurement, a subsidiary database of hydraulic test measurements was used where, for each bore, the following measurements were simultaneously available:

- transmissivity (calculated from transient drawdown measurements made during the pumping test conducted at the bore); and
- the specific capacity (calculated using only the discharge and final drawdown for the same pumping test).

The transmissivity / specific capacity measurement pairs for each bore were used to find a linear relationship between these quantities, by regression analysis. The subsidiary database comprised 23 such bores where single rate test transient drawdown data were available. For the correlation between transmissivity and specific capacity, a simple linear relationship was found to provide a good fit (as shown in Figure 28a), where transmissivity was calculated to be 1.4 times the specific capacity. This relationship was then used to convert the specific capacities from the government database to equivalent transmissivities. This process assumes bore losses are roughly similar between bores. This assumption is reasonable since the relation removes much of the well loss component in each specific capacity value (since transmissivities are interpreted from transient drawdown measurements by finding the gradient in head change, thereby eliminating the well loss component).

Transmissivities were then converted to horizontal hydraulic conductivities using the total screened or sand pack interval. The calculated hydraulic conductivities are slight overestimates as they do not incorporate partial aquifer penetration however their distribution with depth is useful to assess the variation in aquifer properties. Vertical hydraulic head profiles (see below) created by pumping in the Lachlan Formation suggest that vertical hydraulic conductivity ($K_v$) is smaller than horizontal hydraulic conductivity ($K_h$).
### Table 5. Hydraulic Test Results for the Mine Lease and BCPB Area

<table>
<thead>
<tr>
<th>Bore</th>
<th>Test Duration (hours)</th>
<th>Flow Rate (m³/day)</th>
<th>Trans. (m³/day)</th>
<th>Hydraulic Conductivity (m/day)</th>
<th>Storativity</th>
<th>Screen Interval (m bgl)*</th>
<th>Sand Pack Interval (m bgl)*</th>
<th>Stratum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bore 1 (GW701660) ¹</td>
<td>0.4</td>
<td>2,894</td>
<td>660</td>
<td>28</td>
<td>N/A</td>
<td>95</td>
<td>116</td>
<td>92 116</td>
</tr>
<tr>
<td>Bore 2 (GW701659) ¹</td>
<td>24</td>
<td>4,752</td>
<td>870</td>
<td>26</td>
<td>N/A</td>
<td>92</td>
<td>125</td>
<td>92 125</td>
</tr>
<tr>
<td>Bore 3 (GW701658) ¹</td>
<td>24</td>
<td>4,752</td>
<td>1,240</td>
<td>50</td>
<td>N/A</td>
<td>107</td>
<td>128</td>
<td>105 130</td>
</tr>
<tr>
<td>Bore 4 (GW701657) Test 1 ¹</td>
<td>24</td>
<td>4,752</td>
<td>1,080</td>
<td>98</td>
<td>N/A</td>
<td>108</td>
<td>117</td>
<td>106 117</td>
</tr>
<tr>
<td>Bore 4 (GW701657) Test 2 ³</td>
<td>8</td>
<td>4,752</td>
<td>1,080</td>
<td>98</td>
<td>N/A</td>
<td>108</td>
<td>117</td>
<td>106 117</td>
</tr>
<tr>
<td>Bores 1 to 4 as a single test ³</td>
<td>-</td>
<td>-</td>
<td>750</td>
<td>32</td>
<td>0.00018</td>
<td>-</td>
<td>-</td>
<td>99 122</td>
</tr>
<tr>
<td>BLRP2 Test 1 ²,³</td>
<td>48</td>
<td>2,678</td>
<td>460</td>
<td>12</td>
<td>0.00020</td>
<td>106</td>
<td>126</td>
<td>90 130</td>
</tr>
<tr>
<td>BLRP2 Test 2 ²,³</td>
<td>168</td>
<td>5,702</td>
<td>482</td>
<td>12</td>
<td>0.00015</td>
<td>106</td>
<td>126</td>
<td>90 130</td>
</tr>
<tr>
<td>P350 ⁴</td>
<td>48</td>
<td>173</td>
<td>24</td>
<td>1.2</td>
<td>0.00130</td>
<td>15</td>
<td>46</td>
<td>10 51</td>
</tr>
<tr>
<td>P322 ⁵</td>
<td>48</td>
<td>914</td>
<td>36</td>
<td>0.5</td>
<td>0.00030</td>
<td>5</td>
<td>88</td>
<td>Trans. &amp; Rock ⁶</td>
</tr>
<tr>
<td>Duff (GW702230) 2009 ⁶</td>
<td>91</td>
<td>1,452</td>
<td>98</td>
<td>33</td>
<td>N/A</td>
<td>61.5</td>
<td>64.5</td>
<td>- -</td>
</tr>
<tr>
<td>Duff (GW702230) 2004</td>
<td>24</td>
<td>1,597</td>
<td>104</td>
<td>35</td>
<td>N/A</td>
<td>61.5</td>
<td>64.5</td>
<td>- -</td>
</tr>
<tr>
<td>WB01</td>
<td>72</td>
<td>294</td>
<td>215</td>
<td>4.4</td>
<td>N/A</td>
<td>13</td>
<td>37</td>
<td>3 52</td>
</tr>
<tr>
<td>PD6 and PD20 ⁸</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.2</td>
<td>N/A</td>
<td>-</td>
<td>-</td>
<td>- -</td>
</tr>
</tbody>
</table>

¹ Analysis of data presented in electronic bore records supplied by email from the NOW database in 2006.
² Coffey (1994a).
³ Coffey (1995c).
⁵ Coffey (1994c).
⁶ GCS (2010).
⁸ Automated parameter estimation for the Upper Cowra only, using pumping test results from PD6 and PD20 (dewatering bores) and 10 other dewatering bores on the mine site.
⁹ Transported sediments (28 m) and volcanic rock (60 m).

m²/day - Square metres per day.
Hydraulic conductivities from the entire database are shown graphically in Figure 28b, plotted against the midpoint of the screen or filter pack interval. Hydraulic conductivities of low permeability sediments within the Upper and Lower Cowra Formations may be under-represented as these low permeability sediments are not targeted during bore installation for water supply purposes, but do form a significant proportion of the sequence for the Cowra Formation.

Based on the distribution of hydraulic conductivity with depth, three distinct alluvial sequences are interpreted to be present. These are as follows (Figure 28b):

- **Upper Cowra Formation**: this sequence generally occurs from ground surface to an average depth of around 45 m to 50 m over most of the study area. The average depth to groundwater is around 7 m, giving an average saturated thickness of just over 40 m. This sequence generally shows decreasing hydraulic conductivity with depth and the slope of the distribution (when viewed with similar results north of the Corinella Constriction) suggests more stratification than deeper layers, providing for a lower average ratio of vertical hydraulic conductivity ($K_v$) to horizontal hydraulic conductivity ($K_h$).

- **Lower Cowra Formation**: this sequence generally occurs over an average depth interval of around 50 m to 90 m over most of the study area. This layer appears to have different hydraulic properties to the Upper Cowra Formation, and is likely to have a higher average value of $K_v/K_h$ than the overlying sequences.

- **Lachlan Formation**: this sequence generally occurs over an average depth interval of around 90 m to 120 m in the Bland Creek Palaeochannel and between 75 m and 110 m in the Burragorang Palaeochannel. Within this formation there are assessed to be two distinct sequences as follows:
  - High conductivity sands and minor gravels close to and within the deeper parts of the palaeochannel.
  - Lower conductivity sediments that generally occur further away from the deeper parts of the palaeochannel and surround the high permeability sands and minor gravels. The hydraulic properties of this sequence appear similar to the Lower Cowra Formation.
  - The Lachlan Formation has the highest average hydraulic conductivity in the area, with a geometric mean (as measured from hydraulic tests) of about 30 m/day (see Figure 28b).

Bedrock in the Bland Creek Palaeochannel consists mostly of sedimentary sequences (at burial depths exceeding 100 m) except in the upper reaches of the Burragorang Palaeochannel where igneous basement is present. At the mine site, hydraulic conductivity of weathered and fresh rock follows a pattern of decreasing permeability with depth. Saplrite retains some of the rock structure and does have the capacity to maintain open defects, exhibiting a behaviour similar to fractured rocks.

Figure 28b indicates that the hydraulic conductivity contrast between the high-conductivity parts of the Lachlan Formation, and adjacent underlying bedrock, is likely to be about 1,000 times. The majority of the bedrock profile in the study area is considered to have significantly lower permeability than unconsolidated sediments except in structurally disturbed areas.
Hydraulic test results pertain to the screened intervals of bores, which are usually located within the highest permeability sediments. For the layer as a whole, the transmissivity would also include contributions from other untested horizons. From a modelling perspective, calibrated transmissivities are generally higher than transmissivities interpreted from hydraulic tests due to the scaling phenomenon.

### 3.17.2 Storativity

No hydraulic test data were available from which an assessment of the specific yield of the Cowra Formation could be made. Numerical modelling conducted by Williams (1993) assumed a value of 5% for the pore volume available for increased storage at the water table in the Upper Cowra Formation in the Jemalong Plains Irrigation District. Surface sediments in that district are known to be more permeable than surface sediments in the Bland Creek Palaeochannel.

Water provided by gravity drainage of fine-grained sediments can take significant lengths of time to fully develop. Williams and Lohman (1949) assessed that, based on pumping test results at several sites, specific yield developed at those sites would have reached 80% of the laboratory-derived values after two years of pumping, and be fully developed after three years of pumping. Prill et al. (1965) concluded from column drainage experiments that even for sand-size materials, a period of two months to more than one year would be required for gravity drainage to reach equilibrium and thus give the specific yield.

Results from hydraulic tests undertaken in 2004 in BCPB bores provide several values of confined storativity. Those results indicate an average storativity of $1.9 \times 10^{-4}$ for the Lachlan Formation (GCS, 2006), or an average specific storage of $9.5 \times 10^{-6}$ per metre ($m^{-1}$) assuming a 20 m aquifer interval. A pumping test of seven days duration conducted at BLPR2 in 1995 (Coffey, 1995b) gave an average storativity of $1.7 \times 10^{-4}$ for the Lachlan Formation, or an average specific storage of $8.5 \times 10^{-6} m^{-1}$ (assuming minimal drainage at the water table during the test, and a 20 m aquifer interval). These results are likely to be influenced by vertical drainage from the base of the Lower Cowra Formation.

### 3.18 Aquifer Parameters (Local)

Coffey (2006) reviewed hydraulic testing data conducted in pumping bores and observation piezometers screened within the Lachlan and Cowra Formations within the BCPB (formerly known as the Jemalong Borefield Area), located to the north-east of the mine site. Transmissivities averaged 35 m²/day within the Upper Cowra Formation (up to 50 m depth) and 8 m²/day within the Lower Cowra Formation (average depth 50 m to 90 m). Interpreted horizontal hydraulic conductivities, converted from transmissivity values using the total screened interval of the borehole, typically ranged from 0.1 to 10 m/day.

The adopted parameter values for the calibrated model used in a previous pit dewatering assessment (Coffey, 2008a) are shown in Table 6.
Table 6. Adopted Model Parameters (Coffey, 2008a)

<table>
<thead>
<tr>
<th>Hydrogeological Unit</th>
<th>Geological Unit</th>
<th>Horizontal Hydraulic Conductivity (m/day)</th>
<th>Vertical Hydraulic Conductivity (m/day)</th>
<th>Specific Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transported</td>
<td>Cowra Formation</td>
<td>$1.0 \times 10^{-3}$</td>
<td>$1.0 \times 10^{-4}$</td>
<td>0.15</td>
</tr>
<tr>
<td>Saprolite</td>
<td>Lake Cowal Volcanics</td>
<td>$5.0 \times 10^{-2}$</td>
<td>$5.0 \times 10^{-2}$</td>
<td>0.02</td>
</tr>
<tr>
<td>Sarpock</td>
<td>Ordovician Host Rock</td>
<td>$1.0 \times 10^{-2}$</td>
<td>$1.0 \times 10^{-2}$</td>
<td>0.02</td>
</tr>
<tr>
<td>Primary Rock</td>
<td>Ordovician Host Rock</td>
<td>$1.0 \times 10^{-2}$</td>
<td>$1.0 \times 10^{-2}$</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Source: Coffey, 2008a.

A calibrated groundwater model developed by Coffey (2009a) to assess groundwater level changes at the mine site adopted the parameter values shown in Table 7.

Table 7. Adopted Model Parameters (Coffey, 2009a)

<table>
<thead>
<tr>
<th>Hydrogeological Unit</th>
<th>Geological Unit</th>
<th>Horizontal Hydraulic Conductivity (m/day)</th>
<th>Vertical Hydraulic Conductivity (m/day)</th>
<th>Specific Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transported</td>
<td>Cowra Formation</td>
<td>$1.0 \times 10^{-2}$</td>
<td>$3.0 \times 10^{-3}$</td>
<td>0.05</td>
</tr>
<tr>
<td>Saprolite</td>
<td>Lake Cowal Volcanics</td>
<td>$1.0 \times 10^{-1}$</td>
<td>$1.0 \times 10^{-2}$</td>
<td>0.002</td>
</tr>
<tr>
<td>Sarpock</td>
<td>Ordovician Host Rock</td>
<td>$1.0 \times 10^{-3}$</td>
<td>$1.0 \times 10^{-3}$</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Source: Coffey, 2009a.

A recovery test conducted in monitoring bore PD3 (see Figure 23 for bore location), screened over the Transported and Saprolite units, suggested those units possessed a collective transmissivity of 1.2 m²/d (Coffey, 2008a). In consideration of the 90.5 m total screen interval of PD3, the estimated horizontal hydraulic conductivities over both the Transported and Saprolite units were estimated at 0.01 m/day.

Coffey (2009a) collated falling head permeability test data from piezometers located both within and to the east of the TSF area. Results suggested the following hydraulic conductivity values:

- an arithmetic mean of 0.02 m/day and a geometric mean of 0.01 m/day for the Transported at 6 to 16 m below ground surface; and
- an arithmetic mean of 0.05 m/day and a geometric mean of 0.02 m/day for the Saprolite at 18 to 36 m below ground surface.

These values are relatively consistent with the PD3 recovery test result noted above and the values adopted in the calibrated pit dewatering assessment model (Coffey, 2008a), as shown in Table 7.

No hydraulic test data were available from which an assessment of the specific yield of the Cowra Formation could be made. Numerical modelling conducted by Williams (1993) assumed a value of 5% for the pore volume available for increased storage at the water table in the Upper Cowra Formation in the Jemalong Plains Irrigation District. Based on lithology and literature (Johnson, 1967) a specific yield of 4% was adopted for groundwater supply modelling (Coffey, 2006).
Coffey analysed results from pumping tests undertaken in the dewatering bores in 2004 (Coffey, 2005). Bores were screened over the full sequence of Transported, Saprolite and Saprock units. This introduces some uncertainty as flow components attributable to individual aquifer horizons are unknown. The horizons are somewhat gradational and precise boundaries are difficult to identify. The average hydraulic conductivity from the analysed data was 0.06 m/day.

Based on pumping test, recovery test and slug test data (Coffey, 1995a), Hawkes (1998) adopted the model parameters shown in Table 8 for a pit dewatering model. It should be noted that the model developed by Hawkes (1998) considered alternating aquifer and aquitard model layers throughout (i.e. contrasting high and low hydraulic conductivity units alternated with depth), and divided the Transported unit into two aquifers (relatively high hydraulic conductivity units) and two aquitards (relatively low hydraulic conductivity units). Data were sufficient for this approach in modelling the pit area alone.

A calibrated groundwater model developed by NOW (unknown publication date) for the Upper Lachlan catchment adopted horizontal hydraulic conductivities generally range from one to 20 m/day in the Lower Cowra Formation and from one to 35 m/day in the Upper Cowra Formation over the present model domain.

Table 8. Adopted Model Parameters (Hawkes, 1998)

<table>
<thead>
<tr>
<th>Hydrogeological Unit</th>
<th>Geological Unit</th>
<th>Horizontal Hydraulic Conductivity (m/day)</th>
<th>Vertical Hydraulic Conductivity (m/day)</th>
<th>Specific Yield</th>
<th>Confined Storage Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transported</td>
<td>Cowra Formation</td>
<td>2.0×10^4 to 3.0×10^5</td>
<td>1.0×10^-4</td>
<td>1.0×10^-3</td>
<td>1.5×10^-1</td>
</tr>
<tr>
<td>Saprolite</td>
<td>Lake Cowal Volcanics</td>
<td>-</td>
<td>1.0×10^-4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Saprock</td>
<td>Ordovician Host Rock</td>
<td>1.5×10^0</td>
<td>-</td>
<td>1.0×10^-2</td>
<td>1.0×10^-3</td>
</tr>
<tr>
<td>Primary Rock</td>
<td>Ordovician Host Rock</td>
<td>-</td>
<td>1.0×10^-4</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>


Analysis of pumping tests conducted in 2004 in bores of the mine (Jemalong) borefields, located to the north-east of the mine site area, provide several values of confined storativity, giving an average storativity of 1.9×10^-4 for the Lachlan Formation (GCS, 2006), or an average specific storage of 9.5×10^-6 m^-1, assuming a 20 m thick aquifer. A pumping test of seven days duration conducted at BLPR2 (located approximately 18 km to the north-north east of pit E42) gave an average storativity of 1.7×10^-4 for the Lachlan Formation, or an average specific storage of 8.5×10^-6 m^-1, assuming a 20 m thick aquifer. The lower permeability sediments that occur further away from the deeper parts of the palaeochannel appear to possess similar hydraulic properties to the Lower Cowra Formation (Coffey, 2006). However, in practical terms, a portion of the assessed storativities will be influenced by vertical leakage from the base of the Lower Cowra Formation during pumping tests.

A calibrated groundwater model developed by NOW (unknown publication date) for the Upper Lachlan catchment adopted specific yield values generally ranging from 0.06 to 0.3 in the Upper Cowra Formation. Storage coefficients in the same model generally ranged from 5.5×10^-6 to 1.7×10^-5 in the Lower Cowra Formation.
GCS (2008) co-ordinated a pumping test by Barrick in the Transported materials (Cowra Formation). The testing was conducted to assess the potential yield of the Saline Supply Borefield, located within the ML 1535. Test results suggest a hydraulic conductivity of the Transported material of approximately 5 m/day and a specific yield of approximately $1.6\times10^{-3}$.

A summary of the available data is presented in Tables 9 and 10.

### Table 9. Summary of Horizontal Hydraulic Conductivity Data

<table>
<thead>
<tr>
<th>Hydrogeological Unit (Geological Unit)</th>
<th>Value (m/day)</th>
<th>Region</th>
<th>Source</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transported (Cowra Formation)</td>
<td>$1\times10^{-1}$ to $1\times10^{2}$</td>
<td>Jemalong Borefield</td>
<td>Hydraulic testing</td>
<td>Coffey (2006)</td>
</tr>
<tr>
<td></td>
<td>$5\times10^{0}$</td>
<td>Saline Supply Borefield, ML 1535</td>
<td>Pumping test</td>
<td>GCS (2008)</td>
</tr>
<tr>
<td></td>
<td>$1\times10^{-2}$</td>
<td>TSF</td>
<td>Slug test</td>
<td>Coffey (2009a)</td>
</tr>
<tr>
<td></td>
<td>$1\times10^{-2}$</td>
<td>Mine Site</td>
<td>Modelling</td>
<td>Coffey (2009a)</td>
</tr>
<tr>
<td></td>
<td>$1\times10^{-3}$</td>
<td>E42 open Pit</td>
<td>Modelling</td>
<td>Coffey (2008a)</td>
</tr>
<tr>
<td></td>
<td>$2\times10^{0}$ to $3\times10^{0}$</td>
<td>E42 open Pit</td>
<td>Modelling</td>
<td>Hawkes (1998)</td>
</tr>
<tr>
<td></td>
<td>$1\times10^{0}$ to $3.5\times10^{1}$</td>
<td>Upper Lachlan catchment</td>
<td>Modelling</td>
<td>NOW (unknown)</td>
</tr>
<tr>
<td></td>
<td>1 to 2</td>
<td>Jemalong</td>
<td>Regional Modelling</td>
<td>Coffey (2011)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Elsewhere</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transported (Cowra Formation) and Saplholite</td>
<td>$1\times10^{0}$</td>
<td>E42 open Pit</td>
<td>Recovery test</td>
<td>Coffey (2008a)</td>
</tr>
<tr>
<td>Transported (Cowra Formation), Saplholite and Saprock (Ordovician Host Rock)</td>
<td>$6\times10^{2}$</td>
<td>E42 open Pit</td>
<td>Pumping test</td>
<td>Coffey (1995a)</td>
</tr>
<tr>
<td>Saplholite</td>
<td>$2\times10^{0}$</td>
<td>TSF</td>
<td>Slug testing</td>
<td>Coffey (2009a)</td>
</tr>
<tr>
<td></td>
<td>$1\times10^{-1}$</td>
<td>Mine Site</td>
<td>Modelling</td>
<td>Coffey (2009a)</td>
</tr>
<tr>
<td></td>
<td>$5\times10^{2}$</td>
<td>E42 open Pit</td>
<td>Modelling</td>
<td>Coffey (2008a)</td>
</tr>
<tr>
<td>Saprock (Ordovician Host Rock)</td>
<td>$1\times10^{-2}$</td>
<td>Mine Site</td>
<td>Modelling</td>
<td>Coffey (2009a)</td>
</tr>
<tr>
<td></td>
<td>$1\times10^{-3}$</td>
<td>E42 open Pit</td>
<td>Modelling</td>
<td>Coffey (2008a)</td>
</tr>
<tr>
<td></td>
<td>$1.5\times10^{0}$</td>
<td>E42 open Pit</td>
<td>Modelling</td>
<td>Hawkes (1998)</td>
</tr>
<tr>
<td>Primary Rock (Ordovician Host Rock)</td>
<td>$1\times10^{-2}$</td>
<td>E42 open Pit</td>
<td>Modelling</td>
<td>Coffey (2008a)</td>
</tr>
<tr>
<td>Lachlan Formation</td>
<td>$3\times10^{2}$ to $1\times10^{7}$</td>
<td>Jemalong Borefield</td>
<td>Hydraulic testing</td>
<td>Coffey (2006)</td>
</tr>
<tr>
<td></td>
<td>3 to 28</td>
<td>Regionally</td>
<td>Regional Modelling</td>
<td>Coffey (2011)</td>
</tr>
</tbody>
</table>
Table 10. Summary of Specific Yield and Storage Data

<table>
<thead>
<tr>
<th>Unit(s)</th>
<th>Specific Yield</th>
<th>Storage Coefficient</th>
<th>Region</th>
<th>Source</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transported (Cowra Formation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0×10⁻³</td>
<td>1.5×10⁻¹</td>
<td>E42 open Pit</td>
<td>See text</td>
<td>Hawkes (1998)</td>
</tr>
<tr>
<td></td>
<td>1.5×10⁻¹</td>
<td>-</td>
<td>E42 open Pit</td>
<td>Modelling</td>
<td>Coffey (2008a)</td>
</tr>
<tr>
<td></td>
<td>5.0×10⁻¹</td>
<td>-</td>
<td>Mine Site</td>
<td>Modelling</td>
<td>Coffey (2009a)</td>
</tr>
<tr>
<td></td>
<td>6.0×10⁻² to 3.0×10⁻¹</td>
<td>5.5×10⁻⁶ to 1.7×10⁻⁵</td>
<td>Upper Lachlan catchment</td>
<td>Modelling</td>
<td>NOW (unknown)</td>
</tr>
<tr>
<td></td>
<td>1.6×10⁻³</td>
<td>-</td>
<td>Saline Supply Borefield, Mine Lease</td>
<td>Pumping test</td>
<td>GCS (2008)</td>
</tr>
<tr>
<td></td>
<td>4.0×10⁻²</td>
<td>1.5×10⁻⁵</td>
<td>Regionally</td>
<td>Regional Modelling</td>
<td>Coffey (2011)</td>
</tr>
<tr>
<td>Saprolite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.0×10⁻²</td>
<td>-</td>
<td>E42 open Pit</td>
<td>Modelling</td>
<td>Coffey (2008a)</td>
</tr>
<tr>
<td></td>
<td>2.0×10⁻³</td>
<td>-</td>
<td>Mine Site</td>
<td>Modelling</td>
<td>Coffey (2009a)</td>
</tr>
<tr>
<td>Saprock (Ordovician Host Rock)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0×10⁻²</td>
<td>1.0×10⁻³</td>
<td>E42 open Pit</td>
<td>See text</td>
<td>Hawkes (1998)</td>
</tr>
<tr>
<td></td>
<td>2.0×10⁻²</td>
<td>-</td>
<td>E42 open Pit</td>
<td>Modelling</td>
<td>Coffey (2008a)</td>
</tr>
<tr>
<td></td>
<td>2.0×10⁻²</td>
<td>-</td>
<td>Mine Site</td>
<td>Modelling</td>
<td>Coffey (2009a)</td>
</tr>
<tr>
<td>Primary Rock (Ordovician Host Rock)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.0×10⁻²</td>
<td>-</td>
<td>E42 open Pit</td>
<td>Modelling</td>
<td>Coffey (2008a)</td>
</tr>
<tr>
<td>Lachlan Formation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.9×10⁻⁴</td>
<td>-</td>
<td>Jemalong Borefield</td>
<td>Pumping test</td>
<td>GCS (2006)</td>
</tr>
<tr>
<td></td>
<td>1.7×10⁻⁴</td>
<td>-</td>
<td>Jemalong Borefield</td>
<td>Pumping test</td>
<td>Coffey (1995c)</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>1.5×10⁻⁵</td>
<td>Regionally</td>
<td>Regional Modelling</td>
<td>Coffey (2011)</td>
</tr>
</tbody>
</table>

The bedrock has relatively low hydraulic conductivity (Table 9). Coffey (1995a) noted that there was little apparent difference in transmissivity between the major structural features (fractured dykes) within the pit area and relatively fresh bedrock. Therefore, aquifer parameters are expected to be similar for bedrock and geological fault features. The bedrock consists mostly of sedimentary sequences and is considered to have significantly lower permeability than unconsolidated sediments, except in structurally disturbed areas.

3.18.1 Tailings Storage Facilities

Based on test drilling data, geophysical studies and piezometer installations around the proposed TSF reported by North Limited (1998):

- The foundation of the TSF comprises silty clay with some gravelly clay, and highly weathered rock occurring at shallow depth in the west. The thickness of unconsolidated sediments decreases from east to west.
• The groundwater movement through the tailings areas prior to mine development was essentially from west to east with a hydraulic gradient of about $7 \times 10^{-3}$ m.

• Field permeability testing of strata expected to be of higher permeability indicate low horizontal permeability of the order of $2 \times 10^{-4}$ to $1 \times 10^{-3}$ m/day for gravely clay and $0.6 \times 10^{-4}$ to $3.5 \times 10^{-4}$ m/day for weathered rock.

• Laboratory infiltration tests indicate vertical permeability of the less permeable soils of the order of $0.9 \times 10^{-8}$ to $1.3 \times 10^{-6}$ m/day.

URS Australia Pty Limited (2005, 2006) conducted field investigations and laboratory testing for both the Northern and Southern TSF, concluding that:

• Investigations consistently showed the uppermost 5 m of the TSF footprints to be essentially clay soils of extremely low permeability.

• Laboratory testing of typical samples from within 5 m of floor level yielded permeabilities less than the target permeability of $1 \times 10^{-9}$ metres per second (m/s) ($9 \times 10^{-5}$ m/day).

• Inspections of cut-off trench excavation and storage floor did not reveal any significant extensive or continuous zones or lenses of high permeability soil that might provide a leakage path.

Surface infiltration tests carried out by site personnel in shallow test pits to the east of the TSF area (Coffey, 1995b) indicated a low infiltration permeability range from $8 \times 10^{-4}$ m/day to $3 \times 10^{-5}$ m/day, with an arithmetic mean of $2 \times 10^{-4}$ m/day and a geometric mean of $1 \times 10^{-4}$ m/day.

Falling head permeability tests and consolidation tests were conducted by Knight Piesold Pty Ltd (1994) on saturated tailings samples with unrestricted drainage from the base. Results are shown in Table 11 and indicate the permeability of saturated tailings (prior to additional consolidation due to tailings loading or air drying).

### Table 11. Tailings Permeability Data (Knight Piesold, 1994)

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Sample</th>
<th>Permeability (m/day)</th>
<th>Dry Density (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falling Head Permeability Tests</td>
<td>Primary Tailings</td>
<td>0.02</td>
<td>1.29</td>
</tr>
<tr>
<td></td>
<td>Primary Tailings</td>
<td>0.02</td>
<td>1.29</td>
</tr>
<tr>
<td></td>
<td>Oxide Tailings</td>
<td>0.01</td>
<td>1.18</td>
</tr>
<tr>
<td></td>
<td>Oxide Tailings</td>
<td>0.01</td>
<td>1.20</td>
</tr>
<tr>
<td>Consolidation Tests</td>
<td>Primary Tailings</td>
<td>0.09</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>Primary Tailings</td>
<td>0.02</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>Oxide Tailings</td>
<td>0.27</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Oxide Tailings</td>
<td>0.03</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>Oxide Tailings</td>
<td>0.01</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>Oxide Tailings</td>
<td>0.01</td>
<td>1.13</td>
</tr>
</tbody>
</table>

Source: Knight Piesold Pty Ltd, 1994.

t/m³ – tonnes per cubic metre.
A calibrated groundwater model developed by Coffey (2009a) to assess groundwater level changes associated with the tailings facilities adopted the parameter values shown in Table 12 for tailings materials.

Table 12. Adopted Model Parameters (Coffey, 2009a)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Horizontal Permeability (m/day)</th>
<th>Vertical Permeability (m/day)</th>
<th>Specific Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deposited Tailings</td>
<td>5.0×10⁻²</td>
<td>5.0×10⁻³</td>
<td>0.01</td>
</tr>
<tr>
<td>TSF Embankment - Clay</td>
<td>1.0×10⁻⁴</td>
<td>1.0×10⁻⁴</td>
<td>0.15</td>
</tr>
<tr>
<td>TSF Embankment - Fill</td>
<td>5.0×10⁻⁰</td>
<td>5.0×10⁻⁰</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Source: Coffey, 2009a.

A summary of the above information is presented in Table 13.

Table 13. Summary of TSF Parameters

<table>
<thead>
<tr>
<th>Hydrogeological Unit</th>
<th>Horizontal Permeability (m/day)</th>
<th>Vertical Permeability (m/day)</th>
<th>Specific Yield</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSF Foundation</td>
<td>1×10⁻³ to 6×10⁻⁵</td>
<td>1.3×10⁻⁶ to 9×10⁻⁷</td>
<td>N/A</td>
<td>North Limited (1998)</td>
</tr>
<tr>
<td>N/A</td>
<td>8.6×10⁻⁵</td>
<td>N/A</td>
<td>URS (2005, 2006)</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>2×10⁻⁴</td>
<td>N/A</td>
<td>Coffey (1995b)</td>
<td></td>
</tr>
<tr>
<td>Deposited Tailings</td>
<td>N/A</td>
<td>1×10⁻² to 6.2×10⁻¹</td>
<td>N/A</td>
<td>Knight Piesold (1994)</td>
</tr>
<tr>
<td>5.0×10⁻²</td>
<td>5.0×10⁻³</td>
<td>0.01</td>
<td>Coffey (2009a) (model)</td>
<td></td>
</tr>
<tr>
<td>TSF Embankment - Clay</td>
<td>1.0×10⁻⁴</td>
<td>1.0×10⁻⁴</td>
<td>0.15</td>
<td>Coffey (2009a) (model)</td>
</tr>
<tr>
<td>TSF Embankment - Fill</td>
<td>5.0×10⁻⁰</td>
<td>5.0×10⁻⁰</td>
<td>0.15</td>
<td>Coffey (2009a) (model)</td>
</tr>
</tbody>
</table>

3.19 Representation of Mining Activities

3.19.1 Mine Production

The indicative mine production schedule for the Modification, provided by Barrick, is shown in Table 14.

3.19.2 Excavation Schedule

Open pit geometries were provided at six-monthly intervals from December 2005 to June 2010, as well as for December 2011 and December 2012. The proposed pit geometry for 2014, 2020 and mine closure were provided by Barrick. The pit geometry provided for mine closure did not differ significantly from that for 2020.

Based on these data, Figure 29 shows the base elevation of the open pit.
### Table 14. Indicative Mine Production Schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>CGM Year</th>
<th>Waste Rock mined (Mt)</th>
<th>Ore Mined (Mt)</th>
<th>Ore Processed (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oxide</td>
<td>Primary</td>
</tr>
<tr>
<td>2005 to 2013</td>
<td>1 to 9</td>
<td>203.1</td>
<td>16.5</td>
<td>52.9</td>
</tr>
<tr>
<td><strong>Forecast</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>10</td>
<td>22.4</td>
<td>0.0</td>
<td>8.0</td>
</tr>
<tr>
<td>2015</td>
<td>11</td>
<td>26.9</td>
<td>0.0</td>
<td>6.8</td>
</tr>
<tr>
<td>2016</td>
<td>12</td>
<td>18.8</td>
<td>0.0</td>
<td>6.8</td>
</tr>
<tr>
<td>2017</td>
<td>13</td>
<td>11.8</td>
<td>0.0</td>
<td>8.9</td>
</tr>
<tr>
<td>2018</td>
<td>14</td>
<td>9.2</td>
<td>0.0</td>
<td>9.8</td>
</tr>
<tr>
<td>2019</td>
<td>15</td>
<td>2.1</td>
<td>0.0</td>
<td>11.2</td>
</tr>
<tr>
<td>2020</td>
<td>16</td>
<td>1.8</td>
<td>0.0</td>
<td>5.9</td>
</tr>
<tr>
<td>2021</td>
<td>17</td>
<td>0.2</td>
<td>0.0</td>
<td>1.4</td>
</tr>
<tr>
<td>2022</td>
<td>18</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2023</td>
<td>19</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2024</td>
<td>20</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>296.3</td>
<td>16.5</td>
<td>111.7</td>
</tr>
</tbody>
</table>

Mt – million tonnes

### 3.19.3 Open Pit Dewatering

A ring of vertical dewatering bores, comprising bores PD1 to PD28, PD30 and P322, have historically operated to control groundwater levels around the pit. The vertical bore dewatering system was commissioned progressively, commencing in January 2005 to full operation by mid-2005. Records of dewatering volumes for the vertical bores for the period February 2005 to December 2009 indicate relatively consistent results after August 2005.

By 2012, all of the initial sets of bores had been decommissioned. Seven new dewatering bores (PD101 to PD107) were installed during 2011 as part of the Stage E pit cutback and began pumping groundwater in November 2011 (see Figure 23 for locations of both active and decommissioned bores).

In addition to the vertical dewatering bores, horizontal bores (drains) have been progressively installed (and some decommissioned) within the open pit since 2006.

Groundwater seepage from the pit, groundwater flows from in-pit horizontal drains (bores), and rainfall runoff in the pit are directed to pit sumps (before being pumped to water storage dams).

Barrick records the volumes pumped out of in-pit sumps and the volumes abstracted by the vertical dewatering bores on a monthly basis. The volume pumped out of in-pit sumps in any month is the sum of the volumes from the vertical dewatering bores, rainfall runoff, pit face seepage, and horizontal bores (drains). As such, it is not clear what proportion of the volumes reporting to the in-pit sumps is rainfall runoff rather than pit seepage/drainage. Mine staff report that rainfall runoff within the pit is generally significant for daily rainfall over 30 mm.
Figure 30 shows the measured dewatering flow rate (sumps and vertical bores) over the mine life, as well as daily rainfall events over 30 mm. There is a correlation between daily rainfall events over 30 mm and relatively high sump flows between 2010 and 2012. In 2005, 2006 and 2007, this correlation does not appear to be present. However, this may be due to relatively dry pre-existing ground conditions (in 2004, and from 2006 to 2009, the annual rainfall was significantly below the mean annual rainfall, potentially resulting in dry conditions relative to 2010 and 2012, and reduced rainfall runoff for rainfall events over 30 mm). Figure 30 also displays the number of horizontal bores (drains) installed in the pit per month. As might be expected, there is some correlation between months of high dewatering rates and significant numbers of horizontal bores (drains) installed.

Groundwater inflows to the pit due to pit seepage and horizontal dewatering bores (drains) between 2010 and 2012 were estimated, considering significant rainfall events and horizontal dewatering bore installation frequency. The interpreted inflows (for pit face seepage and horizontal dewatering bores only, excluding rainfall runoff) are shown in Figure 31. As of the end of 2012, it is estimated that groundwater inflows are at approximately 400m³/day (i.e. approximately 146ML/annum), with approximately 90% of inflows from the Fractured Rock groundwater system and 10% of inflows from the Alluvial groundwater system. The interpreted flows were adopted as the measured values against which the model was calibrated.

3.19.4 Storage Dams

Storage dams located on the mine site are shown in Figures 2 and 22.

Historical water levels within the storage dams D1, D2, D3, D4, D5, D6, D8B and D9 were reviewed. Dams D1, D2, D4, D5, D6 and D8B were small and located such that their impact on groundwater levels is likely to be insignificant.

Dam D3 is located in close proximity to the E42 open pit and this may result in impact of dam seepage water on groundwater levels. However, recorded water depths within the dam remain low and are considered unlikely to have a significant impact on groundwater levels.

Available groundwater monitoring data (PP06, screened within the Transported unit, as shown in Figure 24) suggest that water seepage from dam D9 does not impact groundwater levels. Early transient model calibration simulations supported this assessment and the dam D9 was not included within the model thereafter.

3.19.5 Tailings Storage Facilities

Tailings are understood to have been released to:

- the Southern TSF from 20 April 2006 to 15 May 2007;
- the Northern TSF 15 May 2007 to 12 September 2008;
- the Southern TSF from 12 September 2008 to 8 December 2009;
- the Northern TSF from 8 December 2009 to 16 January 2011; and
- the Southern TSF from 16 January 2011 to 1 February 2012.

Crest levels provided by Barrick are shown in Table 15.
## Table 15. Estimated Tailings Dam Crest Level and Low Point

<table>
<thead>
<tr>
<th>Status Start Date</th>
<th>Northern TSF</th>
<th>Southern TSF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operation Status</td>
<td>Crest Level (m AHD)</td>
</tr>
<tr>
<td>20-Apr-06</td>
<td>Inactive</td>
<td>-</td>
</tr>
<tr>
<td>15-May-07</td>
<td>Active</td>
<td>222.0</td>
</tr>
<tr>
<td>12-Sep-08</td>
<td>Inactive</td>
<td>222.0</td>
</tr>
<tr>
<td>8-Dec-09</td>
<td>Active</td>
<td>225.0</td>
</tr>
<tr>
<td>16-Jan-11</td>
<td>Inactive</td>
<td>228.2</td>
</tr>
<tr>
<td>1-Feb-12</td>
<td>Active</td>
<td>228.2</td>
</tr>
<tr>
<td>1-Apr-13</td>
<td>Inactive</td>
<td>229.3</td>
</tr>
<tr>
<td>23-Mar-14</td>
<td>Active</td>
<td>231.3</td>
</tr>
<tr>
<td>27-Feb-15</td>
<td>Inactive</td>
<td>231.3</td>
</tr>
<tr>
<td>19-Jan-16</td>
<td>Active</td>
<td>234.5</td>
</tr>
<tr>
<td>25-Jan-17</td>
<td>Inactive</td>
<td>234.5</td>
</tr>
<tr>
<td>1-Feb-18</td>
<td>Active</td>
<td>238.1</td>
</tr>
<tr>
<td>8-Feb-19</td>
<td>Inactive</td>
<td>238.1</td>
</tr>
<tr>
<td>15-Dec-19</td>
<td>Active</td>
<td>241.4</td>
</tr>
<tr>
<td>20-Oct-20</td>
<td>Inactive</td>
<td>241.4</td>
</tr>
<tr>
<td>10-Aug-21</td>
<td>Active</td>
<td>244.8</td>
</tr>
<tr>
<td>16-Jun-22</td>
<td>Inactive</td>
<td>244.8</td>
</tr>
<tr>
<td>4-Feb-23</td>
<td>Active</td>
<td>247.6</td>
</tr>
<tr>
<td>8-Jun-23</td>
<td>Inactive</td>
<td>247.6</td>
</tr>
<tr>
<td>31-Dec-24</td>
<td>Active</td>
<td>247.6</td>
</tr>
</tbody>
</table>

Due to tailings solids deposition, the surface of deposited tailings rises over time within each TSF dam. The lowest elevation of the surface of deposited tailings within each TSF dam was estimated based on the nominated crest levels, known TSF dam geometries, and assuming a tailings beach slope of 0.5%. Table 15 presents the estimated lowest deposited tailings surface elevation within each TSF dam.

Historical tailings dam water levels were not available. However, historical percentage water coverage data for the tailings dams were provided from May 2006 to September 2010, and for March 2012 to November 2012. Based on the geometry of the tailings dams, the maximum water depth within both the Northern and Southern TSF averaged over these periods is estimated to be 0.2 m.

The average surface water elevation within each of the TSF is estimated to be the lowest deposited tailings surface point plus 0.2 m (i.e. 0.2 m of standing water lie above the deposited tailings in each dam at any time). The estimated average water elevations are shown in Figure 32.

Since the hydraulic conductivity of the TSF foundation material is lower than that of the deposited tailings (Table 13), the surface water lying within the storage facility ponds is expected to maintain full hydraulic connection with the top of the TSF foundation material (through the deposited tailings).
3.20 Groundwater Supply

The majority of CGM’s supply water has historically been sourced from the Bland Creek Palaeochannel, with purchased water from the open market (delivery via the Jemalang irrigation channel), pit dewatering and captured surface run-off providing additional sources.

Water supply sources external to ML 1535 that may impact groundwater levels in the vicinity of ML 1535 include the mine lease saline groundwater supply borefield, which is pumped from production bores located in the south-east of ML 1535. Barrick has currently installed two of four approved production bores.

The ESB, located approximately 10 km east of Lake Cowal’s eastern shoreline and the BCPB, located approximately 20 km to the east-northeast of the CGM, are at a significant distance from the mine site. These borefields are considered in the Bland Creek Palaeochannel Model.

In 2010, Barrick explored the potential to obtain additional water supply from the Cowra Formation (Barrick, 2010a and 2010b). Sourcing water from the Cowra Formation offers potential advantages over the Lachlan Formation, due to the water’s elevated salinity (relative to water sourced from the Lachlan Formation), expected sufficient bore yields, and proximity to established infrastructure.

In July 2008, two bores (named 1535WB01 and 1535WB20 – see Figure 22 for bore locations) were drilled in the Cowra Formation, forming the saline groundwater supply borefield within ML 1535. The bores are not used to extract water when Lake Cowal is inundated.

Subsequent to September 2008 the saline supply bores were used intermittently. Based on available information, it is understood that one bore was pumped at 0.5 ML/day for the month of September 2008, followed by weekday operation from December 2008 to April 2009. As at November 2009, bore 1535WB20 was not being used as its yield of 1.5 litres per second (L/s) was considered uneconomic.

Two additional bores, named SB01 and SB02, have been drilled into the Cowra Formation within the BCPB and are operated in accordance with DA 2011/0064 approved by the Forbes Shire Council. These bores are collectively referred to as the ESB. Bore SB02 has operated for periods at a discharge rate of 1.8 ML/day and 1.2 ML/day. Bore SB01 has operated for periods at 1.35 ML/day and at 0.8 ML/day. Both bores will continue to provide supply until January 2015. Building Certificates (No. 2010/0009a, b & c) have also been issued by Forbes Shire Council for the two groundwater production bores and buried water supply pipeline associated with the ESB.

Development consent permits maximum daily water extraction from the Bland Creek Palaeochannel bores (PB1 to PB4) of up to 15 ML/day and maximum annual extraction of up to 3,650 ML/year.

Known historical groundwater extraction rates for the saline supply borefield are shown in Table 16.

### Table 16. Mine Water Supply Bores and Historical Extraction Rates

<table>
<thead>
<tr>
<th>Bore Name</th>
<th>AMG Easting</th>
<th>AMG Northing</th>
<th>Ground Level (m AHD)</th>
<th>Screen Interval (m AHD)</th>
<th>Historical Discharge Rate (ML/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1535WB01</td>
<td>539219</td>
<td>6277198</td>
<td>203.7</td>
<td>166.7 to 172.7, 184.7 to 190.7</td>
<td>Sept 2008: 0.5, Dec 2008 to Apr 2009: 0.36, May 2009 to Apr 2010: 0.5</td>
</tr>
<tr>
<td>1535WB20</td>
<td>539359</td>
<td>6276872</td>
<td>203.0</td>
<td>161.5 to 167.5, 171.0 to 177.0</td>
<td>Sep 2008: 0.13</td>
</tr>
</tbody>
</table>

The dominant form of groundwater consumption in the regional area is extraction from bores. Usage for the BCPB and ESB is supplied by Barrick and is available to November 2012. Pumping bores are listed in Table 17. Locations of pumping bores are shown in Figure 33.

Major pumping in the Lachlan Formation currently occurs from three main areas (and specific bores) as follows (areas are defined in Figure 33).

- BCPB Area (CGM Bores 1, 2, 3, and 4). The ESB is located just north-east of the BCPB but pumps from the Upper and Lower Cowra Formations.
- Billabong Area (Billabong 4 and 6 bores).
- Maslin Area (the Maslin bore). It is understood that the Warrakimbo bore, located very close by and also owned by Maslin, is licensed for irrigation.

The NSW government monitors groundwater levels in the Lachlan Formation in each of these areas (at the request of the Bland Palaeochannel Groundwater Users Group) using the following observation bores (with respective trigger levels):

- BCPB Area: Bore GW036553 (Investigation Trigger Level 137.5 m AHD and Mitigation Trigger Level 134 m AHD);
- Billabong Area: Bore GW036597 (Trigger Level 145.8 m AHD); and
- Maslin Area: Bore GW036611 (Trigger Level 143.7 m AHD).

The regulatory constraints for BCPB pumping by CGM, under the current licence conditions, are:

- daily maximum of 15 ML;
- yearly maximum of 3,650 ML; and
- CGM Limit of 30,000 ML

The total extracted groundwater volume for the period 30 June 2004 to 30 November 2012 (excluding the volumes pumped during pumping testing of the four bores in early 2004 under a testing licence) was 14,050 ML (at an average rate of 4.57 ML/day). The approximate proportion pumped by each bore was 34%, 27%, 30%, and 9% for Bores 1 to 4 respectively. The amount available for future extraction under the current licensed limit of 30,000 ML for the BCPB was 15,950 ML as at the end of November 2012 (or an average extraction of 3.6 ML/day between 30 November 2012 and 31 December 2024).
### Table 17. Regional Pumping Bores

<table>
<thead>
<tr>
<th>Bore Number and/or Name</th>
<th>Owner</th>
<th>MGA Easting</th>
<th>MGA Northing</th>
<th>Ground Elevation (m AHD)</th>
<th>Collar Elevation (m AHD)</th>
<th>Screen Interval (m bgl)</th>
<th>Screened Stratum</th>
<th>Allocation (ML/year)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active Pumping Bores in the Model Area</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bore1 (GW701660)</td>
<td>Barrick</td>
<td>553276</td>
<td>6287386</td>
<td>209.7</td>
<td>210.4</td>
<td>95</td>
<td>116</td>
<td>Ln</td>
<td>BCPB².</td>
</tr>
<tr>
<td>Bore2 (GW701659)</td>
<td>Barrick</td>
<td>553071</td>
<td>6285635</td>
<td>208.7</td>
<td>209.4</td>
<td>92</td>
<td>125</td>
<td>Ln</td>
<td>BCPB.</td>
</tr>
<tr>
<td>Bore3 (GW701658)</td>
<td>Barrick</td>
<td>555360</td>
<td>6283678</td>
<td>209.4</td>
<td>210.1</td>
<td>107</td>
<td>128</td>
<td>Ln</td>
<td>BCPB.</td>
</tr>
<tr>
<td>Bore4 (GW701657)</td>
<td>Barrick</td>
<td>552408</td>
<td>6282736</td>
<td>208.5</td>
<td>209.2</td>
<td>108</td>
<td>117</td>
<td>Ln</td>
<td>BCPB.</td>
</tr>
<tr>
<td>SB01 (GW703944)</td>
<td>Barrick</td>
<td>555740</td>
<td>6287128</td>
<td>210.7</td>
<td>211.3</td>
<td>54</td>
<td>66</td>
<td>LC</td>
<td>- ESB. Started February 2010.</td>
</tr>
<tr>
<td>SB02 (GW703943)</td>
<td>Barrick</td>
<td>556315</td>
<td>6288003</td>
<td>210.6</td>
<td>211.5</td>
<td>45</td>
<td>66</td>
<td>UC/LC</td>
<td>- ESB. Started February 2010.</td>
</tr>
<tr>
<td>SB03</td>
<td>Barrick</td>
<td>557116</td>
<td>6289198</td>
<td>-</td>
<td>211.6</td>
<td>46</td>
<td>64</td>
<td>UC/LC</td>
<td>- ESB. Site D17 (installed mid to late 2011).</td>
</tr>
<tr>
<td>SB04</td>
<td>Barrick</td>
<td>557324</td>
<td>6288376</td>
<td>-</td>
<td>211.7</td>
<td>59</td>
<td>65</td>
<td>LC</td>
<td>- ESB. Site D1 (installed mid to late 2011).</td>
</tr>
<tr>
<td>SB05</td>
<td>Barrick</td>
<td>556447</td>
<td>6286849</td>
<td>-</td>
<td>211.1</td>
<td>58</td>
<td>64</td>
<td>LC</td>
<td>- ESB. Site D16 (installed mid to late 2011).</td>
</tr>
<tr>
<td>GW029094 (Billabong 1)</td>
<td>Private</td>
<td>547041</td>
<td>6267503</td>
<td>-</td>
<td>-</td>
<td>100</td>
<td>107</td>
<td>Ln</td>
<td>Decommissioned in March 2006.</td>
</tr>
<tr>
<td>GW057974 (Billabong 2)</td>
<td>Private</td>
<td>547063</td>
<td>6268041</td>
<td>-</td>
<td>-</td>
<td>96</td>
<td>108</td>
<td>Ln</td>
<td>Decommissioned in March 2004.</td>
</tr>
<tr>
<td>GW701646 (Billabong 3)</td>
<td>Private</td>
<td>545265</td>
<td>6265654</td>
<td>-</td>
<td>208.0</td>
<td>98</td>
<td>109</td>
<td>Ln</td>
<td>Replaced by Billabong 6.</td>
</tr>
<tr>
<td>GW701267 (Maslin)</td>
<td>Private</td>
<td>552787</td>
<td>6266197</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>125³</td>
<td>Ln</td>
<td>2000 -</td>
</tr>
<tr>
<td>GW701454 (QuandiallaTWS)</td>
<td>Private</td>
<td>555158</td>
<td>6240472</td>
<td>-</td>
<td>-</td>
<td>98</td>
<td>106</td>
<td>Ln</td>
<td>266 -</td>
</tr>
<tr>
<td>GW701958 (Muffet)</td>
<td>Private</td>
<td>556273</td>
<td>6270630</td>
<td>-</td>
<td>-</td>
<td>88</td>
<td>93</td>
<td>100</td>
<td>Sandpack from 87 m bgl to 95 m bgl.</td>
</tr>
<tr>
<td>GW702013 (Hart)</td>
<td>Private</td>
<td>556516</td>
<td>6278585</td>
<td>-</td>
<td>-</td>
<td>102</td>
<td>109</td>
<td>Ln</td>
<td>-</td>
</tr>
<tr>
<td>GW702262 (MooraMoora)</td>
<td>Private</td>
<td>549674</td>
<td>6293195</td>
<td>-</td>
<td>212.8</td>
<td>117</td>
<td>125</td>
<td>Ln</td>
<td>- Also known as Koreela / McDonald.</td>
</tr>
<tr>
<td>GW702286 (Trigalana)</td>
<td>Private</td>
<td>555904</td>
<td>6279944</td>
<td>-</td>
<td>208.3</td>
<td>102</td>
<td>113</td>
<td>Ln</td>
<td>- Also known as the Fuge bore.</td>
</tr>
<tr>
<td>Trigalana East</td>
<td>Private</td>
<td>556501</td>
<td>6279959</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>110³</td>
<td>Ln</td>
<td>-</td>
</tr>
</tbody>
</table>
### Table 17 (Continued). Regional Pumping Bores

<table>
<thead>
<tr>
<th>Bore Number and/or Name</th>
<th>Owner</th>
<th>MGA Easting</th>
<th>MGA Northing</th>
<th>Ground Elevation (m AHD)</th>
<th>Collar Elevation (m AHD)</th>
<th>Screen Interval (m bgl)</th>
<th>Screen Interval (m bgl)</th>
<th>Allocation (ML/year)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW701579 (Coles)</td>
<td>Private</td>
<td>553767</td>
<td>6269660</td>
<td>-</td>
<td>-</td>
<td>107</td>
<td>111</td>
<td>Ln</td>
<td>-</td>
</tr>
<tr>
<td>GW701681 (Warrakimbo)</td>
<td>Private</td>
<td>552812</td>
<td>6266221</td>
<td>-</td>
<td>-</td>
<td>96</td>
<td>111</td>
<td>Ln</td>
<td>- Used as observation bore until 2006.</td>
</tr>
<tr>
<td>GW702100 (Hammond)</td>
<td>Private</td>
<td>552407</td>
<td>6285421</td>
<td>-</td>
<td>-</td>
<td>107</td>
<td>115</td>
<td>Ln</td>
<td>-</td>
</tr>
<tr>
<td>GW702230 (Duff)</td>
<td>Private</td>
<td>555812</td>
<td>6287547</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>66(^1)</td>
<td>UC/LC</td>
<td>Pump tested for ESB.</td>
</tr>
<tr>
<td>GW702285 (Matiske)</td>
<td>Private</td>
<td>553174</td>
<td>6286458</td>
<td>-</td>
<td>-</td>
<td>105</td>
<td>114</td>
<td>Ln</td>
<td>1,960</td>
</tr>
<tr>
<td>GW703033 (YerraYerra)</td>
<td>Private</td>
<td>555926</td>
<td>6278354</td>
<td>-</td>
<td>-</td>
<td>109</td>
<td>114</td>
<td>Ln</td>
<td>Sandpack from 60 m to 115 m bgl.</td>
</tr>
<tr>
<td>GW703039 (Oakhurst)</td>
<td>Private</td>
<td>548300</td>
<td>6248113</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>40(^1)</td>
<td>UC/LC</td>
<td>-</td>
</tr>
<tr>
<td>GW703638 (Billabong 5)</td>
<td>Private</td>
<td>547160</td>
<td>6267785</td>
<td>-</td>
<td>-</td>
<td>90</td>
<td>108</td>
<td>Ln</td>
<td>Replacement for Billabong 1 and 2.</td>
</tr>
<tr>
<td>Low</td>
<td>Private</td>
<td>550000</td>
<td>6277500</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Licence application lodged.</td>
</tr>
<tr>
<td>Tullock</td>
<td>Private</td>
<td>544000</td>
<td>6243000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,000</td>
<td>Licence application lodged.</td>
</tr>
</tbody>
</table>

\(^1\) Completed depth (screen details unavailable).

\(^2\) BCPB denotes Bland Creek Palaeochannel Borefield, ESB denotes Eastern Saline Borefield.

\(^3\) Screen base is an estimate based on structure contour surfaces developed for modelling.

**Glossary:** BCPB: Bland Creek Palaeochannel Borefield. ESB: Eastern Saline Borefield. \(mbgl\): metres below ground level. \(UC\): Upper Cowra Formation. \(LC\): Lower Cowra Formation. \(Ln\): Lachlan Formation. \(SWL\): static water level.
3.21 Hydrogeological Conceptual Model

Recharge to the groundwater system occurs by the following processes:

- rainfall infiltration;
- leakage from Bland Creek when flowing;
- intermittent flooding;
- deep drainage from irrigation practices (mostly in the northern areas); and
- groundwater inflow through the Corinella Constriction.

There will also be a minor component of recharge to the fringes of the alluvial sequence from shallow bedrock which will have higher conductivity due to lower overburden pressures.

Discharge from the groundwater system occurs by the following processes:

- extraction from water supply bores for stock/domestic, irrigation, and industrial uses;
- intermittent evaporation from surface ponds (local groundwater flow systems only); and
- groundwater outflow through the Corinella Constriction.

An unknown number of unregistered stock/domestic bores extract unknown amounts of groundwater from the Upper Cowra Formation.
4 MODELLING APPROACH

Two numerical models were utilised to assess potential impacts of the Modification.

The first model, the Bland Creek Palaeochannel Model, was developed in 2006 to assess impacts from the Barrick BCPB. The Hydrogeological Conceptual Model for this numerical model was previously discussed in Coffey (2006). This model was updated to include an additional layer, with the layers now representing the Upper Cowra, Lower Cowra, and Lachlan Formations, respectively. This approach was taken to more appropriately assess pumping from the Lower Cowra Formation. The model was re-calibrated as part of this assessment.

The second model (Mine Site Model) is a multi-layered model of the pit area and surrounds. This model was used to assess potential impacts from the operation of ML 1535 saline groundwater supply borefield, the potential for hydraulic connection between Lake Cowal and the mine site groundwater system, groundwater inflows to the open pit and the short and long-term effects of mine closure on groundwater conditions.
5 MINE SITE HYDROGEOLOGICAL MODELLING

5.1 Conceptual Model

5.1.1 Model Domain

The domain covered by the Mine Site Model is shown in Figure 34, along with also shows the model domains considered in previous Coffey models (Coffey, 1995d, 2006, 2009a and 2009b). The model covers the area from MGA E530000 to E545000 and MGA N62650000 to N62880000.

The model domain adopted for groundwater flow modelling is bounded in the west by a high ridge (Cowal West Hill), which is approximately 3 km west of the Gilmore Suture, and in the east by the Bland Creek Palaeochannel. Cowal West Hill in the west separates surface flow (recharge) between an easterly and westerly direction. The Cowal West Hill feature is therefore adopted as the western boundary, over which a constant (with respect to time) groundwater head is likely. The constant (with respect to time) value may vary from north to south.

The Bland Creek Palaeochannel contains a deep alluvial layer which is much more transmissive than the upper regional alluvial aquifer system. Since groundwater heads are likely to be relatively stable in this region, this has been selected as the eastern boundary of the model domain. Groundwater heads within the shallow sediments (Transported unit) beneath Lake Cowal are expected to be similar to the lake surface water head values. Coffey (2006) data for December 1997 suggest the groundwater head along the eastern model boundary outside of Lake Cowal, and within deep strata below the lake, is likely to be approximately 200 m AHD. Similarly, NOW (unknown publication date) model considered a groundwater head within the Upper Cowra Formation of approximately 200 m AHD in this area. Data (Coffey, 2006) suggest groundwater head values at the eastern boundary decline running south to north.

Assessment of groundwater levels at the Nerang Cowal and Marsden sections (Coffey, 1995) suggested groundwater levels at these locations would not be affected by mine dewatering. Net flow into/out of the domain over the western portion of the northern model domain boundary (western end of Nerang Cowal section) is expected to be negligible. Data were not available for water levels within Lake Nerang Cowal. However, groundwater levels within shallow sediments (Transported unit) beneath Lake Nerang Cowal at the northern model boundary are expected to follow a similar trend to those beneath Lake Cowal, and the levels beneath Lake Nerang Cowal are expected to be slightly lower in value than those beneath Lake Cowal (when the lakes are inundated). This results in groundwater flow in a direction from Lake Cowal towards Lake Nerang Cowal, as confirmed by the historical data shown in Figures 20 and 21, and reported in Coffey (2006).

At the southern model boundary, data (Coffey, 2006) suggest net groundwater flow into or out of the domain is zero.

Groundwater modelling by NOW (unknown publication date) adopted initial (pre-mining) groundwater head values in the vicinity of ML 1535 and Lake Cowal approximately ranging from 200 to 230 m AHD (heads falling in an easterly direction) in the Upper Cowra Formation and values of 230 m AHD in the Lower Cowra Formation. For the Transported hydrogeological unit in the present conceptual model, this is likely to equate to initial (pre-mining) groundwater head values of approximately 200 to 230 m AHD. The eastern values are similar to those reported for April 1996 by Hawkes (1998).
5.1.2 Hydrogeological Units

In terms of the site mining activities and site geological investigation (Coffey, 1995c; North Limited, 1998), the following seven hydrogeological units have been identified for the purposes of modelling (Mine Site Model):

- **Transported unit**: Comprises alluvial deposits of relatively low hydraulic conductivity clays and to a gravel aquifer within the alluvium which includes Gilgai, Czr, Qa, Qr and Qal sediments (see Figure 10). The waste rock emplacement is represented by this unit, though it generally possesses higher permeability than other alluvial deposits. The recharge from the waste rock dumping is not considered to significantly impact groundwater movement. This unit becomes the Upper Cowra Formation further east.

- **Saprolite unit**: Comprises a soft oxide material (extremely weathered mudstone, sandstone or diorite). This unit lies directly above the base of the Cowra Formation alluvium and forms a more permeable zone throughout the mine site, extending beneath Lake Cowal with unknown thickness.

- **Saprock unit**: Comprises a hard oxide material (weathered mudstone, sandstone or diorite) of relatively low hydraulic conductivity lying above the weathered fractured surface of the Lake Cowal Volcanics. This unit has relatively high clay content and limited water carrying capacity. The Saprolite and Saprock units are considered equivalent to the Lower Cowra Formation.

- **Lachlan Formation unit**: Comprises high permeability sands and minor gravels close to and within the deeper parts of the Bland Creek Palaeochannel and lower permeability sediments that generally occur further away from the deeper parts of the palaeochannel and surround the high permeability sands and minor gravels. It features over a small area in the far western portion of the modelled domain.

- **Primary Rock (Bedrock) unit**: Mainly consists of volcaniclastic rocks of low permeability.

The TSF are represented by the following distinct hydrogeological units:

- **Tailings Storage Facilities unit**: The TSF comprise about 55% solids, with finely ground rock residue remaining after the flotation and leaching process. The consolidated residue was found to be of low permeability.

- **Tailings Storage Facilities Embankment unit**: A basal barrier and impermeable liner with an equivalent vertical permeability not greater than $1 \times 10^{-9}$ m/s ($9 \times 10^{-5}$ m/day) over a thickness of 2 m was laid at the base of tailings dams.

5.1.3 Groundwater Recharge

Groundwater recharge sources over the Mine Site Model domain include rainfall and surface water bodies (mine storage dams and Lake Cowal). These are discussed in Section 5.3.1.

5.1.4 Groundwater Discharge

Groundwater discharges within the ML1535 include open pit dewatering and groundwater supply from ML1535 saline borefield. These are discussed in Section 5.3.1.
The Mine Site Model domain lies outside areas of known irrigation such as the Bland Creek Palaeochannel. Irrigation bores identified within the model developed by NOW (unknown publication date) for the Upper Lachlan catchment area all lie outside the Mine Site Model domain. Groundwater extraction due to irrigation is therefore not considered significant within the Mine Site Model.

An unknown number of private stock and domestic bores extract unknown amounts of groundwater from the Upper Cowra Formation. However, the extraction quantities are small and therefore considered unlikely to be significant within the Mine Site Model domain.

5.2 Numerical Model Development

Based on the Hydrogeological Conceptual Model presented in Section 4, a transient three-dimensional finite element model for simulation of groundwater flow and transport of solutes in the subsurface was developed. The existing model was updated with recent conditions. This section discusses the original model development and updates.

Following review of existing modelling software platforms and existing Coffey models for CGM, the finite element software package FEFLOW 6.0, developed by WASY GmbH (now DHI-WASY), was identified as a suitable software platform for this modelling project.

5.2.1 Model Domain, Layers and Discretisation

The model domain covers the same domain as the Mine Site Model Hydrogeological Conceptual Model discussed in Section 7.1. A three-dimensional schematic representation of the Hydrogeological Conceptual Model of the study area is shown in Figure 35.

The model domain was discretised in a three-dimensional finite element mesh comprising 14 layers. The total number of elements in the mesh is 225,442. Figure 36 displays the model mesh.

The depth of the model extends from ground surface elevation to -500 m AHD, covering the proposed base depth of the open pit at -264 m AHD from 2020. The modelled area covers 370 km².

The 14 model layers were divided over the Transported, Saprolite, Saprock and Primary Rock hydrogeological units. This division of layers permits future refinement of the model layers (e.g. further subdivision of hydrogeological units) to be made with greater ease. The division is as follows:

- The Transported hydrogeological unit is represented by the top three layers, each with equal thickness, except over the TSF areas where:
  - the base area of each dam in model Layer 1 is assigned properties in accordance with the deposited tailings material (Table 13);
  - the perimeter wall of each dam in model Layer 1 is assigned properties in accordance with the TSF embankment clay material (Table 13); and
  - the base area of each dam in model Layer 2 is assigned a 1 m thick liner with properties in accordance with the TSF embankment fill material (Table 13).

- The Saprolite hydrogeological unit is defined as model Layers 4 and 5 and the Saprock hydrogeological unit is defined as model Layer 6, except that the model considers the presence of Primary Rock to the west of the Gilmore Suture for these three layers (Primary Rock is interpreted to outcrop near the surface west of the Gilmore Suture).
The Primary Rock hydrogeological unit is assigned for model Layers 7 to 14. Topographic (ground surface) elevations and the base elevations of the Transported, Saprolite and Saprock hydrogeological units were provided by Barrick for the ML 1535 area. Topographic surface was also provided (at lower resolution) for the wider region. The surfaces of hydrogeological units were linearly extrapolated from the boundaries of ML 1535 to regions outside ML 1535. Figures 14 to 17 show the model adopted surface contours for ground surface level, and the base of the Transported, Saprolite and Saprock units, respectively.

Mesh sizes were designed to meet the following criteria:

- Mesh cell sizes were refined around the open pit to allow effective simulation of dewatering and water level changes in the surrounding area.
- Mesh cell sizes were refined around the TSF dams to allow effective simulation of water level changes in these areas.
- Small mesh sizes were used in the vicinity of the open pit.
- Mesh cell densities were reduced in areas where groundwater conditions were less important for accomplishing modelling objectives, or where data relating to the characteristics of the groundwater system were sparse, or where resolution was unlikely to significantly improve simulation outcomes. Cell density reductions achieved significant decreases in model processing time.

The transient model time step varied throughout numerical simulation, depending on convergence of the model solution, but was restricted to a maximum allowable time step of 10 days.

### 5.3 Model Calibration

A steady state model was developed to provide initial groundwater head values for the transient model. Transient calibration considered the period 1 January 2005 (pre-mine-development) to 1 January 2013. Simulations were performed in the saturated unconfined aquifer FEFLOW mode. This mode permits calculation of unsaturated conditions using a simplified approach.

The calibrated model used in the pit dewatering assessment (Coffey, 2008a) utilised similar aquifer parameters to those estimated from field data (Coffey, 2008a, 2009a). Transient calibration adopted parameter values over the same ranges as those reported in Tables 9 and 10. Given the approximately north-south faulting in the region (Figure 10), the horizontal hydraulic conductivity was considered to be anisotropic within the rock units.

Extensive calibration of open pit boundary conditions and aquifer properties was undertaken. Calibration to groundwater monitoring and recorded dewatering flow rates was conducted with particular focus on the influence of:

- hydraulic conductivities and storativity within the Transported, Saprolite, Saprock and Primary Rock units;
- net accession (recharge and evaporation) rates; and
• varying combinations of seepage boundary conditions (with varying combinations of seepage (drainage) conditions located at the base of the Transported, Saprolite and Saprock units) and varying spatial sizes of “pit sump” time-varying head boundary conditions.

5.3.1 Model Boundary Conditions

5.3.1.1 Recharge and Surface Water Bodies at Mine Site

As discussed in Section 3.8.1, the mean rainfall recharge rate of all streamflow data assessed for Station 412103 (Bland Creek at Morangarell) between 1976 and 2003 was 0.3% of mean annual rainfall. A recharge rate of 0.3% mean annual rainfall has been adopted for the domain.

As discussed in Section 3.19, except for the TSF, surface water bodies on-site were not considered likely to impact groundwater conditions significantly and therefore have not been included in the model. The model adopts the water levels (time-varying constant head boundary conditions) within the Northern and Southern TSF shown in Figure 32.

The inundation of Lake Cowal is represented in the model by application of a constant head boundary condition (with values in accordance with Figure 26) at ground surface (model Layer 1) over the area of Lake Cowal for the period over which Lake Cowal was observed to be inundated.

5.3.1.2 Model Domain Boundaries

Transient model boundary conditions adopted at the boundaries of the model domain were as follows:

- The Cowal West Hill ridge was adopted as the western boundary. At the western model boundary, a constant (with respect to time) head condition from 212 m AHD in the south, falling in value to 205 m AHD approximately 1.8 km north of the mine site, over all layers.

- At the northern model boundary, a constant head at Lake Nerang Cowal of 198 m AHD, and a constant head of 199 m AHD to the east of Lake Nerang Cowal, over all layers.

- The Bland Creek Palaeochannel was adopted as the eastern boundary of the model domain. Lake Cowal is understood to have been dry during 2005. Over the area covered by Lake Cowal, a groundwater level of 200 m AHD (some 1.5 m below lake bed level) was adopted for dry lake conditions; this is consistent with the range of groundwater head elevations modelled by the Bland Creek Palaeochannel Model in this area. Constant (with respect to time) head boundary conditions ranging from 200 m AHD within Lake area to (i) 199 m AHD in the north, and (ii) 205 m AHD in the south, were applied to the north and to the south of Lake Cowal, respectively.

- No-flow boundaries at all other model domain extremities over all layers.

5.3.1.3 Open Pit

The open pit was modelled using seepage face and constant head boundary conditions in three stages. The stages correspond with significant lateral expansion of the open pit, the installation of significant numbers of horizontal dewatering bores, and the inundation of Lake Cowal. The periods of the three stages are:

- beginning of mine life to March 2008 (when the open pit expanded significantly and significant numbers of horizontal bores were installed);
March 2008 to June 2010 (when the lake began to fill); and

June 2010 to December 2012.

The progressive deepening of the open pit was represented by a time-varying constant head boundary condition was applied equal to the base elevation of the pit over a base region within the pit (in model Layer 10 for Stages 1 and 2, and model Layer 11 for Stage 3; those model layer elevations are consistent with the base elevations of the open pit of the stage periods). The elevation of the pit base during the life of the Modification is shown in Figure 29.

The progressive widening of the open pit was represented by applying a seepage boundary condition ring around the exposed pit face at the base of the Transported, Saprrolite and Saprock units, which expanded over the three modelling stages in order to represent the progressive lateral expansion of the open pit. The seepage face boundary conditions applied in the pit area are shown in Figure 37.

5.3.1.4 Dewatering Bores

The dewatering bores included in the model are listed in Table 18 (and their locations are shown in Figure 23). The locations of the modelled dewatering bores (PD1 to PD14) provide reasonable representation of the locations of dewatering bores throughout the mine life, including the dewatering bores PD101 to PD107 commissioned in November 2011 (which are located in the vicinity of PD1 to PD10).

The total recorded monthly pumping rates from January 2005 to February 2013 for all dewatering bores were divided equally among the 13 bores included in the model. The adopted pumping rates are shown in Figure 30.

<table>
<thead>
<tr>
<th>Bore Identification</th>
<th>MGA Northing</th>
<th>MGA Easting</th>
<th>Screen Interval (m AHD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD1</td>
<td>538259</td>
<td>6278229</td>
<td>204.3 to 141.3</td>
</tr>
<tr>
<td>PD2</td>
<td>538327</td>
<td>6277974</td>
<td>204.2 to 105.2</td>
</tr>
<tr>
<td>PD3</td>
<td>538324</td>
<td>6277875</td>
<td>204.3 to 113.8</td>
</tr>
<tr>
<td>PD4</td>
<td>538325</td>
<td>6277786</td>
<td>204.4 to 100.4</td>
</tr>
<tr>
<td>PD5</td>
<td>538310</td>
<td>6277688</td>
<td>204.3 to 114.3</td>
</tr>
<tr>
<td>PD6</td>
<td>538243</td>
<td>6277578</td>
<td>204.3 to 113.3</td>
</tr>
<tr>
<td>PD7</td>
<td>538178</td>
<td>6277523</td>
<td>204.4 to 108.0</td>
</tr>
<tr>
<td>PD8</td>
<td>538068</td>
<td>6277459</td>
<td>204.4 to 108.9</td>
</tr>
<tr>
<td>PD9</td>
<td>537958</td>
<td>6277434</td>
<td>204.5 to 116.5</td>
</tr>
<tr>
<td>PD10</td>
<td>537863</td>
<td>6277430</td>
<td>204.6 to 112.1</td>
</tr>
<tr>
<td>PD11</td>
<td>537713</td>
<td>6277428</td>
<td>205.1 to 120.1</td>
</tr>
<tr>
<td>PD12</td>
<td>537520</td>
<td>6277490</td>
<td>211.0 to 135.5</td>
</tr>
<tr>
<td>PD14</td>
<td>537243</td>
<td>6277944</td>
<td>210.9 to 133.9</td>
</tr>
</tbody>
</table>
5.3.1.5 Groundwater Supply Extraction

ML 1535 saline groundwater supply bores (see Figure 22 for bore locations) may exert influence on the groundwater drawdown behaviour and were therefore included within the model. The following conditions were applied to ML 1535 saline groundwater supply bores located within ML 1535:

- Groundwater extraction from WB01 and WB20 occurred at 0.5 ML/day and 0.13 ML/day, respectively for five days per week, during September 2008 (equivalent continuous pumping rate of 0.35 ML/day and 0.09 ML/day, respectively).
- After September 2008, groundwater was not extracted from WB20.
- After September 2008, groundwater extraction from WB01 occurred at 0.5 ML/day for five days per week from December 2008 to April 2010 (equivalent continuous pumping rate of 0.36 ML/day).
- From April 2010, groundwater was not extracted from the saline supply bore field due to Lake Cowal being inundated (this situation continued for the remainder of the calibration period).

5.3.1.6 Summary of Applied Boundary Conditions

A summary of the applied boundary conditions for the transient model is provided in Table 19.

Table 19. Summary of Boundary Conditions Employed in Transient Numerical Model

<table>
<thead>
<tr>
<th>Boundary Location</th>
<th>Boundary Condition Type and Values Adopted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>Recharge rate: 0.3% of mean annual rainfall (1.44 mm/day)</td>
</tr>
<tr>
<td>Eastern Boundary</td>
<td>Bland Creek Palaeochannel: constant head from 199 m AHD to 205 m AHD, except at the boundary locations at which Lake Cowal is present</td>
</tr>
<tr>
<td>Southern Boundary</td>
<td>No-flow</td>
</tr>
<tr>
<td>Western Boundary</td>
<td>Cowal Hill Ridge: constant head from 205 m AHD in the north to 212 m AHD in the south (calibrated from steady state model)</td>
</tr>
<tr>
<td>Northern Boundary</td>
<td>Over Lake Nerang Cowal, a fixed head of 198 m AHD, a no-flow boundary west of Lake Nerang Cowal, and a constant head of 199 m AHD east of Lake Nerang Cowal</td>
</tr>
<tr>
<td>Lake Cowal</td>
<td>Time-varying constant head in Layer 1 (see Figure 26)</td>
</tr>
<tr>
<td>Open Pit</td>
<td>Base elevation of the pit: Time-varying constant head in Layers 10 or 11 (see Figure 29)</td>
</tr>
<tr>
<td></td>
<td>Pit walls: Seepage face boundary (drain) in Layers 4, 6 and 7 (see Figure 37)</td>
</tr>
<tr>
<td>TSF</td>
<td>Southern and Northern TSFs: Time-varying constant head (see Figure 32)</td>
</tr>
</tbody>
</table>
5.3.1.7  Model Assumptions

The following assumptions were employed in the model:

- the Mine Site Model does not include regional areas over which significant groundwater pumping by private owners occurs (e.g. irrigation over farmland);
- the open pit is assumed to be dry (not flooded) during mining (observed conditions on-site support this assumption);
- changes in deposited tailings materials (e.g. due to consolidation or operation processes) were not considered;
- the Jemalong and eastern saline supply borefields are at sufficient distance for drawdown impacts not to effect groundwater levels at the mine site;
- deposited tailings are not removed from the TSF; and
- the TSF and Lake Cowal are the only surface water bodies within ML 1535 exerting significant impact on groundwater levels.

5.3.1.8  Calibration

The calibration process involved changes to model parameters to better match model outputs with measured response. The results for the adopted model after the calibration process are discussed below.

Figures 38 to 41 show modelled and observed groundwater levels at the locations of the groundwater monitoring piezometers for the calibrated model.

The modelled groundwater levels and trends are generally consistent with those observed. Modeled levels are slightly elevated in some piezometers near the tailings dams (Figures 40 and 41).

In the immediate vicinity of the pit, modelled groundwater levels at piezometer PDB4A (screened in the Saprock unit) compares favourably to observed groundwater levels (Figure 38). Modeled groundwater levels at piezometers PDB3A and PDB3B are somewhat elevated relative to observed groundwater levels. This is likely due to the influence of horizontal bores (W911 and W912) in the pit, which are located relatively close to the PDB3 piezometers and likely cause significant localised drawdown that may not be representative of other areas in the vicinity of the pit (Section 5.14.2). As the horizontal bores (drains) are not modelled explicitly, these localised effects are not shown in the calibration results. As that impact is expected to be localised, the calibration results are considered reasonable.

At greater distance from the open pit, modelled groundwater levels in piezometers PDB1A and PDB1B (Figure 38) compare favourably with observed groundwater levels. Modelled groundwater levels in piezometers PDB5A and PDB5B (Figure 39) compare reasonably well with observed groundwater levels, capturing the slight rise from mid-2010, although the rise in PDB5B (screened in the Transported unit) is slightly underestimated.

Modeled groundwater levels in piezometers located in the processing plant area (Figure 39) compare favourably with observed groundwater levels.
In general, the modelled groundwater levels and rates of drawdown compare favourably with those observed. The aquifer parameters adopted in the model are shown in Table 20 and were employed for the predictive modelling. For available data, aquifer parameter values lie within two orders of magnitude of those adopted in previous studies (Tables 9 and 10).

Modelled groundwater head contours for the Transported (Layer 2), Saprolite (Layer 4), Saprock (Layer 6) units, and mid-Primary Rock (Layer 11) unit at the end of the calibration period (January 2013) are presented in Figures 42 to 45. Groundwater levels fall in the vicinity of the pit but the extent of drawdown is generally limited to the ML 1535 area. When compared against groundwater heads observed prior to mine development (Figures 20a to 20c), the influence of drawdown in January 2013 is clearly confined to within the modelled domain.

**Table 20. Adopted Model Parameters**

<table>
<thead>
<tr>
<th>Model Layer(s)</th>
<th>Hydrogeological Unit</th>
<th>Hydraulic Conductivity (m/day)</th>
<th>Specific Storage (m³)</th>
<th>Specific Yield (/-)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Kₓ (east-west)</td>
<td>Kᵧ (north-south)</td>
<td>Kᵢ (vertical)</td>
</tr>
<tr>
<td>1 to 3</td>
<td>Transported Material</td>
<td>1.0x10⁻²</td>
<td>1.0x10⁻²</td>
<td>6.5x10⁻⁴</td>
</tr>
<tr>
<td>4 and 5</td>
<td>Saprolite*</td>
<td>3.4x10⁻²</td>
<td>1.7x10⁻²</td>
<td>1.7x10⁻²</td>
</tr>
<tr>
<td>6</td>
<td>Saprock*</td>
<td>4.0x10⁻³</td>
<td>2.0x10⁻³</td>
<td>2.0x10⁻³</td>
</tr>
<tr>
<td>7 to 14</td>
<td>Primary Rock</td>
<td>Varies^</td>
<td>Varies^</td>
<td>5.0x10⁻⁴</td>
</tr>
<tr>
<td>1</td>
<td>TSF Embankment Clay</td>
<td>4.3x10⁻¹</td>
<td>4.3x10⁻¹</td>
<td>4.3x10⁻²</td>
</tr>
<tr>
<td>1</td>
<td>Deposited Tailings</td>
<td>5.0x10⁻²</td>
<td>5.0x10⁻²</td>
<td>5.0x10⁻⁴</td>
</tr>
<tr>
<td>2</td>
<td>TSF Foundation</td>
<td>1.0x10⁻⁴</td>
<td>1.0x10⁻⁴</td>
<td>1.0x10⁻⁴</td>
</tr>
</tbody>
</table>

* Parameter values applied over domain to the east of Gilmore Suture. West of the Gilmore Suture, Primary Rock values apply for the layer.

^ Primary rock horizontal hydraulic conductivity reduces with depth. Kₓ varies from 2.3x10⁻³ m/day in Layers 7 to 10, reducing approximately linearly to 5x10⁻⁴ m/day in Layers 14 to 15. Kᵧ is consistently double the value of Kₓ in Layers 7 to 13.

The modelled and interpreted average monthly total dewatering rate (vertical dewatering bores plus pit face seepage inflows) are shown in Figure 46. Measured dewatering rates compare favourably with modelled rates, providing confidence in the model's ability to accurately represent groundwater flow conditions.

The mass balance error for the calibration model final stage was 0.3%.
5.4 Predictive Groundwater Flow Modelling

The calibrated model was utilised to predict groundwater flow and drawdown for the Modification. Two scenarios were considered: Lake Cowal being either dry or inundated.

5.4.1 Modelled Conditions

5.4.1.1 Lake Cowal

For the inundated Lake Cowal scenario, a lake water level of 205.8 m AHD (mean value over March 2011 to April 2013 – [Figure 26]) was assumed to exist in perpetuity over the lake area.

For the dry Lake Cowal scenario, the lake level was considered to fall consistent with Figure 26, until it became dry in February 2016, after which time it remained dry.

5.4.1.2 Open Pit

The base elevation of the pit was modelled consistent with that shown in Figure 29, using a constant head boundary condition in model Layer 13. Adopted pit seepage boundary conditions were identical to those used in the calibrated model.

5.4.1.3 Tailings Dams

The tailings dams were assumed to continue rising as shown in Figure 32.

5.4.1.4 Groundwater Supply Abstraction

Groundwater is extracted from the saline supply borefield only when Lake Cowal is dry. Therefore, only the dry scenario considered abstraction.

For the dry scenario, abstraction was modelled from the saline supply borefield at a rate of 1 ML/day for five days per week (equivalent continuous pumping rate of 0.71 ML/day) from February 2016 to the end of the simulated period.

5.4.1.5 Open Pit Dewatering Bores

Since the commissioning of vertical dewatering bores PD101 to PD107 in November 2011, the dewatering flow rate from the vertical dewatering bores has averaged 19 m³/day, approximately 5% of the total pit dewatering flow rate (see Figure 29). The vertical dewatering bores are therefore not considered to provide a significant contribution to pit dewatering from November 2011 and were therefore not included in the forward predictions.

5.4.2 Predictive Modelling Results

5.4.2.1 During Mining

Over the future life of the mine, predicted groundwater levels in the immediate vicinity of the open pit continue to fall in all units due to increasing excavation of the pit. In the vicinity of the TSF, groundwater levels tend to rise in response to the increased water levels within the storage facilities.
For the dry lake scenario during December 2020, when the open pit attains its maximum depth, Figures 47 to 50 display model predicted groundwater drawdown contours for the Transported (Layer 2), Saprolite (Layer 4), Saprock (Layer 6) and Primary Rock (Layer 11) units respectively. The same modelling results for the inundated lake scenario are shown in Figures 51 to 54.

For the dry lake scenario at the end of mine life (December 2024), Figures 55 to 58 display model predicted groundwater head contours for the Transported (Layer 2), Saprolite (Layer 4), Saprock unit (Layer 6) and Primary Rock (Layer 11) units respectively. The same modelling results for the inundated lake scenario are shown in Figures 59 to 62.

Figures 47 to 62 reveal that:

- The predicted groundwater drawdown under a dry lake scenario extends approximately 300 m further to the east relative to the inundated lake scenario, due to the absence of the lake.
- The predicted groundwater drawdown at the end of mine life is similar to during December 2020, for the same hydrogeological units and lake scenarios.
- The predicted groundwater drawdown due to groundwater extraction from ML 1535 saline groundwater supply borefield is insignificant relative to the groundwater drawdown induced by the open pit.
- Significant groundwater drawdown predicted by the model is generally limited to within ML 1535 (to the proposed mine closure) for both dry and inundated lake conditions.
- When compared against groundwater heads observed prior to mine development (shown in Figures 20 and 21), the influence of drawdown at the end of mine life is limited to within the confines of the modelled domain.

The modelled average monthly total dewatering rate (vertical dewatering bores plus groundwater seepage) to mine closure is shown in Figure 63 for both the dry and inundated lake scenarios. Because the modelling was conducted in numerous stages, modelling outputs have been interpreted considering the transitions in rates between each model stage.

Groundwater inflows to the open pit range between approximately 400 m³/day and 600 m³/day between 2013 and mine closure. There is a negligible difference between the dry and inundated lake scenarios. Groundwater inflows are estimated to have generally decreased since 2008 as the adjacent aquifers surrounding the CGM have become depressurised.

The proportion of the modelled groundwater flow sourced from the various hydrogeological units in 2013 is as follows: approximately 10% from the Transported unit, 40% from the Saprock unit and 50% from the Primary Rock unit (the proportion sourced from the Saprolite unit is insignificant). Over the life of the mine, the proportion of groundwater sourced from the upper hydrogeological units reduces and that from the Primary Rock unit increases as the groundwater table falls. At the end of mine life 2025, the modelled groundwater flow sourced from the various hydrogeological units is as follows: approximately 5% from the Transported unit, 5% from the Saprock unit and 90% from the Primary Rock unit (the proportion sourced from the Saprolite unit remains insignificant).

Thus, the proportion of modelled groundwater inflow to the pit sourced from the alluvium is approximately 10% in 2013, reducing to approximately 5% by 2025. The remaining proportion of inflow is sourced from the rock. Note that the proportion of inflow sourced from the different hydrogeological units may vary depending on local conditions.
The mass balance error for the predictive model was 0.3%.

5.4.2.2 Post-Mine Closure

Post-mine closure, the open pit is expected to gradually fill with water (from groundwater seepage and rainfall), attaining a long-term equilibrium level that will depend on the competing effects of groundwater seepage and rainfall inflowing to the pit and evaporative losses.

Figures 64 to 67 present model-predicted groundwater drawdown (relative to pre-mining conditions) 20 years after mine closure (2044) for, respectively, the Transported unit (Layer 3), Saprolite unit (Layer 5), Saprock unit (Layer 7) and Primary Rock unit (Layer 11) units for the dry lake scenario. (Groundwater drawdown is presented for the dry lake scenario because it is greater than for the inundated lake scenario).

These predictions represent a conservative estimate of groundwater drawdown, since the modelling assumes the open pit remains empty and modelled groundwater inflows to the pit are therefore higher than expected.

The predicted groundwater drawdown for all units at 20 years after mine closure (2044) is not significantly different from the drawdown at the end of mine life (2024).

5.4.2.3 Potential Impact on Lake Cowal

The presence of the open pit void is expected to induce additional vertical seepage from Lake Cowal (towards the void) over the long-term.

The model was used to predict the long-term (steady state, post-mine closure) vertical leakage from Lake Cowal considering the lake was inundated in the presence of the open pit void. The model-predicted vertical leakage over the lake area was $3.7 \times 10^6$ m$^3$/day/m$^2$. This equates to a seepage rate of some 4 L/s over the entire lake and is relatively consistent with the findings of Coffey (1997). The leakage under these conditions is insignificant, particularly when compared to the total lake storage and evaporation losses under natural conditions. For all practical purposes the lake bed sediments act as an impeding layer to vertical leakage from the lake.

The impact of the open pits, pit dewatering and groundwater extraction from the mine lease saline supply borefield on the waters of Lake Cowal is therefore considered negligible.
5.4.2.4 Waste Rock Emplacement Seepage

The Modification would involve extension of the Northern Waste Rock Emplacement's basal layer design to direct seepage from the emplacement towards the open pit. The Northern Waste Rock Emplacement will be extended in a westerly direction by some 650 m. The final layout of the extension is shown in the 2014 site layout displayed in Figure 22.

Gilbert and Associates (undated) assessed the expected performance of proposed basal layer design. The proposed extension to the basal layer over the Northern Waste Rock Emplacement will be consistent with the existing basal layer, sloping downgradient towards the open pit. The extension is not expected to impact groundwater levels or flow regimes significantly.

5.4.2.5 Model Sensitivity

There is limited available aquifer test data in the vicinity of open pit. Assessment of the underlying sensitivity of the model to aquifer parameters was undertaken to provide some assessment of this uncertainty.

The key parameters of influence in the model include both the horizontal and vertical hydraulic conductivity, and the specific storage. Abstraction is not a key parameter in the model, since the drawdown induced by ML1535 saline supply bores is insignificant relative to that of the open pit, and the contribution of the open pit vertical dewatering bores to total dewatering flows is negligible.

The key potential impacts of the Modification include the impact on Lake Cowal and the impact on groundwater levels (and inflows to the open pit). To assess the sensitivity of the model to aquifer parameters in the context of these impacts, two sensitivity scenarios were simulated:

- Increasing the vertical hydraulic conductivity of all units by a factor of two. This potentially increases the vertical leakage of groundwater from Lake Cowal, thereby providing an indication of the sensitivity of assessment of impacts on Lake Cowal.
- Increasing the horizontal hydraulic conductivity of all units by a factor of two. This results in increased inflows to the open pit and groundwater drawdown, providing an indication of the sensitivity of assessment of impacts on groundwater levels.

Adoption of these aquifer property values does not provide model calibration results as favourable as those attained with the parameter values adopted for the basecase, but nevertheless provide passable calibration.

Results of the sensitivity analysis conducted on both horizontal and vertical hydraulic conductivity indicate the extent of groundwater drawdown in the hydrogeological units increases, and drawdown associated with ML1535 saline supply borefield increases. However, significant drawdown (>2 m) remains within ML1535.

Groundwater inflows to the open pit of up to 670 m$^3$/day and 740 m$^3$/day are predicted between 2013 and mine closure for, respectively, the increased vertical hydraulic conductivity simulation and the increased horizontal hydraulic conductivity simulation (compared to 600 m$^3$/day for the basecase).
5.5 Groundwater Quality Related to Open Pit Dewatering

The quality of groundwater collected by the dewatering system (including groundwater both pumped from vertical dewatering bores and seeping into the open pit) is expected to be similar to existing groundwater quality and would be used as a water supply for the processing plant. The expected concentration/value range for a number of analytes is provided in Table 21. Pit dewatering is not expected to impact groundwater quality significantly.

Table 21. Expected Dewatering Groundwater Quality

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Concentration (mg/L) or Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.8 to 7.1</td>
</tr>
<tr>
<td>Dissolved sodium</td>
<td>8,000 to 13,000</td>
</tr>
<tr>
<td>Sulphate</td>
<td>2,500 to 7,000</td>
</tr>
<tr>
<td>Alkalinity (bicarbonate)</td>
<td>80 to 500</td>
</tr>
</tbody>
</table>
6 CONTAMINANT MIGRATION

This section discusses the potential impact to water quality in the vicinity of the TSF through seepage of stored water.

6.1 Seepage From Tailings Storage Facilities

The mean vertical leakage from the Northern and Southern TSF, respectively, in 2012 is estimated by the model to be 180 m$^3$/day and 220 m$^3$/day.

The mean vertical leakage from the Northern and Southern TSF, respectively, predicted by model is approximately 250 m$^3$/day and 280 m$^3$/day over the future mine life (2013 to 2024). This is equivalent to approximately 0.21 m$^3$/day/m and 0.23 m$^3$/day/m in cross-section across for the Northern and Southern TSF, respectively, which is consistent with the values of 0.12 m$^3$/day/m and 0.45 m$^3$/day/m reported in the EIS at two different sections across the Northern and Southern TSF (North Limited, 1998).

6.2 Potential Impact on Groundwater Quality

Assessment of potential impacts to groundwater quality due to seepage from the TSF water was undertaken using an analytical particle tracking approach. The assessment did not include geochemical processes such as sorption, chemical oxidation and degradation reactions that may hinder contaminant migration. This approach provides a conservative estimate of the likely contaminant travel times through the subsurface.

Groundwater flow conditions at mine closure for the inundated lake case were considered. Such conditions lead to a conservative assessment, since water levels in Lake Cowal are high under this scenario and therefore potentially induce greater flows when Lake Cowal is dry.

Groundwater seepage velocities within the most permeable unit (Saprolite) in the vicinity of the TSF were calculated based on long-term model-predicted groundwater heads and assuming a (conservative) Saprolite effective porosity of 1%.

Figure 68 displays the possible extent of groundwater quality changes after 50 and 100 years, assuming groundwater begins moving from immediately outside the TSF wall. After 100 years, the potential for groundwater quality changes due to seepage from the TSF stored water extends a distance of approximately 2 km from the TSF wall.

Cyanide is used in the gold extraction process and is present in tailings released to the TSF. As noted in Section 3.16.1, the groundwater monitoring results suggest that, as of December 2012, there is no consistent trend to suggest that significant concentrations of cyanide have leached from the TSF into the surrounding groundwater. Cyanide is therefore considered unlikely to be present within groundwater over the site (outside the TSF).

The results of the analytical seepage assessment suggest that cyanide would not reach beyond 2 km from the TSF wall before 100 years. This assessment represents a conservative case, since cyanide associated with potential seepage from the TSF degrades due to hydrolysis, volatilisation (to HCN gas), oxidation and biological activity. For this reason, and the fact that the assessment ignores the hindrance to solute migration imposed by the TSF liner, the likely groundwater transport of cyanide from the TSF is expected to be much more limited.
Schmidt et al (1981) measured an (equivalent) cyanide half life of 3.6 to 30 days in tailings liquors. Burden and Kidd (1987) found half life constants ranging from 36 to 300 days in laboratory-tested tailings mass. The EIS adopted a cyanide decay half life of 300 days (North Limited, 1998). Thus, cyanide concentrations at the extent of the 100 year potential groundwater quality change contour shown in Figure 68 are likely to be essentially zero.

The transport of cyanide through groundwater is further retarded due to sorption processes. The EIS adopted a (conservative) cyanide retardation factor of four (North Limited, 1998). Data collected by Allison and Allison (2005) suggest cyanide partition coefficients for soil-soil water range from approximately 4×10⁻³ litres per kilogram (L/kg) to 20 L/kg (mean 5 L/kg). Assuming clay-like (Transported or Saprolite unit) material with bulk density of up to 1.3 t/m³ and effective porosity ranging from 1 to 30%, retardation factors may range from 1 to well above 2,000, and a mean value of around 600. These retardation factors indicate transport of cyanide would be significantly impeded over the site.

The EIS reported a potential migration of cyanide (at 0.1% of tailings source concentration) to 200 m eastwards from the TSF after eight years, for high permeability aquifer materials and a cyanide retardation factor of four and decay half life of 300 days (North Limited, 1998). In the long-term, cyanide would degrade in the tailings storage and surface of the underlying aquitard and would be effectively removed from the subsurface. This assessment is less conservative than the above assessment (which does not explicitly consider retardation or decay).

In addition to cyanide, other contaminants such as arsenic, zinc and other heavy metals have the potential to be released from the TSF. Based on the analytical migration assessment, such contaminants would similarly not reach beyond 2 km from the TSF wall before 100 years. Again, to provide a conservative assessment of contaminant migration, biological processes and sorption of contaminants to the soil/rock matrix are not considered as these processes would further retard contaminant migration.

Figure 69 shows long-term groundwater head contours and groundwater flow direction for the dry lake scenario. The flow directions for the inundated lake scenario are consistent with those for the dry lake scenario. Contaminants associated with potential seepage from the TSF would flow in the direction of the final pit void and ultimately terminate in that void. The final pit void therefore becomes a long-term sink for all groundwater within ML 1535. As a result, analytes are expected to concentrate within the pit voids over hundreds of years (e.g. water salinity in the pit will rise). Analytes associated with potential seepage from the TSF are expected to remain within groundwaters between the TSFs and the final void over the long-term.
7 BLAND CREEK PALAEOCHANNEL MODELLING

7.1 Numerical Model Development and Calibration

In 2006 Coffey developed a three-dimensional numerical groundwater flow model for assessing the impacts of pumping from the BCPB on the surrounding environment and other groundwater users (Coffey, 2006) which was calibrated and used for predictive analysis. In 2010, due to changes in the mine plan and the introduction of the ESB, the model was upgraded and used to assess the impacts from proposed future changes in pumping from the BCPB and ESB. The ESB pumps mainly from the Lower Cowra Formation. The 2010 upgrade comprised the following:

- Division of the Cowra Formation into two model layers (the Upper and Lower Cowra Formations), making a 3-layer model (with the bottom layer representing the Lachlan Formation as before), so that pumping from the Cowra Formation could be simulated in more detail.
- Inclusion of the five ESB bores (SB01 to SB05).

Because of the inclusion of an additional layer in the model, and also to ensure that the model is continually updated, the model was recalibrated at the time of the upgrade. This task included the addition of new pumping and monitoring records collected since 2006.

The work undertaken in the current study incorporates additional BCPB pumping measurements, and additional monitoring piezometer measurements, up to the end of 2012.

7.1.1 Model Structure

Numerical simulations were conducted using the 2000 version of the groundwater simulation algorithm MODFLOW, compiled by the United States Geological Survey (Harbaugh et al., 2000). MODFLOW is a three-dimensional, finite difference, block-centred flow algorithm. It is an internationally recognised groundwater simulation algorithm accepted by most water resource authorities in Australia and world-wide. The graphical user interface employed for the algorithm is Visual MODFLOW Version 3, Build 180, a commercial package produced by Waterloo Hydrogeologic of Canada.

7.1.1.1 Date Precision

Water level measurements are made manually using electronic water level meters, with measurements accurate to ± 1 centimetre (cm). Survey information for water level measurement points are generally accurate to the same level. Pumping rates for the BCPB and ESB are to within metred accuracy. Private bore pumping information is provided as a single measurement per bore per financial year, and the accuracy is unknown. The measurement accuracy for water levels is small compared to observed water level changes in the Cowra and Lachlan Formations, and does not significantly impact results.

7.1.1.2 Mesh and Layering

The layer structure contour surfaces are considered to be accurate to within ± 5 cm, which is small compared to layer thicknesses and therefore has minimal effect on transmissivities. Kriging is used for interpolation of modelled water levels and drawdowns. Model calibration uses discreet targets, without the effects of interpolation.
The model active area covers an area of about 1,800 km\(^2\). Figure 1 shows the calculated extents of the Upper Cowra, Lower Cowra, and Lachlan Formations, and the boundary of the modelled area (for the uppermost model layer). ML 1535 is also shown, with the pit and the tailings impoundments.

Figure 70 shows the modelled areas for each of the three model layers. The total extents of the Cowra and Lachlan Formations (calculated from borehole data and bedrock outcrop) are also shown in Figure 70 as the darker lines. The model areas do not extend to the extremities of the calculated total extents of the sediments since in these areas the sediments in each formation thin out considerably and practical limits were applied to the model boundaries. The model grid consists of a uniform mesh of 50 m by 50 m cells over the BCPB area (covering an area of about 36 km\(^2\)) gradually expanding to a maximum cell size of 1 km by 1 km at the edges of the model area. Cell dimensions increase by no more than a factor of 1.2 between cells to maintain model stability and allow accurate calculation of heads.

The groundwater system is simulated using three layers as follows:

- **Layer 1**: The Upper Cowra Formation (unconfined). The base of the Upper Cowra Formation is set to 47 m bgl based on conductivity data and downhole gamma logs (Figures 9 and 28) from bores in the vicinity of the BCPB.

- **Layer 2**: The Lower Cowra Formation (confined / unconfined).

- **Layer 3**: The Lachlan Formation (confined / unconfined).

The Upper Cowra Formation has one aquifer parameter zone (Figure 70). The Lower Cowra Formation has three aquifer parameter zones (northern, central, and southern) of approximately equal extent, broadly based on geology. The Lachlan Formation has two parameter zones representing:

- high permeability sands and gravels close to and within the deeper parts of the palaeochannel; and

- lower permeability, finer-grained sediments that generally occur further away from the deeper parts of the palaeochannel and surround the high permeability sands and gravels.

The use of three model layers is considered adequate for simulating the attenuation of depressurisation in the vertical direction (which is governed by kv for each layer). This formulation allows an acceptable calibration to be achieved.

An assessment of hydraulic conductivity indicates that bedrock conductivity is approximately 1,000 times lower, at the same depth, than the high conductivity part of the Lachlan Formation in the deeper parts of the palaeochannel (about 100 m depth). Therefore, bedrock in the Bland Creek Palaeochannel underlying the alluvial sequence has been assumed to be impermeable for the purpose of numerical simulation, and has not been modelled. This is considered reasonable because the rock occurs at burial depths exceeding 100 m (significantly lowering its hydraulic conductivity), and is separated from the alluvial sequence by a low conductivity clay palaeosol of several metres thickness (meaning the bedrock will have a negligible component in the water balance for the alluvial sediments).

Measured drawdowns from pumping in the Upper Cowra Formation were not available for calibration of specific yield. Based on the lithology of the Upper Cowra Formation and the research of Johnson (1967), a specific yield of 4% has been adopted for modelling purposes for the study area. Figure 71a (after Johnson, 1967) shows that a specific yield of 4% is appropriate for a sandy clay or clayey silt.
7.1.1.3 Boundary Conditions

Rainfall recharge is applied at a uniform percentage of incident rainfall (on a daily, monthly, or yearly basis, depending on stress period size) over the entire extent of the Cowra Formation in the model domain.

The northern boundary of the model was chosen at a point where narrowing of the Bland Creek Palaeochannel is interpreted to occur in the Lachlan Formation at the Corinella Constriction (Figure 70). Including the area to the north of this point and beyond would have involved the added complexity of treatment of the Lachlan Valley groundwater system and the associated groundwater interactions. To allow groundwater flow across this boundary, a general head condition was applied in all three layers. The general head boundary conditions assigned at this location allow aquifer flow to enter and leave the model at a rate proportional to the difference in head across the boundary.

Parameters for the general head boundaries were initially calculated by assuming that the Lachlan River and Goobang Creek to the north act as ultimate hydraulic controls, and calculating the conductances based on average cell widths, distances to these boundaries from the Corinella Constriction, and estimated layer hydraulic conductivities over this distance. Conductances were then varied slightly during calibration based on the hydrograph for the Koreela bore and government monitoring piezometer GW090093 (Figure 18c).

Based on a thorough review of stream flow and river stage data from the Government Pinneena database (covering the period 1976 to 2003), and field observations, the following water courses have been included in the model using the River package:

- Barmedman and Bland Creeks near Lake Cowal; and
- Lake Cowal.

These water courses were selected based on groundwater hydrographs and duration of water flow. Riverbed elevations were assessed from topographic maps, digital elevation data, and stream gauging station survey information. These data were used to assign smoothly-varying riverbed elevations over the model area for the creeks and Lake Cowal. River water level heights were obtained from the Pinneena database. Water levels for Lake Cowal were estimated from data presented in the EIS.

Leakage from Lake Cowal is expected to flow in a north-westerly direction, out of the model active area. To the north-west of Lake Cowal lies Nerang Cowal and a thin cover of surface soil overlying rock. In the model, flow of lake leakage is not possible from the lake to the north-west (because the Upper Cowra Formation is not present there), therefore the calibrated conductance of the lake bed material allows only that flow which reports to the active area of the Upper Cowra Formation in the model.

The Saline Supply Bores within ML 1535 has been included in the local groundwater model and is not included in the regional model used for this component of the work. This is considered reasonable since the Saline Supply Bores within ML 1535 pumps from the Upper Cowra Formation only, at relatively small rates, and is considered unlikely to significantly affect drawdown in the Upper Cowra, Lower Cowra, or Lachlan Formations further east.

The current mine pit has been included in the local groundwater model and is not included in the regional model. The mine pit is located on the western margin of the model and intersects “transported” material, saprolite (clay), and weathered and fresh rock. The transported material is the Upper Cowra Formation equivalent, and has been impacted slightly by drainage into the mine pit (see the December 1997 Upper Cowra Formation water level surface, discussed below).
The Lower Cowra and Lachlan Formations are not present at the mine site. The drawdown in the Upper Cowra Formation from pit drainage has been small (several metres) and localised, and is considered unlikely to significantly affect drawdown in the Upper Cowra, Lower Cowra, or Lachlan Formations further east. Drawdown in the Saprolite, Saprock, and fresh rock from drainage at the mine pit is not likely to influence groundwater processes in the active model area, apart from the localised effect near the pit of inducing vertical drainage from the Upper Cowra Formation (in addition to lateral drainage towards the pit face).

7.1.1.3.1 Pumping Bores

Excluding Barrick-owned pumping bores, supplied usage data have allowed 12 private water supply bores to be simulated in the numerical model. These are listed in Table 22 and are active during the calibration verification, or predictive periods (see below). Table 22 also lists the cut-off date of the last supplied usage data.

<table>
<thead>
<tr>
<th>Bore</th>
<th>Cut-off Date of Last Supplied Usage Data</th>
<th>Numerical Simulation Active Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW029094 (Billabong 1)</td>
<td>June 2004</td>
<td>Active during calibration period only (ceased in March 2006).</td>
</tr>
<tr>
<td>GW057974 (Billabong 2)</td>
<td>June 2004</td>
<td>Active during calibration period only (ceased in March 2004).</td>
</tr>
<tr>
<td>GW701646 (Billabong 3)</td>
<td>June 2008</td>
<td>Active during calibration period only (replaced by Billabong 6 in 2008).</td>
</tr>
<tr>
<td>GW702127 (Billabong 4)</td>
<td>June 2010</td>
<td>Active for all simulation periods (commenced October 2005 as replacement for Billabong 1 and Billabong 2).</td>
</tr>
<tr>
<td>GW703639 (Billabong 6)</td>
<td>June 2010</td>
<td>Active during verification and predictive periods only (Replacement for Billabong 3. Commenced after 30 June 2008).</td>
</tr>
<tr>
<td>GW701267 (Maslin)</td>
<td>June 2010</td>
<td>Active for all simulation periods.</td>
</tr>
<tr>
<td>GW701454 (Quandialla TWS)</td>
<td>June 2010</td>
<td>Active for all simulation periods.</td>
</tr>
<tr>
<td>GW701958 (Muffet)</td>
<td>No data supplied*</td>
<td>Active for all simulation periods (from 1 July 2007).</td>
</tr>
<tr>
<td>GW702013 (Hart)</td>
<td>No data supplied*</td>
<td>Active for all simulation periods (from 1 July 2007).</td>
</tr>
<tr>
<td>GW702262 (Moora Moora)</td>
<td>No data supplied*</td>
<td>Active for all simulation periods (from 1 July 2007).</td>
</tr>
<tr>
<td>GW702286 (Trigalana)</td>
<td>No data supplied*</td>
<td>Active for all simulation periods (from 1 July 2007).</td>
</tr>
<tr>
<td>Trigalana East</td>
<td>No data supplied*</td>
<td>Active for all simulation periods (from 1 July 2007).</td>
</tr>
</tbody>
</table>

* Estimates of (at the time) future pumping for these bores were supplied by the Lachlan Valley Water Group in 2007. These estimates were used for all simulation periods. Subsequent confirmation of actual pumped volumes have not been received.

For five bores, no usage data were available and the calibration period has relied on usage estimates supplied by the Lachlan Valley Water Group in 2007. Although these bores are smaller groundwater users, this will add error to the calibration beyond the control of the model. Of the remaining bores, no usage data have been received for bores (that are active in the verification period) after 30 June 2010. No private bores have been identified in the fractured rock groundwater system in the vicinity of the CGM.
7.1.1.4 Recharge and Discharge Processes

Model recharge processes are:

- rainfall recharge;
- leakage from rivers (Bland Creek and Lake Cowal); and
- flow into the model from the Corinella Constriction in all layers.

Model discharge processes are:

- groundwater extraction from the Upper Cowra, Lower Cowra, and Lachlan Formations;
- leakage to rivers (Bland Creek and Lake Cowal); and
- flow out of the model to the Corinella Constriction in all layers.

Evaporation is not modelled because the average depth of the water table in the Upper Cowra Formation is around 5 m and well below the extinction depth typical for fine-grained sediments (1 m to 2 m).

Intermittent recharge from flooding from remnant ponds outside the water course channels is not modelled since no flooding was known to have occurred in the area during the model calibration period. However, the calibrated riverbed conductances and rainfall recharge will incorporate this process.

7.1.2 Model Calibration

Recalibration of the numerical model was undertaken by Coffey in 2010. The recalibration was conducted for the period 1 January 1998 to 30 June 2008 using monthly stress periods. This period begins at a time of relative equilibrium in groundwater levels in the BCPB area and significant pumping in the Billabong area. The overall set of calibration parameters for the model has been:

- lateral hydraulic conductivity;
- vertical hydraulic conductivity;
- specific storage;
- rainfall recharge;
- riverbed conductance; and
- general head boundary conductance.

Preliminary modelling indicated a significant positive correlation between the specific yield of the Cowra Formation and rainfall recharge. Specific yield was therefore fixed to a reasonable prior value based on lithology, previous studies, and literature (see above). In this way, rainfall recharge became the independent parameter and was varied during calibration of this pair.

Initial estimates for riverbed conductance were based on consideration of values used for river systems in the Lower Namoi Valley groundwater flow model (Merrick, 1989). The Lower Namoi Valley and Bland Creek Palaeochannel display many similar characteristics such as climate, aquifer types, and river types.
Calibration targets comprised water level measurements over time for 39 observation bores as listed in Table 2. Seven of these bores are screened in the Upper Cowra Formation, 10 in the Lower Cowra Formation, and 20 in the Lachlan Formation. Locations of observation bores are shown in Figures 18a to 18c.

Initial heads were obtained by steady-state simulation of observed hydraulic heads for December 1997, a time of relatively little change in hydraulic heads (except in the Billabong area).

7.1.2.1 Results

7.1.2.1.1 Hydraulic Heads

To allow a reasonable calibration to water levels at observation bore GW036597 (Table 2), located in the Billabong area, groundwater extraction was required in the model in the vicinity of the Billabong area at a rate of 8 ML/day between 1 January 1998 to 1 April 1998. Without this extraction, calibration of GW036597 could not be achieved. The extraction was applied at GW701646 (nominal pump capacity 100 L/s) and estimates possible pumping at a rate of approximately 6 ML/day for a longer period (commencing around October 1997, just prior to the start of the calibration period).

In addition, the water levels for GW036597 suggest that groundwater extraction from the Lachlan Formation occurred in the Billabong Area in the summer of 2000/2001, probably at a rate similar to the extraction rate in subsequent summer seasons. This extraction, although not reported in government records, has been applied in the model. With this extraction included, calculated water levels for GW036597 provide a far better match with observations.

Automated parameter estimation conducted as part of the 2006 modelling process indicated that the calibrated values for various parameters were considered defensible and appropriate based on site-specific observations, published studies, and model formulation. A finding of the estimation study was that in the more southerly parts of the model domain the vertical leakance in the Cowra Formation was likely to be lower than the calibrated value of the 2006 model. It was considered that, based on available data, the vertical leakance between the Cowra and Lachlan Formations was likely to decrease in a southerly direction. This finding was taken into account by dividing the Lower Cowra Formation into three zones (northern, central, and southern) of approximately equal extent, broadly based on geology, so that vertical leakance could be varied between zones.

Appendix B shows the model-calculated heads versus observed heads at the end of the calibration period (30 June 2008). The head residuals (model-calculated head minus observed head) are distributed around a residual mean of 0.15 m. The average absolute residual is 3.69 m, an improvement from the 2006 model. Appendix B also has the calibrated and observed hydrographs for all monitoring bores. The normalised root-mean-squared residual for the target dataset is 6.1%, which is considered acceptable.

Water level matches in the hydrographs are considered acceptable. Given the large vertical gradients set up in the Lower Cowra Formation from pumping in the Lachlan Formation, matches between observed and modelled heads in this layer are expected to show greater variation because small differences in the elevation of the screened sections (of observation bores) at a location can result in different observed water levels; the model assumes that a water level is the same throughout the thickness of a layer, and hence departures from observed water levels are more likely.
7.1.2.1.2 Aquifer Parameters

Calibrated aquifer parameters are listed in Table 23. Calibrated broad-scale transmissivities are 840 m$^2$/day and 90 m$^2$/day for the high and low permeability zones respectively in the Lachlan Formation.

Riverbed conductances are low and in keeping with the surface sediments found in the area. Most river leakage occurs to or from Bland and Barmedman Creeks. Assuming an average river channel width of 20 m (including overbank ponds), an average river reach of 1,200 m in each cell, and 0.2 m of barrier material in the river bottom, the calibrated riverbed conductance for Bland and Barmedman Creeks is equivalent to a vertical hydraulic conductivity for the riverbed barrier material of $9 \times 10^{-5}$ m/day. For Lake Cowal leakage occurs over the entire area of each cell and so the riverbed conductance is equivalent to a vertical hydraulic conductivity in the lake bed material of $1 \times 10^{-6}$ m/day. This compares favourably with results from laboratory analysis of lakebed sediments indicating an average vertical hydraulic conductivity of $5.0 \times 10^{-7}$ m/day (Hawkes, 1998) allowing for upscaling from a laboratory sample scale to a regional scale. Hydraulic test results in Hawkes (1998) also indicate an average lateral hydraulic conductivity for the lake bed material of $5.5 \times 10^{-5}$ m/day for one location on the lake.

<table>
<thead>
<tr>
<th>Table 23. Calibrated Aquifer Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>Lateral Hydraulic Conductivity (m/day)</td>
</tr>
<tr>
<td>Average Thickness over Model Area (m)</td>
</tr>
<tr>
<td>Average Transmissivity over Model Area (m$^2$/day)</td>
</tr>
<tr>
<td>Vertical Hydraulic Conductivity (m/day)</td>
</tr>
<tr>
<td>Specific Storage (m$^3$)</td>
</tr>
<tr>
<td>Specific Yield</td>
</tr>
<tr>
<td>General Head Boundaries</td>
</tr>
<tr>
<td>External Head (m AHD)</td>
</tr>
<tr>
<td>Conductance (m$^3$/day)</td>
</tr>
<tr>
<td>River Bed Conductance (m$^2$/day)</td>
</tr>
<tr>
<td>Bland and Barmedman Creeks</td>
</tr>
<tr>
<td>Lake Cowal</td>
</tr>
<tr>
<td>Rainfall Recharge (% of average annual rainfall)</td>
</tr>
</tbody>
</table>

Rainfall recharge is calibrated to 1% of annual rainfall and compares favourably with other estimates for the area (between 0.3% and 2%). It is an overall average for the model area, mostly comprising recharge from rainfall and irrigation, but also likely to contain a small component representing seepage from shallow, higher conductivity rock on the fringes of the alluvial sediments. It is also likely that the calibrated value includes the effects of intermittent ponding associated with water courses.
The calibrated specific storage \( (1.5 \times 10^{-5} \text{ day}^{-1}) \) is supported by pumping test results (average of around \( 9 \times 10^{-6} \text{ day}^{-1})\).

### 7.1.2.2 Flow Budgets

Table 24 lists the water budgets for the calibrated model for:

- 30 June 1999 (Model Day 546), a time when no pumping was occurring and the groundwater system was close to steady-state conditions; and
- 30 June 2008 (Model Day 3834), the end of the calibration period.

From 30 June 1999 to 30 June 2008, replenishment of aquifer storage fell by 15.9 ML/day (from 10.8 ML/day) to result in storage removal of 5.1 ML/day. Flows out of the model at the Corinella Constriction (modelled with the general head boundary) also fell, resulting in a net flow into the model. These changes were due to a fall in rainfall together with an increase in groundwater pumping.

The model is considered to be acceptably calibrated for its current purpose.

### Table 24. Calibration Model Flow Budget

<table>
<thead>
<tr>
<th>Flow Budget Term</th>
<th>30 June 1999</th>
<th>30 June 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In (ML/day)</td>
<td>Out (ML/day)</td>
</tr>
<tr>
<td>Aquifer Storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Cowra</td>
<td>-</td>
<td>9.55</td>
</tr>
<tr>
<td>Lower Cowra</td>
<td>-</td>
<td>0.24</td>
</tr>
<tr>
<td>Lachlan</td>
<td>-</td>
<td>1.00</td>
</tr>
<tr>
<td>Pumping Bores</td>
<td>-</td>
<td>0.00</td>
</tr>
<tr>
<td>Rainfall Recharge</td>
<td>11.86</td>
<td>-</td>
</tr>
<tr>
<td>River Leakage</td>
<td>-</td>
<td>0.61</td>
</tr>
<tr>
<td>Flow across the Corinella Constriction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Cowra</td>
<td>-</td>
<td>0.25</td>
</tr>
<tr>
<td>Lower Cowra</td>
<td>-</td>
<td>0.15</td>
</tr>
<tr>
<td>Lachlan</td>
<td>-</td>
<td>0.03</td>
</tr>
<tr>
<td>TOTAL</td>
<td>11.86</td>
<td>11.83</td>
</tr>
<tr>
<td>Discrepancy (%)</td>
<td>0.23</td>
<td>0.08</td>
</tr>
</tbody>
</table>

### 7.1.2.3 Eastern Saline Borefield Calibration

The ESB commenced pumping in early 2010, nearly two years after the end of the calibration period. When the model was recalibrated in 2010, predictive runs were initially used as calibration runs for the observation bores near the ESB (PZ01, PZ02 and PZ05). Although private bore usage data were available only for some bores after June 2008, it was nevertheless considered that some additional calibration of Lower Cowra Formation parameters could be done with the ESB pumping stress, considering that:

- most private bores in this area are understood to pump small quantities; and
comparison of modelled and predicted water levels in the BLPR series (close to the ESB) indicated acceptable agreement.

Additional ESB monitoring piezometers PZ09 to PZ11 were installed in late 2011 (Figures 18a and 18b). Calibration plots for PZ01, PZ02, PZ05, and PZ09 to PZ11 are provided in Appendix B. PZ10 is screened within the upper quarter of the Lower Cowra Formation, therefore, due to the vertical hydraulic head gradients created by pumping, and the calculation of model hydraulic head for the middle of the Lower Cowra Formation, observed and simulated hydrographs for PZ10 will show departures. The overall match between observed and simulated water levels is considered acceptable.

7.1.3 Sensitivity Analysis

The predictions of drawdown due to future operation of the Bland Creek Palaeochannel Borefield depend upon the hydraulic parameters adopted in the groundwater model. As the model has been calibrated against observed responses there is a high level of confidence that the parameters adopted are reasonable representations of the field properties of the key hydrogeological formations. Nevertheless it is important to understand how the predictions would change if different values of the hydraulic parameters were adopted. A series of sensitivity analyses were carried out to evaluate the effect of changes in the adopted values of key hydraulic parameters on the predicted drawdowns. To assess the sensitivity of modelled water levels to changes in parameters, calibrated hydrographs at bores GW036553, GW036597, and GW036611 were compared to modelled water levels for the following cases:

- vertical conductivity ($K_v$) of the Lower Cowra Formation was 10% lower than the calibrated value;
- horizontal conductivity ($K_h$) of the Lachlan Formation was 10% lower than the calibrated value;
- specific storage of the Lachlan Formation was 10% lower than the calibrated value; and
- private pumping in the Lachlan Formation was 10% higher than values used for the calibration period (based on available records).

The drawdown at the trigger bores is most sensitive to $K_v$ of the Lower Cowra Formation, and to pumping. The GW036553 water level is also sensitive to the $K_h$ of the Lachlan Formation. Under the perturbations used above, the model predicts that the maximum drawdown at the trigger bores varies within an envelope spanning about 7m of drawdown or less. This is small compared to the total drawdown and suggests observed drawdown departures from model predictions are likely to be manageable, with mitigation measures able to be undertaken.

7.1.4 Model Verification

The model has been used to simulate water level observations made between the end of the model calibration period (1 July 2008) and the following times, as a verification procedure:

- 30 November 2012 for monitoring piezometers significantly affected by the BCPB and ESB. This date is the cut-off date of reliably measured supplied extraction data for these pumping bores.
- 30 June 2010 for monitoring piezometers significantly affected by the large private groundwater users (GW036597 and GW036611). No usage data have been received for these pumping bores for the period following 30 June 2010 (Table 22).
These observation data were not used during the calibration period. Verification hydrographs are shown in Appendix C. Hydrographs in the BCPB area show good agreement, while hydrographs in the Maslin and Billabong areas show less, but still acceptable, agreement. For GW036611, some seasonal offset between actual pumping (probably at the Maslin bore) and modelled pumping is evident. However there is unavoidable approximation in transferring a single supplied usage volume for one year, to 12 separate monthly values. The match between simulated and observed water levels indicates the model is acceptably verified, and suitable for use in a predictive capacity.

7.2 Predictive Simulation

The predictive model is based on a calibrated model that simultaneously calibrates to observed heads, flows, hydraulic conductivities, and rainfall recharge rates. This provides the strongest imaging of the natural system. Predictive simulation has been undertaken according to the following constraints:

- ESB pumping at a total of 1.5 ML/day between 1 January 2013 and 31 December 2015.
- Assessment of the maximum possible BCPB total pumping rate, with ESB operation, such that the trigger levels for monitoring piezometers GW036553, GW036597 and GW036611 are not reached.

The following future conditions are applied:

- Average rainfall occurs from 30 November 2012. It is applied as an invariant annual rate equivalent to 1% of 476 mm/year (the average rainfall at BoM’s Wyalong Post Office between 1896 and 2010).
- Water levels for Lake Cowal, and Bland and Barmedman Creeks, have been assigned by calculating their average water levels over the period of record and applying these averages over the entire simulation period. These averages are 0.35 m for Bland and Barmedman Creeks and 0.5 m for Lake Cowal.

7.2.1 Pumping

For the period covered by predictive simulations, the pumping in the model area occurs from bores that can be divided into three groups, for the purpose of impact assessment. These groups are:

- The ESB (two bores), owned and operated by Barrick. The ESB pumps from the Upper and Lower Cowra Formations, with most of the screen interval occurring in the Lower Cowra Formation.
- The BCPB (four bores), owned and operated by Barrick. The BCPB pumps from the Lachlan Formation.
- The private bores (nine bores). These nine bores all pump from the Lachlan Formation. There are no private bores in the model that pump from the Upper or Lower Cowra Formations.

Simulation covers a future period of about 26 years commencing on 1 December 2012 and ending on 31 December 2038.
7.2.1.1 Barrick Bores

Mining (and associated water demand) ends in 2024. The BCPB stops pumping on 31 December 2024, so the model calculates 14 years of water level recovery in the BCPB area. Pumping is distributed amongst the four bores of the BCPB according to the proportions pumped by each bore up to 30 November 2012. Under current license conditions, the BCPB would be permitted, as at the end of 30 November 2012, to extract a further 15,950 ML. If pumping ends on 31 December 2024, this represents an average rate of 3.61 ML/day.

The ESB comprises five bores, only two of which will be used (SB01 and SB02). To date, SB01 and SB02 have pumped 21% and 79% of the total abstraction for the ESB, respectively. Future pumping rates would be 1.25ML/day for SB02 and 0.25ML/day for SB01. The only drawdown constraint applied to pumping is that the groundwater level not fall below the base of the bore screens. Based on supplied information, the elevation of the base of the bore screen for each ESB bore is as follows:

- SB01: 144.7 m AHD; and
- SB02: 144.6 m AHD.

7.2.1.2 Private Bores

There are nine private (non-Barrick) pumping bores that are active in the predictive simulation. These bores, along with their estimated average annual future usage (as advised by the Lachlan Valley Water Group in 2007), are listed in Table 25a (see also Tables 16 and 22).

<table>
<thead>
<tr>
<th>Private Bore Pumping Group</th>
<th>Private Bore</th>
<th>Estimated Future Usage (Lachlan Valley Water Group)</th>
<th>Estimate used for Predictive Simulation (ML/day)</th>
<th>Date Future Estimate Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Capacity</td>
<td>Billabong 3/6 *</td>
<td>811 Annual (ML/year) 2.22 Daily (ML/day)</td>
<td>1.90 ^</td>
<td>1 December 2012</td>
</tr>
<tr>
<td></td>
<td>Billabong 4</td>
<td>876 Annual (ML/year) 2.40 Daily (ML/day)</td>
<td>1.94 ^</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maslin</td>
<td>1652 Annual (ML/year) 4.52 Daily (ML/day)</td>
<td>3.01 ^</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quandialla TWS</td>
<td>37 Annual (ML/year) 0.10 Daily (ML/day)</td>
<td>0.10 ^</td>
<td>1 July 2010</td>
</tr>
<tr>
<td>Low Capacity</td>
<td>Hart</td>
<td>7 Annual (ML/year) 0.02 Daily (ML/day)</td>
<td></td>
<td>1 July 2007</td>
</tr>
<tr>
<td></td>
<td>Moora Moora</td>
<td>48 Annual (ML/year) 0.13 Daily (ML/day)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Muffet</td>
<td>7 Annual (ML/year) 0.02 Daily (ML/day)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trigalana</td>
<td>30 Annual (ML/year) 0.08 Daily (ML/day)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trigalana East</td>
<td>49 Annual (ML/year) 0.13 Daily (ML/day)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>7.33 Annual (ML/year)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Billabong 3 was replaced by Billabong 6 in 2008 (refer to Tables 17 and 22).
^ Historical average (refer to Table 25b).

For the three largest users (Billabong 3/6, Billabong 4, and Maslin), and Quandialla TWS, collectively referred to as the High Capacity Group, actual usage data are available up to 2010. For the remainder, referred to as the Low Capacity Group, no actual usage data have ever been received.
Nearly 10 years of actual usage data are available for each of the High Capacity bores. These data cover a period of drought (from around 2002 to 2010), and have been used to calculate average annual pumping rates over the respective data periods. These averages (and selection method for time periods used for averaging) are listed in Table 25b and have been used as future estimates of usage for the High Capacity Group.

Future usage for bores of the Low Capacity Group comprise the estimates provided by the Lachlan Valley Water Group.

The average total annual future usage for these private bores is 7.33 ML/day, and is applied until the end of the simulation (31 December 2038).

There are an additional 10 licensed private (non-Barrick) bores in the model area that have the potential to pump large amounts, but for which no usage data are available. It is not known if any of these may be pumping groundwater (Tables 17 and 22). As at 2010, it was understood that the bore installed by Mr Mattiske in 2007 (not active in the model) approximately midway between Bores 1 and 2 of the BCPB, did not operate, and the bore is not included in predictive simulations.

Pumping bore Billabong 5 was completed on 23 December 2008 as a replacement for Billabong 1 and 2. The potential for this bore to have been used since 2008, or to be used in the future, is high, but no actual usage data nor future usage estimates have ever been received, and the bore is not included in predictive simulations.

7.2.1.3 Calibration of Private Bore Pumping Rates

There is an absence of actual usage data for the three largest groundwater users in the model area (Billabong 3/6, Billabong 4, and Maslin) between 1 July 2010 and the beginning of predictive simulation on 1 December 2012. Pumping from these bores significantly affects water levels in trigger bores GW036597 and GW036611. To obtain modelled hydrographs at these bores that are reasonable matches with observations at the start of the predictive period, it was necessary to estimate the pumping rates of these bores between 2010 and 2012, since the water levels at the start of the predictive period at these trigger bores are crucial to assessing the compliance of BCPB pumping.

Assuming Billabong 5 has never pumped, pumping calibration indicated that the Billabong bores were most likely to have been inactive over this period, while the Maslin bore required the following pumping:

- 30-Jun-11 to 30-Nov-11: 5.00 ML/day; and
- 30-Sep-12 to 31-Jan-13: 12.00 ML/day.

Figure 71b shows how these calibrated values compare with actual usage data. The calibrated usages are within the bounds seen in measured pumping periods. Appendix D shows the modelled water levels over the period for the three trigger bores (GW036553, GW036597, and GW036611) resulting from these pumping rates. Simulated water levels remain slightly conservative (lower than measured) at GW036553 and GW036597. Pumping calibration has slightly affected the goodness of fit between observed and simulated water levels at GW036553.

Note that calibration of pumping rates is not standard practice but has been undertaken here due to the large amount of observed pumping data available for the Maslin and Billabong bores, and the closeness of fit obtained between modelled and observed water levels.
# Table 25b. Future Usage Estimates for Private Pumping Bores in the High Capacity Group

<table>
<thead>
<tr>
<th>Bore</th>
<th>Bore Commissioning Information</th>
<th>Period covered by Usage Data (used for Averaging of Pumping Rate)</th>
<th>Average of Supplied Usage Data (ML/day)</th>
<th>Estimate from Lachlan Valley Water Group (2007) (ML/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW701267</td>
<td>Bore completed 1 November 2000*. The license was issued 17 May 1999*. Therefore supply was available from 1 November 2000. Supplied usage data begin from the latter half of 2004.</td>
<td>From 31-Jul-2004  To 30-Jun-10</td>
<td>3.01</td>
<td>4.52</td>
</tr>
<tr>
<td>(RBMaslin)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GW701454</td>
<td>Bore completed 28 February 2002*. The license was issued 28 December 2001*. Therefore supply was available from 28 February 2002. Supplied usage data begin from July 2003.</td>
<td>From 30-Jun-2003  To 30-Jun-10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>(Quandialla)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GW701646</td>
<td>Bore completed 31 March 1996*. The license was issued 12 May 1999* however usage is likely to have occurred from prior to the start of supplied usage data (1 January 1998).</td>
<td>From 31-Dec-97  To 30-Jun-10</td>
<td>1.90</td>
<td>2.22</td>
</tr>
<tr>
<td>(Billabong3/6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GW702127</td>
<td>Bore completed 30 March 2005*. As at late 2005, the license application had been lodged but a license had not been issued*. Supplied usage data begin from the last quarter of 2005.</td>
<td>From 30-Sep-05  To 30-Jun-10</td>
<td>1.94</td>
<td>2.40</td>
</tr>
<tr>
<td>(Billabong4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Information contained in electronic bore records supplied by email from the NOW database in 2006.
7.2.2 Results

Figure 72 shows the modelled drawdown in the Lower Cowra Formation in the vicinity of SB01 and SB02, and the drawdown at trigger piezometer GW036553. Figure 73 shows the modelled water levels at trigger piezometers GW036597 and GW036611. Trigger piezometers GW036597 and GW036611 are unverified from 1 July 2010.

Baseflow losses from the Lachlan River due to pumping at the BCPB are expected to be negligible, due to the absence of direct contact between the river channel and the Lachlan Formation, the significant vertical anisotropy of the sediments, the very large distance between the BCPB and the river, and the presence of the Corinella Constriction.

The maximum allowable total pumping rate for the BCPB that does not cause the water level to fall below the trigger values at GW036553, GW036597 and GW036611 is 7.2 ML/day. However when accumulated, this is in excess of the licensed amount (average of 3.6 ML/day to 2024). Barrick will therefore seek to remove the 30,000ML life of mine extraction limit as part of the Modification. Barrick will operate within the existing daily and annual extraction limits of 15 ML/day and 3,660 ML/annum for the Modification. Modelled water levels in the Cowra Formation at the ESB remain comfortably above the base of the pumping screens during ESB operation. BCPB pumping at 7.2 ML/day results in minimum water levels in the Lachlan Formation of 0.04 m, 3.05 m and 2.59 m above the trigger levels at GW036553, GW036597 and GW036611 respectively.

There are limitations in using numerical groundwater models to assess borefield performance (Section 10).

7.2.2.1 Water Level Drawdown

Figures 74a to 74c show the modelled drawdowns in the Upper Cowra, Lower Cowra, and Lachlan Formations (respectively) for 31 December 2015 (just before pumping stops at the ESB). Figures 75a to 75c show the drawdowns for the same formations for 31 December 2024 (just before pumping stops at the BCPB).

The maximum modelled drawdown in the Upper and Lower Cowra Formations occurs just before the end of ESB pumping (31 December 2015) (Figures 74a and 74b). At this time, maximum drawdowns of about 4.5 m and 33 m occur in the Upper and Lower Cowra Formations respectively, centred on the ESB. Drawdown in the Upper Cowra formation due to the ESB is confined to a small area surrounding the ESB.

The maximum modelled drawdown in the Lachlan Formation occurs just before the end of BCPB pumping (31 December 2024) (Figure 75c). At this time, a maximum drawdown of about 68 m occurs in the Lachlan Formation, centred on the BCPB.

There are some private registered bores screened in the Lachlan Formation in the area of the BCPB. However, impacts on these bores are being monitored and mitigation measures have been developed to mitigate potential impacts (see below).
Drawdown in the Lower Cowra Formation is moderate however mitigation measures may be required for bores, depending on the bore depths. Table 26 lists privately owned bores which appear to be screened in the Upper and Lower Cowra Formations (depths less than 90 m) within 15 km of the BCPB and ESB, based on a search of government bore records in 2011. The list excludes the following:

- government and private monitoring bores that are not used for pumping;
- bores of the ESB; and
- bores deeper than 90 m (considered to be in the Lachlan Formation).

GW702230 is located within the ESB and is known as the Duff bore. It is understood to be under an agreement between the mine and the owner allowing its use for mine water supply.

GW029574 is located within the Bland Creek Palaeochannel, inside the modelled area. A maximum modelled drawdown of about 13 m in the Lower Cowra Formation is calculated for GW029574. However the bore is 88 m deep and may be able to continue operation if the screen length is sufficiently long and optimally located.

Table 26. Private Water Bores within 15 km of the BCPB and ESB in the Cowra Formation (Depth Less than 90 m)

<table>
<thead>
<tr>
<th>Bore</th>
<th>MGA Easting</th>
<th>MGA Northing</th>
<th>Completed Depth (m bgl)</th>
<th>Water Level (m bgl)</th>
<th>Licensed use</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW000926</td>
<td>573578</td>
<td>6277218</td>
<td>53</td>
<td>-</td>
<td>Unknown</td>
</tr>
<tr>
<td>GW000941</td>
<td>574203</td>
<td>6284759</td>
<td>53</td>
<td>27</td>
<td>Unknown</td>
</tr>
<tr>
<td>GW000947</td>
<td>569187</td>
<td>6282733</td>
<td>58</td>
<td>-</td>
<td>Unknown</td>
</tr>
<tr>
<td>GW000968</td>
<td>566215</td>
<td>6274130</td>
<td>58</td>
<td>-</td>
<td>Unknown</td>
</tr>
<tr>
<td>GW000984</td>
<td>567310</td>
<td>6275970</td>
<td>51</td>
<td>-</td>
<td>Unknown</td>
</tr>
<tr>
<td>GW000993</td>
<td>564694</td>
<td>6273894</td>
<td>48</td>
<td>-</td>
<td>Unknown</td>
</tr>
<tr>
<td>GW001128</td>
<td>573133</td>
<td>6286492</td>
<td>40</td>
<td>-</td>
<td>Unknown</td>
</tr>
<tr>
<td>GW012714</td>
<td>564028</td>
<td>6293795</td>
<td>23</td>
<td>-</td>
<td>Domestic</td>
</tr>
<tr>
<td>GW012715</td>
<td>561686</td>
<td>6294734</td>
<td>18</td>
<td>-</td>
<td>Domestic</td>
</tr>
<tr>
<td>GW012717</td>
<td>564436</td>
<td>6293022</td>
<td>28</td>
<td>-</td>
<td>Domestic</td>
</tr>
<tr>
<td>GW012718</td>
<td>563778</td>
<td>6294967</td>
<td>26</td>
<td>-</td>
<td>Stock</td>
</tr>
<tr>
<td>GW013488</td>
<td>567773</td>
<td>6286901</td>
<td>47</td>
<td>-</td>
<td>Unknown</td>
</tr>
<tr>
<td>GW013489</td>
<td>569076</td>
<td>6285290</td>
<td>48</td>
<td>-</td>
<td>Stock</td>
</tr>
<tr>
<td>GW013859</td>
<td>570412</td>
<td>6291718</td>
<td>17</td>
<td>-</td>
<td>Stock</td>
</tr>
<tr>
<td>GW013860</td>
<td>569816</td>
<td>6291291</td>
<td>27</td>
<td>-</td>
<td>Stock</td>
</tr>
<tr>
<td>GW013861</td>
<td>570208</td>
<td>6291966</td>
<td>38</td>
<td>-</td>
<td>Stock</td>
</tr>
<tr>
<td>GW013876</td>
<td>570827</td>
<td>6291900</td>
<td>38</td>
<td>-</td>
<td>Stock</td>
</tr>
<tr>
<td>GW025198</td>
<td>548006</td>
<td>6299524</td>
<td>24</td>
<td>-</td>
<td>Unknown</td>
</tr>
<tr>
<td>GW029574</td>
<td>553360</td>
<td>6273194</td>
<td>88</td>
<td>30</td>
<td>Stock</td>
</tr>
<tr>
<td>GW030636</td>
<td>548006</td>
<td>6299524</td>
<td>30</td>
<td>-</td>
<td>Unknown</td>
</tr>
<tr>
<td>GW032827</td>
<td>564669</td>
<td>6293206</td>
<td>28</td>
<td>-</td>
<td>Stock</td>
</tr>
<tr>
<td>GW051007</td>
<td>572594</td>
<td>6273129</td>
<td>40</td>
<td>-</td>
<td>Domestic</td>
</tr>
<tr>
<td>GW051069</td>
<td>574492</td>
<td>6298833</td>
<td>20</td>
<td>-</td>
<td>Stock</td>
</tr>
</tbody>
</table>
### Table 26 (Continued). Private Water Bores within 15 km of the BCPB and ESB in the Cowra Formation (Depth Less than 90 m)

<table>
<thead>
<tr>
<th>Bore</th>
<th>MGA Easting</th>
<th>MGA Northing</th>
<th>Completed Depth (m bgl)</th>
<th>Water Level (m bgl)</th>
<th>Licensed use</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW052190</td>
<td>569206</td>
<td>6285443</td>
<td>47</td>
<td>-</td>
<td>Stock</td>
</tr>
<tr>
<td>GW052224</td>
<td>574482</td>
<td>6287499</td>
<td>18</td>
<td>-</td>
<td>Stock</td>
</tr>
<tr>
<td>GW056399</td>
<td>572278</td>
<td>6289394</td>
<td>64</td>
<td>-</td>
<td>Stock</td>
</tr>
<tr>
<td>GW701820</td>
<td>570693</td>
<td>6287470</td>
<td>81</td>
<td>-</td>
<td>Stock</td>
</tr>
<tr>
<td>GW701913</td>
<td>561749</td>
<td>6278523</td>
<td>60</td>
<td>10</td>
<td>Stock</td>
</tr>
<tr>
<td>GW702230</td>
<td>555812</td>
<td>6287547</td>
<td>66</td>
<td>-</td>
<td>Irrigation</td>
</tr>
<tr>
<td>GW702306</td>
<td>550115</td>
<td>6297268</td>
<td>55</td>
<td>6.2</td>
<td>Stock</td>
</tr>
<tr>
<td>GW702331</td>
<td>561755</td>
<td>6294581</td>
<td>38</td>
<td>5</td>
<td>Test Bore</td>
</tr>
<tr>
<td>GW703371</td>
<td>558784</td>
<td>6276810</td>
<td>35</td>
<td>-</td>
<td>Stock</td>
</tr>
<tr>
<td>GW703460</td>
<td>551480</td>
<td>6297801</td>
<td>36</td>
<td>4.3</td>
<td>Stock</td>
</tr>
</tbody>
</table>

The remaining bores are all located outside the modelled area, with 29 located to the east and north-east, on the other side of rock ridges or interpreted shallow bedrock. Three are located to the north-north-east, past the northern model boundary and within the northernmost parts of the Corinella Constriction.

#### 7.2.2.2 Flow Budgets

Table 27 lists the modelled groundwater flow budget for 31 December 2015, just before the end of the period of highest pumping (from the BCPB and ESB combined). Table 27 also lists the flow budget for the case where the ESB and BCPB are inactive for the entire simulation period (to allow an assessment of the water sources for BCPB and ESB pumping).

### Table 27. Predictive Model Flow Budget at the end of ESB Pumping (31 December 2015)

<table>
<thead>
<tr>
<th>Flow Budget Term</th>
<th>ESB and BCPB Inactive</th>
<th>ESB and BCPB Active</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In (ML/day)</td>
<td>Out (ML/day)</td>
</tr>
<tr>
<td>Rainfall Recharge</td>
<td>17.74</td>
<td>-</td>
</tr>
<tr>
<td>Aquifer Storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Cowra</td>
<td>-</td>
<td>11.96</td>
</tr>
<tr>
<td>Lower Cowra</td>
<td>0.66</td>
<td>-</td>
</tr>
<tr>
<td>Lachlan</td>
<td>1.38</td>
<td>-</td>
</tr>
<tr>
<td>Flow across the Corinella Constriction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Cowra</td>
<td>-</td>
<td>0.25</td>
</tr>
<tr>
<td>Lower Cowra</td>
<td>-</td>
<td>0.04</td>
</tr>
<tr>
<td>Lachlan</td>
<td>0.82</td>
<td>-</td>
</tr>
<tr>
<td>River Leakage</td>
<td>-</td>
<td>1.03</td>
</tr>
<tr>
<td>Pumping Bores</td>
<td>-</td>
<td>7.33</td>
</tr>
<tr>
<td>TOTAL</td>
<td>20.60</td>
<td>20.61</td>
</tr>
</tbody>
</table>

Discrepancy (%) = -0.06, -0.11
At 31 December 2015, the pumping from the ESB and BCPB is modelled as being sourced from the following:

- Upper and Lower Cowra Formation storage: 49%;
- Lachlan Formation storage: 49%; and
- River Leakage: 2%.

The river leakage contribution is likely to be smaller, because the future water levels in Bland and Barmedman Creeks are based on limited data, and also due to the intermittent nature of the creeks, and the effect that flooding has on aquifer recharge. Upward leakage from bedrock is taken as being negligible based on bedrock conductivity at depth, and the presence of clay (probably residual weathered bedrock) between the Lachlan Formation and bedrock.

### 7.2.2.3 Drawdown in the Lachlan Formation to the North of the Model

Drawdown in the Lachlan Formation to the north of the BCPB and ESB, past the end of the model at the general head boundary, can be assessed by considering the modelled drawdowns in conjunction with observed drawdowns at:

- piezometers in the model area; and
- piezometers GW036523 and GW036552 north of the modelled area.

Figure 76 shows modelled drawdowns in the Upper Cowra, Lower Cowra and Lachlan Formations for the calibrated and predictive models, and the observed drawdowns for June 2008. Koreela is a private pumping bore, and its drawdown is also caused by its own pumping. GW090093 is a government monitoring bore with the lower screen reported as covering 130 m to 136 m depth (penetrating bedrock), and the screen filterpack covering 100 m to 139 m depth.

The Corinella Constriction ends at around MGA northing 6297000, north of which the Lachlan formation rapidly expands in width, into the Lachlan floodplain area. About 1,500 m north of the end of the constriction, the Lachlan Formation width has expanded to three times the Corinella Constriction width. At this northing location are the monitoring piezometers GW036523 and GW036552, in the southern Lachlan River floodplain. Figure 76 shows that the observed Lachlan Formation drawdown measurements south of the Corinella Constriction follow a rising trend from the BCPB towards GW036523 and GW036552. The greater volume of Lachlan Formation Sediments north of the Corinella Constriction does not seem to have diffused the drawdown, although pumping occurring to the north can also be affecting GW036523 and GW036552. Observed drawdowns in the Upper and Lower Cowra Formations are relatively small within the model area, but appear to increase moving north, suggesting an influence from increased pumping occurring north of the Corinella Constriction at this location.

By extrapolation, and using the patterns of observed and simulated drawdowns for June 2008, the drawdown at the end of BCPB operation at GW036523 and GW036552 is estimated to be:

- minimal in the Upper Cowra Formation;
- about 5 m in the Lower Cowra Formation; and
- about 10 m in the Lachlan Formation.
The drawdowns due to BCPB pumping are expected to rapidly diminish north of GW036523 and GW036552, as a greater volume of sediments in the wider Lachlan floodplain can be engaged to dissipate the drawdown.

### 7.2.2.4 Post Mining Water Levels

When ESB and BCPB pumping stops, groundwater levels recover to approximately the following levels after 10 to 20 years (refer to Figures 72 and 73):

- GW036553: around 180 m AHD (a fall of about 15 m from prior to mining);
- GW036597: around 160 m AHD (a fall of about 35 m from prior to mining); and
- GW036611: around 165 m AHD (a fall of about 30 m from prior to mining).

It may take significant amounts of time for water levels to recover to levels seen in the late 1990s (prior to the drought and extensive pumping) because of the low rate of aquifer recharge and continuing pumping for agricultural purposes.

### 7.3 Ground Settlement

Monitoring of ground surface elevation has been conducted by Barrick in the BCPB area at six locations since 2007. The purpose of the monitoring is to review potential ground settlement due to pumping from the Lachlan Formation at the BCPB. Monitoring locations and results are shown in Appendix E.

The peak to peak variation in readings at any particular monitoring location ranges between 40 mm and 80 mm. The variability in the recorded elevations appears to increase towards the south suggesting this may be related to the measurement method (understood to be a differential Global Positioning System method). No long-term trends are apparent in relation to lateral movement.

Within the scatter of the settlement monitoring records a settlement trend may be present with a settlement of approximately 20 mm over the six year monitoring period from 2007 to 2012 in the vicinity of the BCPB.

Settlement arising from groundwater extraction at the BCPB is expected to arise from:

- settlement associated with depressurisation of the Lachlan Formation; and
- settlement associated with depressurisation of the Cowra Formation.

#### 7.3.1 Settlement Due to Drawdown within the Lachlan Formation

Significant depressurisation of the Lachlan Formation associated with groundwater extraction occurred within the first six months of operation of the BCPB. The magnitude of drawdown has gradually increased but drawdown is not expected to increase markedly over the remainder of the remaining 12 years life of the CGM. Within the vicinity of the borefield, drawdown of approximately 55 m occurred within the first two years of operation. Drawdown at the end of the mine life is not predicted to increase more than a further 10 m from the existing drawdown. The effect of the existing drawdown within the Lachlan Formation is expected to be fully transmitted over the full depth of the formation. Based on these observations additional settlement within the Lachlan Formation is not likely to be more than 15% of settlement which has already occurred within that formation. The settlement within the Lachlan Formation for the expanded mine life would not differ significantly from that which would have occurred under the currently approved mine life.
7.3.2 Settlement Due to Drawdown within the Cowra Formation

Drawdown within the Cowra Formation in response to operation of the BCPB will occur at the lower surface of the Cowra Formation in response to drawdown within the Lachlan Formation. Over time the drawdown effects will propagate upwards through the Cowra Formation at a rate that would depend upon the vertical permeability and the storage characteristics of the sediments of the Cowra Formation. For a uniform material, settlement associated with upward propagation of drawdown will increase linearly with the square root of time until the full thickness of the formation is affected, at which time the settlement will begin to stabilise.

An assessment of settlement within the Cowra Formation at the proposed completion of groundwater extraction can be made based upon the monitored settlement and on the following assumptions:

- All settlement which has occurred since installation of the settlement monitoring network in August 2007 (taken as 20 mm) is associated with settlement of the Cowra Formation.
- Drawdown is considered as commencing at the beginning of 2006 and since that time an average drawdown of 40 m has occurred in the Lachlan Formation in the borefield area (this assumption is consistent with groundwater level measurements).
- Drawdown at the end of operation of the BCPB would be 60 m in the Lachlan Formation.

Based on the above assumptions and taking account of the remaining time of operation and the predicted increase in drawdown, further settlement of 70 mm (allowing 50 mm for the Cowra Formation and a further 20 mm for the Lachlan Formation) is assessed for the period 2013 to 2024. This assessment applies in the vicinity of the BCPB and settlement at other locations would be less due to the reduced extent of drawdown at those locations. It is recommended that this assessment be reviewed over time as further settlement monitoring results are recorded.

7.3.3 Settlement Due to Eastern Saline Borefield Operation

The operation of the ESB would increase the settlement component associated with the consolidation of the Cowra Formation. The limited period of operation of ESB bores does not provide sufficient background monitoring for a direct assessment of settlement associated with the operation of the ESB. As the extent of drawdown associated with operation of the ESB is limited, the lateral extent of drawdown impacts would be similarly limited.

In the vicinity of the ESB bores the settlement due to the ESB within the Cowra Formation is assessed to be less than twice the settlement of the Cowra Formation in response to pumping from the Lachlan Formation. It is therefore anticipated that the additional settlement associated with operation of the ESB would not exceed 100 mm and would be a maximum in the vicinity of the borefield and reduce with distance according to the drawdown experienced within the Lower Cowra Formation.

7.3.4 Significance of Settlement

The settlement monitoring network covers a distance of some 15 km so settlements of the order of 100 mm are unlikely to be of practical significance in the agricultural setting of the area. It is clear that substantial ongoing settlement is unlikely to occur.

There is uncertainty in the assessment of settlement as a result of the scatter in the monitoring results.

It is recommended that settlement projections be reviewed periodically to take account of the results of future monitoring.
8 GROUNDWATER LICENSING AND AQUIFER INTERFERENCE POLICY CONSIDERATIONS

8.1 Licensing

The NSW Water Act, 1912 governs water licensing, and the trading and allocation of licences, for both groundwater and surface water resources in NSW where a water sharing plan has not been implemented. The Water Act, 1912 applies to extraction of groundwater, extraction of water from a river, aquifer interference and capture of surface runoff to dams. The Water Act, 1912 is in the process of being progressively phased out and replaced by the NSW Water Management Act, 2000 (WMA). Water licensing and the Aquifer Interference Policy Considerations are also discussed in Attachment 5 of the EA.

Water Sharing Plans are statutory plans for specific water resource areas under the WMA that provide the rules for sharing and managing water resources in NSW. The Water Act, 1912 is repealed for a water resource area once a Water Sharing Plan has commenced for that area, and existing licences are converted to new consents under the WMA.

There are two Water Sharing Plans that relate to CGM’s mining operations. These are as follows (Figures 77a and 77b):

- The Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources, 2012 commenced on 14 September 2012 and provides the framework for managing groundwater in the Lachlan aquifer until July 2023. The BCPB and ESB operated by CGM draw groundwater from the Lachlan Formation for mine use. These borefields lie within the Upper Lachlan Alluvial Zone 7 Management Zone. ML1535 lies within the Upper Lachlan Alluvial Zone 7 Management Zone.

- The Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources, 2011 commenced on 16 January 2012 and provides the framework for managing groundwater in the fractured rock aquifers until July 2022. ML1535 lies within the Lachlan Fold Belt groundwater source of the Murray-Darling Basin, and groundwater dewatering of and seepage to the open pit result in extraction of groundwater from the Lachlan Fold Belt (alluvial areas are excluded in this source area). Table 28 lists the statistics for the Murray-Darling Basin groundwater source as provided in the water sharing plan.

<table>
<thead>
<tr>
<th>Use</th>
<th>Share Component (ML/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock and domestic</td>
<td>74,311</td>
</tr>
<tr>
<td>Town water supply</td>
<td>5,101</td>
</tr>
<tr>
<td>Recharge</td>
<td>189,362.54 (high environmental value areas)</td>
</tr>
<tr>
<td></td>
<td>3,285,001.88 (non-high environmental value areas)</td>
</tr>
<tr>
<td>Environmental water</td>
<td>189,362.53 (high environmental value areas)</td>
</tr>
<tr>
<td></td>
<td>3,285,001.88 (non-high environmental value areas)</td>
</tr>
<tr>
<td>Long-term annual average extraction limit</td>
<td>189,362.53 (high environmental value areas)</td>
</tr>
<tr>
<td></td>
<td>3,285,001.88 (non-high environmental value areas)</td>
</tr>
</tbody>
</table>
8.1.1 Mine Site

The numerical modelling predicts monthly dewatering rates (due to open pit dewatering and seepage) as shown in Figure 63. The equivalent average annual groundwater take from 2013 to the end of mine life is approximately 200 ML/year. Peak dewatering flows (groundwater take) may exceed that value (by up to 40 ML/year) during major campaigns of horizontal drain (bore) installation in the open pit or vertical dewatering bore commissioning. The groundwater taken is predominantly sourced from the rock hydrogeological units.

It is recommended that, for the purposes of water licensing, a required take of 240 ML/year be considered to account for variability in dewatering and seepage inflows.

The predicted annual groundwater volumes required to be licensed within each Water Sharing Plan for the Modification are summarised in Table 29.

### Table 29. Groundwater Licensing Requirement Summary

<table>
<thead>
<tr>
<th>Water Sharing Plan</th>
<th>Management Zone/ Groundwater Source</th>
<th>Predicted Groundwater Inflow/Extraction Volume requiring Licensing (ML/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Existing</td>
</tr>
<tr>
<td>Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources</td>
<td>Upper Lachlan Alluvial Zone 7 Management Zone</td>
<td>Maximum 275*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSW Murray Darling Basin Fractured Rock Groundwater Sources</td>
<td>Lachlan Fold Belt Groundwater Source</td>
<td>Maximum 167</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Includes 256 ML/year extraction associated with the saline supply bores within ML 1535.

8.1.2 Additional Allocation for the BCPB

Predictive modelling results indicate that the BCPB could operate at an average extraction rate of 7.2 ML/day. If license applications are considered for the additional amount, the licensing would be subject to the Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources 2012 (which commenced on 14 September 2012 for a term of 10 years).

Under this plan, available water determinations are made at the start of each water year for aquifer access licences, with 1 ML per unit of share component or lower amount is applied, as a result of a growth in extractions response. A supplementary water access licence can be applied for if a growth in use response is triggered. These licences are issued to individuals based on history of extraction as established at the commencement of the Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources.

Licence applications would be assessed against the long-term average annual extraction limit of the water source, which is 94,168 ML/year. The additional amount of potential extraction for the BCPB (7.2 ML/day) is about 2,628 ML/year.
8.2 Aquifer Interference Policy Requirements

8.2.1 Mine Site

NOW’s Aquifer Interference Policy (September 2012) provides a framework for assessing the impacts of aquifer interference activities on water resources. Aquifer Interference Policy (the Policy) (NOW, 2012) is relevant to CGM as it applies to mining activities such as open cut voids and the disposal of water taken from aquifers.

Groundwater quality within ML1535 has EC generally in the range of 30,000 µS/cm to 55,000 µS/cm for the Transported, Saprolite and Saprock units. Data are not available for the Primary Rock, but the EC in the Primary Rock is expected to be similar (or higher due to the presence of salts in the rock). This equates to a TDS concentration of between 19,200 mg/L and 35,200 mg/L. The groundwater source at CGM is therefore defined by the Policy as a:

…less productive groundwater source…

The minimal impact considerations specified in the Policy for a less productive groundwater source include:

(i) No more than a specified cumulative variation in the water table within 40 m from a high priority groundwater dependent ecosystem or a high priority culturally significant site.

(ii) No more than a specified limited in the water table decline at any water supply work.

(iii) No more than a specified cumulative pressure head decline at any supply work.

(iv) Any change in groundwater quality that lowers the beneficial use category of the groundwater source beyond 40 m from the activity.

(v) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point of activity.

(vi) No mining activity below the natural ground surface within 200 m laterally from the top of the high bank and 100 m vertically beneath of a highly connected surface water source that is defined as a “reliable water supply”.

The model predicted groundwater drawdown up to 20 years post-mine closure remains essentially within ML1535. As there are no groundwater dependent ecosystems, priority culturally significant sites or supply works within ML1535 (or 40 m within the boundary of ML1535), minimal impact considerations (i) to (iii) have been met.

The relevant Water Sharing Plans for the mine site and BCPB identify three springs as groundwater-dependent ecosystems, within 65 km of the mine lease but not closer than 40 km. Two springs appear to be located in rock terrain to the east, on the other side of the Bland Creek Palaeochannel from the mine. The third spring is located in rock terrain far to the south of the mine. The springs are presumably maintained by groundwater in the rock. Significant groundwater drawdown predicted by the model is generally limited to within ML 1535 (to the proposed mine closure) for both dry and inundated lake conditions, therefore, the impacts to these springs is expected to be negligible.
During the life of the mine, pit dewatering activities are not expected to modify groundwater quality significantly. Over the longer term, groundwater will flow towards the open pit void, ultimately terminating there. This groundwater quality in the region surrounding the open pit void is not expected to change significantly due to this process, though the quality of the water within the open pit is expected to change (e.g. salinity will increase). The beneficial use of groundwater is not expected to change due to dewatering or the presence of the open pit void. Thus, minimal impact consideration (iv) is met.

Assuming that the equilibrium surface water level in the final pit void is not as high as ground surface, water from the pit void is not expected to be released (or used). Thus it is not classified as a highly connected surface water source, meeting minimal impact consideration (v).

Coffey is not aware of any “reliable water supplies” within 200 m laterally from the top of the high bank. Lake Cowal is an ephemeral lake, and is therefore not considered by Coffey to be a “reliable water supply”. Thus, minimal impact consideration (vi) is met.

### 8.2.2 Bland Creek Palaeochannel Borefield

Groundwater salinity of the Lachlan Formation at the BCPB is measured at the BLPR series of monitoring piezometers. Over the period June 2004 to December 2012, the average EC for the Lachlan Formation was 2,031 µS/cm. This excludes BLPR3 which is screened in the Lower Cowra Formation. The conversion factor to obtain TDS is calculated from 16 coincident measurements of EC and TDS at the BLPR series piezometers and the BCPB water bores, and is 0.58. This gives an average TDS of 1,184 mg/L. The water supply bores are equipped with works which are able to pump at greater than 5 L/s each. This means that the BCPB groundwater source would be classified as a highly productive groundwater source (HPGS) according to the following criteria for an HPGS, as listed in the Aquifer Interference Policy document:

- One that is declared in the Regulations.
- One that has a TDS concentration of less than 1500 mg/L.
- One that has supply works that can yield water at greater than 5 L/s.

The Lachlan Formation at the BCPB is declared in the water sharing plan applying to the area as an alluvial groundwater source, therefore the BCPB groundwater source is an Alluvial HPGS. The following sections discuss the operation of the BCPB in relation to meeting each of the groundwater source thresholds for key minimal impacts that apply to alluvial HPGSs, as listed in Table 1 of the Aquifer Interference Policy document.

In analysing the minimal impact considerations (MICs), the “post-water sharing plan” maximum pressure head applies to the first year after commencement of the plan. For the BCPB, the commencement date of the first plan is 14 September 2012, and the first year of the plan ends on 13 September 2013.

#### 8.2.2.1 The Water Table

MIC:

1. **Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40m from any:**
   
   (a) high priority groundwater dependent ecosystem; or
(b) high priority culturally significant site;
listed in the schedule of the relevant water sharing plan; or
A maximum of a 2m decline cumulatively at any water supply work.

2. If more than 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40m from any:
   (a) high priority groundwater dependent ecosystem; or
   (b) high priority culturally significant site;
listed in the schedule of the relevant water sharing plan then appropriate studies(5) will need to demonstrate to the Minister’s satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site.
If more than 2m decline cumulatively at any water supply work then make good provisions should apply.

Regarding MIC 1, there are no known groundwater ecosystems or culturally significant sites close enough to the BCPB where water table drawdown from Lachlan Formation extraction would be expected to occur during BCPB operation.

Regarding water table declines at the BCPB, water table monitoring data are available for WT50 and Bore15, but the data only extend to October 2006. These piezometers are several kilometres to the north and south of the BCPB, and are operated by Lachlan Irrigation. Between 2004 and 2006, the water level in WT50 fell by about 0.5 m, and that in Bore 16 fell by less than 0.5 m. Numerical simulation indicates that the water table at WT50 and Bore 16 continues to rise slightly, during BCPB operation. Based on these considerations, it is possible that the maximum decline at the water table at the BCPB may be less than 2m cumulatively, and less than 10% of the cumulative variation.

8.2.2.2 Water Pressure

MIC:

1. A cumulative pressure head decline of not more than 40% of the “post-water sharing plan” pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work.

2. If the predicted pressure head decline is greater than requirement 1. above, then appropriate studies are required to demonstrate to the Minister’s satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.

Regarding MIC 1, hydraulic heads in the Lachlan Formation at the BCPB are available up to December 2012. Water level measurements are from the BLPR series, which are in close proximity to the pumping bores, and from GW036553. Data from BLPR3 are not used. Hydraulic head elevations, maximum pressure heads, and other details observed since commencement of the water sharing plan are listed in Table 30. The analysis conservatively assumes that the base of the water source is the bottom of the water bore screened interval, and that the maximum change in pressure head is caused by the operation of the BCPB only.
Table 30. Observed Hydraulic Heads since Commencement of the Water Sharing Plan
(14 September 2012)

<table>
<thead>
<tr>
<th>Monitoring Piezometer</th>
<th>BLPR1</th>
<th>BLPR2</th>
<th>BLPR4</th>
<th>BLPR5</th>
<th>BLPR6</th>
<th>BLPR7</th>
<th>GW036553 (Ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Hydraulic Head (m AHD):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>154.6</td>
<td>152.4</td>
<td>150.1</td>
<td>161.4</td>
<td>156.7</td>
<td>157.9</td>
<td>156.7</td>
</tr>
<tr>
<td>Average</td>
<td>158.3</td>
<td>154.4</td>
<td>152.0</td>
<td>162.6</td>
<td>159.9</td>
<td>160.5</td>
<td>161.9</td>
</tr>
<tr>
<td>Maximum</td>
<td>162.5</td>
<td>155.6</td>
<td>153.2</td>
<td>163.6</td>
<td>162.5</td>
<td>162.6</td>
<td>167.9</td>
</tr>
<tr>
<td>Maximum Change</td>
<td>7.9</td>
<td>3.2</td>
<td>3.1</td>
<td>2.2</td>
<td>5.8</td>
<td>4.7</td>
<td>11.3</td>
</tr>
<tr>
<td>Aquifer Base (m AHD)*</td>
<td>83.7</td>
<td>83.7</td>
<td>93.7</td>
<td>91.5</td>
<td>83.7</td>
<td>81.4</td>
<td>83.7</td>
</tr>
<tr>
<td>Maximum Pressure Head (m)</td>
<td>78.8</td>
<td>71.9</td>
<td>59.5</td>
<td>72.1</td>
<td>78.8</td>
<td>81.2</td>
<td>84.2</td>
</tr>
<tr>
<td>Maximum Hydraulic Head Change as a percentage of the maximum pressure head (m)</td>
<td>10%</td>
<td>4%</td>
<td>5%</td>
<td>3%</td>
<td>7%</td>
<td>6%</td>
<td>13%</td>
</tr>
</tbody>
</table>

* Taken as the base of the screened interval of the closest BCPB water supply bore.

Although the maximum change in hydraulic head is less than 40% of the maximum pressure head, the absolute change in change is greater than 2 m. Thus, in regard to MIC 2, the exceedance of the absolute change threshold is managed using the trigger values and response plan discussed in Section 9. The trigger values mitigate against impacts to other local groundwater users, and against structural damage to the aquifer (settlement). The response plan contains a range of measures to mitigate against impact to other groundwater users and provide alternative water supplies if required.

8.2.2.3 Water Quality

MIC:

1. (a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity; and

(b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity.

Redesign of a highly connected(3) surface water source that is defined as a “reliable water supply”(4) is not an appropriate mitigation measure to meet considerations 1.(a) and 1.(b) above.

(c) No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a “reliable water supply”.

(d) Not more than 10% cumulatively of the three dimensional extent of the alluvial material in this water source to be excavated by mining activities beyond 200m laterally from the top of high bank and 100m vertically beneath a highly connected surface water source that is defined as a “reliable water supply”.

2. If condition 1.(a) is not met then appropriate studies will need to demonstrate to the Minister’s satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.

If condition 1.(b) or 1.(d) are not met then appropriate studies are required to demonstrate to the Minister’s satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity.
If condition 1.(c) or (d) are not met, then appropriate studies are required to demonstrate to the Minister’s satisfaction that:

- there will be negligible river bank or high wall instability risks;
- during the activity’s operation and post-closure, levee banks and landform design should prevent the Probable Maximum Flood from entering the activity’s site; and
- low-permeability barriers between the site and the highly connected surface water source will be appropriately designed, installed and maintained to ensure their long-term effectiveness at minimising interaction between saline groundwater and the highly connected surface water supply.

Regarding MIC 1(a), filtered monitoring data (to remove unrepresentative spikes – see Figure 27) for all BLPR series piezometers except BLPR3 (Lower Cowra Formation) and BLPR 5 (large offset difficult to incorporate into a regression analysis) indicate that EC has been decreasing at the rate of 0.36 µS/cm per year at the BCPB. The average variation around this trend is 94 µS/cm, indicating a reasonably stable trend (when compared to the absolute EC). These results suggest the beneficial use category of the Lachlan Formation at the BCPB has not been impacted so far. The current monitoring program will continue so that potential changes in EC can be identified, to mitigate the potential for higher salinity water to move downward from the Cowra Formation into the Lachlan Formation from extraction in the Lachlan Formation.

Regarding MIC 1(b), there are no natural water sources in the BCPB area that are perennial, or that are highly connected to the Lachlan Formation. Irrigation canals are present however these have minimal hydraulic communication with the Lachlan Formation due to the depth of pumping and the vertical anisotropy of the sediments. The irrigation canals are understood to lose water rather than accept baseflow from the surrounding medium, due to the typical water table depths (about 5m below ground). The other MICs are not applicable as the interference activity (operation of the BCPB) is not mining.
9 MANAGEMENT AND MITIGATION MEASURES

9.1 Contingency Strategy for the Lachlan Formation Water Source

The groundwater level in the Lachlan Formation in the BCPB area is monitored on a continuous basis by the NOW using its groundwater monitoring bore on Burcher Road (GW036553). Contingency measures have been developed for implementation when water levels reach an elevation of either 137.5 m AHD (Investigation Trigger Level A) or 134 m AHD (Mitigation Trigger Level B). These trigger levels were developed in consultation with NOW and other water users within the Bland Creek Palaeochannel, including stock and domestic users and irrigators. Coffey understands the following contingency measures are associated with each trigger level:

- In the event that the groundwater level in GW036553 is below 137.5 m AHD, one or more of the following contingency measures will be implemented in consultation with the NOW:
  - investigate the groundwater level in the Trigalana bore (GW702286) or any other impacted stock and domestic bores;
  - determine the pump setting in relevant stock and domestic bores;
  - determine the drawdown rate in GW702286 and other impacted stock and domestic bores; and
  - develop an impact mitigation plan for impacted stock and domestic bores, and/or set up an alternative water supply for the owner of GW702286 and other owners of stock and domestic bores, if necessary;
- In the event that the groundwater level in GW036553 is below 134 m AHD, one or both of the following contingency measures will be implemented in consultation with the NOW:
  - alter the pumping regime to maintain the water level in the impacted stock and domestic bores; and
  - maintain a water supply to the owner/s of impacted stock and domestic bores.

9.2 Mitigation Measures for the Lachlan Formation Water Source

Prior to the drought last decade, stock and domestic water supplies were generally drawn from surface water delivered through the Jemalong Irrigation Limited irrigation channel network. The reduced availability and increased cost of this water, driven by reduced rainfall from around 2002 onwards, led to establishment of stock/domestic bores which utilised the Lachlan Formation aquifer. Several consortia were established to share the costs of bore installation and to deliver the water across multiple properties.

Barrick was independently approached by various parties for assistance in upgrading the pumping systems such that their design capacity could be met independently of the abstraction from the Lachlan Formation. The known schemes are listed below and shown on Figure 33:

- Moora Moora (bore GW702262);
- Hammond (also known as the West Plains Bore, or bore GW702100);
- Trigalana (also known as Trigalana West, or bore GW702286); and
- Trigalana East.
Table 2 provides the bore construction details. Each of the schemes is understood to comprise the following key elements:

- a single bore equipped with a submersible pump;
- above-ground storage tanks located near the bore;
- a surface-mounted pump to pressurize the pipeline system; and
- a pipeline system with control valves at the user offtake.

The private bore known as “Muffet” (GW701958) is understood to have provided stock water on a single property, through a solar-powered pumping system. Other private, single-farm systems are reported to be powered by solar, diesel, and mains powered pumps.

It is understood that the following measures were implemented by Barrick for ameliorating the impacts of pumping at the BCPB on stock/domestic bores:

- From 2006 to 2007:
  - Moora Moora: Replacement of the pump, installation of a new pump to a greater depth and upgrade of the electrical power supply to enable the system to maintain design flow;
  - West Plains and Trigalana: Provision of water through a metered polyethylene pipeline direct to the stock water tanks; and
  - Muffet: Replacement of an existing solar powered submersible pump with a new pump of larger capacity, setting of the new pump to a greater depth, and upgrade of the solar panel array to increase its electrical output.

- During 2011:
  - West Plains: The bore failed and Barrick paid for replacement of the bore in mid-2011. The bore was operating by the fourth quarter of 2011; and
  - Isolation of the West Plains and West Trigalana schemes from the direct supply of water from Barrick’s pipeline (although water could still be supplied in an emergency since the pipelines remain in place).

9.3 Groundwater Levels around the Tailings Storage Facilities

Groundwater levels in piezometers in the vicinity of the tailings dams have shown increases in levels in recent years. Of these, the largest rises were recorded at MON02A and MON02B (screened in the Saprock and Saprolite units, respectively) which have displayed a significant rise since late 2006. Groundwater level variation around the TSF was investigated by Coffey (2009a), where the rises were assessed to be related to the percolation and the movement of seepage from TSF.

Ground elevation at the MON02 piezometer nest is about 222 m AHD, about 13 m above the groundwater levels at MON02 in late 2012. The screen midpoints are at about 66 m and 27 m below ground at MON02A and MON02B respectively. The equality of water levels at these piezometers suggest minimal vertical hydraulic head gradients, with the potential for shallow hydraulic heads to be the same as deeper in the profile, at that location.
If the current trends were extrapolated linearly the water level at MONO2B would reach the ground surface in about 2022. This provides sufficient time to develop and design mitigation measures should they prove necessary. Following mine closure the elevated groundwater levels are expected to dissipate over time as the water levels within the tailings dams gradually reduce.

As the water level rises at MONO2A and MONO2B are interpreted to be associated with seepage from the tailings dam Coffey recommends:

- continuation of monitoring of piezometers in the vicinity of the tailings dams;
- review of groundwater levels on an annual basis; and
- should existing trends continue, develop a groundwater control plan and design control measures to address water level rise which could include:
  - augmentation of the existing monitoring network;
  - pumping groundwater from bores introduced in the vicinity of MON02 back to the TSF; and/or
  - installation of trench drains and sumps to collect groundwater and suppress further rise in groundwater levels.
10 LIMITATIONS

10.1 Numerical Simulation

The results reported are specific to the modelled conditions. In the absence of data, the models adopt conditions and parameter values assumed relevant. Should conditions differ from those adopted in the assessments made, results may vary significantly.

The results reported are subject to the uncertainty inherent in numerical modelling. The numerical models are necessarily simplifications of the real system and rely on calibration to data of unknown precision to produce predictive results. The results are estimates only and may differ from future observations.

10.2 Assessed Maximum Pumping Rates

Use of the numerical model to assess maximum pumping from a bore that would maintain saturation in the aquifer has not considered well bore losses. This is an optimistic condition and, depending on bore construction, there is the potential for the assessed pumping rates to be too high at a bore.

In addition, the drawdown in the cell or element within which the pumping bore is located is calculated algebraically, and does not consider the curvature of the hydraulic head surface moving away from the bore. The calculated drawdown overestimates the drawdown at the cell (or element) extremity and underestimates the drawdown near the bore. This is also an optimistic condition and its impact depends on aquifer parameters and pumping rate. There is the potential for this added constraint to further make the assessed pumping rates too high at a bore.

In practice, additional bores may need to be installed to achieve the pumping rates assessed for the predictive scenarios.

10.3 Pumping Well Screens

MODFLOW, the numerical algorithm used in this work, calculates the drawdown from groundwater pumping algebraically. MODFLOW does not use well screen information, and only requires the identification of the model layer from which the specified pumping will occur.

Where a well screen straddles two or more model layers, the pumping allocated to each layer cannot be specified a priori because the relative proportion of pumping from each layer will depend on the ratio of drawdowns (together with aquifer parameters), which in turn is dependent on the pumping rates. In this situation the Visual MODFLOW platform uses the length of the well screen intersecting each model layer, and the hydraulic conductivity of each well cell, to assign the proportion of the total well pumping rate to each layer for that well. The following equation is used to calculate the pumping rate for each layer for a well whose screen straddles n layers:

\[ Q_i = \frac{L_i K_i}{(L_i K_i)} Q_T \]

Where,

- \( Q_i \) is the discharge from layer \( i \) to a particular well in a given stress period;
- \( Q_T \) is the well discharge in that stress period;
- \( L_i \) is the screen length in layer \( i \);
• $K_x$ is the hydraulic conductivity in the $x$-direction in layer $i$; and
• $(L_i K_x)$ represents the sum over layers $i = 1$ to $n$ of the products of screen length and hydraulic conductivities in the $x$-direction of layers $i$ to $n$.

This equation is useful but does not take into account the vertical hydraulic conductivities, and cannot vary the pumping proportions according to drawdowns, as would occur in the actual system.

The drawdowns calculated above for the Upper and Lower Cowra Formations depend on the screen information supplied by GCS, and are approximate. The calculated drawdowns should be used as a guide only, and may differ from observed drawdowns.
11 CONCLUSIONS

11.1 Groundwater Impacts due to Open Pit Mining

The Mine Site Model predicted groundwater drawdown due to open pit mining and dewatering to generally remain within ML 1535. Groundwater inflows to the open pit range between approximately 400 m$^3$/day and 600 m$^3$/day between 2013 and mine closure (i.e. up to approximately 200 ML/year). Peak dewatering flows (groundwater take) may exceed that value (by up to 40 ML/year) during major campaigns of horizontal drain (bore) installation in the open pit or vertical dewatering bore commissioning. This would result in maximum groundwater inflows of 228 ML/year within the fractured rock groundwater system and 24 ML/year within the alluvial groundwater system. There is a negligible difference between the dry and inundated lake scenarios.

Pit dewatering effluent water quality is expected to be similar to historical conditions. Groundwater quality within ML 1535 is expected to be similar to historical conditions.

11.2 Impacts on Lake Cowal due to Open Pit Mining

Modelling results suggest negligible impact on Lake Cowal and the associated groundwater system due to the open pit, pit dewatering and groundwater extraction from ML 1535 saline groundwater supply borefield.

11.3 Groundwater Quality Impacts due to Potential Seepage from the Tailings Storage Facilities

The mean vertical leakage from both TSF dams is predicted to be collectively approximately 400 m$^3$/day during the mine life. Conservative assessment of potential impacts to groundwater quality due to seepage from the TSF suggest that after 100 years the potential for groundwater quality changes due to seepage from the TSF stored water will extend a distance of up to approximately 2 km from the TSF walls. However, the movement of some solutes (such as cyanide) will be impeded by sorption and geochemical processes, and their extent of transport within groundwater is likely to be significantly less.

Long-term (post-mine closure) groundwater conditions indicate that solutes associated with potential seepage from the TSF would flow towards, and ultimately terminate within the final pit void. As a result, analytes associated with potential seepage from the TSF are expected to remain within groundwaters between the TSFs and the final void over the long-term.

11.4 Groundwater Impacts in the Bland Creek Palaeochannel on the Alluvial Groundwater System

An existing model has been used to predict groundwater impacts associated with operation of the ESB and BCPB under a new mine plan. Under current licence conditions, the BCPB would be permitted, as at the end of November 2012, to extract a further 14,050 ML. If pumping ends on 31 December 2024, this represents a maximum average rate of 3.6 ML/day. Barrick would therefore seek to remove the 30,000 ML life of mine extraction limit as part of the Modification. Barrick would operate within the existing daily and annual extraction limits of 15 ML/day and 3,660 ML/annum, respectively, throughout the Modification.
Predictive modelling indicates that the BCPB can pump at a maximum rate of 7.2 ML/day, up until 31 December 2024, without reaching the GW036553 trigger level, with the ESB pumping at 1.5 ML/day until 31 December 2015. Under this scenario, BCPB pumping does not draw water levels in the Lachlan Formation below the trigger levels at GW036553, GW036597 and GW036611.

As the existing Groundwater Contingency Strategy, developed in consultation with NOW and other groundwater users, would be maintained for the Modification, and given there would be no change to the currently approved daily or annual extraction limits from the Bland Creek Palaeochannel Borefield, no additional impacts to other users of the Bland Creek Palaeochannel are predicted.

11.4.1 Water Quality

Based on the groundwater data, EC has remained steady at all monitoring locations within the BCPB since the commencement of the CGM. The current monitoring program will continue so that potential changes in EC can be identified, and if necessary, mitigation measures implemented.

11.5 Impacts of BCPB and ESB Drawdown on Settlement

Settlement monitoring data to August 2012 does not show that ground settlement is occurring. The current monitoring program will continue so that potential changes in ground settlement can be identified, and if necessary, mitigation measures implemented.
12 RECOMMENDATIONS

12.1 Continued Model Verification and Calibration

As for any numerical model, continual update of the regional model is recommended. A record of at least 12 months of pumping from the ESB and BCPB, and associated hydraulic head observations from reliable piezometers with appropriate screens, should be collated and used as continued verification of the model. If necessary, model recalibration should be undertaken. Regulatory constraints may require that model predictions be continually compared to monitoring data.

12.1.1 Regional Model Verification for Southern Monitoring Piezometers

To calculate verification hydrographs for monitoring bores significantly affected by private (non-Barrick) water extraction that is active in the regional model (particularly trigger bores GW036597 and GW036611), Barrick should continue to seek usage data for all non-Barrick water supply wells that are active in the model for the verification period.

12.2 Salinity Impacts

The current monitoring program should continue so that potential changes in EC can be identified, and if necessary, mitigation measures implemented.

12.3 Data and Monitoring

Coffey recommend:

- Continued groundwater monitoring to validate the predictive modelling, particularly in the vicinity of ML 1535 saline groundwater supply borefield.

- Continued monitoring of groundwater salinity in the BCPB to assess potential saline migration

- A final pit void water balance post-mine closure be conducted to assess long-term water levels in the pit void and the potential impact on groundwater quality in the immediate vicinity of the pit void.

- The Mine Site Model predicts that groundwater levels in the vicinity of the TSF continue to rise. Coffey recommend review of these predictions in the planning of potential future strategies to manage TSF water.

- Settlement projections be reviewed periodically to take account of the results of future monitoring.
13 REFERENCES


Coffey Partners International Pty Ltd (1997), Groundwater Studies – Hydrogeological Assessment.


Gilbert and Associates Pty Ltd (undated). Review of factors affecting the performance of the proposed basal layer below the mine waste rock emplacement at the Cowal Gold Project. Report No. HAL-02-07 Task 2 001A.


Figures
COWAL GOLD NINE EXTENSION MODIFICATION

FIGURE 2
Modification Layout
The graph shows the apparent annual baseflow (ML) for different years from 1977 to 2000, plotted against the length of the time window for selecting the flow minimum (days). The x-axis represents the length of the time window, ranging from 2 to 20 days, and the y-axis represents the apparent annual baseflow, ranging from 0 to 40,000 ML.

Key observations:
- The baseflow decreases as the time window increases.
- The baseflow for Year 2000 is the highest compared to other years.
- The baseflow for Year 1977 is the lowest compared to other years.

The graph helps in understanding the variability of baseflow over time, which is crucial for hydrological studies and resource management.
Figure 7a. Water table piezometers affected mainly by rainfall.

Figure 7b. Water table piezometers affected mainly by irrigation.
FIGURE 8

LEGEND
- Water table significantly affected by irrigation
- Water table affected mainly by rainfall
- Intermediate behaviour (no dominant process)

NERANG COWAL
LAKE COWAL

Easting (MGA) 550000 555000 560000 565000 570000

Northing (MGA) 6260000 6265000 6270000 6275000 6280000
Interpreted base of Upper Cowra
Interpreted boundary of high permeability light grey sands and gravels

LEGEND

UPPER COWRA FORMATION
LOWER COWRA FORMATION
LACHLAN FORMATION
Host units for the Water Sharing Plan for the Lachlan Unregulated and and Alluvial Water Sources.

Host units for the NSW Murray Darling Basin Fractured Rock Groundwater Sources.

Nerang Cowal Cross-Section

Marsden Cross-Section

Coffey (2006)
Figure 14

Key:
- Contour of Ground Surface (mAHD)
- Interpreted extent of Lachlan Formation
- Interpreted extent of Cowra Formation

Client: BARRICK AUSTRALIA LIMITED
Project: COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT
Title: SURFACE CONTOURS FOR MODEL-ADOPTED GROUND LEVEL

Drawn: BR
Approved: RJB
Date: 7 MAY 2013
Scale: 1:70,000
Original size: A3

Figure no: GEOTLCOV21910AW
KEY

Contour of Ground Surface (mAHD)

Interpreted extent of Lachlan Formation

Interpreted extent of Cowra Formation

SURFACE CONTOURS FOR MODEL-ADOPTED BASE OF TRANSPORTED UNIT

FIGURE 15
FIGURE 16

SURFACE CONTOURS FOR MODEL-ADOPTED BASE OF SAPROLITE UNIT

BARRICK AUSTRALIA LIMITED

client:

COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT

project:

KEY

Contour of Ground Surface (mAHD)
Interpreted extent of Lachlan Formation
Interpreted extent of Cowra Formation

drawn: BR
approved: RJB
date: 7 MAY 2013
scale: 1:70,000
original size: A3

project no: GEOTLCOV21910AW

figure no: FIGURE 16

Lake Cowal
LOCATIONS OF OBSERVATION PIEZOMETERS SCREENED IN THE LOWER (AND UPPER) COWRA FORMATIONS.

Legend:
- Bore screened in the Upper Cowra only
- Bore screened in the Upper and Lower Cowra Formations

Note: PZ09 is screened in the Upper Cowra Formation, and PZ10 is screened in both the Upper and Lower Cowra Formations.
Client: BARRICK AUSTRALIA LIMITED

Project: COWAL GOLD MINE
EXTENSION MODIFICATION
HYDROGEOLOGICAL ASSESSMENT

Title: LOCATIONS OF OBSERVATION PIEZOMETERS
SCREENED IN THE LOWER COWRA

Drawn: PT
Approved: RJB
Date: 28 May 2013
Scale: 1:300,000
Original Size: A4

Project No: GEOTLCOV21910AW
Figure No: FIGURE 18b
Figure 19a. Hydrographs for approximately coincident piezometers in the BCPB area.

Drawdown as a proportion of drawdown in the Lachlan Formation

Figure 19b. Distribution of depressurisation in the Lachlan Formation into the Upper and Lower Cowra Formations over a 12 year period (1998 to 2010).
WATER LEVELS IN THE UPPER COWRA FORMATION FOR DECEMBER 1997

LEGEND

200 Water level contour (mAHD)

Client: BARRICK AUSTRALIA LIMITED
Project: COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT
Title: WATER LEVELS IN THE UPPER COWRA FORMATION FOR DECEMBER 1997

PT
RJB
7 Dec 2010
1:300,000
A4

figure no: FIGURE 20a
WATER LEVELS IN THE LOWER COWRA FORMATION
FOR DECEMBER 1997

Client: BARRICK AUSTRALIA LIMITED
Project: COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT
Title: WATER LEVELS IN THE LOWER COWRA FORMATION FOR DECEMBER 1997
Project No: GEOTLCOV21910AW
Figure No: FIGURE 20b

Easting (MGA) 530000 535000 540000 545000 550000 555000 560000 565000 570000 575000
Northing (MGA) 6230000 6235000 6240000 6245000 6250000 6255000 6260000 6265000 6270000 6275000 6280000 6285000 6290000 6295000

LEGEND
Water level contour (mAHD) 200

NERANG COWAL
LAKE COWAL
MARSDEN
NEWELL HIGHWAY
NERANG COWAL
CARAGABAL
QUANDIALLA
BUNDABURRAH
BLAND
QUANDIALLA

530000 535000 540000 545000 550000 555000 560000 565000 570000 575000
6230000 6235000 6240000 6245000 6250000 6255000 6260000 6265000 6270000 6275000 6280000 6285000 6290000 6295000

PT
RJB
7 Dec 2010
1:300,000
A4

Coffey Geotechnics
Specialists Managing the Earth

drawn
approved
date
scale
original size
WATER LEVELS IN THE LACHLANN FORMATION FOR DECEMBER 1997

Client: BARRICK AUSTRALIA LIMITED
Project: COWAL GOLD MINE
Project No: GEOTLCOV21910AW
Original Size: A4

Drawn: PT
Approved: RJB
Date: 7 Dec 2010
Scale: 1:300,000

Legend:
- Water level contour (mAHED)

Figure 20c
WATER LEVELS IN THE UPPER COWRA FORMATION
FOR SEPTEMBER 2006

Client: Barrick Australia Limited
Project: Cowal Gold Mine
Extension Modification
Hydrogeological Assessment

Title: WATER LEVELS IN THE UPPER COWRA FORMATION
FOR SEPTEMBER 2006

Figure: FIGURE 21a
WATER LEVELS IN THE LOWER COWRA FORMATION FOR SEPTEMBER 2006

LEGEND

- Water level contour (mAHD)

Easting (MGA)

530000 535000 540000 545000 550000 555000 560000 565000 570000 575000

Northing (MGA)

6230000 6235000 6240000 6245000 6250000 6255000 6260000 6265000 6270000 6275000 6280000 6285000 6290000 6295000

Client: Barrick Australia Limited
Project: Cowal Gold Mine Extension Modification Hydrogeological Assessment
Title: WATER LEVELS IN THE LOWER COWRA FORMATION FOR SEPTEMBER 2006
Project no: GEOTLCOV21910AW
Figure no: FIGURE 21b

Scale: 1:300,000
Original Size: A4

Drawn: PT
Approved: RJB
Date: 7 Dec 2010
BARRICK AUSTRALIA LIMITED
COWAL GOLD MINE
EXTENSION MODIFICATION
HYDROGEOLOGICAL ASSESSMENT

HYDRAULIC HEAD CROSS-SECTION FOR DECEMBER 1997

FIGURE 21d

H: 1:250,000
V: 1:2,500

Water Table

tyhead measurement (mAHd)

Pumping bore screen projected onto cross-section

Vertical to horizontal exaggeration 1:100

Host units for the Water Sharing Plan for the Lachlan Unregulated and and Alluvial Water Sources.

Host units for the NSW Murray Darling Basin Fractured Rock Groundwater Sources.

Lake Cowal full capacity perimeter 7km to the west

NERANG COWAL LAKE COWAL NEWELL HIGHWAY

Host units for the NSW Murray Darling Basin Fractured Rock Groundwater Sources.
FIGURE 21e

HYDRAULIC HEAD CROSS-SECTION FOR JANUARY 2010

NERANG COWAL LAKE COWAL NEWELL HIGHWAY

Barrick pumping bore Private pumping bore

VERTICAL TO HORIZONTAL EXAGGERATION 1:100

NORTH

Host units for the Water Sharing Plan for the Lachlan Unregulated and and Alluvial Water Sources.

Host units for the NSW Murray Darling Basin Fractured Rock Groundwater Sources.

SOUTH

UPPER COWRA FORMATION

LOWER COWRA FORMATION

LACHLAN FORMATION

LOWER COWRA FORMATION

ROCK

Higher Conductivity Rock

Lower Conductivity Rock

195
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

Distance along section (m)

Elevation (mAHD)

0 50 100 150 200 250 300

0 100 200 300 400 500 600

50 100 150 200 250 300

client: BARRICK AUSTRALIA LIMITED

project: COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT

title: HYDRAULIC HEAD CROSS-SECTION FOR JANUARY 2010

project no: GEOTLCOV21910AW

figure no: FIGURE 21e

drawn: PT

approved: RJB

date: 14 Jun 2013

scale: H: 1:250,000

V: 1:2,500

original size: A4
Figure 27a. Electrical conductivity of groundwater in the regional area.

Figure 27b. Electrical conductivity of groundwater at the BCPB.

Figure 27c. Electrical conductivity of groundwater at the BCPB, with spikes and anomalous data removed.
Figure 28a. Correlation of Pump Test Transmissivity and Associated Specific Capacity.

Figure 28b. Lateral Hydraulic Conductivity versus Depth for the Regional Area.

- Lachlan Floodplain Sediments (NOW records)
- Lachlan Pump Tests
- Bland Creek Palaeochannel Sediments (NOW records)
- Lachlan (pump testing)
- Lachlan (Bores 1 to 4 as a single test)
- Upper Cowra (pump testing)
- Lower Cowra (pump testing)
- Volcanic Rock, minesite (pump testing)
- Saprock, minesite (pit bore pumping)
- Upper Cowra, minesite ("Transported") (slug test with large differential)
- Upper Cowra, minesite ("Transported") (pit bore pumping)
- Saprolite, minesite (long duration airlifting recovery)
- Saprolite, minesite (pit bore pumping)
Figures 30

Monthly Flow (m³/day)

- Daily Rainfall Events > 30 mm
- Bores Measured
- Measured Total (Sumps and Bores)
- Number of Horizontal Bores (Drains) Installed in Month

- Daily Rainfall Events > 30 mm Only

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<th>Monthly Flow (m³/day)</th>
<th>Daily Rainfall (mm) for Daily Rainfall Events Greater Than 30 mm Only</th>
<th>Number of Horizontal Bores (Drains) Installed in Month</th>
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- Bores Measured
- Measured Total (Sumps and Bores)

- RJB

- NTS
FIGURE 31

Measured Vertical Dewatering Bores
Measured Total (Sumps and Vertical Bores)
Interpreted Total Dewatering (Sumps and Vertical Bores)

Monthly Flow (m$^3$/day)

Jan/05 Jul/05 Dec/05 Jun/06 Dec/06 Jun/07 Dec/07 Jun/08 Dec/08 Jun/09 Dec/09 Jun/10 Dec/10 Jun/11 Dec/11 Jun/12 Dec/12

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

Measured Vertical Dewatering Bores
Measured Total (Sumps and Vertical Bores)
Interpreted Total Dewatering (Sumps and Vertical Bores)

Monthly Flow (m$^3$/day)

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

drawn
approved
date
scale
original size
client: BARRICK AUSTRALIA LIMITED
project: COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT
title: INTERPRETED PIT DEWATERING RATES
project no: GEOTLCOV21910AW
figure no: FIGURE 31
Estimated Tailings Storage Facility Water Elevation (m AHD)

- Northern TSF
- Southern TSF

Drawn: BR
Approved: RJB
Date: 10 May 2013
Scale: NTS
Original size: A4

Client: BARRICK AUSTRALIA LIMITED
Project: COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT
Title: TAILINGS STORAGE FACILITY WATER LEVELS
Project no: GEOTLCOV21910AW
Figure no: FIGURE 32
LOCATIONS OF REGIONAL PUMPING BORES

- Barrick bore (all active in model).
- Private bore active in model. Usage data available to June 2010, or decommissioning*, whichever earlier (except for Billabong 1, where supplied usage data ends June 2004, but bore was decommissioned in March 2006).
- Private bore active in model. No usage data available but necessarily included in model (from 2007) for calibration and predictive periods. Usage estimates supplied by Lachlan Valley Users Group.
- Private bore inactive in model (no usage data available).

* Decommissioning* refers to the process of ceasing operations and shutting down a bore or well, typically due to economic or environmental reasons.

Drawn by: PT
Approved by: RJB
Date: 31 May 2013
Scale: 1:300,000

Client: BARRICK AUSTRALIA LIMITED
Project: COWAL GOLD MINE
Extension Modification
Hydrogeological Assessment

Title: LOCATIONS OF REGIONAL PUMPING BORES
Figure No: FIGURE 33
East of Lake Nerang Cowal: approximately 199 m AHD

West of Lake Nerang Cowal: Zero net flow in/out of domain

Lake Cowal region (MGA N6273000 to N6283000): Lake Cowal water level in upper layer (Transported), approximately 200 m AHD head within deeper strata

Southeast (MGA N6265000 to N6273000): Groundwater levels recorded in Bland Creek area of approximately 200 to 205 m AHD, declining in value northwards

Western Ridge Boundary: Zero net flow in/out of domain
South of ML (MGA N6284500): 205 m AHD varying to 212 m AHD

Lake Nerang Cowal (from MGA E533000 to E539300): 198 m AHD

East of Lake Nerang Cowal: 199 m AHD
West of Lake Nerang Cowal: Zero net flow

Transported
Saprolite
Saprock
Primary

Mine Open Pit
TSF dams

Zero net flow in/out of domain

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client: BARRICK AUSTRALIA LIMITED

project: COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT

title: 3D REPRESENTATION OF MODEL DOMAIN AND BOUNDARY CONDITIONS

project no: GEOTLCOV21910AW
figure no: FIGURE 35
As Shown

FIGURE 38

KEY
Solid line - modelled result
Points - monitoring data
PDB1A (82-88) - Bore ID
(screen interval, mbgl)

Pit vicinity: PDB1

PDB1A
PDB1A (82 to 88)

PDB1B
PDB1B (14 to 20)

Elevation (m AHD)

2005 2006 2007 2008 2009 2010 2011 2012
Year of Mine Life: 1 2 3 4 5 6 7 8

Pit vicinity: PDB3 and PDB4

PDB3A
PDB3A (94.5 to 100.5)
PDB3B
PDB3B (23.6 to 29.6)
PDB4A
PDB4A (74 to 80)
PDB4A (74 to 80)

Elevation (m AHD)

2005 2006 2007 2008 2009 2010 2011 2012
Year of Mine Life: 1 2 3 4 5 6 7 8
As Shown

FIGURE 40

KEY

Solid line - modelled result
Points - monitoring data
PDB1A (82-88) - Bore ID
(screen interval, mbgl)
As Shown

21 May 2013

RJB

BARRICK AUSTRALIA LIMITED

COWAL GOLD MINE

EXTENSION MODIFICATION

HYDROGEOLOGICAL ASSESSMENT

---

**Modelled Total Inflow (Sumps and Bores)**

**Measured Total Inflow (Sumps and Bores)**

**Monthly Flow (m\(^3\)/day)**

---

**January 05** to **December 12**

**0** to **2000**

**Modelled Total Inflow (Sumps and Bores)**

**Measured Total Inflow (Sumps and Bores)**

---

**21 May 2013**

**RJB**

**BARRICK AUSTRALIA LIMITED**

**COWAL GOLD MINE**

**EXTENSION MODIFICATION**

**HYDROGEOLOGICAL ASSESSMENT**

**CALIBRATION OPEN PIT INFLOWS**

**GEOTLCOV21910AW**
LEGEND

Approximate Extent of Open Pit
Lake Protection Bund
Mine Lease Boundary
Model Predicted Groundwater Drawdown (m)

drawn | BR
--- | ---
approved | RJB

date | 28 May 2013

scale | 1:50,000

original size | A4

client: BARRICK AUSTRALIA LIMITED

project: COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT

MODELLED GROUNDWATER DRAWDOWN IN TRANS- PORTED UNIT DURING DECEMBER 2020, DRY LAKE

project no: GEOTLCOV21910AW

figure no: FIGURE 47
LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- Model Predicted Groundwater Drawdown (m)

drawn: BR
approved: RJB
date: 28 May 2013
scale: 1:50,000
original size: A4

client: BARRICK AUSTRALIA LIMITED
project: COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT
project no: GEOTLCOV21910AW

MODELLED GROUNDWATER DRAWDOWN IN SAPROLITE UNIT DURING DEC, 2020, INUNDATED LAKE

FIGURE 52
LEGEND

Approximate Extent of Open Pit

Lake Protection Bund

Mine Lease Boundary

Model Predicted Groundwater Drawdown (m)

drawn: BR
approved: RJB
date: 28 May 2013
scale: 1:50,000
original size: A4

client: BARRICK AUSTRALIA LIMITED
project: COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT

title: MODELLED GROUNDWATER DRAWDOWN IN SAPROCK UNIT DURING DEC, 2020, INUNDATED LAKE
project no: GEOTLCOV21910AW
figure no: FIGURE 53
LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mine Lease Boundary
- Model Predicted Groundwater Drawdown (m)

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<td>Project</td>
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<td>Title</td>
<td>Modelled Groundwater Drawdown in Saprolite Unit at End of Mine Life, Dry Lake</td>
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<td>Figure No.</td>
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Monthly Flow (m$^3$/day)

- Measured Total Inflow (Sumps and Bores)
- Modelled Total Inflow (Sumps and Bores) - Inundated Lake
- Modelled Total Inflow (Sumps and Bores) - Dry Lake

NOTE: ANNUAL AVERAGE FLOW INCREASES BY UP TO 100 m$^3$/day ASSOCIATED WITH PIT EXPANSION AND MAJOR HORIZONTAL DRAINAGE CAMPAIGNS CAN BE ANTICIPATED.

OPEN PIT ATTAINS FULL DEPTH

BARRICK AUSTRALIA LIMITED
COWAL GOLD MINE
EXTENSION MODIFICATION
HYDROGEOLOGICAL ASSESSMENT

MODEL-PREDICTED INFLOW TO OPEN PIT

FIGURE 63
LEGEND

- Approximate Extent of Open Pit
- Lake Protection Bund
- Mining Lease Boundary
- Possible Groundwater Quality Change for Groundwater Released From TSF Wall After Time (Years) Assuming Hydraulic Conditions at Mine Closure

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Client: BARRICK AUSTRALIA LIMITED
Project: COXVAL GOLD MINE
Title: EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT
Figure: PREDICTED EXTENT OF GROUNDWATER QUALITY CHANGE WITH TIME IN SAPROLITE UNIT
Project no: GEOTLCOV21910/W
Figure no: 68
NOTE:
1. Model layer boundaries are indicated by the thicker lines.
2. Interpreted total extents of the formations (to zero thickness) are indicated by the thinner lines.
3. Storage parameter zones are the same as hydraulic conductivity zones.
4. Map axes are in MGA.

KEY TO BOUNDARY CONDITIONS:
- General Head
- River or lake
- Pumping well

---

drawn PT
approved RJB
date 7 Dec 2010
scale 1:600,000
original size A4

client: BARRICK AUSTRALIA LIMITED
project: COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT
title: MODEL LAYER BOUNDARY CONDITIONS AND AQUIFER PARAMETER ZONES
project no: GEOTLCOV21910AW
figure no: FIGURE 70
Figure 71a. Adopted specific yield of the Cowra Formation using Figure 1 of Johnson (1967) in conjunction with site information (after Johnson, 1967).

Adopted specific yield of 4%

Figure 71b. Observed and Calibrated Pumping Rates at the Maslin Pumping Bore.
Figure 72a. Modelled Water Levels in the Lower Cowra Formation in the vicinity of SB01 and SB02.

Figure 72b. Modelled Water Levels in the Lachlan Formation at GW036553.
Figure 73a. Modelled Water Levels in the Lachlan Formation at GW036597.

Figure 73b. Modelled Water Levels in the Lachlan Formation at GW036611.
Figure 74a

Modelled drawdown in the Upper Cowra Formation at the end of ESB pumping (31 Dec 2015)

Client: BARRICK AUSTRALIA LIMITED

Project: COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT

Title: MODELLED DRAWDOWN IN THE UPPER COWRA FORMATION AT THE END OF ESB PUMPING (31 DEC 2015)

Project No: GEOTLCOV21910AW

Figure No: FIGURE 74a
MODELLED DRAWDOWN IN THE LOWER COWRA FORMATION AT THE END OF ESB PUMPING (31 DEC 2015)
Barrick bore (all active in model).
- Private bore active in model. Usage data available to June 2010, or decommissioning*, whichever earlier (except for Billabong 1, where supplied usage data ends June 2004, but bore was decommissioned in March 2006).
- Private bore active in model. No usage data available but necessarily included in model (from 2007) for calibration and predictive periods. Usage estimates supplied by Lachlan Valley Users Group.
- Private bore inactive in model (no usage data available).

Drawdown contour (m)

---

530000 535000 540000 545000 550000 555000 560000 565000 570000 575000
Easting (MGA)

6230000 6235000 6240000 6245000 6250000 6255000 6260000 6265000 6270000 6275000 6280000 6285000 6290000 6295000
Northing (MGA)

---

Barrick bore (all active in model).
- Private bore active in model. Usage data available to June 2010, or decommissioning*, whichever earlier (except for Billabong 1, where supplied usage data ends June 2004, but bore was decommissioned in March 2006).
- Private bore active in model. No usage data available but necessarily included in model (from 2007) for calibration and predictive periods. Usage estimates supplied by Lachlan Valley Users Group.
- Private bore inactive in model (no usage data available).
MODELLED DRAWDOWN IN THE UPPER COWRA FORMATION AT THE END OF BCPB PUMPING (31 DEC 2024)

LEGEND

Drawdown contour (m)

10

NERANG COWAL
LAKE COWAL
MARSDEN
CARAGABAL
BUNDABURRAH
BLAND
QUANDIALLA
BUNDABURRAH
CARAGABAL
BLAND
QUANDIALLA

530000 535000 540000 545000 550000 555000 560000 565000 570000 575000
500000 6225000 6230000 6235000 6240000 6245000 6250000 6255000 6260000 6265000 6270000 6275000 6280000 6285000 6290000 6295000

Drawn: PT
Approved: RJB
Date: 25 Jun 2013
Scale: 1:300,000
Original Size: A4

Client: BARRICK AUSTRALIA LIMITED
Project: COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT
Title: FIGURE 75a
Private bore active in model. Usage data available to June 2010, or decommissioning*, whichever earlier (except for Billabong 1, where supplied usage data ends June 2004, but bore was decommissioned in March 2006).

Private bore active in model. No usage data available but necessarily included in model (from 2007) for calibration and predictive periods. Usage estimates supplied by Lachlan Valley Users Group.

Private bore inactive in model (no usage data available).

---

**Drawdown contour (m)**

- 10

---

**Client:** BARRICK AUSTRALIA LIMITED

**Project:** COWAL GOLD MINE

**Title:** MODELLLED DRAWDOWN IN THE LACHLAN FORMATION AT THE END OF BCPB PUMPING (31 DEC 2024)

**Scale:** 1:300,000

---

**Drawn:** PT

**Approved:** RJB

**Date:** 25 Jun 2013

**Original Size:** A4

---

**Legend:**
- Green circle: Barrick bore (all active in model).
- Pink circle: Private bore active in model. Usage data available to June 2010, or decommissioning*, whichever earlier (except for Billabong 1, where supplied usage data ends June 2004, but bore was decommissioned in March 2006).
- Yellow circle: Private bore active in model. No usage data available but necessarily included in model (from 2007) for calibration and predictive periods. Usage estimates supplied by Lachlan Valley Users Group.
- Black circle: Private bore inactive in model (no usage data available).
Observed and estimated drawdown north of the Corinella Constriction

- **Drawdown (m)**
  - Distance north from the BCPB (m)
  - Key:
    - Calibrated drawdown (31 December 2008)
    - Simulated drawdown at end of BCPB pumping (31 Dec 2024)
    - Observed Drawdown
    - Upper Cowra Formation
    - Lower Cowra Formation
    - Lachlan Formation
    - Bedrock below the Lachlan Formation

**Client:** BARRICK AUSTRALIA LIMITED

**Project:** COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT

**Title:** OBSERVED AND ESTIMATED DRAWDOWN NORTH OF THE CORINELLA CONSTRICTION

**Figure No.:** FIGURE 76
COWAL Gold Mine Extension Modification

Source: NSW Office of Water (2013)

Legend
- Towns
- Regulated Rivers / Dams
- Unregulated Rivers and Creeks
- Waterbodies
- Bellsula Valley Alluvial Groundwater Source
- Upper Lachlan Alluvial Groundwater Source

1 - Upper Lachlan Alluvial Zone 1 Management Zone
2 - Upper Lachlan Alluvial Zone 2 Management Zone
3 - Upper Lachlan Alluvial Zone 3 Management Zone
4 - Upper Lachlan Alluvial Zone 4 Management Zone
5 - Upper Lachlan Alluvial Zone 5 Management Zone
6 - Upper Lachlan Alluvial Zone 6 Management Zone
7 - Upper Lachlan Alluvial Zone 7 Management Zone
8 - Upper Lachlan Alluvial Zone 8 Management Zone

Source: NSW Office of Water (2013)
Appendix A

Groundwater Salinity
<table>
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<tr>
<th>Bore</th>
<th>General Area</th>
<th>EC (uS/cm)</th>
<th>TDS (mg/L)</th>
<th>Factor</th>
<th>Depth (mbgl)</th>
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<td>1030</td>
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<td>106</td>
<td>Average for 2004 to 2008. Supplied by Barrick.</td>
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<td>Average for 2004 to 2008. Supplied by Barrick.</td>
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<td>1002</td>
<td>0.67</td>
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<td>Lake Cowal</td>
<td>1920</td>
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Appendix B
Calibrated Water Level X-Y Plot and Hydrographs
Model-calculated water levels versus observed water levels at the end of the calibration period (model day 3834, equivalent to 30 June 2008).
GW036597 (Lachlan) and GW036595 (Lower Cowra) and GW036613 (Lower Cowra)

GW036597 (Lachlan) and GW036595 (Lower Cowra) and GW036613 (Lower Cowra)

GW036605 (Lachlan)

GEOTLCOV21910AW Appendix B
GW090093 (Upper Cowra, Lower Cowra, and Rock Below Lachlan) and GW702262 "Koreela" (Lachlan)

GW090093 (Upper Cowra, Lower Cowra, and Rock Below Lachlan) and GW702262 "Koreela" (Lachlan)

GW702286 "Trigalana" (Lachlan) and GW701958 "Muffet" (Lachlan)
Eastern Saline Borefield Monitoring Piezometers
(Upper Cowra / Lower Cowra)

Water Level Elevation (m AHD)

Graph showing water level elevation trends for different piezometers from 1998 to 2013.

- PZ01-UC/LC (Observed and Simulated)
- PZ02-UC/LC (Observed and Simulated)
- PZ05-UC/LC (Observed and Simulated)
- PZ09-UC (Observed and Simulated)
- PZ10-UC/LC (Observed and Simulated)
- PZ11-LC (Observed and Simulated)
Appendix C

Model Verification
GW036609 (Lachlan)

Water Level Elevation (mAHDS)

Observed
Simulated

GW036611 (Lachlan)

Water Level Elevation (mAHDS)

Observed
Simulated
GW090093 (Upper Cowra, Lower Cowra, and Rock Below Lachlan) and GW702262 "Koreela" (Lachlan)
Appendix D

Modelled Water Levels at Trigger Piezometers for 2010 to 2013 (following Pumping Calibration)
Appendix E

Bland Creek Palaeochannel Ground Settlement Monitoring Results
**Client:** BARRICK AUSTRALIA LIMITED  
**Project:** COWAL GOLD MINE EXTENSION MODIFICATION HYDROGEOLOGICAL ASSESSMENT  
**Title:** GROUND SETTLEMENT MONITORING RESULTS  
**Figure No:** FIGURE E-1

**Drawn:** BR  
**Approved:** RJB  
**Date:** 22 JUN 2013  
**Scale:** 1:200,000  
**Original Size:** A4

**Legend:**  
- Pink dot: Bore usage data available for a limited period  
- Blue dot: No bore usage data available  
- Red plus sign: Settlement Monitoring Point  
- Red line: Lateral Movement of Monitoring Point (Movement Scale 1:2 at A4 Size)  
- Red box: Elevation (mAHD) of Monitoring Point With Time

**Easting (MGA):**

- 535000 to 565000
- 627000 to 631000

**Northing (MGA):**

- 627000 to 630000
- 628500 to 629000

**Bore usage data available for a limited period**

**Settlement Monitoring Point**

**Lateral Movement of Monitoring Point** (Movement Scale 1:2 at A4 Size)

**Elevation (mAHD) of Monitoring Point With Time**

**Site Names:**
- Moora Moora
- Trigalana East
- Hart
- SB02
- SB01
- NERANG COWAL
- LAKE COWAL

**Coordinates:**
- Bore1
- Bore2
- Bore3
- Bore4
- P709003
- P709004
- P709005
- P709006
- P709007
- P709008
- P709009
- SB02
- SB01

**Dates:**
- Oct-2006
- Feb-2008
- Jun-2009
- Nov-2010
- Mar-2012
- Aug-2013

**Notes:**
- SETTLEMENT MONITORING REFERENCE PIN
- LEGEND