10 GROUNDWATER

10.1 INTRODUCTION

This chapter considers the potential impacts of the proposed mining activities on existing groundwater aquifers within the MLAs and surrounds. The chapter generally characterises the groundwater environment at Wandoan within the MLA's and surrounds with more detailed groundwater investigations concentrated within MLA 50230 where mining will be undertaken in the first five years. It is proposed to expand the ongoing groundwater investigations to provide more detailed characterisation of the groundwater environment in the three MLAs.

A detailed technical report is attached in TR 10-1-V1.5. Note that figures/documents with numbering ending in V1.5 refer to figures/documents contained in Volume 1, Book 5 of the EIS.

Other groundwater related issues have been addressed in separate studies:

- the southern and western Coal Seam Methane (CSM) and Glebe Option water supply pipelines (Volumes 2, 3 and 4)
- the Great Artesian Basin (GAB) as a potential construction water supply for the Project (Chapter 5).

The MLA areas and surrounds is underlain by Quaternary age sediments along the major creek lines, namely Frank Creek, Mud Creek, Woleebee Creek, and their tributaries. The majority of the MLA areas and surrounds and the Quaternary sediments are underlain by the Surat Basin, which is further underlain by the sedimentary rocks of the Great Artesian Basin.

The topography is undulating, with low ridge lines separating the main drainage lines.

10.2 METHODOLOGY OF ASSESSMENT

Relevant policy, legislation and guidelines

The Water Act 2000 (Water Act) is the key piece of legislation that regulates the interference and extraction of groundwater in Queensland. The regulatory authority for the Water Act is the Department of Natural Resources and Water (NRW).

Section 808 of the Water Act states that it is an offence to interfere with water (including groundwater) without approval to do so. Therefore, an approval would be required for any activities that interfere with groundwater in the MLA areas and surrounds.

The Water Act provides for NRW to grant licences and permits for the extraction, use and interference of the flow of water, including groundwater. All bores that 'take' water (i.e. pumped) are required to have a development permit which gives the authority to construct a bore and defines the conditions of extraction (i.e. maximum depth). The licence grants a share of the resource (i.e. entitlement). A water permit allows for the extraction of water and designates the use, purpose, volume for extraction and time frame.

Monitoring bores that take water for a pumping test (i.e. production bores as described in this Chapter) require a development permit and a water permit (if the extraction exceeds 24 hours). Each borehole drilled for hydrogeological purposes as part of the program for the Project was regulated by a development permit issued by NRW. An application was made to NRW which subsequently granted the water permit for the proposed production bores.

The Great Artesian Basin Water Resource Plan (2006) and Great Artesian Basin Resource Operation Plans (2006) are also to be considered in relation to the actual extraction of water from the Great Artesian Basin. However, the implications of extraction from the GAB are discussed in separate studies.

The *Environmental Protection Act 1994* (EP Act) and Environmental Protection (Water) Policy 1997, principally sections 15 to 20, govern the discharge of wastewater to land, surface waters, and groundwater. It provides a framework for defining the environmental value of water and guidelines for water quality. The policy aims to protect groundwater to the designated environmental value.

Discharge of water generated from the pumping test into an existing dam at the proposed Austinvale pit location did not require a specific Environmental Protection Authority (EPA) licence. Water discharged onsite was managed through a Standard Environmental Authority (mining activities) with the Authority Permit No. M4489.

The Environmental Protection (Water) Policy 1997 defines environmental values for enhancement and protection of water resources. These are considered in Section 10.3.3.

The *Aboriginal Cultural Heritage Act 2003* (ACH Act) protects areas of land and objects of heritage to the Aboriginal people. These areas are considered to be of cultural significance and thereby protected. 'Undisturbed' land must be inspected to determine if additional protection and management practices are required. The ACH Act requires a site supervisor to maintain a 'duty of care' approach. The legislation requires that activities that may cause harm to cultural heritage are minimised and reported where necessary. The Wandoan Joint Venture (WJV) has developed procedures to manage its duty of care to protect cultural heritage in its induction courses which are compulsory for all persons entering the Mining Lease Application (MLA) areas.

Methodology for assessment

The groundwater technical study TR 10-1-V1.5 was undertaken during the period December 2007 to July 2008 and builds upon the work done in the prefeasibility study (PB, 2007).

The groundwater technical study involved:

- literature and data search
- hydrocensus of existing bores
- drilling and bore construction
- a pumping test
- hydrogeological assessment, including hydrochemistry
- groundwater impact assessment.

A program of pump testing in MLA 50230 was undertaken to determine the likely groundwater regime within the Jurandah coal seams which are targeted to be mined.

10.2.1 FIELD INVESTIGATIONS

Hydrocensus

A hydrocensus was conducted across MLA's 50229, 50230 and 50231 to identify bores that could potentially be affected by the Project, or that may provide additional information on the hydrogeology of the area.

The purpose of the hydrocensus was to achieve the following goals:

- determination of the status of all identified bores, including private and WJV owned, that may be potentially affected by proposed mining operations
- collection of water level, and where possible water quality, data to establish a baseline monitoring database
- identification of potential water supply bores (such as community bores) for use during construction and operation phases of the mine.

Property owners generally within 2 km of the MLA's were contacted to determine whether they had bores on their properties and if so, the bore's status, construction details and usage records.

The hydrocensus identified 77 existing private groundwater bores located in and within 2 km of the MLA's area. Of these, seven were identified as community bores which supply multiple landholders through a network of bore drains and extract groundwater from the GAB. The hydrocensus bores that were identified are shown in Figure 10-5-V1.3.

Additionally, data was also obtained from the WJV's existing mine exploration boreholes as general background information.

Existing bores identified by the hydrocensus were inspected, photographed, and where possible, basic field measurements were recorded including total depth, water level and field electrical conductivity, pH and temperature. The collection and recording of this data was an essential component in determining the location, use and purpose of bores that could potentially be affected by mining and provided a base for future measurements.

In certain instances water quality data could not be collected from all hydrocensus bores due to:

- no access to the bore site
- no access to the bore due to the nature of pump installation
- no geological log or construction details available hence the source of the sample cannot be ascertained.

A number of bores listed on the NRW register could not be located.

The prefeasibility study (PB 2007) and the hydrocensus recognised that the existing monitoring bore network, including the existing private bores, did not provide sufficient information to address all hydrogeological aspects of the Project and that further investigations were required.

Groundwater drilling and bore construction

The groundwater drilling program occurred during the period from December 2007 to April 2008 to determine the existence or otherwise of a groundwater regime.

In total, four locations were identified and drilled for pump testing in the initial pits in MLA 50230. Only one site produced sufficient water to warrant construction of a production/test pumping bore and pumping test. The location of the drilling sites is shown in Figure 10-1-V1.3. The other sites produced minimal groundwater.

The boreholes were drilled to target the coal seams of the Juandah Coal Measures, specifically the Kogan, Macalister and Wambo coal seam groups. Therefore, maximum drilling depths were in the order of 100 m below ground level, which is beyond the maximum proposed pit depth of 75 m.

The installation of groundwater bores was undertaken by an appropriately licensed Class 2 water bore driller in accordance with the Minimum construction requirements for water bores in Australia (LWBC, 2003). A qualified hydrogeologist supervised the drilling and construction at all times to ensure these standards were applied. A summary of the drilling results is shown in Table 10-1 below.

Table 10-1: New borehole summary

WJV borehole no	Bore name	Easting	Northing	Total depth	Depth of first water inflow	Water levels	Purpose
		(m MGA)	(m MGA)	(m bgl)	(m bgl)	(m bgl)	
R9095	WPB1	786937	7106175	96	27	22.47	Production bore – pumping test
R9096	WMB1-D	786921	7106177	94	25.5	22.88	Monitoring
	WMB1-S	786921	7106177			23.78	Monitoring
R9097	WMB2	795005	7105981	118	~70	40	Monitoring
R9098	WMB3-D	789498	7110003	118	55	41.09	Monitoring
	WMB3-S	789498	7110003			41.12	Monitoring

Groundwater monitoring program — levels

The WJV's groundwater monitoring program was established to determine baseline and ongoing groundwater levels within the MLAs and surrounding areas. The monitoring program is currently comprised of a total of sixteen monitoring bores, ten of which are open holed (converted exploration boreholes intersecting various coal seams) and six specifically designed monitoring or production bores. Water level data collected and analysed focused on groundwater within the Juandah Coal Measures (the upper sequence of the Walloon Coal Measures). All bores monitored as part of the WJV's existing and ongoing groundwater monitoring program are measuring water levels from bores either screened or open holed through the Juandah Coal Measures to maximum depths of 100 m.

Automated water level and temperature data loggers (Seven CeraDiver's) were installed in the newly constructed bores including one existing WJV monitoring bore.

Additional monitoring bores are proposed to be installed progressively across the MLA's which will enable further recorded water levels. A regional groundwater contour map will be developed for the Project as additional data is collected.

The seasonal variations within the aquifers have not been established at this time. Longer term baseline monitoring will be continued for the duration of the Project to allow for time series data to be collected and any variations established.

Pumping tests

Only borehole R9095 (WPB1) produced sufficient water to warrant construction of a production bore and a pumping test. The purpose of the pumping test was to determine the hydraulic characteristics of the water bearing zones in the coal seams. A three stage (step) multi-rate test (3 by 2 hours) and a 24 hour single (constant) rate pumping test with recovery monitoring were performed in accordance with AS 2368-1990 Test pumping of water wells (Standards Australia, 1990).

It is proposed that approximately 10 new sites will be drilled and that these will result in 10 additional monitoring and possibly three test pumping boreholes being constructed if sufficient water is detected. The three new production bores are proposed to be located in the main mine pit areas to provide information for determination of aquifer hydraulic parameters, pit inflows and to facilitate groundwater modelling and hence the magnitude and timing of groundwater drawdown.

Groundwater quality measurement

Groundwater quality measurement across the MLA areas included field parameters (electrical conductivity, pH and temperature) during drilling and the collection and analysis of samples from the production and installed monitoring boreholes.

10.3 EXISTING ENVIRONMENT

10.3.1 GEOLOGY AND STRATIGRAPHY

The MLA areas are located in the northern portion of the Surat Basin. Alluvium (Quaternary deposits) is found within the major creeks in the area. Average depth of weathering is about 12 m and ranges between 5 m and 30 m. The only hard strata in the overburden material consist of thin ironstone and lensoidal calcified sandstone bands, both generally less than 1 m thick. Topsoil thickness in the area ranges between 0.5 and 1.5 m.

The geological sequence present within the MLA's consist of early Jurassic through to Middle/Late Jurassic sedimentary rocks of the Surat Basin. Table 10-1 presents the Surat Basin Stratigraphy for the area which is predominantly the rocks of the Injune Creek Group, which is underlain by the Early Triassic Hutton Sandstone.

The Injune Creek Group consists of:

- Westbourne Formation (sandstone and mudstone with coal, about 140 m thick), not found in the MLA areas
- Springbok Sandstone (friable sandstone with beds of mudstone and thin coal seams near its base, about 90 m thick), located in the eastern portion of the MLA areas
- Walloon Subgroup (variable sandstone/siltstone/mudstone/coal lithology with thick banded coal seams, up to 510 m thick). This unit consists of the Juandah Coal

Measures (target for mining in this Project), Tangalooma Sandstone and Taroom Coal Measures

- Eurombah Formation (quartzose sandstone with some silt, mudstone and fine coal fragments).

The proposed mining activities are limited to the Juandah Coal Measures, down to the Wambo coal seams.

The underlying geology is shown on Figure 10-2-V1.3.

A number of historical geological logs from NRW registered bores identify the Birkhead Formation as a distinct geological unit of the Surat Basin. The rocks of this formation consist of coarse sandstones with volcanic matter and are the western equivalents of the Walloon Subgroup.

The Durabilla Formation consisted of coarse sands and was an informal name that is no longer used. The rocks of the Durabilla and Eurombah Formation are part of the Injune Creek Group.

Below the Eurombah Formation is the strata which forms the GAB. The Hutton Sandstone forms the upper sequence of the GAB, which is underlain by the Evergreen Formation and the Precipice Sandstone.

Table 10-2: Surat Basin Stratigraphy — north eastern area

Age			Formation	Description
Late Jurassic			**Gubberamunda Sandstone**	Fine to coarse and pebbly, poorly sorted, friable, cross-bedded, quartzose to sub-labile sandstone. Minor interbedded siltstone and mudstone. Upper fluvial depositional environment.
Middle to Late Jurassic	**Injune Creek Group**		**Westbourne Formation**	Finely interbedded lithic sandstone, mudstone and coal in lower part. Interbedded siltstone and lithic sandstone in upper part. Lacustrine deposition grading to point bar at the top.
			Springbok Sandstone	Litho-feldspathic sandstone, medium to coarse, porous and friable, some calcareous and cemented beds, minor siltstone, mudstone and coal seams. Lower part trough cross-stratified with authigenic matrix, upper part poorly cemented, exhibiting point bar depositional features.
Middle Jurassic		**Walloon Sub-Group**	**Juandah Coal Measures**	Lithic, labile sandstone, interbedded with siltstone, mudstone and coal, with coal deposition more frequent towards top. Argillaceous component of sandstone is mainly authigenic.
			Tangalooma Sandstone	Lithic, labile sandstone, medium grained with argillaceous matrix. Numerous intraformational conglomerate beds. Sedimentary structures suggest channel deposition grading to point bar deposition.
			Taroom Coal Measures	Sub-labile, medium grained sandstone grading upwards to interbedded sandstone, siltstone, mudstone and coal.
			Eurombah Formation	Lithic to sub-labile, poorly sorted, medium grained sandstone with argillaceous matrix. Minor siltstone and mudstone in basal section, more argillaceous towards top.
Early Jurassic			**Hutton Sandstone**	Interbedded labile to quartzose sandstone, siltstone and mudstone and intraformational conglomerate.

Source: Jones and Patrick, 1981

10.3.2 HYDROGEOLOGY

Quaternary sediments (alluvium)

Alluvium occurs along the creeks within the MLA areas and is the youngest geological unit. Each of the major creek systems have a number of tributaries that also flow through the area. These sediments comprise a sequence of clay, silt, sand and minor gravel. The sediments are deposited by flowing surface water systems and in the majority are contained within a few metres of the water course. The thickness and lateral extent of the alluvium will vary across the MLA and did not form part of the investigation.

The alluvium acts as an unconfined aquifer that is directly responsive to rainfall and recharge from creeks. The groundwater/surface water interaction and recharge will need to be determined as part of the investigation for creek diversions. The groundwater from boreholes drilled through the alluvial deposits during the exploration program can not be used for interpretation purposes as other aquifers were also intersected, resulting in a mixing and blending of the groundwater that could lead to incorrect interpretations.

Individually constructed monitoring bores, within the alluvium and underlying aquifer will assist in determining the hydraulic linkages and connectivity. Quaternary Alluvial aquifers have not been considered in detail and further information and assessment of these aquifers is proposed in the near future (see Sections 10.6 and 10.8). The environmental value of the groundwater associated with the quaternary alluvium should consider connection to surface water systems as well as the alluvial groundwater systems themselves. The alluvial aquifers within the pit areas are likely to be removed. The sustainability and integrity of surrounding alluvial aquifers will be investigated when the creek division studies are undertaken for NRW approval.

Middle to Upper Jurassic Injune Creek Group Strata

The Injune Creek Group geological unit is comprised of mudstone, labile sandstone and siltstone, some calcareous rocks and coal, and has potential for limited water supply.

Exploration boreholes within the MLA areas target the Walloon Subgroup which ranges in depth from 15 to 200 m. The Walloon Subgroup is a unit of the Injune Creek Group, and contain two distinct coal-bearing formations namely the lower Taroom Coal Measures and the upper Juandah Coal Measures.

The coal seams of the Juandah Coal Measures are relatively flat lying with a regional dip of no more than two degrees to the south-west. Local increases in dip to three degrees do occur, probably as a result of differential compaction around sandstone bodies. Two of the deposits have defined faulting that could affect mining operations in the area. Igneous intrusions have not been detected within the coal measures sequence.

Typically, the seam groups are continuous over most of the deposit, and exhibit rapid lateral thickness variations (Geoscience Australia 2008).

Groundwater occurs predominantly within the coal cleats. The Juandah Coal Measures generally vary in thickness between 50–200 m with water make depths being highly variable. The interbedded sandstones, siltstones and mudstones act as a semi-confining to a confining layer and separate the water bearing zones within the coal seams.

As additional monitoring bores are installed progressively across the MLA, the recorded water levels will indicate and allow for a regional groundwater contour maps to be compiled for each of the underlying aquifers.

The yields from bores across the MLA areas are highly variable, both vertically and spatially. Limited water volumes are intersected in boreholes between 25-35 m in depth. Between this level and the deeper more significant water bearing horizons below 50 m depth in the Wambo coal seams are semi confining layers which are relatively dry. The flow rates form the WJV exploration bores are shown in Figure 10-3-V1.3.

Pumping test results

Due to three of the four proposed production bores containing insufficient groundwater for pumping tests, only a single pump test was undertaken in borehole R9095 at an average rate of 0.49 L/s, based on the outcome of the multi-rate test, although rates fluctuated between 0.45 and 0.62 L/s. The pumping test was used to calculate the extent of the hydraulic connection, and the following parameters were calculated from the pumping test results:

- T values for the monitoring bores — 7 m^2/day
- storativity value — 3.23 x 10^{-3}.

Water levels measured in the deep coal seams (Upper and Lower Macalister, and Wambo) show a good horizontal hydraulic connection. Water level response was measured in both deep and shallow monitoring bores. Water levels within the shallow monitoring bore (monitoring the Kogan coal seams) did not respond for the duration of the test. This suggests a low vertical hydraulic connection between the shallow and deep coal seams during initial pumping. The low yield of the production borehole and the drawdown achieved after the 24 hours of pumping did not require a longer test to be carried out. The location of the monitoring bore network installed is shown in Figure 10-4-V1.3.

Summary of water levels

Overall, the time series water level response traces appear to be relatively stable. Hydrographs of groundwater levels compared to rainfall in the short term (less than 1 year) indicates little if any correlation. However, rainfall and groundwater data should be correlated over a longer time period (greater than 10 years) to detect longer term changes to groundwater from rainfall patterns. With the available data the results indicate confined to semi-confined aquifers being recharged off site at the outcrops and not vertically through the geologic profile.

It is proposed that further fieldwork and assessment of water levels, quality, and calculations of drawdown will be undertaken to obtain a more detailed understanding of recharge zones, storage, flow directions, and potential water make from the geology in this area.

Groundwater quality

The environmental value of the groundwater associated with the Surat Basin is generally considered to be low due to low yields and poor water quality associated with these aquifers.

Water quality within the Juandah Coal Measures is saline and there is a decrease in salinity with depth. Salinity is sodium-chloride dominant, and Electrical Conductivity (EC) values up to 23,000 µS/cm have been observed in the shallow water bearing seams (up to 50 m depth) of the Kogan seams. EC values are typically between 8,000 and 18,000 µS/cm for the deeper seams (of 50 to 100 m depth) of the Macalister and Wambo seams. pH increases with depth, typically neutral in the shallower water bearing zones to slightly alkaline (up to nine) in the deeper zones.

Low levels of nitrate and phosphorous have been detected in some of the new monitoring bores. These bores may need to be re-sampled, and compared to other bores in the area to obtain a better understanding of these nutrient levels.

Overall, the quality of groundwater within the bores is poor, with major transgressions of guideline values for chloride, total hardness and sodium. The arsenic concentration for bore R9095 (WPB1) is on the cut off limit for human consumption as per the Australian Drinking Water guidelines and falls within the ANZECC trigger values.

Early Jurassic Great Artesian Basin

The Hutton Sandstone forms the upper part of the GAB and comprises interbedded labile to quartzose sandstone, siltstone and mudstone and intraformational conglomerate. This formation is well below the base of the proposed mine and therefore will not be directly affected by proposed mining activities. It is the target formation for local Community bores, due to its highly transmissive nature. The potential for this resource to supply potable water to the mine is discussed in Chapter 11 Water Supply and Management.

Groundwater effects are expected to be confined to the Walloon Coal Measures (in particular the Juandah Coal Measures) and the other overlying/near surface aquifers (e.g. the alluvium). This is due to the thickness of the confining beds within the Walloon Coal Measures and the thickness of strata (greater than 400 m) separating the Juandah Coal Measures and the next significant aquifer namely the Hutton Sandstone.

Currently, there is no evidence to suggest that a link exists between bores extracting groundwater below the proposed base of the pits (60 mbgl) and production bores extracting from the GAB. The vertical hydraulic transmissivity of the Juandah Coal Measures and the extensive sequence of semi-confining material between the Juandah Coal Measures and the GAB, being up to 400 m, is very low

10.3.3 GROUNDWATER USE

Groundwater use in the MLA areas

A search of the NRW Groundwater Database was undertaken to locate all registered bores within approximately 15 km of the MLA boundaries. It is noted that the Groundwater Database does not necessarily provide a complete listing of all bores. This is because in the past it has not always been a requirement for details of bores drilled to be provided to the relevant government department of the time.

The search identified a total of 599 bores, however, due to the variability of publicly available information for each record in the MLA areas and surrounds, less than 25% of these bores were identified as having sufficient information to reliably determine which aquifers are being accessed.

Without knowledge of which aquifers are being accessed, additional information in the Groundwater Database such as water quality and water levels cannot be fully utilised nor can impacts from the Project on existing users be fully determined.

Groundwater use within the MLA areas was ascertained from the hydrocensus undertaken as part of the impact assessment on MLA 50230 and MLA 50231 in March to April 2008, and for MLA 50229 in July 2008 to supplement the insufficient publicly available data.

Stock and/or domestic use

The results of the hydrocensus indicate that there are a number of private bores across the MLA's, some of which are registered with NRW and many that are not. The majority of bores are for stock and domestic purposes utilising shallow groundwater of the alluvium and Walloon Coal Measures with total bore depth of these bores ranging from 7 m to 300 m.

From the eight stock bores for which field water quality parameters were able to be obtained during inspection, it was found that the water was slightly alkaline (pH from 7.26 to 8.37) and relatively saline (EC from 4,740 to 13,140 µS/cm). While water quality data was not available for many bores, there were some cases where the landowners noted that water from their bores was too saline for stock without mixing it with other less saline water.

The depth to groundwater in the stock and or domestic bores inspected during the hydrocensus was found to range between 0 and 42 m below ground level. No information relating to drawdown, recharge or seasonal variations in groundwater levels associated with abstraction was provided during the hydrocensus.

Community bores

There are eight community bores which are referred to as such because they supply more than one property. Available records indicate that these bores are extracting groundwater from either the Hutton Sandstone or Precipice Sandstone aquifers of the GAB from depths of between 600 and 1300 m. Both of these aquifers typically provide a reliable and good quality groundwater supply in comparison the shallower aquifers in the area. The location of the community bores and drains are shown in Figure 10-6-V1.3.

Summary of groundwater resource environmental values

Section 7 of the Environmental Protection (Water) Policy 1997 sets out environmental values to be enhanced or protected for water resources.

Based on the ground water quality and existing uses data obtained to date, the environmental values of the groundwater resources of the Juandah Coal Measures, down to the basal Wambo coal seams, are interpreted as shown in Table 10-3. This excludes consideration of the GAB, which has environmental values distinctly different from that of the coal measures.

Table 10-3: Environmental Values of the groundwater resource

EPP (water) Environmental Value	Interpretation	Environmental Values for the groundwater resources of the MLA areas (excluding the GAB)
If the water: (i) is a pristine water—biological integrity of a pristine aquatic ecosystem; or (ii) is not a pristine water—biological integrity of a modified aquatic ecosystem.	There are no known groundwater dependent aquatic ecosystems in the MLA areas.	Not applicable.
Suitability for recreational use.	No known recreational uses of groundwater in the MLA areas.	Not applicable.
Suitability for minimal treatment before supply as drinking water.	The high levels of salinity in much of the groundwater in the MLA areas demonstrates that substantial treatment would be required to meet drinking water standards.	Not applicable.
Suitability for agricultural use.	Some bores in the MLA areas are used for agricultural use.	Environmental Value1: Agricultural use.
Suitability for industrial use.	Coal seam water is proposed for certain industrial uses for the Project.	Environmental Value 2: Industrial use.

10.4 DESCRIPTION OF PROPOSED DEVELOPMENT

The proposed mining at Wandoan is an open cut mine with pits extending to an estimated maximum depth of 75 m. The target coal is within the Juandah Coal Measures, specifically the Kogan, Upper and Lower Macalister and Wambo coal seams. There are six proposed pits in MLA 50230, three pits in MLA 50231 and three pits in MLA 50229.

Due to subsurface excavation of the pits, there is potential for the mine to intersect minor groundwater inflows from the coal measures. The coal seams are the main shallow water bearing zones in the area, separated by sandstones, siltstones and mudstones that act as semi-confining layers.

The MLA's are intersected by a number of creeks that flow in a northerly direction into Juandah Creek. The creeks that intersect the area include: Frank Creek within MLA 50230, Woleebee Creek within MLA 50231 and Mud Creek within MLA 50229. These creeks have a number of tributaries that also flow through the MLA areas. These creeks have the potential to act as recharge sources to the underlying groundwater aquifers.

10.5 POTENTIAL IMPACTS

10.5.1 POTENTIAL IMPACTS DURING CONSTRUCTION AND OPERATION

Groundwater drawdown

As mining progresses to depths beneath the pre-mine standing water level of the aquifers in the mine pit areas, the potential groundwater drawdown effects will progressively increase. The WJV's ongoing hydrogeological investigations will facilitate the prediction of the rate and magnitude of groundwater drawdown in advance of the mining operation. The drawdown of groundwater may occur in aquifers intersected by the mine pits with lesser drawdown in aquifers having some degree of hydraulic connectivity. The offsite effects should be limited, except where proposed pits come close to the MLA boundary.

A preliminary review of bores identified during the hydrocensus was undertaken to determine the likelihood that they would be affected by the proposed mine. It was assumed that any bores within MLA 50229, MLA 50230 and MLA 50231 would be acquired by WJV, and are therefore not included in the assessment. WJV monitoring bores were also excluded from the assessment of effects on existing bores.

Bores in the north east of the MLA areas are not affected as they are located outside the limit of the mineable seams and would not intersect the minable coal seams.

Deep bores (greater than 600 m) extracting water from the GAB were deemed not to be impacted to due to significant depth of separation and presence of impermeable strata between the mine operations and these aquifers.

As a result of this review it was concluded that about 20 of the bores identified during the hydrocensus would require further investigation to determine whether they may be affected by mining. The remaining bores would not be affected. Figure 10-5-V1.3 illustrates those bores requiring further investigation, and those that will not be impacted.

Preliminary assessment of the zone of influence (extent of drawdown cone) around the mine pits was conducted using the following assumptions:

- the transmissivity value (based on one pump test) of 7 m^2/day
- based on monitored groundwater levels, the saturated thickness in the pit is between 20 and 40 m (pit depth 50 to 65 m)
- the hydraulic conductivity (K) ranges between 5 x 10^{-6} and 2 x 10^{-6} m/s
- the final pit size was assumed for calculating zone of influence.

The assessment determined that the drawdown radius around the centre of the pits ranged between 1,000 m and 2,800 m. This assessment did not consider the increased drawdown that would result from pits being operated simultaneously or take into account that some pits may be dry or become dry over time as mining progressed due to the limited quantity of groundwater present or dewatering of the aquifers.

The effect on the drawdown in the vicinity of the pits will be modelled against the coal seam geology to obtain a more detailed understanding of recharge zones, storage and flow directions.

Effects on groundwater resources are expected to be confined to the Juandah Coal Measures and the other overlying or near surface aquifers such as the alluvium. This is due to the thickness of the confining beds within the Walloon Coal Measures and the thickness of strata (>400 m) separating the Juandah Coal Measures and the next significant aquifer, namely the Hutton Sandstone. Any exception to this would likely be the result of geological structures (e.g. faults) that have not been identified at this time.

Impacts of abstraction from the GAB for Project water supply purposes are not considered here as they have been addressed in the Water Supply and Management Report (PB 2008) TR11-1-V1.5.

Other potential impacts

Potential impacts on the groundwater resources in and surrounding the MLA areas could include:

- alteration to groundwater levels due to dewatering (in pit or advanced) of all intersected aquifers in the open pits
- alteration to groundwater flow patterns due to dewatering and potential artificial recharge
- reduced recharge and increased leakage of aquifers due to their partial removal (e.g. removal of alluvium)
- decrease in the groundwater levels and dewatering of the coal seam aquifers could potentially result in reduced yields in surrounding boreholes within the same aquifers
- reduction in the overall size of the resource due to the discontinuity of a given aquifer created by intersection from mine pits
- changes in groundwater quality where aquifers have a hydraulic connection (e.g. between coal seams). In this situation, as the pressure head is reduced in an overlying aquifer, there may be an increase in upward vertical leakage from the underlying aquifer. Such a situation may result in a reduction in water quality should the underlying aquifer be of a lower quality
- release of hazardous gases due to the reduction in pressure head associated with de-watering the aquifer
- changes in water chemistry due to the release of dissolved and bound gases as the pressure head decreases
- changes in groundwater chemistry due to recharge infiltrating via spoil/backfill
- artificial recharge from washing plant, coal stockpiles, discard and tailings facilities, workshops, or ponding runoff
- artificial recharge from storage, treatment, silt/settlement ponds and dust suppression
- contamination of aquifers due to infiltration from fuel or chemical spills
- alteration of aquifer recharge resulting from diversion of surface water streams and drainage patterns
- contamination associated with ancillary infrastructure (e.g. sanitation and waste management).

Prediction of groundwater inflows

As discussed above, of the four locations drilled, only one site produced sufficient water to warrant construction of a production/test pumping bore and pumping test. Additional pumping tests on additional bores to supply further data to calculate pit inflows and the cumulative drawdown effect on the regional groundwater are proposed. Further groundwater modelling will be developed to assess any additional immediate and cumulative hydrogeological impacts of this Project that could not be confirmed by the existing monitoring program.

The numeric model will assist in determining the following:

- pit inflow volumes including the cumulative dewatering impact on the aquifers
- the sphere of influence — extent and lateral drawdown and changes in groundwater levels away from the pits
- changes in the groundwater flow direction due to pit inflows and the lateral extent
- effect of the pits on groundwater through flow and recharge
- effect the dewatering of the alluvial deposits will have on downstream users
- cumulative impacts and extent of impact over time
- the period required before groundwater returns to pre mining levels.

10.5.2 POTENTIAL IMPACTS POST-MINING

Groundwater resources

Groundwater levels/pressures in aquifers disturbed by mining activity will recover over time and new equilibrium level/pressure ranges will be attained. Aquifers will recover at different rates in different areas depending on the pit size, depth and duration of mining.

It is noted that the quality of water in the impacted aquifers pre-mining is generally poor and often unsuitable for beneficial uses such as stock watering and irrigation without mixing with other better quality water. Accurate determination of post mining water quality of the impacted aquifers is not readily predictable and will require detailed investigation, including ongoing monitoring and further assessment.

Specific assessment of groundwater dependent ecosystems has been addressed in Chapter 17B Ecology (Aquatic).

Existing groundwater users

Upon completion of mining the water levels in each affected aquifer will attain a new equilibrium over time. The magnitude of the water level drawdown and its extent has not yet been fully determined and hence the magnitude and timing of the recovery cannot be known until sufficient data and additional aquifer parameters are known for a groundwater model to be developed to determine required scenarios.

Water quality in some landholder bores may have been either adversely or beneficially altered which will primarily depend on the proximity of these bores to the mine voids and spoil. Only bores that take water from the affected aquifers and are in closest proximity to the mine voids and spoil can expect to experience some a change in water quality. Bores that require further investigation to determine the potential for such effects are shown in Figure 10-5-V1.3.

10.6 MITIGATION MEASURES

10.6.1 CONSTRUCTION PHASE

It is proposed that design considerations and use of appropriate bunding, storage and linings to mitigate potential contamination from spills, infrastructure, and activities will be undertaken to avoid contamination of the aquifers.

The monitoring program will include collection of both water level and water quality data within the coal aquifers and overlying aquifers. Sampling frequency prior to mining will provide data on the natural seasonal variation within each of the hydrogeological units. The monitoring network will be constructed to provide baseline information across the study area, and also to provide data to update and calibrate the numerical groundwater model.

10.6.2 OPERATIONS

It is proposed to ensure continued access and supply of GAB groundwater from community or other multi-user bores for users within the area surrounding the MLA areas.

Where the groundwater modelling or monitoring demonstrates that mining activities will have an unacceptable impact on the local shallow bores within the area surrounding the MLAs, the WJV proposes to consult with impacted users in relation to "make good" mitigation measures. Such measures may include, where appropriate, establishment of new bores, replacement or deepening existing bores, or providing an alternative water supply.

Where there is any risk of contamination from artificial recharge from water storage, design considerations such as the use of appropriate impermeable linings will be assessed.

Potential contamination of aquifers due to infiltration from fuel or chemical spills will be addressed by the design of appropriate storage, bunding and the development and implementation of procedures. As discussed in Chapter 23 Hazard and Risk, the proposed fuel storage facilities will be designed in accordance with AS 1940-2004: The storage and handling of flammable and combustible liquids. In particular, the tank farm will be fully bunded to minimise the risk of leaks and spills.

Monitoring

In consultation with the NRW, the WJV will develop and maintain an ongoing groundwater monitoring program of the coal seam groundwater systems. Management procedures in response to potential and/or actual impacts identified through that monitoring will be developed. The final location and number of monitoring sites will be as agreed with the NRW.

The monitoring program will include collection of both water level and water quality data within the coal aquifers and overlying aquifers units off site and adjacent to identified stock watering bores. Sampling frequency will be such to provide data to assess the impacts of mining, and enable the effectiveness of the mitigation measures adopted to be evaluated.

10.6.3 DECOMMISSIONING AND REHABILITATION

Re-establishment

The mitigation measures for decommissioning and rehabilitation are typically generated following long term monitoring of the groundwater environment. A monitoring program is therefore proposed to gather information to assist the development of decommissioning and rehabilitation mitigation measures.

Monitoring program

The monitoring program will include collection of both water level and water quality data within the coal and overlying hydrogeological units off-site and adjacent to identified stock watering bores. Sampling frequency should be such to provide data to assess the effectiveness of decommissioning, rehabilitation, and the re-establishment of equilibrium in groundwater levels and quality.

10.7 RESIDUAL IMPACTS

Due to the characteristics of open pit mining, there are certain potential impacts that cannot be mitigated where limited practical and /or cost effective mitigation measures exist. The residual impacts on the groundwater resources are expected to be as follows:

- alteration to groundwater levels due to dewatering (in pit or advanced) of all intersected aquifers in the open pits
- alteration to groundwater flow patterns due to dewatering and potential artificial recharge
- reduced recharge and increased leakage of aquifers due to their partial removal
- reduction in the overall size of the resource due to the discontinuity of a given aquifer created by intersection from mine pits
- localised changes in groundwater quality where aquifers have a hydraulic connection
- release of hazardous gases due to the reduction in pressure head associated with de-watering the aquifer
- changes in water chemistry due to the release of dissolved and bound gases as the pressure head decreases
- changes in groundwater chemistry due to recharge infiltrating via spoil/backfill
- reduction or elimination of shallow groundwater (primarily associated with the alluvium) resulting in the potential for adverse impacts on groundwater dependent ecosystems, should they occur.

The magnitude and significance of these residual impacts will be determined as part of WJV's ongoing hydrogeological investigation and monitoring program.

10.8 MONITORING PROGRAM

The existing monitoring program was predominantly focused on MLA 50230 in order to develop baseline groundwater data. A progressive monitoring program is proposed covering operations planned for MLA 50229, MLA 50230 and MLA 50231.

It is proposed that approximately 10 new sites will be drilled and that these will result in 10 additional monitoring and possibly three test pumping boreholes being constructed if sufficient water is detected. The three new production bores are proposed to be located in the main mine pit areas to provide information for determination of aquifer hydraulic parameters, pit inflows and to facilitate groundwater modelling and hence the magnitude and timing of groundwater drawdown.

The long term monitoring program will aim to:

- establish a pre-mining baseline dataset
- aid in revising and defining the groundwater conceptual model (including development of groundwater contour maps and flow directions)
- provide data to calculate aquifer parameters, and allow inflow volumes to be estimated (potentially this involves the development and calibration of a numerical groundwater model)
- enable to determine the effectiveness of mitigation measures
- provide for the monitoring and advance identification of impacts on existing users by locating monitoring bores in strategic locations between mine pits (or other relevant infrastructure) and existing users
- provide for the monitoring and advance identification of impacts on groundwater resources by locating monitoring bores in strategic locations both in the immediate vicinity of mining operations and in the surrounding area including downstream of tailings dams
- enable the effectiveness of the mitigation measures adopted to be evaluated.

The impacts and mitigation measures identified provide the basis and direction for data review and re-evaluation to facilitate the development of such a monitoring program.

The monitoring program will include collection of both water level and water quality data. Data and samples should be collected and stored in accordance with relevant guidelines or as prescribed by licence conditions specified by government departments (e.g. NRW or EPA).

Construction and decommissioning of any bores should be in accordance with the Minimum construction requirements for water bores in Australia (LWBC, 2003) and any other applicable legislative requirements (e.g. development permits).

In summary, four bores were drilled into the proposed coal pits in MLA50230 and only one bore had sufficient water for a sustained pump test. Further investigation in MLA 50229 and alluvial deposits will be undertaken to supplement these investigations.

10.9 REFERENCES

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