WILPINJONG COAL PROJECT

APPENDIX A

Surface Water Assessment

Gilbert and Associates Pty Ltd

HYDROLOGY AND WATER MANAGEMENT CONSULTANTS

REPORT

Wilpinjong Coal Project

Surface Water Assessment

Prepared for: Wilpinjong Coal Pty Limited

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GLOSSARY OF TERMS

Baseflow
: Baseflow comprises a combination of interflow (i.e. rainfall which infiltrates the ground surface and moves sub-surface through the soil mantle and other relatively shallow permeable materials e.g. alluvial/colluvial soils before entering a stream), underflow (i.e. flow in streambed alluvium) and groundwater which may discharge to a stream from deeper groundwater aquifers (under artesian conditions).

Baseflow Index
: Ratio of baseflow volume to total flow volume in a stream averaged over a long period of time.

Baseflow Recession
: The gradual reduction of baseflow in a stream during periods with no surface runoff. Baseflow recession is caused by gradual depletion of baseflow storage.

Baseflow Recession Constant
: Rate of baseflow recession measured as the ratio of baseflow volume on one day to that on the previous day.

Baseflow Storage
: Storage of water beneath the ground from where baseflow is derived.

Box Cut
: An excavation developed to provide access to a lower level of the open cut.

Consolidation
: The time-dependent change in the volume of a soil/rock mass under compressive load that occurs when water/air slowly escapes from the pores or voids of the soil/rock mass.

Decant Recovery
: Mine water (supernatant) recovered from the surface of tailings disposal areas following settlement of tailings solids.

Discharge (Stream)
: Instantaneous rate of flow moving past a given point in a stream.

Drawdown
: Decline in groundwater level due to net loss of groundwater in storage (e.g. due to pumping or groundwater discharge during dry periods).

Evaporation
: Loss of volume of a liquid (water) by conversion into vapour.

Evapotranspiration
: Loss of water by evaporation and transpiration of plants.

Flow Duration Curve
: A curve or relationship between streamflow and the percentage or proportion of time that flow is exceeded on average.

Gauging
: Measurement of flow in a stream. Measurements are typically undertaken using a current meter or other flow velocity measuring device.

Gauging Station (Gauge)
A streamflow monitoring station that records surface water level in a stream at regular intervals.

Groundwater
Water that occurs beneath the ground surface in pores and other voids in the soil/rock mass.

Hydrograph (Flow)
Graphical plot of flow rate versus time.

Infiltration
Process of water movement into the ground surface (i.e. soil) from rainfall or irrigation water application.

Inflection Point
The point on a curve at which the concavity changes (where the recessionary limb begins on a hydrograph).

Interflow
A component of baseflow (see Baseflow).

Interstices
The openings or pore spaces in a soil/rock mass.

Mean Annual Flow
The arithmetic mean of annual flows (usually expressed in megalitres/year).

Megalitre
Measurement of volume. Equal to one million litres or one thousand cubic metres.

Mine Water
Water that accumulates in Project operational areas (e.g. active open cuts, inactive open cuts, tailings disposal areas, CHPP water supply storage, coal washing and handling areas).

Orographic Effects
Effects that are caused by the physical geography of mountains and mountain ranges.

Overland Flow
Overland flow is water that travels over the surface of the catchment. It comprises both sheet flow and channel flow. Also known as quick flow.

Permeability
A measure of the rate at which water will flow into or through soil or rocks.

Recession (Flow)
The recession is the decrease in flow rate in a stream, which occurs following a rainfall event.

Recharge
Addition of water to baseflow storage from the surface (by infiltration).

Runoff
The volume of flow that passes an observation point on a stream. Runoff is normally measured as a depth by dividing total flow volume by the area of catchment contributing to flow upstream of that point. It is usually expressed as a depth per unit time such as millimetres per day or millimetres per year.

Seeps/Seepage (diffuse flow)
Expression of baseflow to the ground surface (small amount).

Sheet Flow
Overland flow which travels in a dispersed form rather than within a defined channel.

Spring (concentrated flow)
Expression of baseflow to the ground surface. This term is often applied to situations where the rate of groundwater discharge is sufficient to generate a measurable or visible surface flow.

Streamflow Variability
Variability of annual flows or coefficient of variation is the ratio of the standard deviation over the mean of annual flows. It is a statistical measure of the amount annual flows vary relative to the average.

Stressors
Physical, chemical or biological factors that may cause degradation of aquatic ecosystems when ambient values are too high/low (e.g. nutrients, biodegradable organic matter, dissolved oxygen, turbidity, suspended particulate matter, temperature, salinity, pH, ammonia, cyanide, heavy metals, biocides and other toxic organic compounds).

Supernatant
The layer of water above settled solids.

Surface Runoff
The proportion of runoff that was derived from overland flow. Variably expressed as either a volume (ML) or as an equivalent depth (mm) by dividing by catchment area (see Runoff).

Tailings
Finely ground residue (fine rejects and slimes) from processing and extraction of product (e.g. coal) from ore.

Toxicants
As defined in the ANZECC (2000) Guidelines "*toxicants is a term used for chemical contaminants that have the potential to exert toxic effects at concentrations that might be encountered in the environment*."

Transmission Loss
Transmission loss is the loss of flow from a stream. It can be caused by seepage of water out of the stream channel through its bed and banks or loss of water to evapotranspiration in vegetated or ponded areas of a stream channel.

Turbidity
State of water clarity. Increased turbidity is accompanied by reduced light penetration into a water body and is measured by the proportion of light scattered as it moves through a given depth of water.

Underflow
A component of baseflow (see Baseflow).

Volumetric Water Supply Reliability
Expressed as a volume of water supplied divided by volume required.

1.0 INTRODUCTION

Wilpinjong Coal Pty Limited (WCPL) is seeking consent to develop an open cut coal mine near the village of Wollar some 40 km north-east of Mudgee in New South Wales (NSW) (Figure 1). The Wilpinjong Coal Project (the Project) is located in the headwaters of the Goulburn River catchment which is a major tributary of the Hunter River. The Project would involve open cut mining of the Ulan seam in six pits. The Project coal deposit is estimated to contain a total open cut reserve of approximately 251 million tonnes (Mt) and has a planned Project life of 21 years. The maximum planned mining rate is 13 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal.

The bulk of the mined ROM coal would be processed (washed) in an on-site Coal Handling and Preparation Plant (CHPP). This would result in the production of approximately 147 Mt domestic coal, 33 Mt export coal, 47 Mt of coarse reject (predominantly gravel and cobble sized fragments) and 24 Mt of tailings (fine rejects and slimes). The CHPP operation process and details of the various inputs (i.e. ROM coal and process water) and outputs (i.e. coarse rejects and tailings) are described in Section 2 of Volume 1 of the Environmental Impact Statement (EIS).

With the exception of a small amount of tailings that would be placed into a partitioned section of the CHPP water supply storage during excavation of the initial box cut, all tailings material produced from the CHPP would be progressively deposited directly into open cut voids as they become available during the life of the Project. Overburden and interburden waste rock and coarse reject from the CHPP would be used to backfill the open cut void behind the advancing mining operation.

The majority of the Project water demand would be consumed in the CHPP, much of which would be internally recycled (via tailings thickening). Make-up water supply demand for the CHPP and other non-potable Project demands, such as water for dust suppression on haul roads and active mine waste rock emplacement areas and sprays on product coal stockpiles, would be supplied from a variety of sources including:

- collection of runoff that accumulates in Project disturbance areas;
- decant recovery of water from the tailings disposal areas;
- water recovered from open cut dewatering activities; and
- advance dewatering bores within pit limits and the dedicated water supply bores.

Upslope runoff would be diverted around Project disturbance areas as much as practicable.

This report presents the findings of a surface water assessment and water management study conducted by Gilbert and Associates Pty Ltd for the Project EIS. It draws on results of geochemical studies of overburden/interburden, coal and coal washery wastes (i.e. coarse rejects and tailings) by Environmental Geochemistry International (EGi, 2005) and results of a groundwater investigation by Australasian Groundwater and Environmental Consultants Pty Ltd (AGEC, 2005).

The scope of this surface water assessment was based on the Director-General's requirements for the Project EIS (Attachment 1, Volume 1 of the EIS) and include:

- characterisation of the existing surface water resources that could be affected by the Project;
- description of the proposed water management system and its hydrological design and operational performance; and
- assessment of potential impacts and associated monitoring and mitigation measures to protect the local and regional surface water resources during the operational phase and post mining.

Water balance and hydrological models have been used to assess the performance and capacity requirements for water supply and water management infrastructure during the operational phase of the Project. The post closure water balance dynamics of the final voids and the impacts of the Project on flows and water quality in Wilpinjong Creek have also been assessed with the aid of hydrological models.

2.0 BASELINE SURFACE WATER HYDROLOGY

2.1 Topography, Land Use and Catchment Drainage

The Project is located in the northern portion of the Western Coalfield. The topography of the Project area comprises predominantly alluvial/colluvial flats lying between the escarpment of the Munghorn Gap Nature Reserve to the south and the Wilpinjong Creek floodplain to the north. The Ulan seam lenses out near the centre of the Project area. This area would be used for most Project infrastructure components including the CHPP, mine facilities area, CHPP water supply storage, ROM/product coal handling areas, train loading infrastructure, rail spur and rail loop (Section 3.9.1). Surface elevations range from approximately RL 470 m AHD along the edge of the sandstone plateaus and hill slopes of the Munghorn Gap Nature Reserve to about RL 360 m AHD in the north-east of the Project area which borders the Gulgong-Sandy Hollow railway. The northern side of the Wilpinjong Creek catchment is bounded by the sandstone escarpment of the Goulburn River National Park – refer Figure 1.

The dominant non-mining land use of the Project area is cattle and sheep grazing with intermittent cropping principally for fodder. The Project area has been substantially cleared and is predominantly grassland.

Surface water drainage from the Project area flows to Wilpinjong Creek via a series of small streams which range from semi-perennial, spring fed streams in the upper reaches near the Munghorn Gap Nature Reserve, to wide, ill-defined ephemeral creeks in the lower reaches near Wilpinjong Creek. The more prominent streams rise into the plateau of Munghorn Gap Nature Reserve and can be seen on the Central Mapping Authority's 1:25,000 scale topographical map (Wollar) as Spring Creek, Narrow Creek and Bens Creek (Figure 2).

The largest drainage feature in the Project area is Cumbo Creek which drains an area of some 69 km^2 including some of the eastern parts of the Project area. Moolarben Creek to the south-west of the Project area drains the western side of the Munghorn Gap Nature Reserve (Figure 1). Moolarben Creek flows to the north-west joining the Goulburn River near the village of Ulan and the Ulan Coal Mines (Figure 1).

The headwaters of Wilpinjong Creek are in the Goulburn River National Park (Figure 2). It initially flows westward toward Ulan and then flows south-east to the north of the Project Mining Lease Application area (MLA1), ultimately flowing into Wollar Creek which joins the Goulburn River in the Goulburn River National Park. The Goulburn River joins the Hunter River at Denman (Figure 2 Inset). Wilpinjong Creek is incised into the valley floor and forms a series of semi-permanent soaks fed primarily from drainage from the surrounding alluvial plain and colluvium which is recharged by runoff from the adjacent sandstone plateau. There are areas of reed growth along the creek bed which form wide swampy areas in places. Vegetation on the banks and overbank areas is predominantly grass with occasional trees and little riparian vegetation.

The Department of Infrastructure Planning and Natural Resources (DIPNR) have operated flow gauging stations on the Goulburn River near the Ulan Coal Mines and at Coggan, Kerrabee and Sandy Hollow on the Goulburn River downstream of the Project area (Figures 1 and 2). DIPNR operated a gauging station on Wollar Creek upstream of the Wilpinjong Creek confluence between 1969 and 1997. WCPL has also established gauging stations on the lower reaches of Cumbo Creek and on Wilpinjong Creek (Figure 2).

The catchment areas of these drainages are tabulated below – refer Table 1.

Table 1
Summary of Local and Regional Catchments

Catchment Name	Catchment Area (km^2)	Location (refer Figures 1 and 2)
Cumbo Creek	69	Upstream of confluence with Wilpinjong Creek
Wilpinjong Creek	89	Upstream of Project area (i.e. west of MLA1 boundary)
Wilpinjong Creek	216	Upstream of Wollar Creek confluence
Wollar Creek	258	At gauging station (GS210082) upstream of Wilpinjong Creek
Wollar Creek	532	Upstream of Goulburn River confluence
Goulburn River	159	At Ulan gauging station (GS210046)
Goulburn River	1,149	Immediately downstream of Wollar Creek confluence
Goulburn River	3,340	Coggan – DIPNR gauging station
Goulburn River	4,950	Kerrabee – DIPNR gauging station
Goulburn River	6,810	Sandy Hollow – DIPNR gauging station
Goulburn River	8,160	Rosemount – DIPNR gauging station, just upstream of Hunter River Confluence at Denman

After: (DIPNR, 2004)

2.2 Rainfall and Evapotranspiration

The Project area experiences a temperate climate with an average annual rainfall of about 650 mm. Long-term historical daily rainfall data is available for a number of stations in the more established areas surrounding the Project area (ie. Gulgong Post Office, Mudgee (George Street), and Jerry's Plains Post Office). The mean average monthly rainfall statistics for these stations are summarised in Table 2 below.

Table 2
Summary of Mean Monthly Rainfall Statistics from Regional Climate Monitoring Stations

Month	Gulgong Post Office		Mudgee (George Street)		Jerry's Plains Post Office	
	Rainfall (mm)	Number Rain Days	Rainfall (mm)	Number Rain Days	Rainfall (mm)	Number Rain Days
January	71.2	5.9	68.6	6.2	78.2	7.9
February	60.7	5.1	63.7	5.7	71.7	7.3
March	54.8	5.0	50.7	5.3	58.2	7.3
April	45.2	4.5	44.9	4.7	44.7	6.3
May	45.9	5.6	50.5	6.5	41.3	6.6
June	50.0	7.1	54.3	8.0	45.3	7.3
July	48.5	7.3	53.3	8.3	44.3	7.0
August	47.2	6.8	54.0	8.0	36.6	7.0
September	46.3	6.6	51.7	7.3	41.3	6.6
October	57.0	6.6	60.5	7.4	51.9	7.5
November	57.9	6.1	59.3	6.7	58.2	7.6
December	63.9	6	63.2	6.3	67.3	7.5
Annual	648.6	72.5	674.6	80.5	638.8	86
No. Years of Record	123.3	119.1	132.8	132.7	118.7	118.4

Source: Bureau of Meteorology (2005)

Whilst rainfall is spread throughout the year, it is on average higher in the summer months. The heaviest daily falls have also generally been recorded during summer (December – February) – refer Table 3.

Maps published by the Institution of Engineers Australia (I E Aust, 1987) indicate that rainfall intensity generally tends to reduce with distance from the coast. Rainfall intensity is also locally affected by the orographic influence of the Great Dividing Range. Short duration rainfall intensity data for the Project area is compared with representative areas in the Hunter Valley and Sydney in Table 4.

Table 3
Summary of Maximum Monthly Rainfall Statistics from Regional Climate Monitoring Stations

Month	Gulgong Post Office		Mudgee (George Street)		Jerry's Plains Post Office	
	Maximum Daily Rainfall (mm)	Maximum Monthly Rainfall (mm)	Maximum Daily Rainfall (mm)	Maximum Monthly Rainfall (mm)	Maximum Daily Rainfall (mm)	Maximum Monthly Rainfall (mm)
January	101.1	238.5	95.3	225.4	97.3	226.3
February	134.4	354.3	169.0	262.6	139.7	340.4
March	122.2	265.9	103.6	303.2	132.1	264.3
April	98.8	212.9	86.9	237.3	86.6	172.2
May	80.5	172.2	73.9	157.8	99.1	314.3
June	65.3	188.1	57.4	200.5	190.8	288.4
July	86.4	168.6	70.6	177.6	137.2	231.6
August	62.0	171.2	68.0	171.4	65.3	206.9
September	95.3	176.7	70.6	188.1	67.3	156.1
October	71.6	199.9	68.1	211.5	68.6	170.0
November	83.8	217.0	102.9	236.8	67.1	217.8
December	102.1	212.8	118.9	267.8	108.0	233.1
Number Years of Record	122.5	123.3	132.4	132.8	118.5	118.7

Source: Bureau of Meteorology (2005)

Table 4
Comparative Rainfall Intensities - mm/hr

Location	1 in 2 year ARI, 1 hour	1 in 2 year ARI, 12 hour	1 in 50 year ARI, 1 hour	1 in 50 year ARI, 12 hour
Wilpinjong (Project area)	25.5	4.7	47.0	8.5
Muswellbrook	22.7	4.8	44.4	8.9
Maitland	29.9	6.0	59.0	13.0
Newcastle	35.0	6.9	66.0	14.0
Sydney	41.9	8.3	87.0	16.8

Source: IEAust (1987)

Examination of local rainfall records obtained from the Bureau of Meteorology indicate that rainfall is highly variable over short distances - probably due to local orographic effects and the influence of the frequent small convective storms which produce localised falls particularly during summer. The average annual rainfall statistics for Ulan Post Office, Wollar (Barrigan St), Wollar (Maree), Budgee Budgee and Mittaville are summarised in Table 5 below. The station locations are shown on Figure 1.

Table 5
Summary of Local Rainfall Data

Station Name	Wollar (Barrigan St)	Wollar (Maree)	Budgee Budgee (Botobolar Vineyard)	Ulan (Mittaville)	Ulan Post Office
Station Number	062032	062056	062084	062045	062036
Recorded Period	1901-present	1962-2004	1971-present	1960-1982	1906-present
Elevation (m AHD)	366	410	575	411	420
January	68.2	84.8	74.3	84.3	73.9
February	63.0	65.9	71.4	67.7	61.7
March	51.7	60.2	52.9	67.7	52.7
April	39.7	46.0	43.8	30.9	41.8
May	39.0	46.1	50.9	46.6	46.2
June	43.1	40.9	41.3	39.4	44.7
July	41.3	50.3	60.0	37.5	47.7
August	42.4	53.5	50.2	44.0	48.7
September	39.5	54.4	52.4	44.4	43.3
October	54.2	67.2	62.0	69.9	55.8
November	52.2	58.8	60.6	49.8	56.2
December	56.6	66.4	56.8	61.4	66.6
Annual	590.7	696.2	675.9	644.5	637.7

Source: Bureau of Meteorology (2005)

An analysis of the available local rainfall recorded at these local stations confirms the spatial and temporal variability over short time periods and the influence of elevation on rainfall. Figure 3 shows the residual rainfall mass curves for Wollar (Barrigan Street), Ulan (Mittaville), Ulan Post Office and Wollar (Maree) over the common period of record. Whilst these stations are in close proximity, the high spatial variability is evident by the departure of the residual curves from each other, in particular the opposing trends in the residual curves for Wollar (Maree) and Ulan (Mittaville).

Average monthly potential evapotranspiration for the Project area are provided in Table 6.

Table 6
Average Monthly Potential Evapotranspiration Rates
for the Project Area (mm)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Total	220	175	170	120	85	65	70	100	120	168	200	235	1,728

Source: Bureau of Meteorology (2001)

A comparison between monthly average rainfall and monthly average potential evapotranspiration over the year (refer Table 7), indicates that on average the area has an excess evaporative capacity over rainfall in all months and can therefore be classified as having a semi-arid climate. There is however significant variability in monthly rainfall and there would be periods when rainfall would exceed evapotranspiration.

Table 7
Average Monthly Rainfall and Evapotranspiration (mm)

Month	Average Potential Evapotranspiration	Average (Mean) Monthly Rainfall*	Potential Rainfall Excess
January	220	68.2	-151.8
February	175	63.0	-112.0
March	170	51.7	-118.3
April	120	39.7	-80.3
May	85	39.0	-46.0
June	65	43.1	-21.9
July	70	41.3	-28.7
August	100	42.4	-57.6
September	120	39.5	-80.5
October	168	54.2	-113.8
November	200	52.2	-147.8
December	235	56.6	-178.4

* Wollar (Barrigan St) – Bureau of Meteorology (2005)

2.3 Runoff and Streamflow

In the absence of streamflow data for the local catchments in the Project area, streamflow records from other regional catchments have been collated, and have been used to guide the development of catchment models of the local creeks. A summary of the runoff statistics for the regional gauged catchments is given in Table 8.

Table 8
Summary of Regional Gauging Stations

Station Number	Station Name	Catchment Area (km^2)	Mean Annual Runoff (mm)	Mean Daily Flow (ML/d)	Period of Record	Latitude	Longitude
210091	Merriwa at Merriwa	465	33.1	42.2	11/4/1972-02/01/1992	32:08:30	150:21:10
210082	Wollar Creek upstream of confluence with Wilpinjong Creek	258	15.0	10.6	1/5/1969-10/9/1997	32:20:25	149:57:05
210046	Goulburn River at Ulan	159	30.3	13.2	9/3/1956-31/8/1982	32:17:01	149:44:34
210006	Goulburn River at Coggan	3,340	21.0	192.2	18/10/1991-current	32:20:40	150:06:08
210031	Goulburn River at Sandy Hollow	6,810	26.1	487.4	1975-current	32:20:49	150:34:23
210092	Krui River at Collaroy	498	37.7	51.4	13/4/1972-31/12/1988	32:07:50	150:05:40
210066	Merriwa River upstream of Vallences Creek	684	28.7	53.8	22/1/1963-current	32:17:50	150:19:60
210060	Baerami Creek at Baerami	384	28.0	29.5	3/2/1960-16/1/1992	32:26:43	150:27:04
210040	Wybong River at Wybong	676	51.2	94.8	17/5/1955-current	32:16:14	150:38:08

Source: DIPNR (2005)

Analysis of the available flow data indicates that runoff (total catchment yield) is a small percentage of rainfall. The upland tributaries of Wilpinjong Creek rise in the densely vegetated sandstone escarpments of the Munghorn Gap Nature Reserve and Goulburn River National Park. The upland tributaries of Wollar Creek rise in the densely vegetated Great Dividing Range. Some of these tributaries are, in places, fed by fresh water springs. Following periods of high rainfall, valley flats along Wilpinjong and Wollar Creeks are often left water logged for extended periods (DIPNR, 2003).

At approximately 3 km from the eastern boundary of MLA1, Wollar Creek is physically the closest gauged catchment to the Project area (Figure 1). The gauging station (GS210082) on Wollar Creek was located immediately upstream of the confluence with Wilpinjong Creek. It operated for some 28 years between 1969 and 1997. The Wollar Creek catchment has similar catchment area, topography, geology, vegetation and landuse to the Wilpinjong Creek catchment and has been used as a basis for developing a catchment model of Wilpinjong Creek.

Flow records are also available for the upper reaches of the Goulburn River catchment upstream of Ulan for most of the period between 1956 and 1982 (GS210046). The Goulburn River catchment upstream of Ulan, where the river is known as Moolarben Creek, is adjacent to the Wilpinjong Creek catchment (Figure 1). The Moolarben Creek catchment also appears to have similar hydrological characteristics to the Wilpinjong Creek catchment, although the gauging station location is at a higher elevation and the catchment geology differs somewhat compared with Wilpinjong and Wollar Creeks. A small water supply dam was constructed on Moolarben Creek upstream of the Ulan gauging station in 1957 and some water was extracted to supply a small local power station. Water consumption averaged 0.3 ML/day during the operation of the power station between 1957 and 1968 (Kinhill Stearns Engineers, 1983).

2.4 Surface Water Quality

2.4.1 Baseline Surface Water Monitoring Programme

A baseline surface water quality monitoring programme was initiated by WCPL on the local watercourses in June 2004. Surface water quality monitoring results reported in the *Greater Wollar Creek Catchment Dryland Salinity Groundwater Investigation* (DIPNR, 2003) and results from the sampling conducted as part of the Aquatic Ecosystem Assessment (EIS Appendix HD) have been incorporated with results of the baseline surface water quality monitoring programme to provide baseline information on the water quality characteristics of different reaches of local creeks. The surface water quality sampling locations are shown on Figure 2.

A summary of the key water quality parameters over this period is provided in Table 9.

A sub-set of samples collected on the local creeks as part of the baseline water monitoring programme have also been subject to analysis for metal toxicants – refer Table 10 below.

Table 9
Surface Water Quality Ranges – Local Watercourses

Position along Watercourse	Site	Source[1]	Sampling Period/Date	pH			Electrical Conductivity (µS/cm)			Total Dissolved Solids (mg/L)			Total Suspended Solids (mg/L)		
				min	max	mean	min	max	mean	min	max	mean	min	max	median
Wilpinjong Creek															
Upstream of Cumbo Creek confluence and downstream of Planters Creek.	WIL1 WP1 WP2 WI5 WI10	Project Sample Bio-Analysis Bio-Analysis DIPNR DIPNR	Jul 2004 – Mar 2005 May 2004 May 2004 April 2001 May 2001	5.8	9.1	7.0	681	2990	1520	430	2000	1005	<2	362	4
Downstream of Cumbo Creek and upstream of the confluence with Wollar Creek.	WIL2 WP3 WP4	Project Sample Bio-Analysis Bio-Analysis	Jun 2004 – Mar 2005 May 2004 May 2004	7.6	8.0	7.8	1700	5300	3921	1065	3560	2651	<2	7	<2
Wollar Creek															
Immediately downstream of Wilpinjong Creek confluence.	WOL1 WO1	Project Sample Bio-Analysis	Jul 2004 – Mar 2005 May 2004	7.6	8.4	8.1	1690	3500	2347	1140	2480	1588	<2	10	<2
Downstream of the village of Wollar and upstream of Wilpinjong Creek confluence.	WOL2 WO2 WO4	Project Sample Bio-Analysis DIPNR	Jun 2004 – Mar 2005 May 2004 April 2001	7.6	8.7	8.1	1145	2990	1878	955	2445	1348	<2	6	<2
Upstream of the village of Wollar, immediately upstream of Barigan Creek confluence.	WOL3	Project Sample	Jul 2004 – Mar 2005	6.8	7.8	7.2	185	310	221	112	184	138	<2	6	<2
Cumbo Creek															
Immediately upstream of the confluence with Wilpinjong Creek.	CC1[2] W18	Project Sample DIPNR	Jun 2004 – Mar 2005 April 2001	7.9	8.4	8.2	4432	8800	7223	3510	5930	4814	2	22	11
Wilpinjong Road causeway, upstream of CC1 and downstream of site CC5.	CC2[2] CU1 CU2	Project Sample Bio-Analysis Bio-Analysis	Jun 2004 – Mar 2005 May 2004 May 2004	7.5	8.2	7.9	5000	7700	6435	410	5390	4399	<2	12	3
Wollar Road causeway, upstream of site CC5.	CC3[2] CU17	Project Sample DIPNR	Jun 2004 – Dec 2004 April 2001	7.9	8.4	8.2	3132	6300	4933	2510	4340	3493	<2	5	3.5

Table 9 (Continued)
Surface Water Quality Ranges – Local Watercourses

Position along Watercourse	Site	Source[1]	Sampling Period/Date	pH			Electrical Conductivity (µS/cm)			Total Dissolved Solids (mg/L)			Total Suspended Solids (mg/L)		
				min	max	mean	min	max	mean	min	max	mean	min	max	median
Cumbo Creek (Continued)															
Upper Cumbo Road crossing, upstream of site CC3.	CC4 CU5 CU7 CU9	Project Sample DIPNR DIPNR DIPNR	Jun 2004 – Dec 2004 April 1971 and April 2001 April 2001 April 2001	7.1	8.1	7.7	558	7500	4323	1820	4020	3274	<2	73	4
Groundwater seep immediately east of Wilpinjong Road, upstream of site CC2.	CC5	Project Sample	Jun 2004 – Nov 2004	7.1	7.1	I.D.	11000	12000	I.D.	6980	8040	I.D.	8	12	I.D.
Murragamba Creek															
Immediately upstream of the confluence with Wilpinjong Creek.	MC1	Project Sample	Jul 2004 – Dec 2004	5.4	7.0	6.3	330	690	549	210	540	380	7	294	28
Barigan Creek															
Upstream of the confluence with Wollar Creek.	BC1 BA5	Project Sample DIPNR	Jun 2004 – Mar 2005 April 2001	7.2	8.2	7.5	569	2540	1954	1190	1850	1434	4	216	7

[1] Project Sample – Baseline surface water quality sample sites established for the Project (Ecowise, 2005).
Bio-Analysis – Surface water quality sample sites in the Aquatic Ecosystem Assessment, Appendix HD (Bio-Analysis, 2005).
DIPNR – Historic surface water quality sample sites in the *Greater Wollar Creek Catchment Dryland Salinity Groundwater Investigation,* DIPNR (2003).

[2] Water quality samples collected at Project Sample Sites CC1, CC2 and CC3 in January 2005 were taken in pools of fresh rainwater as the creek bed had dried out and rain had recently fallen. The fresh rainwater was found to have significantly different water quality results to previously recorded data and was excluded from the dataset presented in Table 9 accordingly.

I.D. Insufficient Data.

Table 10
Summary of Local Baseline Water Quality – Metal Toxicants*

Location	Site Number	Arsenic (µg/L)		Cadmium (µg/L)		Copper (µg/L)		Lead (µg/L)		Mercury (µg/L)		Selenium (µg/L)		Zinc (µg/L)	
		min	max	min	max	min	max	min	max	min	max	min	max	min	max
Wilpinjong Creek – Upstream of Cumbo Creek Confluence	WIL1	<1	1	<0.05	<0.05	<2	<2	<0.2	0.4	<0.1	<0.1	<1	<1	<5	61
Wilpinjong Creek – Downstream of Cumbo Creek Confluence	WIL2	<1	3	<0.05	<1	<2	3.3	<0.2	<1	<0.1	<0.1	<1	1	<5	5
Wollar Creek – Downstream of Wilpinjong Creek Confluence	WOL1	<1	3	<0.05	<0.05	<2	2	<0.2	1.4	<0.1	<0.1	<1	1	<5	5
Wollar Creek – Downstream of Wollar Village	WOL2	<1	3	<0.05	<1	<2	3	<0.2	<1	<0.1	<0.1	<1	<1	<5	2
Wollar Creek – Upstream of Barigan Creek Confluence	WOL3	<1	<1	<0.05	0.06	<2	3	<0.2	0.5	<0.1	0.5	<1	1	<5	<5
Cumbo Creek – Immediately Upstream of Wilpinjong Creek Confluence	CC1	<1	15	<0.05	<1	<2	5	<0.2	0.4	<0.1	0.1	<1	3	<5	5
Cumbo Creek – MLA1 Boundary (Wilpinjong Road Causeway)	CC2	<1	4	<0.05	<1	<2	3	<0.2	<2	<0.1	0.1	<1	3	<5	5
Cumbo Creek – Upstream of Project Area (Wollar Road Causeway)	CC3	2	4	<0.05	<0.05	<2	<2	<0.2	<0.2	<0.1	<0.1	<1	1	<5	<5
Cumbo Creek – Upper Cumbo Road	CC4	<1	2	<0.05	<1	<2	4.1	<0.2	2	<0.1	<0.1	<1	1	<5	6
Tributary of Cumbo Creek – Upstream of MLA1 Boundary	CC5	<1		<1		<5		<1		<0.1		2		19	
Murragamba Creek – Upstream of Wilpinjong Creek Confluence	MC1	<1	12	<0.05	0.21	<2	6	<1	3.3	<0.1	<0.1	<1	<1	9	120
Barigan Creek – Upstream of Wollar Creek Confluence	BC1	<1	3	<0.05	<1	<2	2.3	<0.2	0.4	<0.1	<0.1	<1	<1	<5	5

Source: Ecowise (2005)
* All results are from unfiltered samples (i.e. indicate total metal concentration).

2.4.2 ANZECC (2000) Guidelines Overview

The ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (herein referred to as the "Guidelines") provide a comprehensive framework for water quality assessment and management. The approach adopted in the Guidelines focuses on site-based risk assessment with a focus on integrated assessment (chemical, physical and biological indicators). The Guidelines recognise that adequate site specific data will often not be available and provide default trigger values for a range of physical and chemical stressors and toxicants. Water quality trigger values are also provided in the Guidelines for livestock drinking water quality.

In the absence of agreed water quality objectives for local streams, the Guideline trigger values provide a quantitative frame of reference for interpreting the results of baseline water quality monitoring.

Physical and Chemical Stressors

Default trigger values for physical and chemical stressors are provided in the Guidelines for four different geographical regions across Australia including south-east, south-west, tropical and south central. The Project area is located in south-east Australia in accordance with the Guidelines and the streams in the Project area fall in the "Upland Rivers" category.

Guideline surface water quality default trigger values for physical and chemical stressors for the protection of aquatic ecosystems are summarised in Table 11.

Table 11
ANZECC (2000) Surface Water Quality Default Trigger Values for the Protection of Aquatic Ecosystems (Physical and Chemical Stressors)

Physical/Chemical Stressor	NSW Upland Rivers[a]
pH	6.5 - 8.0
Total Phosphorus (µg/L - P)	20
Total Nitrogen (µg/L - N)	250
Dissolved oxygen (% saturation)	90 - 110
Specific electrical conductivity (EC) (µS/cm)	350 (NSW rivers)
Turbidity (NTU)	2 - 25 (High values may be observed during high flow events)

Source: ANZECC (2000)
[a] Values for NSW upland rivers (>150 m altitude) in South-east Australia.

Toxicants

The Guidelines recognise three ecosystem conditions as follows:

- high conservation/ecological value systems;
- slightly to moderately disturbed systems; and
- highly disturbed systems.

Each ecosystem condition in the Guidelines is ascribed with a level of protection applicable to toxicants in aquatic ecosystems and is summarised below:

1. High conservation status or highly valued ecosystems are afforded a protection level based on protection of 99% of species.

2. Slightly to moderately disturbed systems are afforded a 95% protection level in most cases although a higher protection level could be applied to slightly disturbed ecosystems.

3. Highly disturbed systems can be afforded a 95% protection level, however depending on the state of the ecosystem, it can be appropriate to apply a less stringent trigger value (i.e. 90% or 80%) as an intermediate target for water quality improvement.

The Guidelines surface water quality default trigger values for toxicants for the protection of aquatic ecosystems are summarised in Table 12.

Table 12
ANZECC (2000) Surface Water Quality Default Trigger Values for the Protection of Aquatic Ecosystems (Toxicants)

Toxicant	Default Trigger Values			
	Protection Levels for Aquatic Ecosystems			
	99%	95%	90%	80%
Arsenic (µg/L)	1	24	94	360
Cadmium (µg/L)	0.06	0.2	0.4	0.8
Copper (µg/L)	1.0	1.4	1.8	2.5
Lead (µg/L)	1.0	3.4	5.6	9.4
Mercury – inorganic (µg/L)	0.06	0.6	1.9	5.5
Selenium – total (µg/L)	5	11	18	34
Zinc (µg/L)	2.4	8	15	31

Source: ANZECC (2000)

Livestock Drinking Water Quality

Water quality trigger values are provided in the Guidelines for livestock drinking water quality (Table 13). As stated in ANZECC (2000) for heavy metals and metalloids:

> *"Unless otherwise stated, the trigger values relate to the total concentration of the constituent, irrespective of whether it is dissolved, complexed with an organic compound, or bound to suspended solids."*

Table 13
ANZECC (2000) Livestock Drinking Water Quality Trigger Values

Livestock Drinking Water Quality	Water Quality Trigger Values
pH	6.0 – 9.0[a]
Specific electrical conductivity (EC) (µS/cm)	Beef Cattle, Horses, Pigs: < 6,000[b] Dairy Cattle: < 3,750[b] Sheep: < 7,500[b]
Total dissolved solids (mg/L)	Beef Cattle, Horses, Pigs: < 4,000 Dairy Cattle: < 2,500 Sheep: < 5,000
Arsenic (µg/L)	500[c] – 5,000[d]
Cadmium (µg/L)	10[c]
Copper (µg/L)	400 (sheep), 1000 (cattle)[c]
Lead (µg/L)	100[c]
Mercury- inorganic (µg/L)	2[c]
Selenium – total (µg/L)	20[c]
Zinc (µg/L)	20,000[c]

Source: ANZECC (2000)
a Values for stock watering (surface water) systems.
b Calculated by approximate conversion from TDS to EC (ANZECC, 2000).
c Concentrations below which there is a minimal risk of toxic effects.
d Higher value may be tolerated if not provided as a food additive and natural levels in the diet are low.

2.4.3 Summary and Comparison of Results with the Guidelines

Comparisons of water quality results for local creeks have been made with the water quality trigger values provided in the Guidelines for:

- physical and chemical stressors in aquatic ecosystems (default trigger values);
- metal toxicants in aquatic ecosystems (80-99% protection level); and
- livestock drinking water quality.

A summary of the results of the baseline surface water quality monitoring programme for local creeks is provided below.

Wilpinjong Creek

Surface water quality samples have been taken along Wilpinjong Creek at numerous locations both upstream and downstream of the confluence with Cumbo Creek (Figure 2 and Table 9).

Sampling results upstream of the confluence with Cumbo Creek indicate an average pH of 7.0 and EC range of 681 to 2,990 µS/cm. Downstream of the confluence with Cumbo Creek, sampling results indicate an average pH of 7.8 and an average EC of 3,921 µS/cm. These results are considered to be consistent with the surface water quality in the lower reaches of Cumbo Creek which is significantly more saline than Wilpinjong Creek and is likely to be a significant source of salinity to the lower reaches of Wilpinjong Creek.

The recorded EC values were higher than the Guideline trigger values for the protection of aquatic ecosystems (ie. 350 µS/cm) however all recorded EC levels were below the Guideline trigger values for livestock watering (beef cattle). Measured pH levels were generally within the Guideline trigger value ranges with the exception of some occasions when samples were taken during periods of low flow.

Measured concentrations of metals (ie. As, Cd, Cu, Pb, Hg, Se and Zn) were generally low and below detection. Exceptions where metals concentrations have been measured above the trigger values for the 80% protection level for aquatic ecosystems in the Guidelines were copper (3.3 µg/L), and zinc (61 µg/L).

Wollar Creek

Surface water quality monitoring has been undertaken in three locations of Wollar Creek *viz.* upstream of the confluence of Barigan Creek, immediately downstream of the village of Wollar, and immediately downstream of the confluence with Wilpinjong Creek (Figure 2 and Table 9).

Sampling results for Wollar Creek upstream of the confluence with Barigan Creek indicate an average pH of 7.2 and EC range of 185 µS/cm to 310 µS/cm. Measured concentrations of metals were generally low and either below detection or below the trigger values for the 95% protection level for aquatic ecosystems (Table 12). The only exception was a single measurement of a copper concentration of 3 µg/L, which was greater than the trigger value for the 80% protection level for aquatic ecosystems.

Immediately downstream of the village of Wollar, sampling results indicate an average pH of 8.1 and an average EC of 1,878 µS/cm. Downstream of the confluence with Wilpinjong Creek, sampling results in Wollar Creek indicate an average pH of 8.1 and EC range of 1,690 to 3,500 µS/cm.

Cumbo Creek

Surface water quality samples have been taken at several locations along Cumbo Creek (Figure 2 and Table 9).

The average EC levels range from 4,323 to 4,933 µS/cm in the mid to upper reaches, upstream of the Project area. A highly saline groundwater seep (EC of 11,000 to 12,000 µS/cm) enters Cumbo Creek immediately east of Wilpinjong Road (CC5) and upstream of the Project area. The water quality of the groundwater seep is consistent with the poorer quality groundwater associated with the Nile Subgroup which surfaces (subcrops) in the area (Appendix B of the EIS). Sampling results at site CC1 (located immediately upstream of the confluence with Wilpinjong Creek) and site CC2 (downstream of the groundwater seep) indicate that average EC levels are 7,223 and 6,435 µS/cm respectively.

Measured EC levels were consistently greater than the Guideline trigger values for the protection of aquatic ecosystems and on occasions, above the Guideline trigger value for livestock watering (beef cattle). Sampling results indicate that pH levels in Cumbo Creek generally range from 7.1 to 8.4 which were within the Guideline trigger value range for livestock drinking water.

Concentrations of other key surface water quality indicators were generally low at all sites along Cumbo Creek, with no measured levels above the Guideline trigger values for livestock watering. Measured copper and mercury levels at sites CC1 to CC5 were above the trigger values for the protection of aquatic ecosystems (99% level of protection). One sample taken at CC5 indicated a zinc concentration (19 µg/L) above the trigger value for the protection of aquatic ecosystems (90% level of protection – Table 12).

Murragamba Creek

Surface water quality sampling results for Murragamba Creek (site MC1 located immediately upstream of the confluence with Wilpinjong Creek – Figure 2) indicate an average pH of 6.3 and EC of 549 µS/cm.

Whilst the average pH and EC values were outside of the Guideline trigger value range for the protection of aquatic ecosystems (Table 11), the results were within the trigger value ranges for livestock drinking water quality (Table 13). Concentrations of other key surface water quality indicators were generally low at site MC1 with no measured levels above the Guideline trigger values for livestock watering.

Metal concentrations for copper (6 µg/L) and zinc (120 µg/L) were above the trigger values for the 80% protection level for aquatic ecosystems in the Guidelines. The concentrations of other detected metals were generally less than those trigger levels prescribed in the Guidelines for the 95% protection level.

Barigan Creek

Surface water quality sampling results for Barigan Creek (site BC1 located upstream of the confluence with Wollar Creek – Figure 2) indicate an average pH of 7.5 and EC of 1,954 µS/cm.

The measured pH levels were generally within the Guideline trigger value range for the protection of aquatic ecosystems and livestock watering, however a maximum pH of 8.2 was measured. EC values were within the Guideline trigger value range for livestock watering however above the Guideline trigger value range for the protection of aquatic ecosystems (Tables 11 and 13). During the sampling period, this site was recorded as having predominantly low or no flow.

Concentrations of metal toxicants were generally low at this site with no measured levels above the Guideline trigger values for livestock watering. However, one sample for copper (2.3 µg/L) was above the trigger value for the protection of aquatic ecosystems (90% level of protection).

Other Local Creeks

Water quality samples were collected from the lower reaches of Planters and Spring Creeks during the Aquatic Ecosystem Assessment in May 2004 (Sites PL1 and SP1 – Figure 2). Sample results indicate pH values of 7.1 and 9.1 and EC levels of 1,781 and 6,000 µS/cm in Spring Creek and Planters Creek, respectively.

2.5 Surface Water - Groundwater Interactions

Streamflow passing any point on a creek predominantly comprises drainage of water from the upstream catchment which originated as rainfall, but may also include flow derived from discharge from groundwater aquifers which extend beyond surface catchment boundaries. Streamflow can be considered as the combination of different components representing different pathways of water movement through the catchment. The dominant components are usually:

(i) *Overland flow* (or surface runoff) which is water that drains directly from the catchment surface as sheet and channel flow. Overland flow occurs during and for short periods after rainfall, as water flowing over the surface of the catchment drains off. It moves across the catchment quickly and is seen flowing in small drainage lines soon after the onset of rainfall. It can be identified on a flow hydrograph as a rapid increase in flow following the onset of rain. The point at which surface runoff ceases is less easily identified on a hydrograph but can sometimes be seen as an inflection point in the recession curve. For short duration rainfall events, overland flow tends to be generated from catchment surfaces that have low permeability or that are saturated or nearly saturated prior to the onset of rainfall and that are in close proximity to drainage lines. During longer events, larger proportions of the catchment contribute to overland flow.

(ii) *Baseflow* is water that discharges from subsurface storage into a stream. This subsurface storage may comprise interflow/underflow (see below) as well as deeper groundwater aquifer systems. Baseflow is the mechanism responsible for the low flow persistence observed during periods of low or no rainfall. Baseflow is predominantly derived from subsurface water storage with a pressure head above the streambed level. It varies over time, increasing during and after rainfall events due to recharge of the subsurface storage and persisting for relatively long periods after rainfall events as this subsurface storage discharges into the creek. It declines slowly during dry periods as the storage is depleted. Baseflow recession tends to follow an exponential decay curve.

(iii) *Interflow/Underflow*, a component of baseflow, is water that infiltrates and moves rapidly through the soil mantle and other permeable strata near or beneath the stream (ie. bank flow or underflow), reappearing during and for moderate periods after a rainfall event. Interflow is often sourced from areas of temporary perched groundwater systems which form in the near surface profile near the stream channels. Interflow/underflow can be distinguished conceptually from baseflow derived from deeper groundwater storage by the fact that it moves more rapidly and because it is derived from shallow, relatively fast flowing groundwater in direct connection with the creek and its banks. However, there is often no clear distinction between the components of baseflow evident in streamflow hydrographs, rather a transition from interflow/underflow as drainage from the storage of water held in the stream banks recedes and drainage from deeper groundwater system is left as the sole contributor to flow. Interflow/underflow is considered to be a component of baseflow in most catchment modelling studies.

The contributions that these components of runoff make to total streamflow are shown in schematic form on Figure 4. A flow hydrograph generated by a typical isolated rainfall event appears as a skewed, pointed curve with a steep rise followed by a sharp peak and concave recession.

The time at which the initial rise starts corresponds to the time at which runoff from the catchment first reaches the monitoring point. The shape and peak of the rising limb reflect the intensity and pattern of rainfall over the catchment and the catchment characteristics as they affect the surface runoff generation. The shape of the post peak recession initially reflects the drainage of surface flow from the catchment and later, as the recession curve becomes flatter, the influence of drainage of baseflow storage. The shape of the lower part of the recession curve is therefore largely independent of rainfall patterns and is a characteristic of the catchment itself. In most cases the baseflow recessions approximate exponential decay curves.

The relative magnitude of streamflow components will change in response to climatic events in the catchment. These changes can result in corresponding changes in water quality, particularly where (as is the case in much of the Hunter Valley) there are marked differences in surface and groundwater quality and where there is significant interaction between the two. Salinity has been identified as a particular issue in the Hunter Valley, in large part due to the high salinity associated with the Permian coal measures that underlie significant parts of the Hunter Valley and the effects of changes to surface vegetation associated with agricultural development.

During protracted dry periods the salinity of groundwater derived streamflow will normally reflect the quality of groundwater itself and the effects of evapo-concentration processes in ponding areas in the stream. During periods of surface runoff streamflow salinity will normally be low. The onset of surface runoff will usually result in an abrupt decline in salinity. The salinity during this initial stage of surface runoff will be affected by wash-off of salts which have accumulated on the catchment surface following the last runoff event. If rainfall is protracted, streamflow salinity may decline as the accumulated salt on the catchment surface is depleted. Immediately following cessation of surface runoff streamflow salinity will typically increase as the shallower (interflow/underflow) and deeper groundwater sources dominate. The shallow groundwater sources would normally have lower salinity compared to the older and deeper groundwater. In the absence of active recharge, the contribution of the shallower (interflow/underflow) component would decline moderately quickly followed by a slow decline in the more saline, deeper groundwater component.

Salinity, as indicated by EC, has been monitored by the DIPNR on a continuous basis at a number of stream monitoring sites in the Hunter Valley – coincident with flow. Inspection of this data confirms that salinity is influenced by the different sources that contribute to flow. Salinity generally increases gradually during periods of recession and decreases rapidly during periods of surface runoff. A good example of this behaviour can be seen in data recorded at the gauging station on Wybong Creek – refer Figure 5.

The higher recorded salt concentrations are associated with baseflow and the influence of high salinity in deeper groundwater. The lower salt concentrations observed during periods of higher flow reflect the surface runoff and limited opportunity for mobilisation of salts which may accumulate on the surface. The salinity of surface runoff can be increased by land use practices such as loss of surface vegetation resulting in dryland salinity.

The salinity of interflow/underflow would depend on the salinity of the near surface soils. It would be affected by upward leakage from deeper groundwater during extended dry periods and become fresher during wetter periods as it is diluted by surface recharge.

Mining activities, as with any landuse can affect the relative contributions of overland flow and baseflow and as a result, can affect both the flow and salinity in downstream watercourses.

2.6 Local Streamflow Characteristics

Local streamflow characterisation was undertaken by:

- inspection of the streams and their catchments;
- examining the available streamflow record at GS210082 (Wollar Creek) and GS210046 (Goulburn River); and
- developing streamflow hydrological models.

The contributions that baseflow and overland flow made to total flow at these two gauging stations were estimated on the basis of recorded hydrographs. Examination of these hydrographs indicates that there tend to be regular, small flow events and an absence of prolonged drought. Baseflow forms a significant component of streamflow and baseflow recession is quite slow. In Wollar Creek there is a distinct transmission loss, reflected by rapid diminution of small flows.

In both streams, there is a gradual transition from surface flow recession to baseflow. The baseflow component of flow has been separated from the flow hydrographs using accepted flow partitioning (separating baseflow from total flow) techniques (Boughton, 1988). This analysis indicates that baseflow is dominant during low flow periods. Whilst baseflow increases during periods of higher flow, it becomes a relatively small proportion of the total under these conditions. The overall contribution that baseflow made to total flow at the two gauging stations for the full period of record is summarised in Table 14.

Table 14
Gauged Stream Catchment Water Balance Contributions over Period of Record

Water Balance Component	Contribution over Period of Record
Wollar Creek Gauging Station (GS210082) – 1969-1997	
Rainfall (mm)*	17,523
Total Flow (ML)	102,388
Surface Runoff (ML)	61,433
Baseflow (ML)	40,955
Goulburn River at Ulan Gauging Station (GS210046) – 1956-1982	
Rainfall (mm)**	16,545
Total Flow (ML)	126,491
Surface Runoff (ML)	74,630
Baseflow (ML)	51,861

* Rainfall derived from average of recorded data at Wollar – Barrigan St (No. 062032) and Wollar – Maree (Stn no. 62056). Where gaps existed in the latter data, only the former dataset was used.

** Rainfall derived from average of recorded data at Ulan Post Office (No. 062036) and Budgee Budgee - Botobolar Vineyard (No. 062084). Where gaps existed in the latter data, only the former dataset was used.

Hydrological models of Wollar Creek and the Goulburn River at Ulan were developed and calibrated against observed rainfall and streamflow data.

The models were then used to generate streamflow sequences using a 116-year period of rainfall data[1] to enable estimation of long-term average flow behaviour in these creeks. A summary of the generated long-term flow statistics are given in Table 15. Flows are expressed as a depth of flow per unit catchment area (ie. mm) for direct comparison with rainfall.

Table 15
Summary of Gauged Stream Catchment Water Balance Statistics

Parameter	Annual Average Over Period of Record (mm)	Annual Average Over Long Flow Sequence (mm)
Wollar Creek (At GS210082)		
Rainfall	662.2	620.9
Total Flow	15.0	12.1
Surface Runoff	9.0	7.2
Baseflow	6.0	4.9
Goulburn River at Ulan (At GS210046)		
Rainfall	629.0	620.9
Total Flow	30.2	42.5
Surface Runoff	17.8	25.1
Baseflow	12.4	17.4

In the absence of actual flow records from Wilpinjong Creek, the characteristics of the two nearby gauged streams are considered to represent those of Wilpinjong Creek by virtue of their proximity and physical similarity (refer Section 2.3).

[1] 116 years (1889-2004) of rainfall data for the Project site was obtained from the Queensland Department of Natural Resources and Mines, Silo Data Drill – refer http://www.nrm.qld.gov.au/silo/datadrill/.

It is recommended that data obtained from the ongoing monitoring of Wilpinjong Creek (Section 7.0) be analysed for the purpose of validating the flow characteristics of Wilpinjong Creek progressively over the Project life.

The following points are noteworthy, with reference to Table 15:

1. Total flow is on average relatively low as a proportion of rainfall.

2. Baseflow (comprising both deeper groundwater and interflow/underflow) is estimated to account for some 40% of total flow in both streams. The dominant proportion of this is likely to comprise delayed flow associated with the alluvial/colluvial deposits in connection with the creek and perching and ponding of water in the near surface soil horizon rather than discharge from the underlying deeper groundwater system. Evidence of this can be seen in the recorded flow data on Wollar Creek and the Goulburn River where delayed drainage and protracted recession flows are a feature of the runoff hydrographs. On Wilpinjong Creek the deeper groundwater inflows are derived in part from the artesian coal seam aquifer (Ulan Seam). The rate of leakage to the creek from this aquifer is limited by the confining nature of the strata overlying the coal seam. The rate of upward leakage can also be equated to the persistent low flows which sustain the creek during protracted drought.

There are a number of ways that the streamflow characteristics of a creek or river can be quantified. Those considered most relevant to this assessment are:

(i) Baseflow Index: the ratio of baseflow volume to the total streamflow volume. This parameter directly reflects the significance of baseflow to total flow.

(ii) Mean Annual Flow: the arithmetic mean of annual flows (usually expressed in ML/year). This parameter reflects the average volumetric flow from a catchment over a long time period.

(iii) Streamflow Variability: the ratio of the standard deviation of annual flows to the Mean Annual Flow. It reflects the relative range of annual flows as a proportion of the average.

(iv) Baseflow Recession Constant: determines the rate at which water in subsurface storage discharges to a creek.

(v) Flow Duration Curve: the relationship between flow rate and the proportion of time that that particular flow is exceeded.

These characteristics have been estimated from the streamflow sequences generated using the hydrological model of the catchments. The results are summarised in Table 16.

Table 16
Estimated Baseline Streamflow Characteristics

Streamflow Characteristic	Wollar Creek (At GS210082)	Goulburn River (At GS210046)
Baseflow Index	0.40	0.41
Mean Annual Flow (ML/annum)	3,133	6,761
Variability of Annual Flows	4.72	6.48
Baseflow Recession Constant	0.99	0.98

2.7 Existing Surface Water Users

A search of records held by DIPNR indicates that there are currently no licences issued for extraction of water from Wilpinjong Creek. Under section 52 of the *Water Management Act 2000* riparian landholders are entitled, without the need for an access licence, to extract water for stock and domestic purposes. There are several properties with frontage onto Wilpinjong Creek within and downstream of the Project area. With the exception of four privately owned properties, all are owned by WCPL. The owners of the four privately owned properties with frontage onto Wilpinjong Creek are:

- SJ Close;
- JAW Smith;
- BC McDermott; and
- JT and JW Fitzpatrick.

A figure showing the locations of these properties is provided in Section 1 of Volume 1 of the EIS.

3.0 PROJECT WATER MANAGEMENT

3.1 Water Management System Design Objectives

Water management requirements for the Project have been assessed consistent with the standard water management practices in the Australian mining industry (MCA, 1997), which include:

1. Efficient use of water based on the concepts of ‘reduce, reuse and recycle’.
2. Avoiding or minimising contamination of clean water streams and catchments.
3. Protecting downstream water quality for beneficial uses.

The broad design objectives of the water management system are:

1. To maintain a low risk of an uncontrolled release of mine water (water that has come in contact with active mining and operational areas) to the downstream environment over the Project life.
2. To minimise risks of disruption to mining operations by efficient mine dewatering.
3. To achieve a high volumetric water supply reliability for the CHPP.
4. To provide the effective diversion of upslope runoff around Project disturbance areas.

3.2 Overview of Water Management System

The water management system (Figure 6) comprises drainage works and other water control facilities associated with active, inactive and backfilled open cut areas, tailings disposal and mine waste rock emplacement areas, coal handling and infrastructure areas, haul roads and other areas disturbed by mining activities (refer Figures 7 to 14).

Different water types (collectively referred to as mine water) would be produced from the different areas of the operation, including:

- Water from dewatering of the active open cut – comprising both groundwater inflow and runoff from rainfall over the active mine catchment.
- Runoff and seepage from active and portions of partially rehabilitated mine waste rock emplacement areas.
- Runoff and seepage from the ROM and product coal stockpiles.
- Decant recovery and rainfall yield from the tailings disposal areas.
- Runoff from haul road and hardstand areas.
- Runoff from the mine facilities area (i.e. workshop and vehicle re-fuelling area).
- Effluent from the domestic sewage treatment facility.

The management of these mine waters would depend on their rate of generation and the capacity for reuse and/or recycling. Mine water would be used in the CHPP, for wash-down of mobile plant, for dust suppression on haul roads and for dust emission control in the ROM and product coal stockpile areas. Some water would also be used for other minor non-potable uses. Mine water quality would vary in salinity depending on the relative contributions of the above sources but would be available for the above uses.

Potable water would be trucked to the site to service the construction camp and for drinking water and ablution facilities in the office and crib areas.

The water balance of the system would vary with climatic conditions and would also be affected by the changing status of mining operations as they evolve over time. The components and linkages in the proposed water management system are shown in schematic form on Figure 6.

Water removed from active and inactive open cuts would be transferred to the CHPP water supply storage (Figure 7) for use in the CHPP and for dust suppression. The open cut voids would become local sinks for groundwater and incident rainfall and runoff from open cut areas and their adjacent undiverted catchments. Overburden and interburden waste rock would be placed in the void formed behind the advancing open cut. Drainage from in-pit mine waste rock emplacement areas would also report to the floor of open cut voids. Water in active open cuts would be pumped out to enable ongoing safe access for mining. If required, water would be stored in inactive open cut voids and sourced progressively to supplement the CHPP water supply storage during dry periods. During wet periods, when there may be an excess of water being generated, water captured in active open cuts would be pumped to inactive open cut voids and/or tailings disposal areas for temporary storage.

Supernatant from tailings disposal areas, generated by settling and consolidation of tailings, would be decanted off and returned to the CHPP water supply storage for reuse. Incident rainfall over tailings disposal areas and any adjacent undiverted catchment would contribute additional water which would combine with the supernatant.

Runoff from haul roads and hardstand areas would be captured in sediment retention storages sized to trap silt and other settleable material. Water in sediment retention storages would be released in accordance with conditions prescribed in an Environment Protection Licence issued under the *Protection of the Environment Operations Act, 1997*.

Runoff from the workshop and vehicle re-fuelling areas would be diverted to an oil-water separator and then to the CHPP water supply storage for reuse.

Effluent from the domestic sewage treatment plant would be irrigated over vegetated and garden areas around the administration and workshop facility area.

Until rehabilitated landforms have satisfactorily stabilised, runoff from these areas would be directed to sediment retention storages, prior to release to local drainages. Thereafter, sediment retention storages would be decommissioned (or left in place as farm dams, if considered practicable) and rehabilitated landforms would be allowed to free drain. A post-mining plan showing rehabilitated landforms is provided on Figure 15.

3.3 Drainage from Undisturbed Catchments

The accepted approach to managing runoff from catchments areas which are undisturbed by surface mining activities is to isolate them and, where practicable, divert them around surface disturbance areas. The objective of this strategy is to minimise the volume of mine water that would need to be managed on site. Over the life of the Project, this would involve the construction of diversion bunds, drains and temporary interception dams around the open cut and mine waste rock emplacement areas so as to divert runoff from undisturbed areas to off site drainages. Toe drains and isolation bunds would also be constructed around the perimeter of any temporary out-of-pit mine waste rock emplacements (Figures 8 and 9) and other areas disturbed by mining to collect and convey drainage from these areas to containment storages thereby isolating drainage disturbed by mining away from undisturbed area runoff. Upslope diversion works would be designed in consultation with DIPNR. The design capacity of these diversion works would depend on:

- the size and nature (eg. soil type) of the upslope catchment;
- the design life of the diversion; and
- the consequences of a breach.

Depending on the above, the design capacity would range from the peak flow generated by the 1 in 2 year average recurrence interval (ARI) through to that generated by the 1 in 100 year ARI. Diversions would be designed to be stable (non-eroding) at the design flows. Stabilisation would be achieved by design of appropriate channel cross-sections and gradients and the use of channel lining with grass or rockfill as required. The conceptual layout and extent of the proposed upslope drainage diversion works is shown on Figures 7 to 15 and described in Section 3.9.

3.4 Floodplain Water Management

Whilst there is no surveyed flood level data available for Wilpinjong Creek, an investigation conducted by WCPL involving discussions with local residents along the creek suggests that major floods in the past have not resulted in extensive flooding outside the creek banks. Whilst some areas within or near the proposed mine area are prone to ponding and water logging local knowledge suggest that this is as a result of local rainfall-runoff and the prevalence of flat areas rather than flood water inundation from Wilpinjong Creek. The largest flood in living memory occurred in February 1955. The available rainfall records for the area confirm that it would have been the largest event since rainfall records started late in the 19^{th} century. Local knowledge confirms that there has not been any event since which has been particularly significant in terms of inundation or damage to property along Wilpinjong Creek.

The Gulgong-Sandy Hollow railway embankment was constructed during the second World War and was therefore in place prior to the 1955 event. The railway line is in places close to Wilpinjong Creek and it therefore provides a useful reference for assessing flood levels since its construction. There is no memory of the railway embankment having been overtopped during the 1955 flood or at any other time since.

Flood levels at the peak of the 1955 flood are thought to have just reached a stable and a shearing shed which existed on the Old Mittaville property. The location of these dwellings are recorded as dots on the 1:25,000 Topographical Sheet (Wollar 8833-2-N), 1986. Based on the available mapping, the levels of these buildings would have been at or below the general railway embankment toe level and significantly below the level of proposed mining activity.

Information from the Australian Rail Track Corporation also indicates that design standards that would have applied to railway culverts on the Sandy Hollow to Maryvale line for significant creek crossings would have been based on a peak 1 in 100 year ARI event and that embankment levels would have been selected to provide immunity against overtopping by floods significantly larger than criteria used for culvert sizing.

Flood bunds may be necessary along some sections of the down slope (northern) end of open cut voids to mitigate against inflows from major flooding in Wilpinjong Creek and backwater up tributary drainages (eg. Cumbo Creek). Given that the pit limits for the open cut mining operation are set-back from the Gulgong-Sandy Hollow railway embankment, any flood bunds would not impede active flood flows and would have negligible effect on floodplain storage in Wilpinjong Creek.

The required level of any flood bunds should be determined by a flood study prior to mining in the northern limit of Pit 1 (ie. approximately Year 2 – refer Figure 8).

3.5 Relocation of Cumbo Creek

The mine plan would require the relocation of Cumbo Creek across a previously mined out and backfilled mine waste rock emplacement in Pit 3 (Figure 10). The relocation would comprise the construction of a block bank and sub-surface cut-off wall across Cumbo Creek upstream of Pit 4 (Figure 10) to direct surface and sub-surface (associated with any alluvium in Cumbo Creek) flows into the relocation corridor. The relocation corridor would be formed following the mining of underlying coal and is expected to occur during Year 8.

The issues most commonly associated with creek relocations across mine waste rock emplacements are:

- stability of the bed and banks of the re-constructed flow path;
- potential for and implications of post construction settlement and particularly differential settlement on the flow path integrity; and
- potential for and implications of seepage losses through the flow path floor.

As shown on Figure 16, the proposed corridor would comprise a low flow path within a high flow flood path. Alluvium from alluvial/colluvial deposits associated with drainages within the open pit limits would be excavated as part of mining operations and relocated to the low flow path to provide natural creek bed material and help minimise erosion during high flow events. Below the relocated alluvium, the invert of the creek would be lined with an engineered low permeability zone (comprising more weathered mine waste rock selectively placed and compacted to engineering specifications) to reduce the potential for leakage of flows to adjacent mine workings. The low permeability zone would be supported on an engineered bridging/transition zone (comprising more weathered mine waste rock selectively placed and compacted as part of run-of-mine operations). The bridging/transition zone would be supported by mine waste rock (run-of-mine).

The relocation works would be subject to detailed geotechnical, hydrological and hydraulic design. The low flow path would be designed to convey flows up to the 1 in 10 year peak flood discharge. Larger flows would be allowed to flow over the adjacent land surface (i.e. high flow flood path).

Containment landforms would be formed on both sides of the high flow flood path to act as a flood levee between the Cumbo Creek relocation corridor and the mine workings (Figure 16) to reduce the risk of flood water entering the mine area during the Project life. The actual design flow capacity of the high flow flood path would be determined as part of detailed design studies using a risk analysis approach incorporating a comparative assessment of the integrity of the original and reconstructed creek under high flow conditions. The corridor would be revegetated with native riparian vegetation to enhance stability during high flow events. The Cumbo Creek relocation corridor would be constructed 12 months prior to being commissioned to allow vegetation elements time to commence establishment and provide stability.

The flow path geometry and geomorphology are to be developed such that flow velocities and boundary shear stresses developed under design flood flow conditions would be similar to those in the existing Cumbo Creek under similar flows and would not exceed critical values for long-term stability.

Prior to detailed design, the following should be undertaken:

- A hydrological assessment of the post mined catchment of Cumbo Creek should be undertaken to establish expected flow characteristics including high flow events. Data from the gauging station installed on Cumbo Creek by WCPL would be used in this assessment.
- A geomorphological investigation of local and regional creeks should be undertaken to establish flow path form for optimal long-term stability.

In carrying out the design, attention should be given to the following:

- Oversizing the low flow path to allow some sedimentation and to limit potential scour during the early establishment phase.
- Incorporation of a temporary retardation storage upstream of the inlet of the reconstructed creek to ameliorate potential scour associated with high flows during the establishment phase.
- Incorporation of an active alluvial layer in the floor and bank toe areas of the low flow path to provide continuity of sediment movement through the catchment. The need for, and extent of this layer should be identified during the geomorphological investigation.
- Use of temporary armouring and reinforcement of banks in riffle zones to provide stability during the vegetation establishment.
- Allowances for any predicted settlement (i.e. consolidation) of mine waste rock through a trial using *in situ* overburden/interburden.

Research into the settlement (i.e. consolidation) of spoil (e.g. overburden/interburden) in mine waste rock emplacements indicates that a main primary settlement occurs during and immediately after spoil placement. A smaller secondary settlement then occurs during subsequent wetting of spoil by rainfall (Nadieran, 1997). Actual post-placement settlements can be reduced by compaction of the upper layers of fill.

Following construction, monitoring should be undertaken to assess ongoing performance of the relocation corridor. Geotechnical/geomorphological monitoring should focus on settlement, bed and bank stability, movement of bed sediment and changes to flow path geometry. Environmental monitoring should focus on vegetation and habitat establishment as well as water quality. Inspections should be undertaken during and following significant flow events to determine if maintenance works are required.

The final design of the Cumbo Creek relocation corridor would be subject to DIPNR approval and would be documented in the Cumbo Creek Relocation Plan as part of the overall site water management reporting process (i.e. Site Water Management Plan).

3.6 Water Management in Open Cut Areas

The general sequence of open cut mining operations for the Project is described in Section 2 of Volume 1 of the EIS.

Upslope diversions as described in Section 3.3 and temporary interception dams with pump out systems would be constructed to limit inflows of undisturbed runoff in active/inactive open cut areas. Groundwater inflows to active open cut areas would combine with rainfall-based runoff from adjacent catchment areas and incident rainfall on the floor of the open cut voids. This water would need to be removed to enable ongoing mining operations to be undertaken safely and efficiently.

Hydrogeological investigations by AGEC (EIS Appendix B) indicate that groundwater inflows to the open cuts would vary significantly during the Project life depending on the elevation of the pit base.

Inflows are expected to be greatest in Years 13 to 14 - coincident with mining of the deeper coal in the north and north-west of the Project area (ie. Pits 4, 5 and 6) coupled with infiltration through the rehabilitated mine waste rock emplacements reporting to the open cut workings in the north.

Whilst inflow derived from direct rainfall and surface water inflows would be predominant during wet periods, groundwater inflow is expected to be more significant in terms of total volume over the Project life. Results of water balance modelling indicate that efficient mine dewatering is likely to necessitate pump-out capacity in the order of 150 L/s. Where the potential for high groundwater inflows from the Ulan Seam is identified, advance dewatering using temporary bores ahead of the open cut mining operation may be conducted.

During mining operations any direct groundwater inflows from alluvium exposed in the highwall of the open cut would be intercepted prior to it reaching the floor of the open cut and pumped back to the nearest creek. This would be achieved by the installation of sumps and a pump/pipe system located on a bench of the open cut (as is the current practice for similar circumstances at coal mines in the Hunter Valley). As discussed in Section 3.5, the proposed relocation of Cumbo Creek would include a block bank and sub-surface cut-off wall across Cumbo Creek upstream of the Project open cut to divert both surface and subsurface flows into the new creek alignment.

Where areas of alluvium intersect the open cut highwall, and there is a potential for significant leakage of waters from the alluvium to the mine waste rock emplacements, specific control measures may be necessary. This would be assessed by detailed investigations and appropriate control measures implemented as required to control these inflows. These measures may include selective placement of more weathered materials against the alluvium, as the open cut excavation is backfilled with mine waste rock. Placement methodologies for these materials (i.e. placement in thinner layers and trafficking with mine fleet) would be developed to achieve the desired degree of seepage control.

3.7 Water Management in Tailings Disposal Areas

Two waste streams would be produced from the CHPP - a coarse-grained, rocky waste material comprising sandstone and shale material (coarse rejects) and a fine grained silty material (fine rejects/slimes). The coarse reject would be placed as a "dry" solid fill in the mine waste rock emplacements (ie. it would be mixed with overburden and interburden). The fine-grained waste stream would be produced as a tailings slurry. CHPP tailings would pass through a thickener to recover water for reuse in the CHPP. The tailings underflow fraction from the thickener is to be pumped to a disposal area. Thickened tailings are expected to have an average solids density[2] of 40% by weight (Thiess, 2005).

Tailings would be predominantly disposed of into completed open cut voids. In all, it is expected that six voids would be backfilled with tailings during the Project life.

[2] Mass of solids as a proportion of total mass.

Following discharge, tailings would settle out and form a beach deposit in the void sloping away from the discharge point. Supernatant would pond at the downslope end of the formed beach from where it would be recovered in a decant facility and pumped to the CHPP water storage for reuse. It is expected that the average dry weather water recovery from tailings disposal areas would be a minimum of 25% of the original tailings slurry water volume discharged (Thiess, 2005). The remainder is lost to evaporation, retained within the interstices of the tailings or is lost to seepage.

The relatively small surface area of the open cut voids that would be used for tailings disposal would limit the opportunity of the tailings to dry (ie. de-saturate during the operational phase).

The acid forming potential and salinity associated with coal washery wastes including tailings has been assessed by EGi (2005) (EIS – Appendix C). Based on results of geochemical tests conducted on tailings derived from washability tests, on a mass weighted basis, it is expected that tailings overall would be potentially acid forming (lower capacity) and moderately saline, but variations would occur reflecting changes in the proportions of different coal plies passing through the CHPP (EGi, 2005).

Provided that appropriate tailings management recommendations are implemented to minimise the risk of sulphide oxidation and acid generation, EGi concluded that "*since the tailings originate from the Ulan Seam and will be disposed of in-pit, it is expected that the groundwater flux through the tailings disposal areas in the long-term will be of a similar groundwater quality to that which currently exists in the Ulan Seam…*". The tailings management recommendations by EGi (2005) are summarised as follows:

- Tailings should remain saturated during the operational phase. Where this is not possible, the exposed (sub-aerial) beach area should be minimised.
- Routine monitoring of the acid forming potential of tailings solids and decant water should be undertaken to confirm study findings and determine if additional mitigation measures are necessary (ie. such as treatment with crushed lime) during the operational phase.
- Examination of the closure requirements for the tailings disposal areas should be undertaken and an engineered cover design developed based on cover design criteria developed during the mining operations.

3.8 Water Management in Mine Waste Rock Emplacement Areas

Mine waste rock (ie. overburden and interburden) would be placed in worked out portions of the mine and in temporary mine waste rock emplacement areas adjacent to the open cut. Coarse reject from the CHPP would also be placed (mixed) with overburden in the open cut voids.

The final surface of the mine waste rock emplacements would be constructed to approximate the existing (pre-mine) drainage topography. Valley areas would be shaped into a network of flow paths located similarly to the existing flow paths (eg. Narrow Creek) (Figure 15).

Sediment retention storages would be constructed at intervals along these flow paths to retard flows and to settle sediment carried in runoff - particularly during the vegetation establishment phase. Sediment retention storages would be provided with low flow outlets so that stored water slowly drains following rainfall-runoff events.

Wide, shallow by-wash spillways would be provided at these storages to facilitate low energy overflows during more intense rainfall events. In areas where high energy flows or high flow volumes are likely to concentrate, specific hydraulic works such as rip rap scour protection, drop structures or other energy dissipation devices would be installed. A combination of riparian vegetation and rock mulching would also be used to stabilise flow paths.

Freshly placed mine waste rock may have a relatively high infiltration capacity depending on its degree of weathering. Water infiltrating waste rock material would either be retained in the interstices or would seep through the waste rock. Pore water retention would be high initially (after placement) and reduce as an 'equilibrium' moisture profile developed in the mine waste rock emplacement profile. A proportion of the rainfall that infiltrates through the surface of the mine waste rock emplacement would be returned to the atmosphere as evapotranspiration.

As vegetation becomes established on rehabilitated mine waste rock emplacement areas the hydrological balance would tend to change, with a greater proportion of rainfall contributing to evapotranspiration and a reduced proportion of deep seepage. As the surface vegetation matures, moisture levels in the near surface root zone would decrease compared to the non-vegetated condition, creating additional storage within the near surface soils for rainfall infiltration, with the result that surface runoff would tend to decrease. The erosion potential associated with decreased runoff would also be reduced by the stabilising effect of vegetation, resulting in a significant reduction in sediment movement off the rehabilitated and revegetated mine waste rock emplacement areas.

The acid forming potential and salinity associated with overburden/interburden and coarse reject has been assessed by EGi (2005). Based on the results of these tests, the overburden/ interburden materials were typically characterised by circum-neutral pH, low total sulphur content and low acid neutralising capacity. The overburden/interburden samples displayed very low soluble salts and EGi (2005) have indicated that overburden/interburden is likely to be non-saline. The coarse rejects samples were predominantly classified as potentially acid forming - low capacity and were slightly saline. EGi (2005) recommended that whilst no special handling methods were warranted for the overburden/interburden (subject to operation validation testing), coarse rejects should be dispersed throughout overburden/interburden materials with the aim of producing a mix that is non acid forming (i.e. to exploit the net acid neutralising potential of the overburden/interburden to exceed the acid potential of the coarse rejects). EGi (2005) also recommended that the outer 5 m of mine waste rock emplacements be constructed with non acid forming overburden to protect surface water quality and promote revegetation.

Once completed mine waste rock emplacements have been re-profiled, stripped subsoil and topsoil would then be spread over the subsoil to assist in vegetation establishment.

Based on these results, it is expected that drainage from mine waste rock emplacement areas would be non-saline and near neutral in pH.

3.9 Water Management System – Staged Development

The water management system would evolve as the Project progresses. The progression of development is illustrated on Figures 7 to 15 which reflect the Project at various key phases from initial infrastructure development through to post-mining. The key features of the water management system at each stage are described in the sub-sections below.

3.9.1 Initial Construction/Infrastructure Development and Initial Mining Year 1

Project infrastructure would be developed ahead of mining operations and would involve the following components (Figure 7):

- Temporary construction camp and temporary access road.
- Mine access road.
- Relocation of the existing 11kV electricity transmission line.
- Mine facilities area including workshops and administration facilities.
- CHPP and ROM coal handling areas (including haul roads).
- Project water supply borefield and CHPP water supply storage.
- Product coal stockpiles/handling area and train loading infrastructure.
- Rail spur and rail loop.
- Realignments of Ulan-Wollar Road.

The initial box cut would also be developed in parallel with these works to provide construction materials and enable access to coal prior to commissioning of the CHPP. It is expected that the initial construction period would last approximately six months.

The main water related issues to be addressed during this period include:

- development of a water supply sufficient to meet construction demands;
- completion of the CHPP water supply storage (Figure 7);
- accumulation of start-up water supply for the CHPP in the CHPP water supply storage via commencement of pumping from Project water supply bores (refer Appendix B), advance dewatering in Pits 5 and 6, dewatering of the initial box cut and containment of runoff from disturbance areas; and
- effective control of erosion and sediment movement from the construction areas.

Construction water would be provided from the development of one or more of the water supply bores or by advance dewatering of the pit areas using temporary bores. Water would be reticulated to portable tanks for easy access by water trucks.

An Erosion and Sediment Control Plan (ESCP) would be developed as part of the detailed infrastructure design phase and it would be incorporated into the works contract. The ESCP would be developed in general accordance with the well developed principles and techniques outlined in *Managing Urban Stormwater – Soils and Construction* published by the NSW Department of Housing (1998) and *Draft Guidelines for the Design of Stable Drainage Lines on Rehabilitated Minesites in the Hunter Coalfields* (DLWC, undated).

As part of the ESCP, diversion works would be constructed upstream of construction areas (where a significant upslope catchment exists) and sediment control structures would be constructed immediately downstream. In particular, an upslope diversion channel would be constructed around Pit 1, the box cut and other construction areas (refer Figure 7), to divert runoff from undisturbed areas of Bens Creek and Narrow Creek around the Project disturbance area. Other important parts of the ESCP would include optimising earthworks schedules to minimise overall disturbance and employment of rapid stabilisation methods on disturbed areas following the completion of earthworks construction. A system of inspections and monitoring would be integrated into the ESCP to facilitate corrective actions if required.

3.9.2 Mining Plan and Associated Water Management Years 2 - 21

Mining operations would progress as shown on Figures 8 to 14.

Overburden/interburden would be predominantly placed adjacent to and behind the advancing open cut in in-pit mine waste rock emplacements. Temporary out-of-pit mine waste rock emplacements would be constructed along the western and eastern side of the Pit 1 and Pit 2 boundary, respectively during initial pit development.

Tailings from mining operations would initially be placed in a partitioned section of the CHPP water supply storage. Once completed, tailings disposal would transfer to the box cut. Thereafter, ongoing tailings disposal would be transferred to open cut voids created over the life of the Project in Pit 1 (north and south), Pit 2 (north and south) and Pit 4.

The main water related issues to be addressed during the mining operation include:

- expansion of the water supply scheme to meet the operational demands of the CHPP and mining operations;
- control of erosion and sediment movement as the Project disturbance area progresses;
- expansion of the upslope diversions to divert undisturbed runoff around open cut mining operations;
- construction of drainage interception works around temporary out-of-pit mine waste rock emplacement areas;
- dewatering and containment of groundwater inflows within the open cut and the interception and containment/reuse of drainage from Project infrastructure areas;
- establishment of revegetation and progressive rehabilitation of mine waste rock emplacements to promote early stabilisation of landforms and reformed flow paths.

Operational sediment and erosion control works would be integrated into mine scheduling and include construction of interception drains and sediment retention storages on drainage lines crossing soil stripping areas ahead of the advancing open cut, haul roads and temporary out-of-pit mine waste rock emplacement areas.

Upslope diversions around Project infrastructure components developed during the construction phase would be progressively expanded around active mining areas. Both temporary and permanent upslope diversion bunds/drains and temporary interception dams would be constructed over the life of the Project, so as to divert runoff from undisturbed areas around the open cut and mine waste rock emplacement areas to off site drainages (ie. Wilpinjong Creek and Cumbo Creek).

Permanent upslope diversion bunds/drains would remain around the two final voids. The Cumbo Creek relocation corridor would provide for the diversion of upslope runoff and flows in Cumbo Creek. Further details of the Cumbo Creek relocation works are provided separately in Section 3.5.

Water from mine dewatering operations would be transferred to the CHPP water supply storage for direct use in the CHPP and for dust suppression on haul roads. At times when this storage is above its normal operating capacity, excess mine water would be transferred to the box cut water supply storage, tailings disposal areas and/or inactive open cut voids.

Surface runoff from rehabilitated mine waste rock emplacement areas would be progressively directed toward the off site drainages (ie. Wilpinjong Creek and Cumbo Creek).

3.9.3 Post Closure Water Management

At the completion of mining, final voids would be left in Pit 3 and Pit 6 (Figure 15). Mine waste rock emplacements would have been formed and rehabilitated during the mining operations to approximate pre-mine topography. A pattern of creek features would be formed over the rehabilitated surface comparable to the pre-mine regime (i.e. in similar locations to the existing Planters Creek, Spring Creek, Narrow Creek and Bens Creek). These reconstructed creek features would convey runoff across the Project area to Wilpinjong Creek. The design details of the creek features would be determined in the Mining Operations Plan and Site Water Management Plan (Section 5, Volume 1 of the EIS).

4.0 SIMULATED PERFORMANCE OF THE WATER MANAGEMENT SYSTEM

4.1 Project Water Management System Simulation Model

The ability of the water management system to achieve its broad design objectives (Section 3.1) was assessed by simulating the dynamic behaviour of the Project water balance over the Project life under variable climatic conditions (based on historic rainfall data). The water balance model developed for the Project simulates all the inflows, outflows, transfers and changes in storage of water on site on a daily basis in ten water storages (including the CHPP and box cut water supply storages, active and inactive open cut voids and tailings disposal areas). The model simulates inflows from rainfall-runoff, groundwater inflows to open cut voids, extraction from the Project water supply borefield and advance dewatering of pit areas. Simulated outflows comprise evaporative losses, water used to satisfy the demands of the CHPP, moisture content in product coal and water used for dust suppression. The general components and linkages of the water management system simulated by the model are shown in schematic form on Figure 6.

The model was set up to run over a large number of different daily rainfall sequences compiled from the historical record[3]. Each sequence comprised a 21-year period – corresponding to the planned Project life. The sequences were formed by moving along the historical record one year at a time with the first sequence comprising the first 21 years in the record. The second sequence comprised years 2 to 22 in the record while the third sequence comprised years 3 to 23 and so on. Using this methodology, 96 21-year sequences of daily rainfall were formulated for use in the model simulations. This method effectively includes all possible historical climatic events in the water balance model, including high, low and median rainfall periods.

The AWBM model (Boughton, 1993) was used to simulate runoff from rainfall on the various catchments and landforms across the Project area. Model rainfall-runoff parameters have been taken from studies conducted at similar mining operations (ACARP, 2002), with calibration against local streamflow records and experience with similar projects. Groundwater inflow rates to the active open cut workings and open cut voids were derived from inflow rates provided by AGEC (2005) and adjusted for the modelled water level in the open cut voids. Evaporative losses from open cut voids and on site water storages (including tailings disposal areas) were estimated on the basis of evaporation rates derived from the same source as the rainfall data and storage/void surface areas. Allowance was also made for evaporative losses from seepage from the highwall faces of the open cut.

The net make-up water demand for the CHPP was derived from data provided by Thiess (2005). Haul road (dust suppression) demands were estimated on the basis of active haul road length derived from Project layout plans (Figures 7 to 14) and evaporation allowance. The peak total make-up water demand (accounting for recycling of water from the tailings thickener) including the operation of the CHPP at 8.5 Mtpa is estimated to be approximately 6.2 ML/day.

4.2 Simulated Performance

4.2.1 Containment of Mine Water

Results of modelling indicate that there would be sufficient on-site storage capacity available in the open cut voids and other storage areas to provide secure containment for all mine water and tailings in all simulated climatic sequences. Under some conditions secure containment would necessitate the pumped transfer of excess water from active open cut areas and/or the active tailings disposal areas to inactive open cut voids for temporary containment.

4.2.2 Make-up Water Supply Requirements

Results of modelling indicate that, under most climatic conditions and particularly during the first half of the Project life, extractions from the borefield, supplemented by advance dewatering within pit areas, are required to maintain operation of the CHPP at design capacity. During the first 10 years of the Project, model predictions indicate that there would be a need to store water pumped from the water supply borefield in water storages available at the time (including inactive open cut voids and tailings disposal areas).

[3] A record of 116 years (1889-2004) was obtained for the site from the Queensland Department of Natural Resources and Mines Silo Data Drill – refer http://www.nrm.qld.gov.au/silo/datadrill/. A 116-year evaporation data set for the site was also obtained from this source.

Model results indicate that from Year 11 of the Project there is unlikely to be a need to source water from the water supply borefield, with demand being met by mine water sources alone. This is mainly as a result of higher predicted inflows to the open cut (AGEC, 2005).

The simulated water supply reliability[4] averaged over all modelled climatic sequences is 95% (including 4 L/s provided by advance dewatering bores and supply drawn from the borefield).

5.0 ASSESSMENT OF POTENTIAL SURFACE WATER IMPACTS – OPERATIONAL PHASE

Potential impacts of the Project on local and regional surface water resources include:

- Potential for export of contaminants (principally sediments and soluble salts) from disturbed area runoff and accidental spills from containment storages and tailings disposal areas (principally sediments, soluble salts, acidity, oils and greases).
- Changes to flows in local creeks due to the open cut mine development excising a portion of the local catchments.
- Changes to baseflow and salt flux into Wilpinjong Creek due to water table drawdown effects caused by mining (ie. open cut dewatering) and groundwater extraction from the water supply borefield.

Details of the proposed enhancement and conservation of local creeks are provided in Section 5 of Volume 1 of the EIS.

5.1 Potential Release of Contaminants

Modelling indicates that the water management system operates as a contained system where all disturbed area runoff including potential contaminant source areas can be contained on site within the range of climatic sequences modelled (Section 4.2.1).

Runoff from undisturbed, rehabilitated and stabilised areas on site would be directed to Cumbo Creek and Wilpinjong Creek via a network of flow paths. There is potential for contaminants to drain off site as a result of accidental spills around infrastructure areas on site (ie. CHPP, mine facilities area, ROM/product coal handling areas and train loading facilities) as well as potential for sediment migration and high turbidity in runoff. The potential for these incidents to occur can be reduced by developing and implementing effective operational management procedures. Such procedures have become standard at most contemporary mining projects in the Hunter Valley. It is recommended that prior to commencing site operations and as part of the Project detailed design, WCPL develop a detailed operational ESCP and Site Water Management Plan and that these documents be updated as required. These management plans should contain procedures for managing potential contaminants on site.

[4] Expressed as a volume of water supplied divided by volume required.

5.2 Potential Effect on Flows in Local Creeks

The potential effects of the open cut mine development on flows in Wilpinjong Creek and downstream watercourses were assessed using a catchment model. The model was developed to simulate creek flows prior to mining using calibration data taken from the closest and most similar gauged catchment to Wilpinjong Creek. The Goulburn River at Ulan and Wollar Creek at Wollar were considered (Attachment 1) and the latter calibration chosen to represent flow conditions in Wilpinjong Creek (adjusted for different catchment area). This decision was based on the similarity of catchment area, topography, geology and landuse (refer Section 2.1). Details of the model calibrations are provided in Attachment 1. The potential effects of mining were then assessed using the catchment model developed to reflect the maximum potential impacts on flow during the Project life (ie. with the maximum area of mine catchment excised and with the maximum predicted reduction of groundwater inflows [baseflow] to Wilpinjong Creek from results of groundwater modelling [AGEC, 2005]).

As discussed in Section 3.8, mine water which reports to active and inactive open cut areas would be retained and reused on site. This water includes a proportion that would have originally flowed to Wilpinjong Creek as runoff. Mining (ie. open cut dewatering) and operation of the water supply borefield would result in drawdown/depressurisation of the coal seam aquifer. Results of groundwater modelling (AGEC, 2005) indicate that depressurisation of the coal seam aquifer would extend beneath Wilpinjong Creek. The maximum simulated effects of mine related drawdown on flow reporting to Wilpinjong Creek have been estimated by AGEC (2005) to occur in Year 14 of operations. AGEC (2005) has conservatively assumed that extractions from the Project water supply borefield would continue until Year 14 of operations, rather than Year 10 as indicated by the water balance model (Section 4.2.2). Year 14 also corresponds to the maximum catchment excision due to mining. Once groundwater extractions from the water supply borefield cease it is expected that the groundwater system directly affected by the borefield would commence a process of gradual recovery.

The predicted maximum effect of runoff capture and potential reduction of baseflow on annual average flows in Wilpinjong Creek and Wollar Creek (downstream of the confluence with Wilpinjong Creek) is summarised in Table 17.

Table 17
Potential Maximum Reduction in Annual Average Flow in Downstream Watercourses (Year 14)

Catchment	Location	Potential Maximum Reduction in Annual Average Flow (%)
Wilpinjong Creek	Upstream of Wollar Creek Confluence	11%
Wollar Creek	At Goulburn River National Park Boundary	4.8%

Results of groundwater modelling indicate that mine induced drawdown/depressurisation in the underlying coal measures would, in particular, reduce groundwater contribution to baseflow in Wilpinjong Creek. Under pre-mine conditions, baseflow in Wilpinjong Creek is estimated to average 2.5 ML/day. This flow would be predominantly derived both from interflow/underflow from the alluvial and colluvial deposits associated within and adjacent to the creek which are recharged by incident rainfall and shallow seepage and runoff from the adjacent elevated Goulburn River National Park escarpment. As discussed in Section 2.6, upward leakage from the underlying artesian aquifer formed in the Ulan seam and underlying Marrangaroo sandstones would also contribute to baseflow.

The effect of mining is expected to result in loss of some of this baseflow as a result of depressurisation of the coal measures. The groundwater model predicts a reduction in the rate of upward leakage into Wilpinjong Creek from the coal measures in the Project affected area. The maximum loss of baseflow is expected to occur in Year 14. Results of groundwater modelling indicate this loss would be some 0.66 ML/day. The simulated maximum effects on low flows in Wilpinjong Creek in Year 14 just upstream of the Wollar Creek confluence and in Wollar Creek at the Goulburn River National Park boundary are shown graphically on a low flow duration curve – refer Figure 17.

Whilst the predicted potential changes to low flows in Wilpinjong Creek would be expected to be noticeable as reduced flow persistence, the predicted effects can be compared to other changes in catchment condition and land use which can result in similar or larger changes in flow regime. Deforestation has been shown to cause large increases in runoff and changes to the baseflow regime. Other more subtle effects such changes in stocking rates, construction of farm dams and water harvesting and bushfire can also result in noticeable changes to low flows. The relative effects on the magnitude and duration of low flows would reduce significantly downstream of the Wilpinjong/Wollar Creek confluence due to the 'diluting' effect of additional (unaffected) inflows from Wollar Creek. As such, the effects of flow reductions further downstream in Wollar Creek and the Goulburn River are expected to be indiscernible when compared to other changes in the catchment, which would be expected to result from future landuse practices (including the proposed creek enhancement works – Section 5, Volume 1 of the EIS) and natural events.

It should be noted that the above impacts have been assessed based on a catchment model of Wilpinjong Creek calibrated using flow data from an adjacent catchment (Wollar Creek). On-going monitoring of Wilpinjong Creek flow would be undertaken to validate predicted impacts (refer Section 7.0). Other local creeks to the west of the Project area (i.e. Murragamba Creek and Moolarben Creek) and to the south (Cumbo Creek) are not expected to be impacted as the mine induced drawdown would not extend to these creeks (refer Appendix B).

Following completion of mining, the extent of the mine induced groundwater drawdown would stabilise and groundwater levels in and around the Project area would recover (AGEC, 2005).

Whilst the groundwater modelling prediction includes reduced piezometric pressures in parts of the coal seam aquifer underlying the Goulburn River National Park sandstone plateau, it is expected that there would be no discernible effect on the groundwater and surface water regimes in the overlying sandstone units (i.e. Narrabeen Group) (AGEC, 2005).

5.3 Changes in Salinity in Downstream Watercourses

The removal of coal and the reduction in the component of baseflow derived from the underlying coal seam aquifer are expected to reduce the salt load in the lower section of Cumbo Creek and in Wilpinjong Creek adjacent to and downstream of the Project.

It is expected that the effect would be progressive over the Project life and result in the salinity of low flow in Wilpinjong Creek adjacent the Project trending toward levels seen in Wilpinjong and Murragamba Creeks upstream of the Project. Whilst the salt load to Cumbo Creek in the lower sections would be reduced, salinity concentrations in Cumbo Creek would continue to be affected by salts associated with the underlying Nile Subgroup which sub-crops in the mid-reaches of the Cumbo Creek catchment, upstream of the Project area. As a net result, however, salt loads in Wilpinjong Creek downstream of the Cumbo Creek confluence are expected to reduce. The long-term water and salt balance for the Project final voids is discussed in Section 6.

The proposed enhancement and conservation of the local creeks are discussed in Section 5, Volume 1 of the EIS.

5.4 Cumulative Surface Water Impacts

The Ulan Coal Mines are located approximately 11 km to the north-west of the Project, near the village of Ulan. The Ulan Coal Mines incorporate both underground and open cut mining areas and associated surface infrastructure including a CHPP, rail loop, rail loading and administrative facilities. The Ulan Coal Mines operate under a number of consents.

The Ulan Coal Mines are located in the Moolarben Creek/Goulburn River catchment which is outside of the Wilpinjong Creek catchment (Figure 1). Any cumulative surface water impacts would therefore relate to the Goulburn River downstream of the Wollar Creek confluence – i.e. downstream of both the Ulan Coal Mines and the Project. An assessment of the potential effects of the Project on flows in relation to the Goulburn River downstream of Wollar Creek confluence (Sections 5.2 and 5.3) concluded that the effects of flow reductions on the Goulburn River are expected to be indiscernible and a potential reduction in salt load would result. On this basis there would be no discernible increased or cumulative adverse impacts on the Goulburn River as a result of the Project.

It is noted that a 2 Mtpa underground mining operation comprising Underground Mine No. 4, a new CHPP, rail loop and train loading facility was approved in October 1985 as part of Stage 2 of the Ulan Coal Mines (hereafter referred to as Ulan Stage 2). The Underground Mine No. 4 and associated surface facilities that comprised part of Ulan Stage 2 were not developed at that time. Other components of Ulan Stage 2 were however developed (i.e. the Stage 2 open cut and Underground Mine No. 3 commenced in the 1980's [Kinhill, 1998]) and form part of the existing Ulan Coal Mines development. Approximately 60 ha of Underground Mine No. 4 underlie the Wilpinjong Creek catchment. However all surface infrastructure associated with the Ulan Stage 2 as delineated in the *Ulan Coal Mines Stage 2 – Colliery Development and Expansion Environmental Impact Statement* (Kinhill Stearns Engineers, 1983) is contained within the Moolarben Creek/Goulburn River catchment. On this basis, it is not expected that the Ulan Stage 2 would have any surface water impacts on Wilpinjong Creek and negligible effect on the Goulburn River.

6.0 ASSESSMENT OF SURFACE WATER IMPACTS - POST MINING

Two final voids would remain at the completion of mining, including a final void at the northern end of Pit 3 and another at the southern end of Pit 6 (Figure 15).

The principal water management issue for mine rehabilitation is the behaviour of the final voids, particularly the long-term water balance and likely salinity. The behaviour of the final voids was investigated using a water and salt balance model. The model was set up to simulate the long-term behaviour of the final voids using a sequence of approximately 700 years of daily rainfall which was formed by replication of the 116-year local data set (refer Section 4.1).

Inflows to the final voids would comprise incident rainfall over the void lake surface, runoff and seepage from the sides of the voids and runoff from their adjacent contributing catchment. In the longer term, it is anticipated that there would be groundwater inflows once groundwater levels in remnant coal measures down-dip recover and infiltration of seepage from the rehabilitated mine waste rock emplacement areas creates flow toward these voids.

Post recovery groundwater seepage rates and groundwater levels were estimated by AGEC (2005). Equilibrium (zero pit inflow) groundwater levels of 365 m AHD and 397 m AHD were estimated for Pits 3 and 6 respectively. Runoff inflows were estimated using the catchment model (incorporating the AWBM) to estimate yield from the rehabilitated areas that would drain to each void.

The salt concentrations in the voids were simulated by applying concentrations to inflows reflective of the salinity in the coal seam for groundwater inflows (2,000 mg/L total dissolved solids - TDS[5]) and indicative values for surface water runoff taken from regional monitoring data (200 mg/L TDS).

The results of these simulations indicate that the voids in both Pits 3 and 6 would slowly fill with water and in the long-term, water levels would approach an equilibrium level significantly below the spill level of the final voids. Model results indicate that that it would take over 300 years for water levels to reach equilibrium in the Pit 6 final void (which would be empty at the end of the 21-year Project life). The period of time to reach equilibrium in Pit 3 would depend on the water level contained in the final void at the end of mining as this pit may be used as water storage in the latter years of mining.

Once the groundwater recovery stabilises the overall groundwater gradient would be to the east-northeast, consistent with the existing groundwater conditions (Appendix B of the EIS). Any tendency for development of dryland salinity developing in the Project area would be mitigated by the proposed woodland revegetation presented in Section 5 of the EIS. In addition, due to the dominance of evaporation over rainfall in this region localised sinks (localised depressions in groundwater levels towards which there is a groundwater gradient) would form around the final voids in Pits 3 and 6 (Appendix B of the EIS).

[5] As stated in EGi (2005) *"… groundwater flux through the tailings disposal areas in the long term will be of a similar groundwater quality to that which exists in the Ulan Seam, provided that the following tailings management recommendations are implemented…"*

The salinity of void waters would slowly increase with time, as a result of the ongoing slow migration of saline groundwater. In the longer term, salt concentrations would also be affected by evapo-concentration. The simulated behaviour of the two voids is shown on Figure 18.

It is recommended that detailed planning and confirmatory void modelling be conducted prior to completion of mining and a Final Void Management Plan be developed as a component of the Mining Operation Plan.

7.0 RECOMMENDED SURFACE WATER MONITORING

The following recommendations are made for monitoring surface waters and the water management system:

1. Two gauging stations should be established on Wilpinjong Creek to enable quantification of low flows and changes in EC.

2. A comprehensive and auditable monitoring and reporting programme should be included in a SWMP. The SWMP should also document management procedures for water pollution control and the operation of the water management system. The SWMP should be updated periodically.

3. The baseline water quality monitoring programme should continue on Wilpinjong Creek, Cumbo Creek and lower Wollar Creek. Water sampling should be conducted during representative flow events. Samples should be collected and analysed, according to relevant Australian Standards, for pH, TDS and total suspended solids.

4. Operational water quality monitoring should be conducted. Monitoring should target all significant runoff events (ie. greater than 20 mm in 24 hours). Samples should also be collected from tailings disposal areas initially on a monthly basis and tested for pH and EC.

5. Water levels (reduced to a common datum) should be recorded in all on site water storages and tailings disposal areas on a monthly basis.

6. A predictive water balance model should be used to monitor the water balance performance of the Project and to inform planned upgrades or changes to the water management system.

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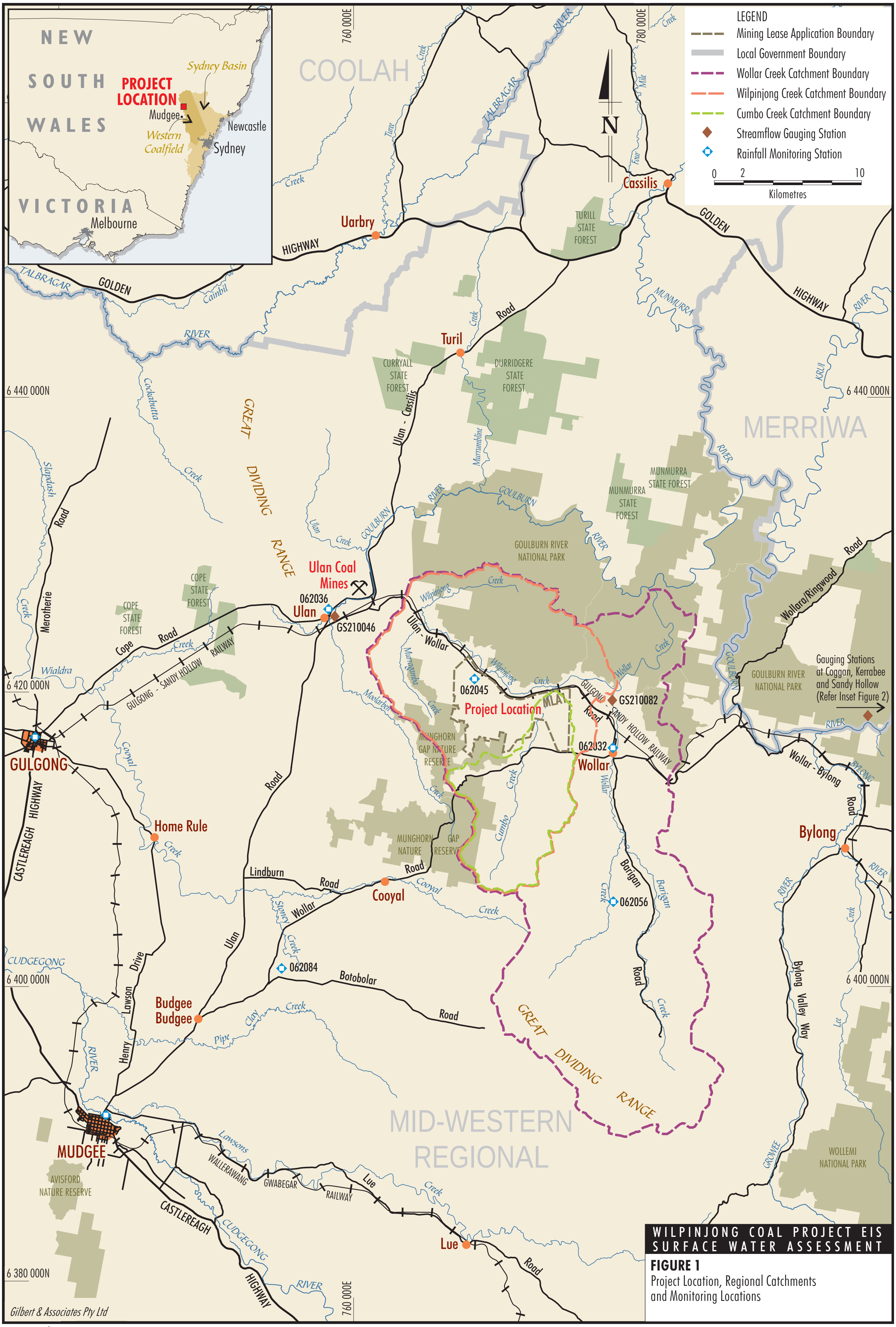
FIGURES



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SURFACE WATER ASSESSMENT

FIGURE 1
Project Location, Regional Catchments and Monitoring Locations

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GREATER WOLLAR CREEK CATCHMENT

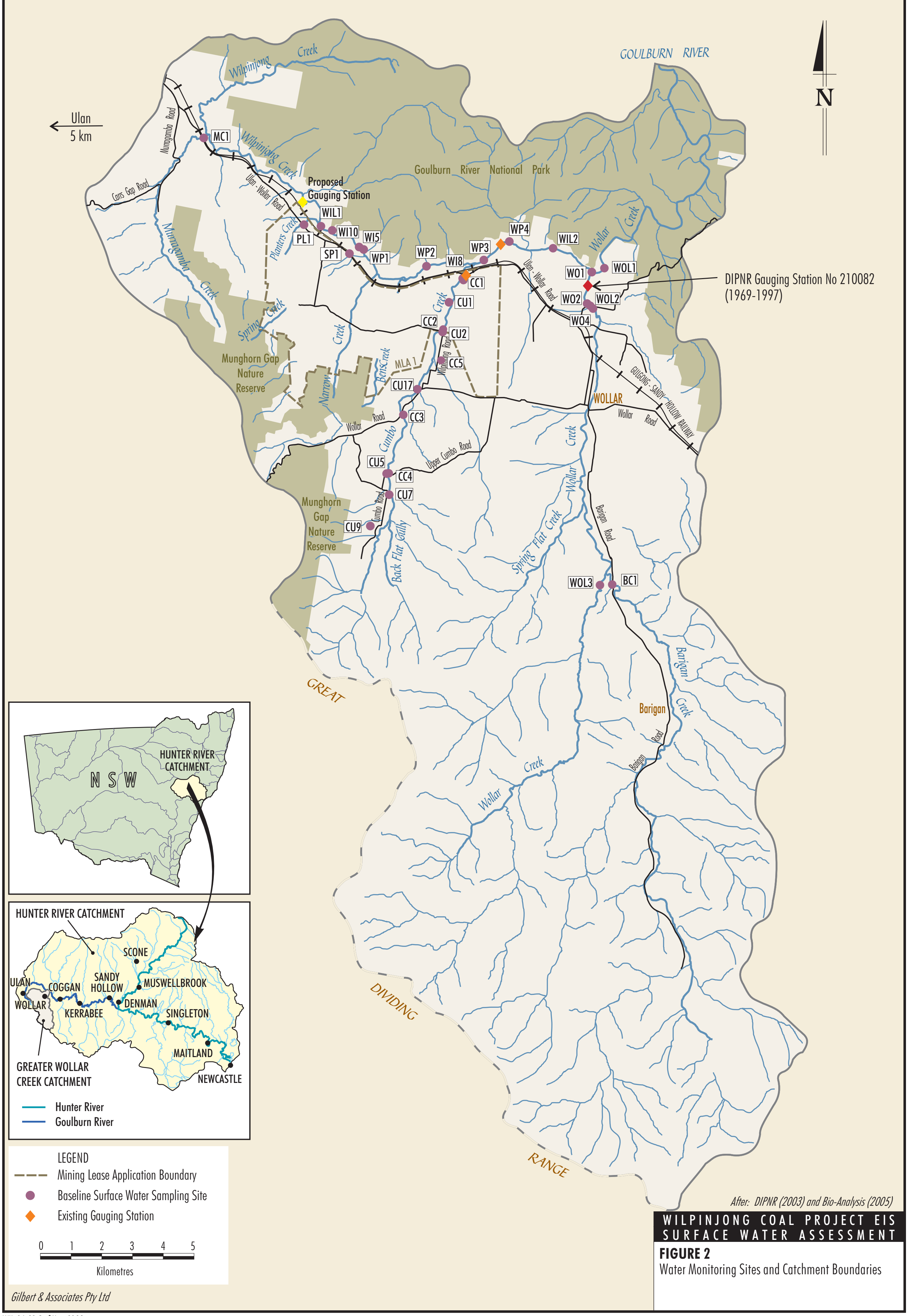

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FIGURE 2
Water Monitoring Sites and Catchment Boundaries

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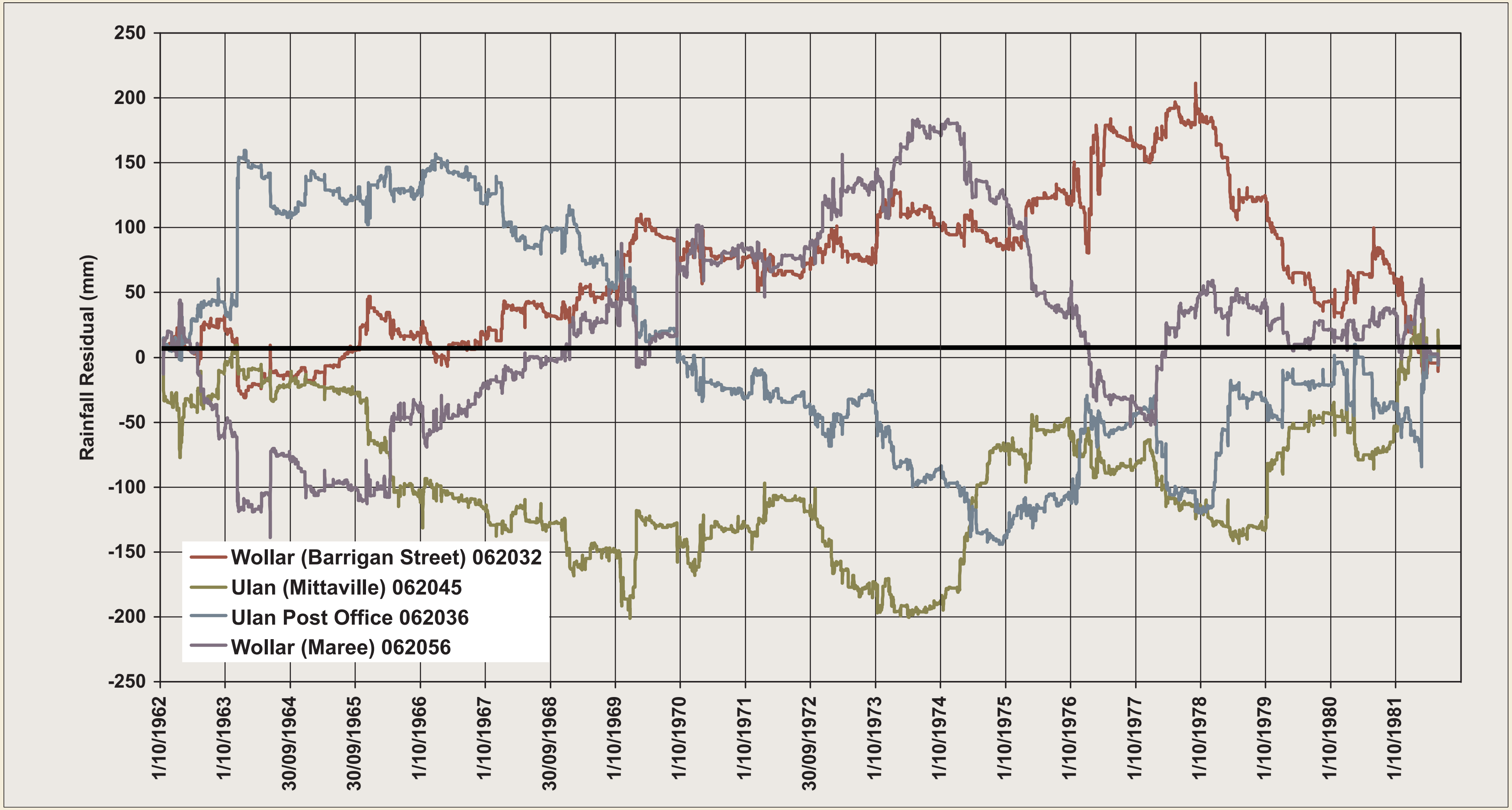

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FIGURE 3
Residual Rainfall Mass Curves
Local Stations

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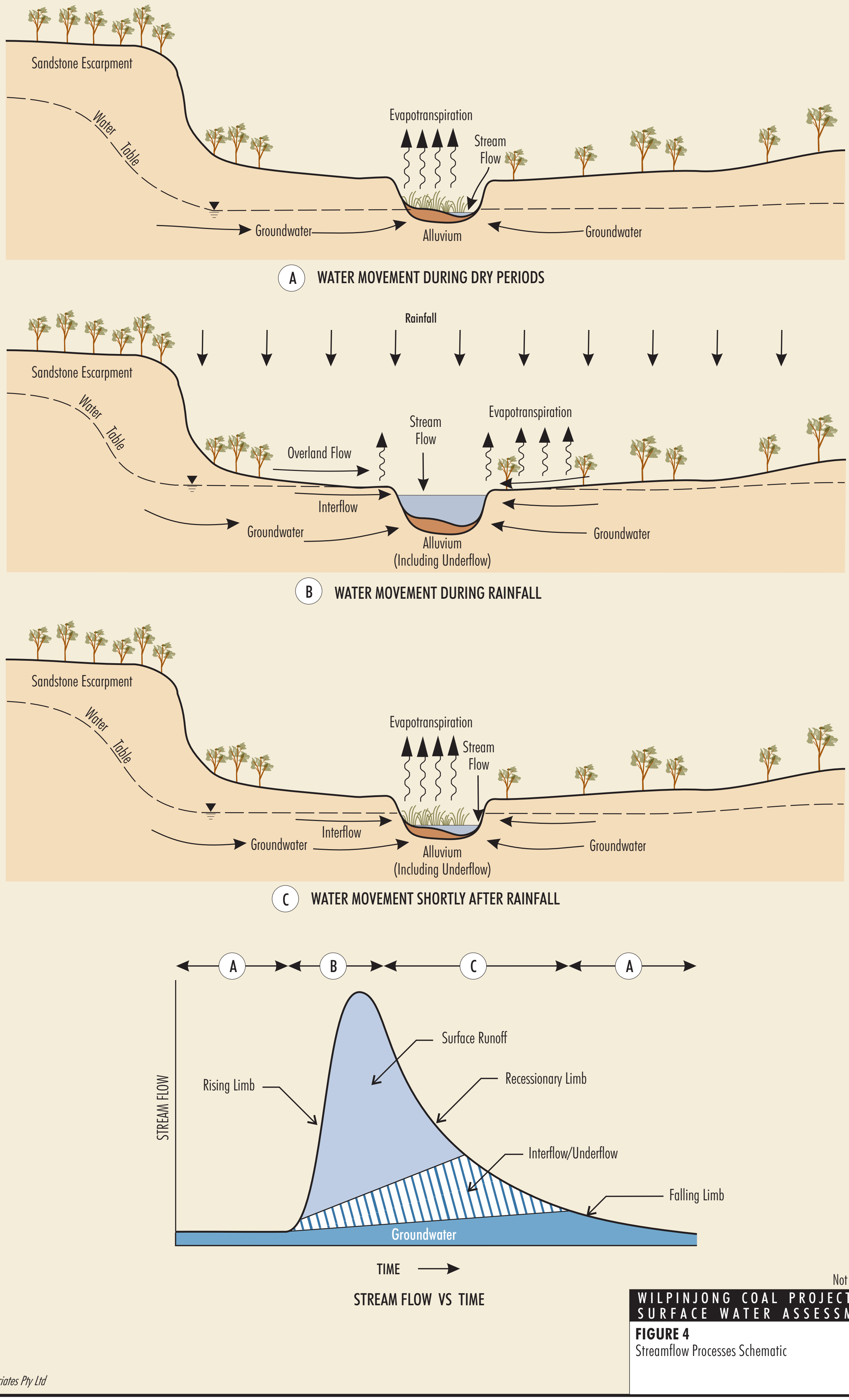

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FIGURE 4
Streamflow Processes Schematic

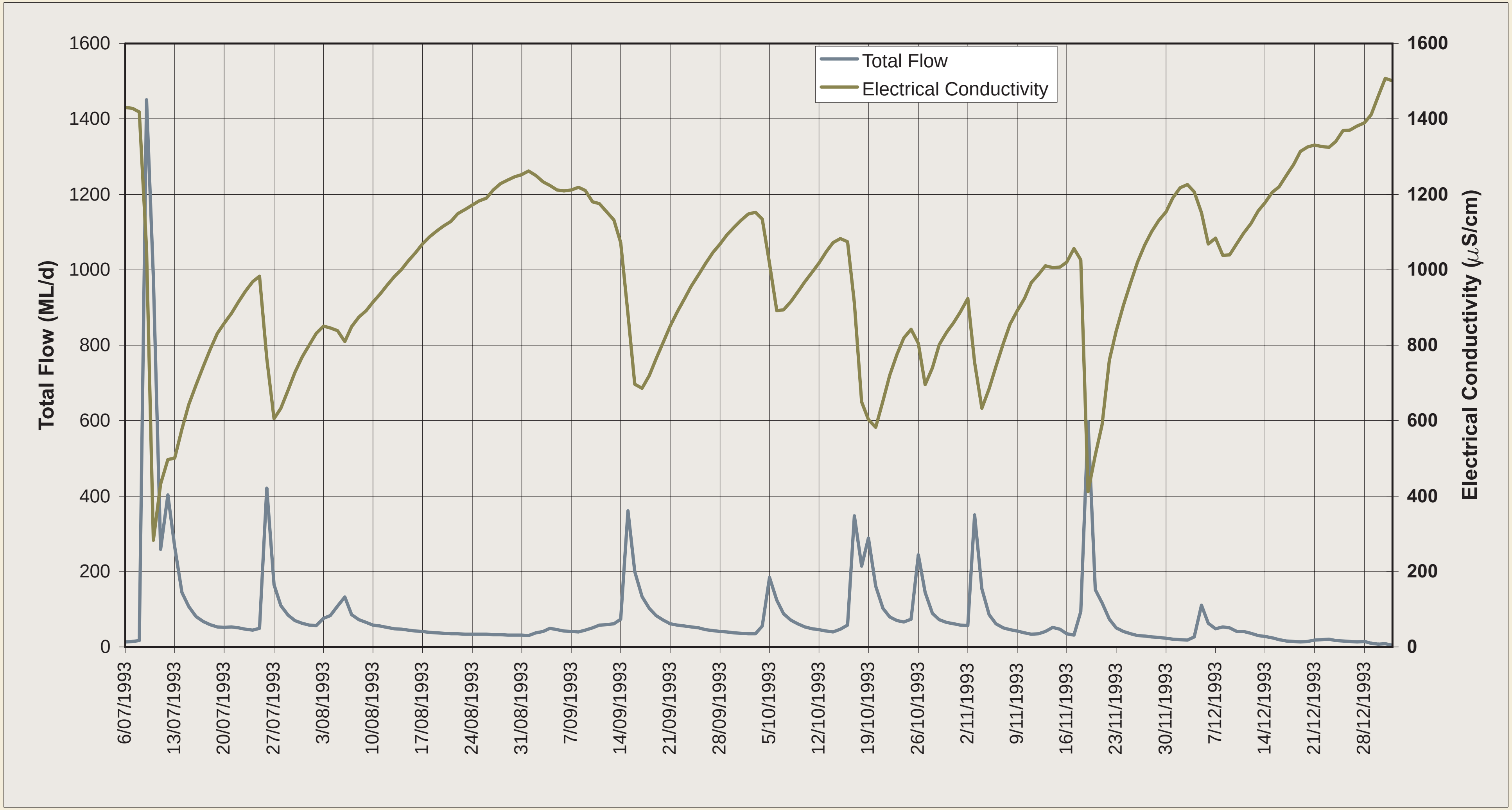

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FIGURE 5
Typical Salinity/Streamflow Characteristics
(Wybong Creek Gauging Station)

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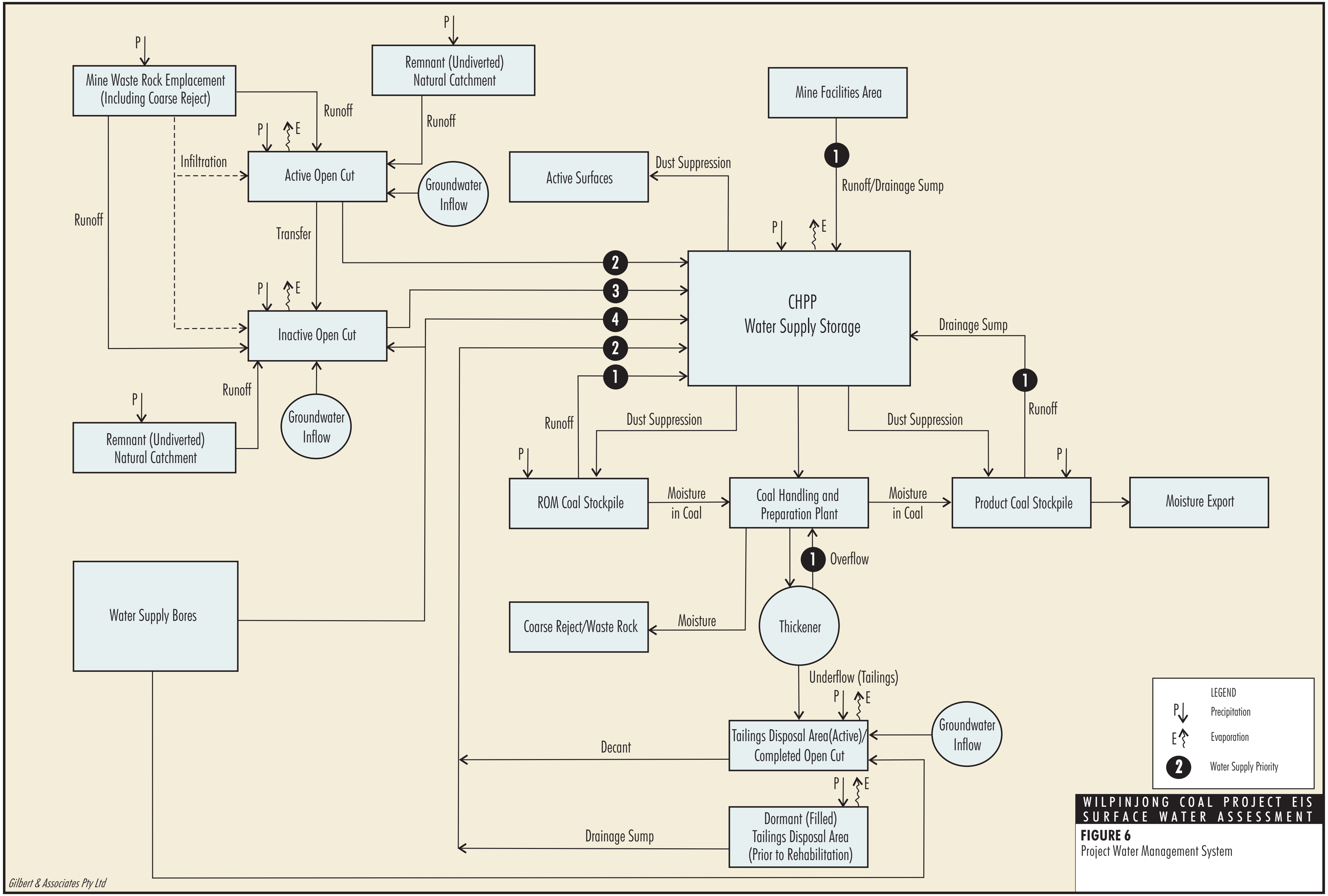

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FIGURE 6
Project Water Management System

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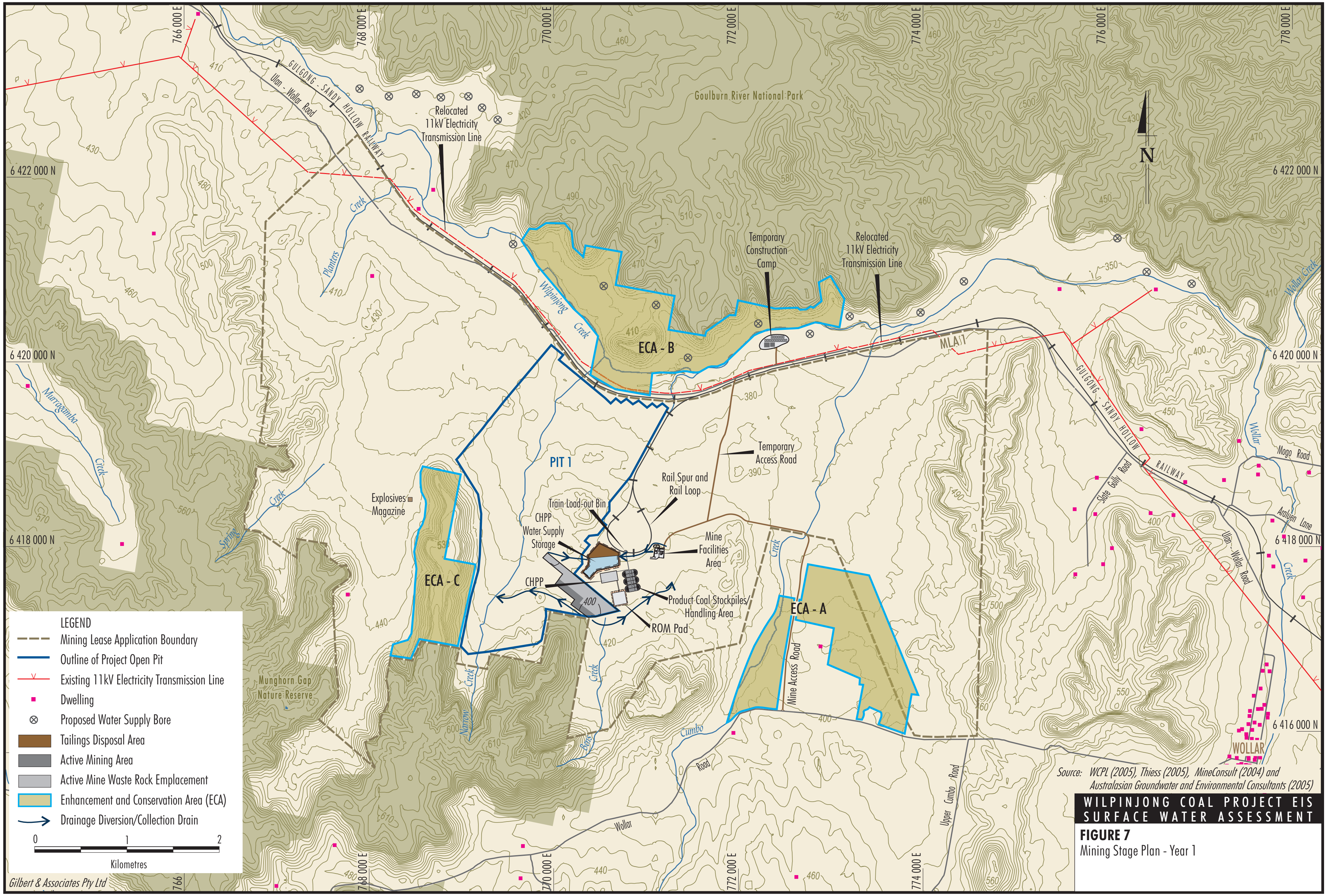

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FIGURE 7
Mining Stage Plan - Year 1

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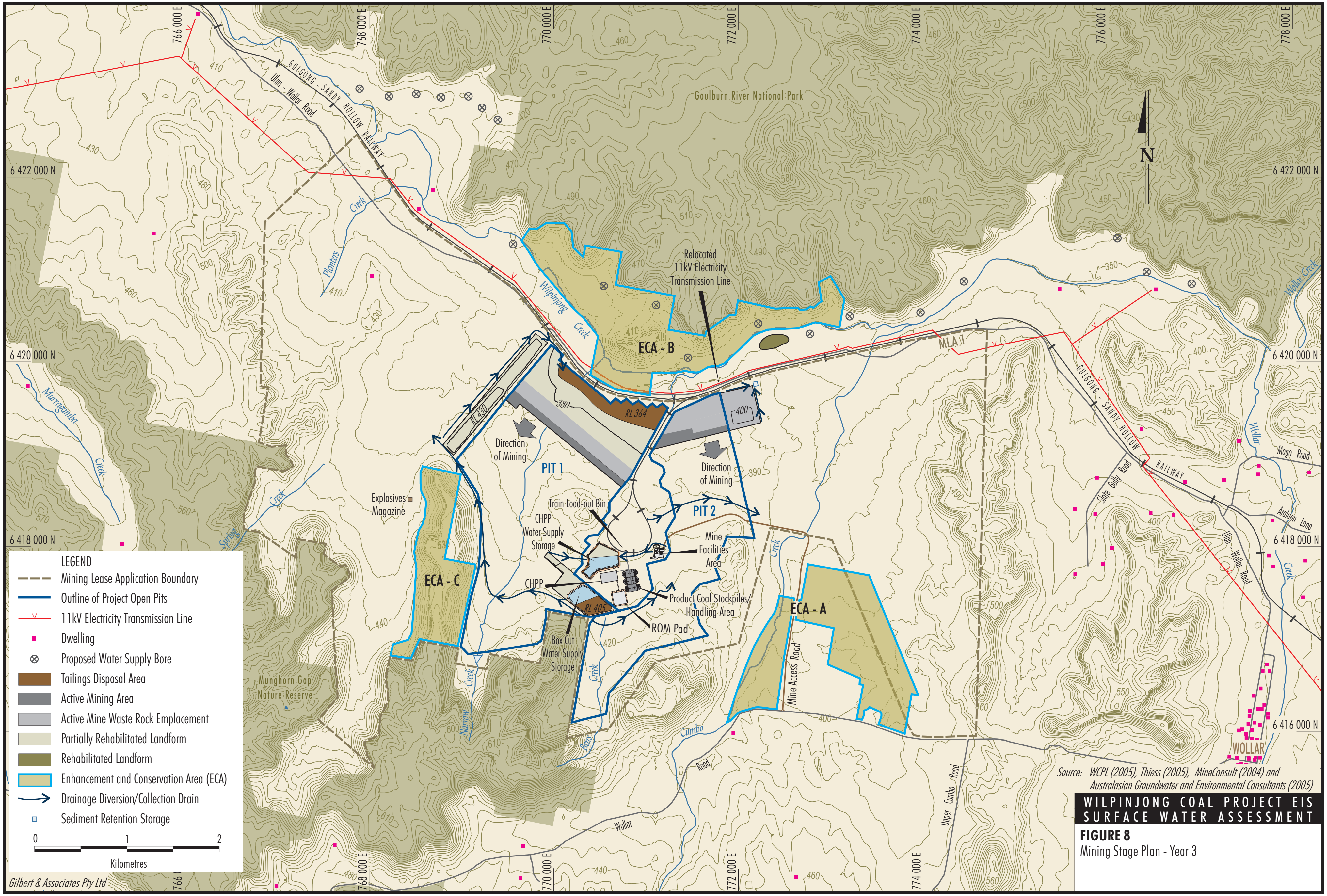

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FIGURE 8
Mining Stage Plan - Year 3

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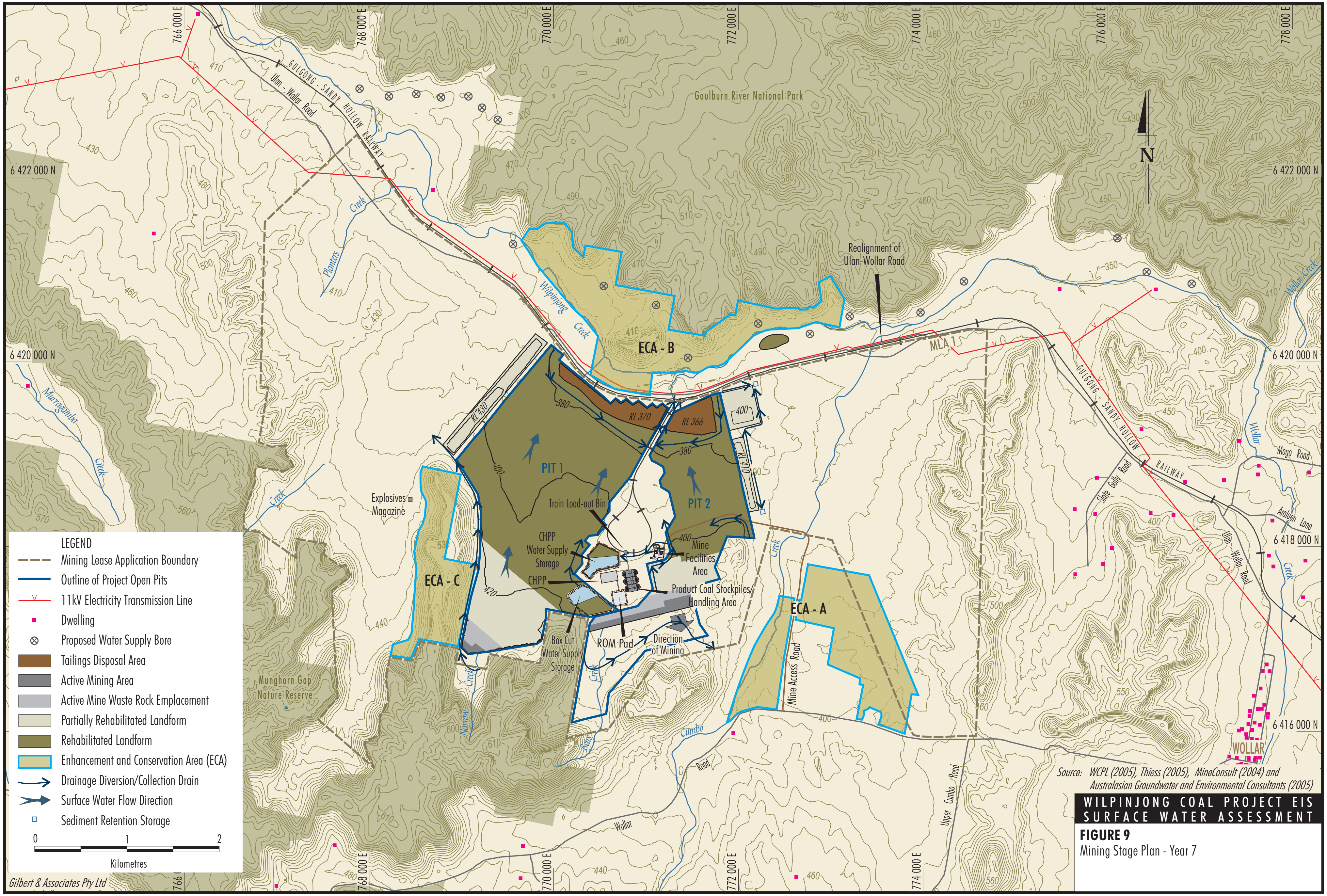

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FIGURE 9
Mining Stage Plan - Year 7

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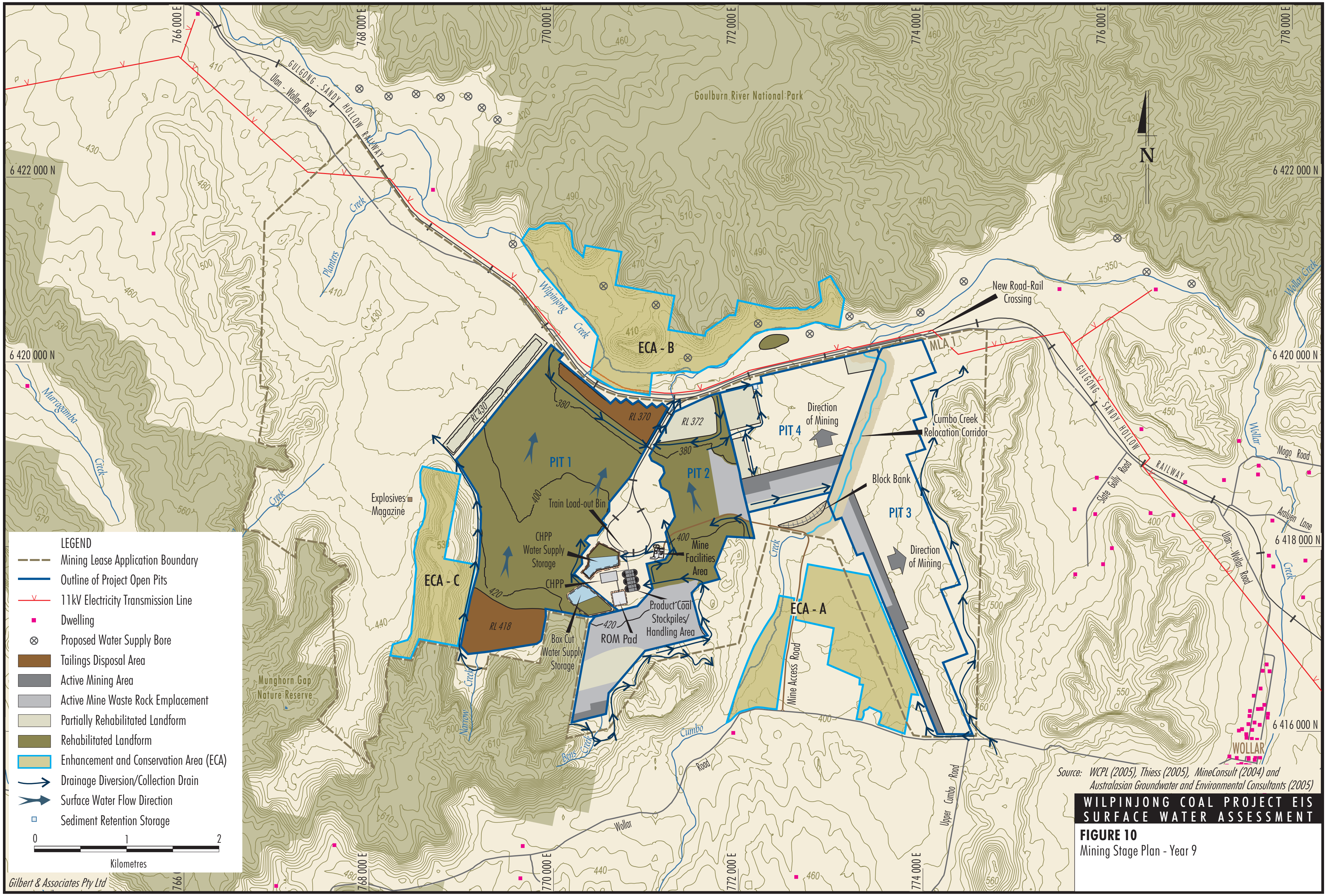

FIGURE 10
Mining Stage Plan - Year 9

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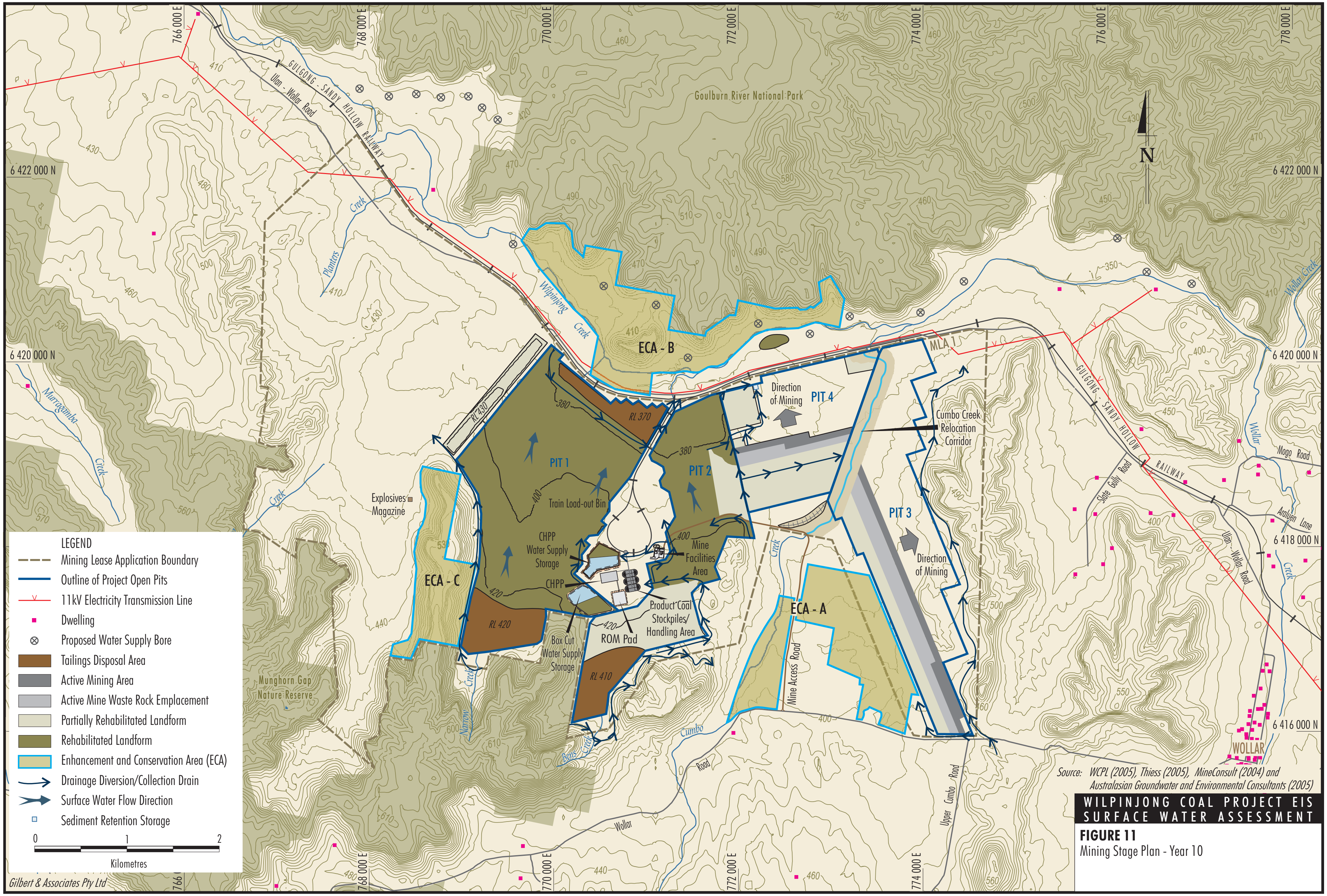

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FIGURE 11
Mining Stage Plan - Year 10

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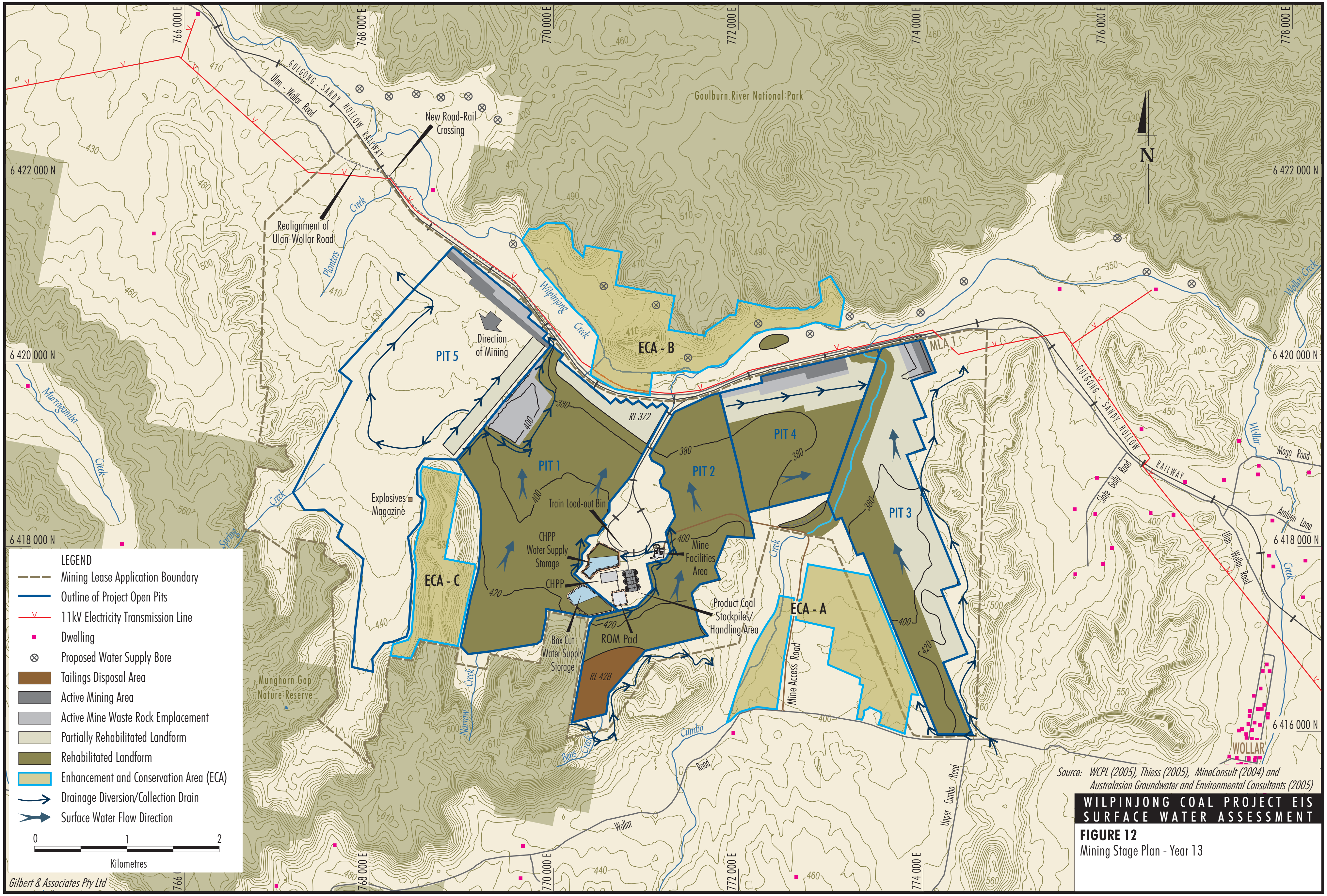

FIGURE 12
Mining Stage Plan - Year 13

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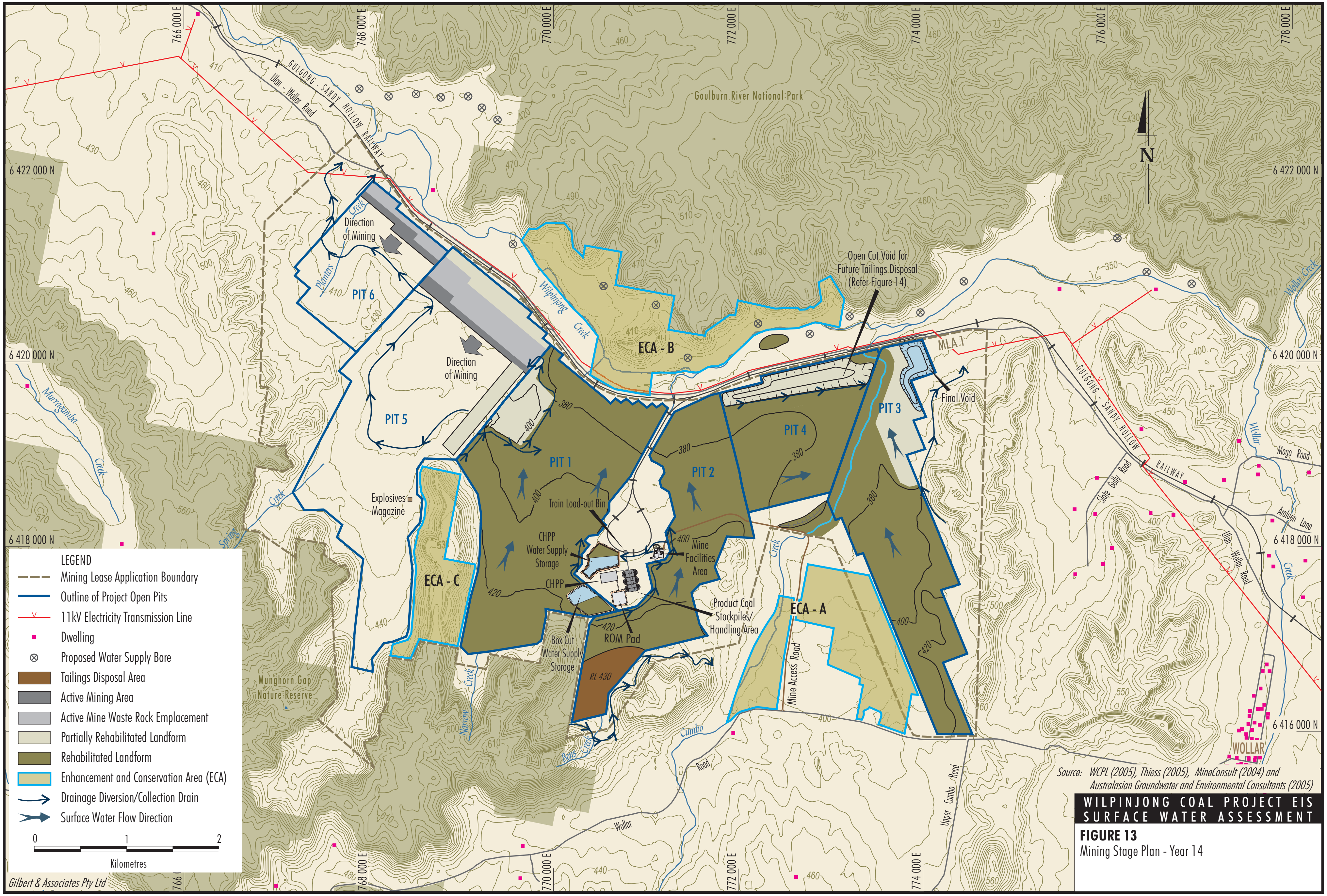

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FIGURE 13
Mining Stage Plan - Year 14

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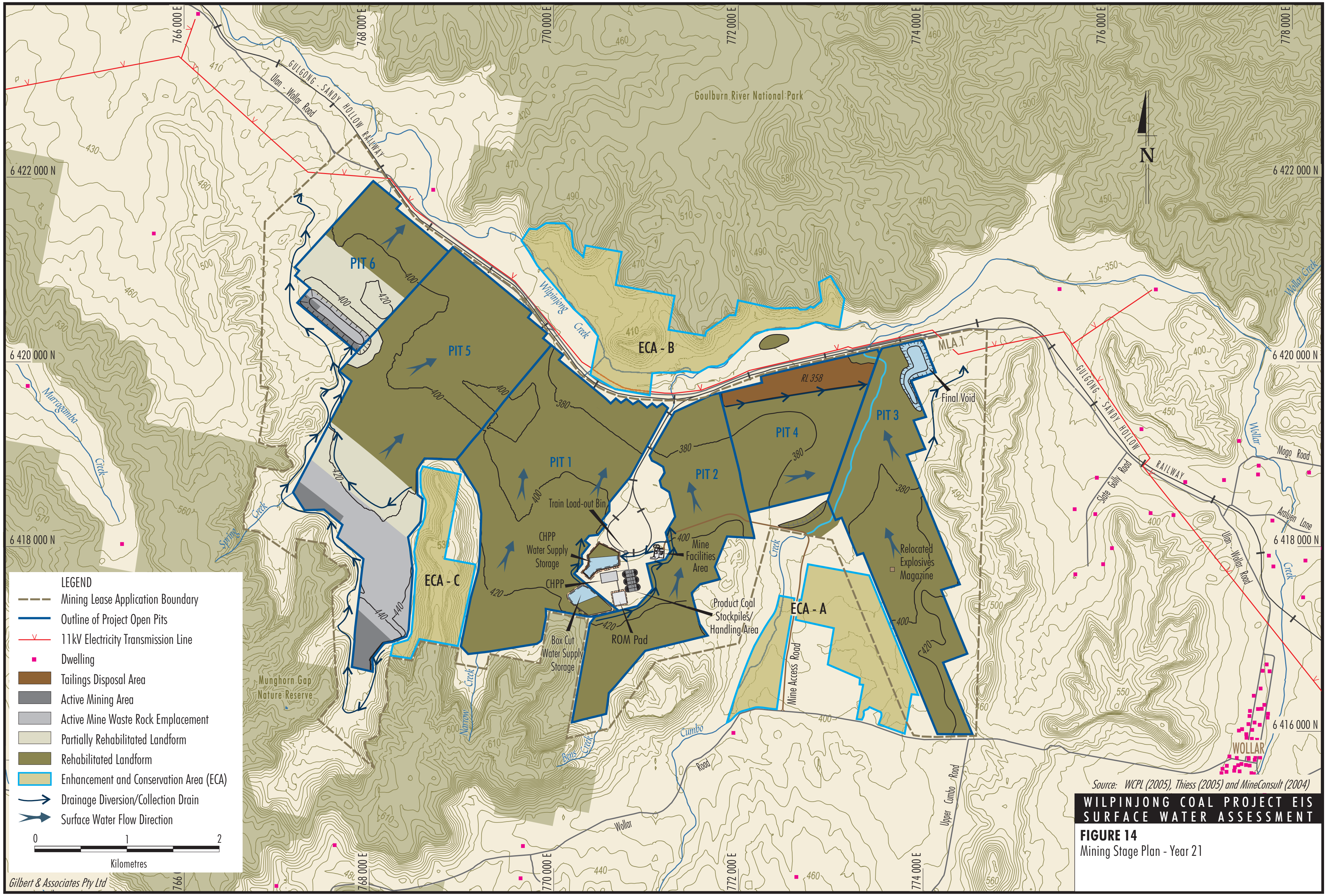

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FIGURE 14
Mining Stage Plan - Year 21

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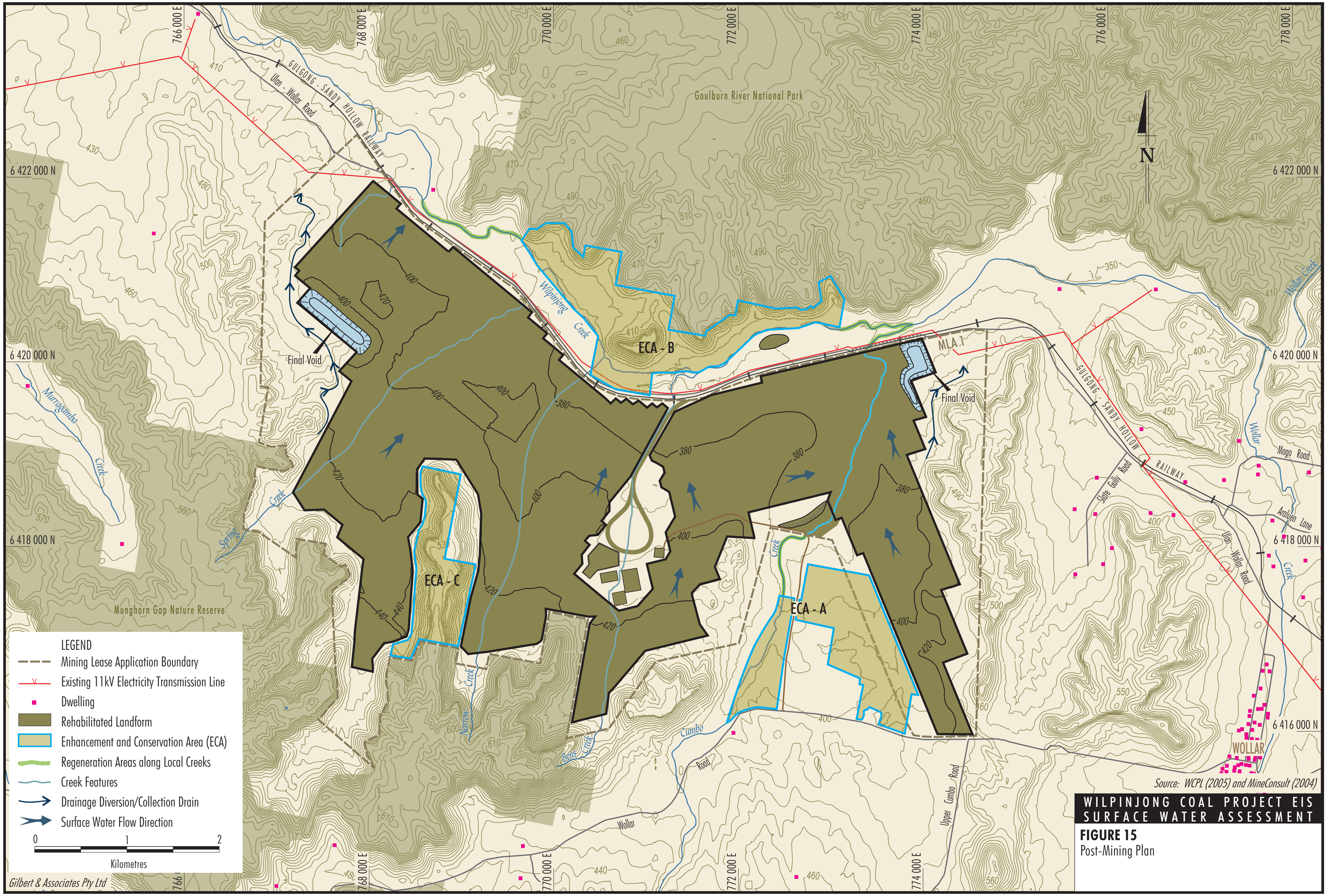

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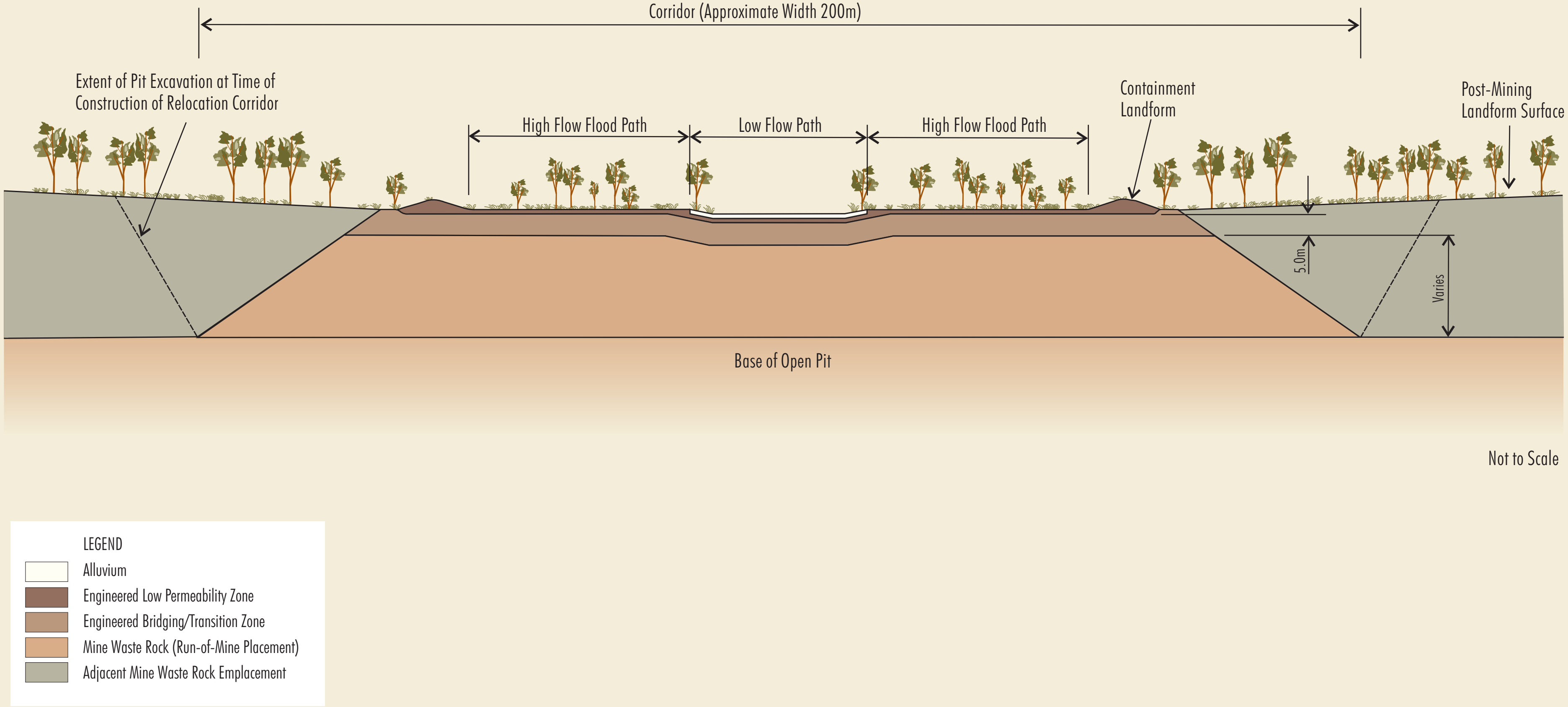

Source: Allan Watson Associates (2004)

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FIGURE 16
Cumbo Creek Relocation (Typical Section)

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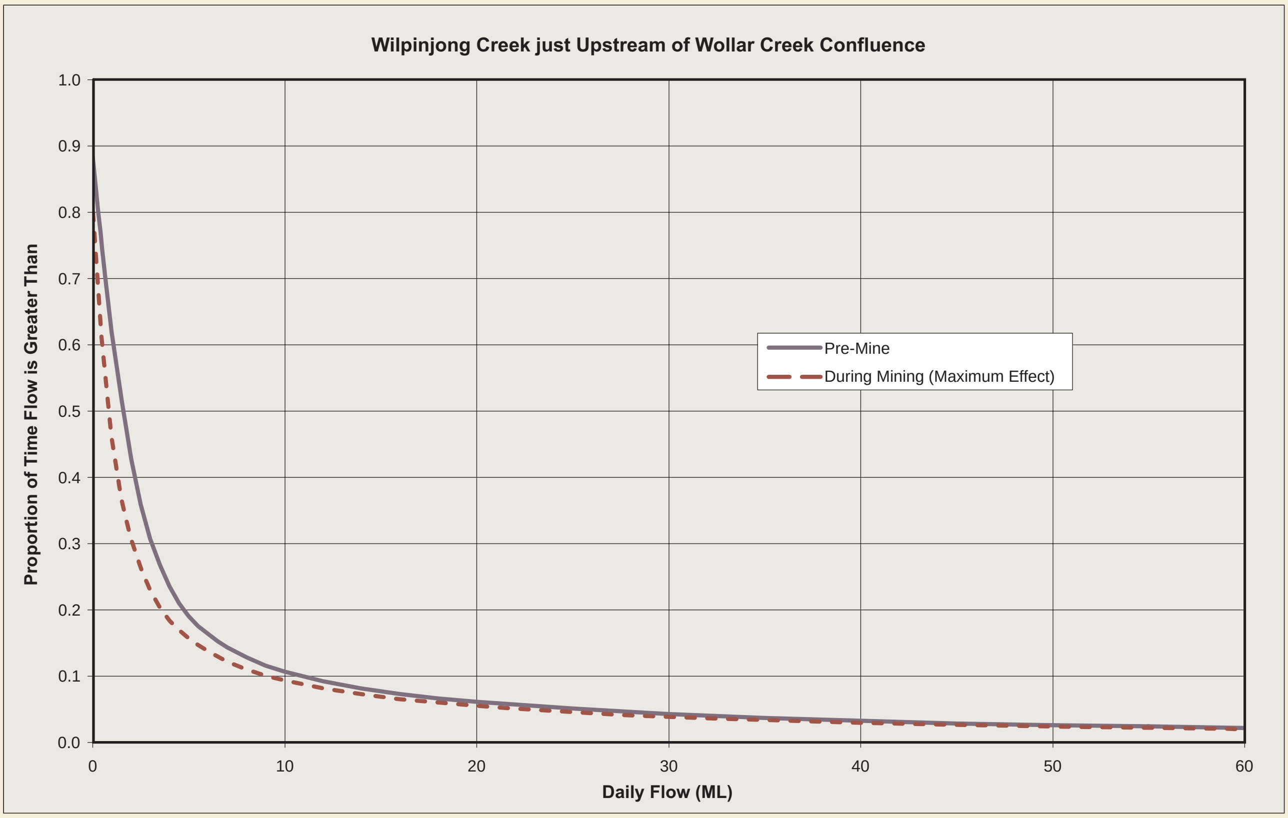

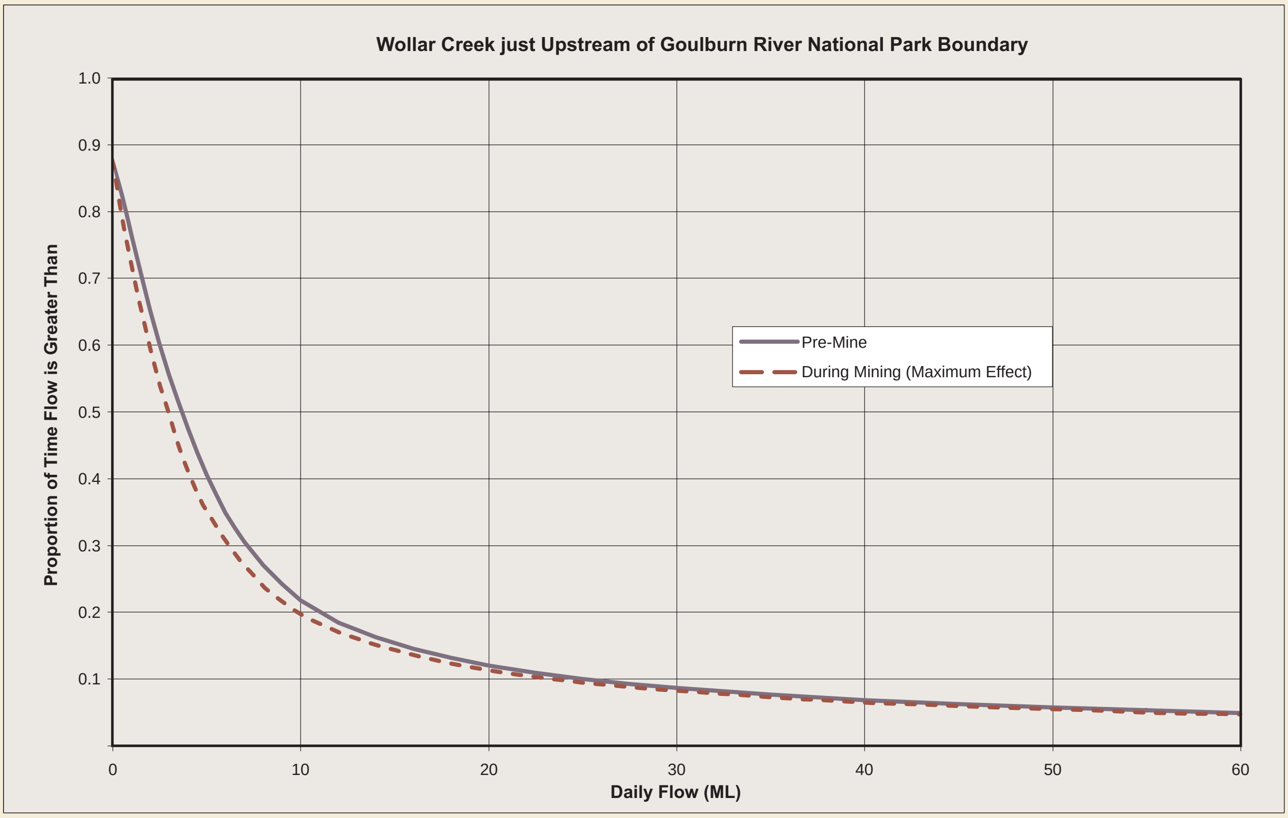

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FIGURE 17
Simulated Flow Duration Curves
Wilpinjong and Wollar Creeks

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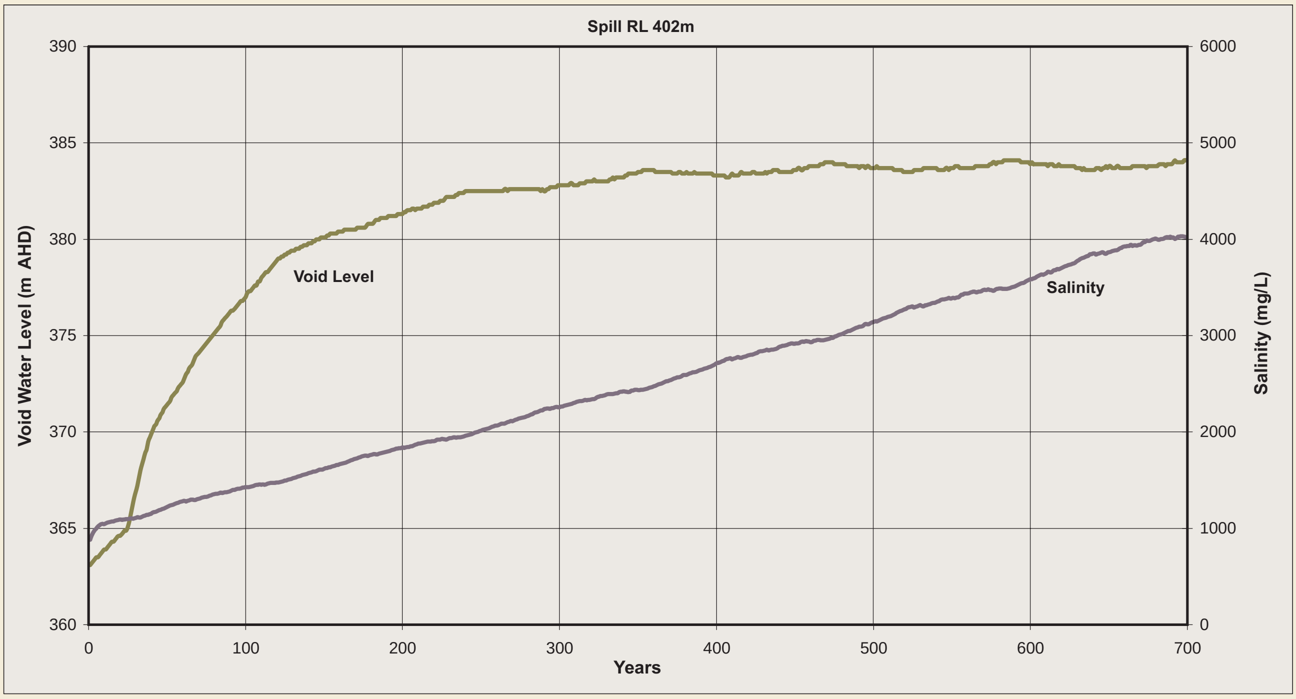
Pit 3



Pit 6

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FIGURE 18
Simulated Final Void Behaviour
Pit 3 and Pit 6

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ATTACHMENT 1

CATCHMENT MODELLING – GOULBURN RIVER AT ULAN AND WOLLAR CREEK AT WOLLAR

CATCHMENT MODELLING – GOULBURN RIVER AT ULAN AND WOLLAR CREEK AT WOLLAR

Hydrological models of Wollar Creek and the Goulburn River were set up and calibrated against observed rainfall and streamflow data. The models were then used to generate streamflow sequences using long period rainfall data to enable the estimation of long-term average flow behaviour in these watercourses.

The hydrological model used was the AWBM (Boughton, 1993). Calibration used gauged flow data for each stream – the longest period of uninterrupted data was extracted from each station's record. Coincident rainfall data from the nearest available Bureau of Meteorology rainfall stations was used in the calibration. Table A-1 provides a summary.

Table A-1
Gauging Station Data used in AWBM Calibration

Stream	Flow Data			Rainfall Data Stations
	Station No.	Period of Record	Calibration Period	
Wollar Creek Upstream Goulburn River	GS210082	1/5/1969-10/9/1997	1/6/1980-18/9/1991	Wollar (Barrigan St), Wollar (Maree)
Goulburn River at Ulan	GS210046	9/3/1956-10/9/1997	1/12/1973-31/8/1982	Ulan Post Office, Budgee Budgee (Botobolar Vineyard)

Recorded pan evaporation data from Wellington (Station No. 65035 – located 90 km west south-west) and Scone (Station No. 61089 located 100 km east north-east) were also used in the model calibration (these are the nearest Bureau of Meteorology stations with significant periods of evaporation record). Recorded pan evaporation data were adjusted by multiplying by 0.7 – this factor was developed as part of model calibration and by comparing the records from the above two stations with that from Kerrabee (Station No. 62046) – which is located 40 km east of Wilpinjong, in similar terrain, with an effective continuous period of record of three years.

Model calibrations are shown graphically in Figures A-1 and A-2.

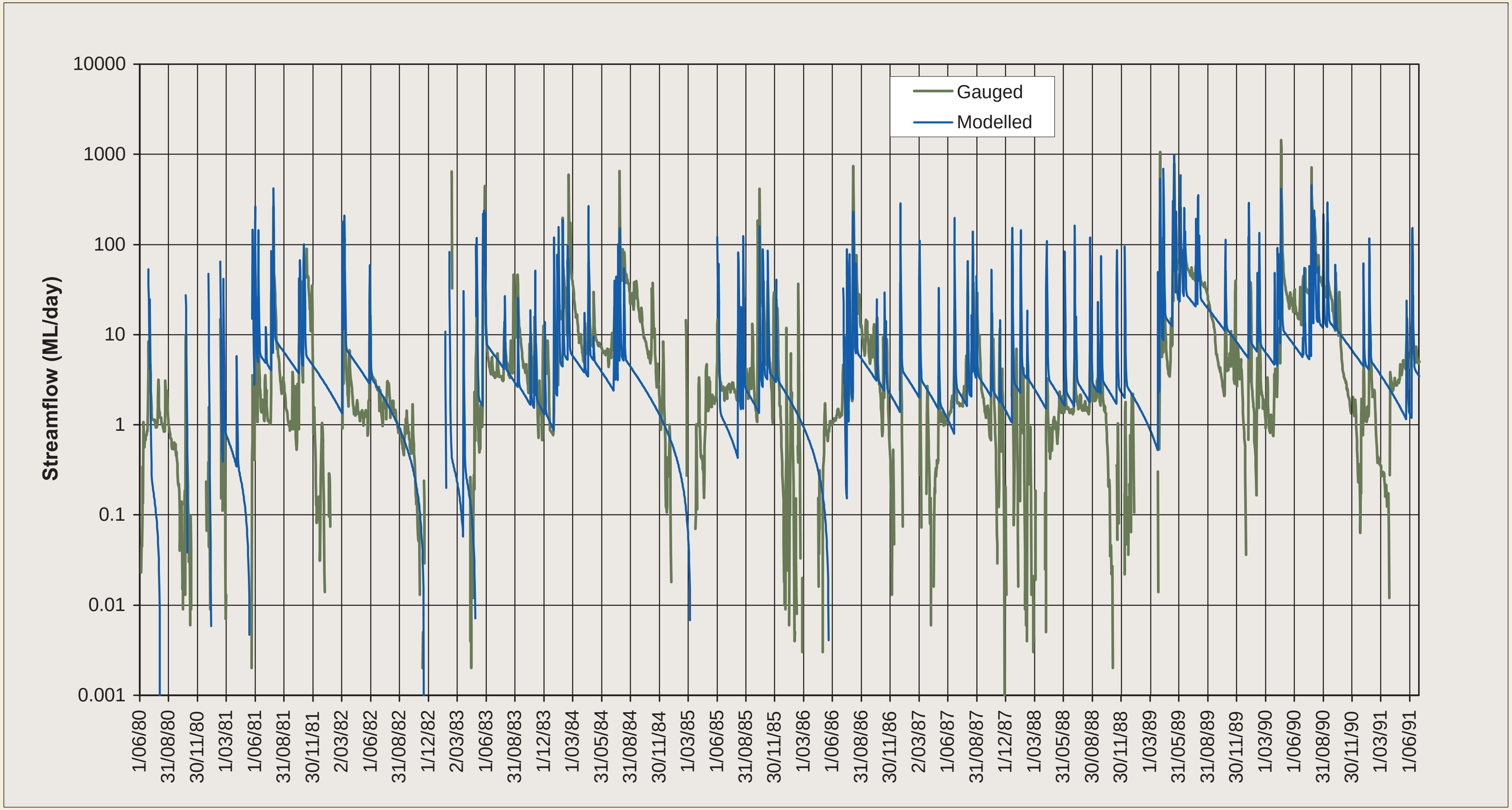

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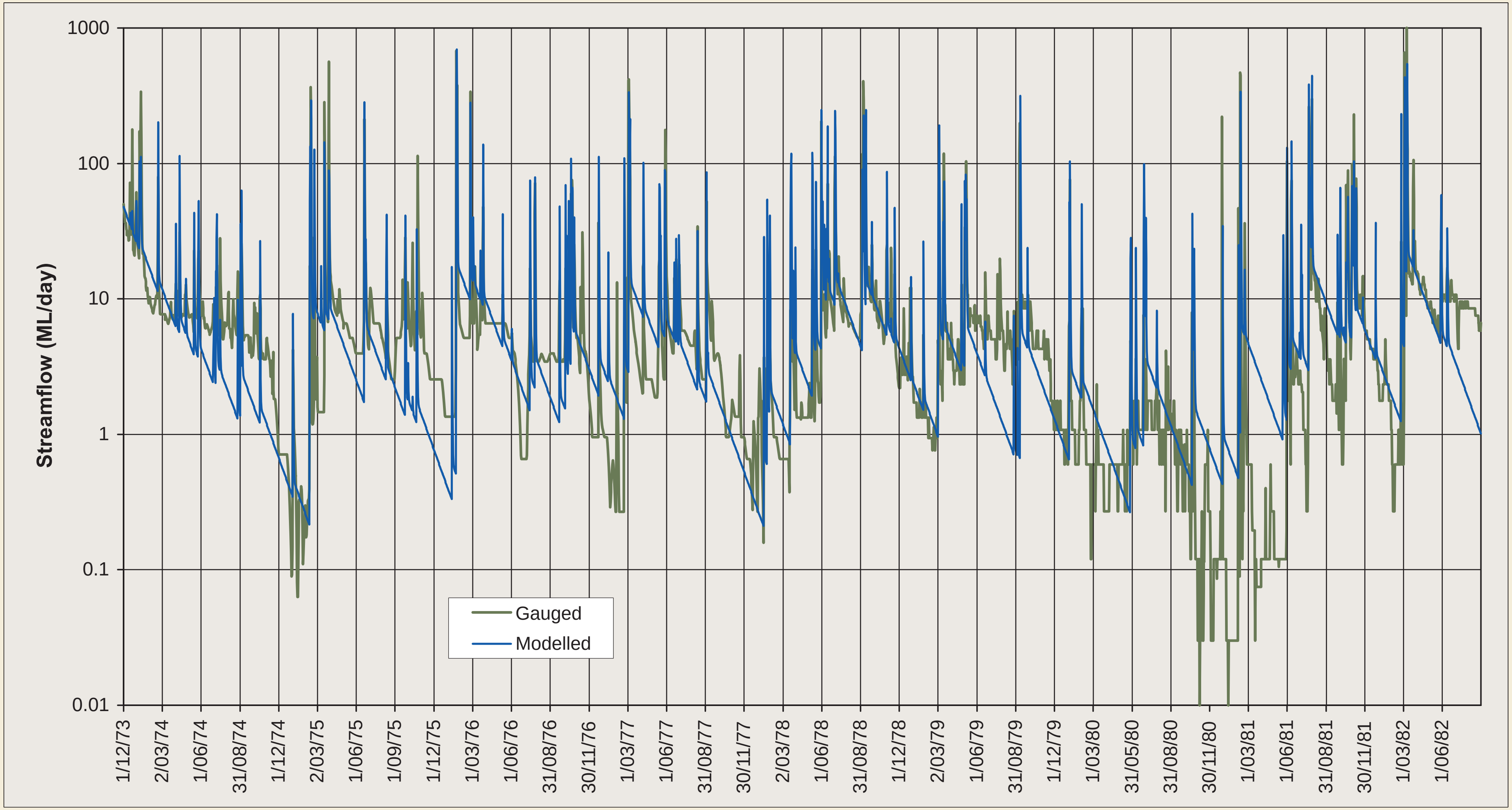
FIGURE A-1
Wollar Creek at GS210082
AWBM Calibration



WILPINJONG COAL PROJECT EIS
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FIGURE A-2
Goulburn River at GS210046
AWBM Calibration

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