Department of Planning & Infrastructure

NRE No 1 Colliery Project

Review of Surface Water Assessments

June 2013

Page intentionally left blank for double sided printing

Summary

This review has been prepared to advise the NSW Department of Planning and Infrastructure in relation to matters relating to the impact of the NRE No 1 Colliery Project on the surface water regime. The project would involve longwall mining in two domains; the Wonga East domain located to the east, and within the catchment, of Cataract Reservoir and the Wonga West domain located to the south of Cataract Reservoir. The catchments that overly the Wonga West domain drain to the Cataract River downstream of the reservoir. All catchments that are potentially affected by the project have significant areas of upland swamps, some of which have been assessed as having special ecological significance.

This review takes account of a range of detailed reports that support the Environmental Assessment for the project including those relating to subsidence, surface water hydrology, groundwater and the upland swamps on the surface of the land overlying the proposed longwall mining; as well as the facilities for water management at the pit top (Russell Vale) and the mine access at the No 4 Shaft.

The detailed reports that form the appendices to the Environmental Assessment each deal with specific subject matter but suffer from a lack of strong linkages that reflect the reality of the pathways and interactions between flows in the creeks, the water regime in swamps and groundwater in the sandstone aquifer. The reports also deal with individual hydrologic elements (swamps, pools, creeks and groundwater) in isolation, rather than as parts of an interconnected system. The assessment would benefit from a more holistic view of the surface water system including the use of a common basis for reference to locations along each creek and a naming convention for swamps which differentiated their hydrologic role (headwater or valley fill) as well as their catchment location.

The key risk to the surface water regime within the catchment overlying the proposed longwall mining area is associated with cracking of the surface rocks leading the potential for drainage from the creeks and swamps. The reports acknowledge that previous longwall mining in the Wonga West domain has led to identifiable cracking in the bed of some creeks and diversion of flow. However, given that many swamps were undermined decades ago, and there do not appear to be any contemporaneous records of swamp conditions at the time, the claim that there were "*no observable adverse effects on stream/swamp flow, water quality or ecosystem health*" needs to be recognised as a judgement based on current conditions rather than before and after observations.

The assessment of potential impacts due to tensile cracking under swamps focusses on swamps that are deemed to be of ecological significance and overlooks the potential for subsidence impacts to also affect other swamps that may play an important role in the surface water hydrology and the maintenance of baseflow to support in-stream ecology.

The assessment of potential impacts of mine subsidence on the flow regime in the creeks is based on calibration of daily rainfall:runoff models using recorded flows from two nearby catchments (Loddon River and Bellambi Creek) that drain to Cataract Reservoir. The data shows that, despite their close proximity to each other and apparent similarities in catchment characteristics, these catchments have very different yield (expressed as a percentage of incident rainfall). No explanation is provided for this difference and no justification is provided for adopting the characteristics from the catchment with the highest percentage runoff (Loddon River) for purposes of assessing potential impacts of the project on flow from Cattai Creek, Lizard Creek and Wallandoola Creek. Although flow records exist for about three years at a location on Lizard Creek (LC3) no attempt has been made to use these records to verify the applicability to Lizard Creek and Wallandoola Creek of the model parameters derived from the longer term records for Loddon River.

In the absence of any quantitative estimates of the location or severity of subsidence induced loss of water from the swamps or creeks, the possible significance of losses have been assessed based on examining the impact of a range of possible loss rates on the overall water yield of the catchments. This approach is legitimate and provides a useful indicator of the effect of possible losses on overall water yield of the catchments. However, the analysis fails to explore the impact of such losses on the low from regime and the potential impacts on in-stream characteristics or pools drying out.

The *Stream Assessment* reports provides an overview of the water quality monitoring program that has been implemented progressively. A range of relevant parameters have been monitored at a number of sites within each catchment. The assessment provides an overview of key statistics but lacks details (e.g. tables of data in an appendix) or an assessment of any proposed water quality 'trigger' values for the project that might differ from the default values provided in the ANZECC Guidelines.

The existing water management system at the Russell Vale pit top area has been developed over many decades. The project proposes to provide a better co-ordinated management system and to upgrade a number of facilities. A key aspect of the proposed upgrades is clearer separation of catchments with different potential for pollution of surface runoff. In general these proposals are reasonable and could be expected to significantly improve the control of flow and quality of site discharge. However, further consideration is required in relation to:

- The justification for provision of '*first flush*' collection of runoff from the workshop, mine portal and hardstand area. This area has numerous pollutant sources including mud, coal dust and hydrocarbons. The effectiveness of any '*first flush*' system to treat runoff from this area is dependent on the capacity of the first flush storage basin and the details of the inlet/outlet arrangements. These are not provided. The risk of stormwater pollution from this area would be significantly reduced if runoff was directed into the 'dirty' water system that treats runoff from the conveyor belt portal and the coal stockpile area.
- Justification for treating large areas within the site as '*clean*'; from which stormwater can be discharged into the Southern Stormwater Channel without treatment. These areas are primarily described as '*laydown areas*' but there is no guarantee that potential pollutant sources would not be stored in these areas. While the proposed site upgrades include provision of an '*energy dissipater and settlement area*' at the end of the Southern Stormwater Channel (prior to discharge into Bellambi Gully), the adequacy of this system for pollution control has not been demonstrated.

The *Water Management Report* provides an assessment of the water requirements for mine operations and an indicative water balance for under current conditions and at two stages in the future. The basis of the groundwater inflow to the workings is not clear. In addition, the water balance assessment appears to have overlooked the return of water provided for operation of the underground mining machinery. If this return of process water is taken into account, it is likely that the mine would have an excess of water and my require additional water treatment capacity to cater for peak requirements when stormwater from the coal stockpile, conveyor belt portal (and workshop/mine portal?) requires treatment before discharge.

The No 4 Shaft facility is located within the catchment of Lizard Creek and is therefore within a Sydney drinking water catchment. Wastewater from the bath-house and amenities is treated in two separate systems; 'grey' water is ultimately treated for re-use while treated effluent from the 'black' water stream is irrigated onto a defined effluent disposal area. The analysis of the adequacy of the wet weather storage and area required for effluent irrigation lacks the detail required for a facility of this size, particularly one that is located within a drinking water catchment.

Table of Contents

1 Introduction i

1.1 Background i

1.2 Previous Mining ii

1.3 Review Documentation ii

1.4 Scope iii

2 Wonga East iv

2.1 Catchment and Creek Characteristics iv

2.1.1 Cataract Creek iv

2.1.2 Cataract River 6

2.1.3 Creek Cross Sections 6

2.2 Hydrology 7

2.2.1 Rainfall - Runoff Estimation 7

2.2.2 Potential Impacts on Cataract Reservoir 10

2.2.3 Baseflow from Swamps 11

2.2.4 Groundwater Baseflow 12

2.3 Pools 12

2.3.1 Distribution 12

2.3.2 Pool Water Levels 13

2.4 Waterfalls 13

2.5 Swamps 13

2.5.1 Distribution 13

2.5.2 Potential Impacts 16

2.6 Water Quality 17

3 Wonga West 19

3.1 Catchment and Creek Characteristics 19

3.1.1 Lizard Creek 19

3.1.2 Wallandoola Creek 20

3.1.3 Channel Cross Sections 21

3.1.4 Comment 22

3.2 Climate and Hydrology 22

3.2.1 Surface Runoff ... 22
3.2.2 Baseflow from Swamps ... 23
3.2.3 Groundwater Baseflow ... 23
3.2.4 Potential Impacts of Mining ... 23
3.3 Pools ... 25
3.3.1 Distribution ... 25
3.3.2 Pool Water Levels ... 26
3.3.3 Subsidence Impacts ... 26
3.4 Waterfalls ... 26
3.5 Swamps ... 27
3.5.1 Distribution ... 27
3.5.2 Potential Impacts ... 29
3.6 Water Quality ... 30
4 Water Management at Mine Facilities ... 32
4.1 Russell Vale ... 32
4.1.1 Overview ... 32
4.1.2 Stormwater Management ... 32
4.1.3 Process Water Requirements and Supply ... 35
4.1.4 Site Discharge ... 37
4.1.5 Flow and Flooding ... 38
4.2 No 4 Shaft ... 38
4.2.1 Overview ... 38
4.2.2 Wastewater Treatment and Disposal ... 38

List of Figures

Figure 2.1: Cataract Creek Wonga East Area 2 Stream Monitoring Sites
Figure 2.2: Cross Sections of Cataract Creek and Cataract River
Figure 2.3: Mean Annual Rainfall Distribution
Figure 2.4: Flow Duration Curves for Bellambi Creek and Loddon River
Figure 2.5: Impact of Catchment Loss on Cataract Reservoir Dry Period Stored Water Volume
Figure 3.1: Cross Sections of Lizard Creek and Wallandoola Creek
Figure 3.2: Impact of Losses on Flow Frequency Curve – Lizard Creek and Wallandoola Creek
Figure 4.1: Catchment Designations within the Russel Vale Site
Figure 4.2: Wonga East (27 Cut through) Groundwater Extraction and Rainfall

List of Tables

Table 2.1: Modelled Cataract Creek Stream Flow Changes

Table 2.2: Wonga East Swamps Previously Affected by Mining

Table 2.3: Swamps Located Above Mining or of Potential Significance in the Wonga East Area

Table 3.1: Modelled Lizard and Wallandoola Creek Stream Groundwater Baseflow Changes

Table 3.2: Effect of Assumed Baseflow Loss on Flow Frequency in Lizard Creek and Wallandoola Creeks

Table 3.3: Wonga West Swamps Previously Affected by Mining

Table 3.4: Swamps Located Above Mining or of Potential Significance in the Wonga West Area

Table 4.1: Summary of Catchment Characteristics and Proposed Stormwater Improvements

Table 4.2: Modelled Groundwater Inflow Rates (ML/day)

Page intentionally left blank for double sided printing

1 Introduction

This review has been prepared to advise the NSW Department of Planning & Infrastructure in relation to matters relating to the impact of the NRE No 1 Colliery Project on the surface water regime including:

- The adequacy of Environmental Assessment and any subsequent responses on behalf of the proponent;
- The suitability and scope of the assessment methodology / modelling / consultation;
- Identifying gaps in the documentation and analysis that may prevent a proper assessment of the proposal;
- The consistency of analysis and reporting between the various reports that address different aspects of subsidence and water in the environment;
- The significance of impacts and key environmental risks.

1.1 Background

Gujarat NRE Coking Coal Pty Ltd (Gujarat) proposes to mine a total of 16 longwall panels in the Wongawilli Seam located in two domains:

- **Wonga East** domain comprising nine longwall panels located within the catchment of, and immediately to the southeast of, Cataract Reservoir. Proposed mining includes three 105 m wide panels located southeast of Mt Ousley Road (Wonga East Area 1) and eight 150 m wide panels located adjacent to or immediately under Cataract Creek to the northwest of Mt Ousley Road (Wonga East Area 2). Two longwall panels in this domain (Longwalls 4 and 5 are the subject of a separate application and extraction commenced in 2012).
- **Wonga West** domain comprising seven longwall panels to the west of Cataract Dam within the catchments of Lizard Creek and Wallandoola Creek, both of which drain to the Cataract River downstream of Cataract Dam. This domain would include five panels of about 385 m width located to the west and south-west of Lizard Creek and two 155 m wide panels to the north-east of the creek. The majority of the proposed panels underlie the catchment of Lizard Creek with about 13% of the Wonga West mine domain underlying the catchment of Wallandoola Creek.

All coal would be taken to the existing pit-top facility at Russell Vale for stockpiling, coal sizing, screening and load out onto trucks for haulage to the Port Kembla Coal Terminal. The proposed project includes some modification to the pit top facilities including upgrading mine water and stormwater controls. Mine access and servicing will also be provided from the No 4 Shaft site located approximately 10 km north-west of the Russel Vale site.

Water for underground operations is provided from a variety of sources at the Russell Vale and No 4 Shaft sites. All groundwater inflow to the workings reports to the Russel Vale site and any excess is discharged together with treated stormwater into Bellambi Gully.

The area for the proposed coal extraction is located on land that slopes relatively gently to the west (slopes of the order of 1 to 5%) from the Illawarra Escarpment while the main mine portal and pit top facilities are located at the base of the Illawarra Escarpment approximately 2 km from the coast.

The landscape that overlies the proposed mining area contains a rich diversity of water related natural features including upland swamps, semi-permanent and ephemeral creeks, pools and waterfalls, all of which have the potential to be impacted by subsidence effects resulting from longwall mining.

Rainfall across the proposed mining area varies significantly. Figure 4.4 of the *Surface Water Modelling* report (WRM, 2012) (reproduced as **Figure 2.3** in this review) shows average annual rainfall of up to 1,800 mm at the top of the Illawarra Escarpment, in the range of 1,650 to 1,750 in the Wonga East domain and 1,300 to 1,100 mm in the Wonga West domain.

Average rainfall at Russel Vale is about 1,280 mm/year with about 60% occurring in summer and autumn.

1.2 Previous Mining

The proposed development is located under previous mine workings in the Bulli and Balgownie coal seams which are located about 25 m and 35 m respectively above the Wongawilli Seam. The previous mining employed a complex mix of different methods at different times:

- At Wonga East, mining has involved bord and pillar mining and pillar extraction in the Bulli seam; bord and pillar and longwall mining in the Balgownie seam;
- In the Wonga West area bord and pillar mining, pillar extraction and longwall mining has been undertaken in the Bulli seam.

Detailed records of subsidence impacts from these previous mining activities are sparse.

1.3 Review Documentation

This review is concerned with all aspects of surface water including the potential impacts of subsidence on upland swamps, creeks, pools flow regimes and water quality; the potential impact of changes in the hydrologic regime on the ecology as well as aspects related to management of mine water and stormwater at the pit-top facilities. Accordingly the key documentation for this review comprises the following:

- *NRE No 1 Colliery Project Application (09_0013) Environmental Assessment* (ERM, February 2013);
- *Water Management Report: Gujarat NRE No 1 Colliery Major Works Part 3A* (Beca, February 2011);
- *Gujarat NRE Stormwater Hydrology Review* (Beca, October 2010);
- *NRE No 1 Colliery Major Expansion: Stream Assessment* (GeoTerra, November 2012);
- *NRE No 1 Colliery: Surface Water Modelling* (WRM, November 2012);
- *NRE No 1 Colliery Major Expansion: Upland Swamp Assessment* (Biosis, November 2012);
- *NRE No 1 Mine: Assessment of Mine Subsidence Impacts on Aquatic habitat and biota* (Cardno Ecology Lab, November 2012)

For purposes of understanding the key processes that might impact on surface water aspects of the project, this review has also taken the following reports into consideration:

- *Review of Subsidence and Related Facets of the NRE No 1 Colliery* (Pells Consulting, October 2011);

- *Gujarat NRE No 1 Colliery: Management of Subsidence Risks Associated with Wongawilli Seam Extraction* (Seedsman Geotechnics July 2012);
- *Review of subsidence predictions after the extraction of LW4* (Seedsman Geotechnics February 2013);

1.4 Scope

Key issues for the NRE No1 Colliery Project relate to:

- The potential impacts of subsidence on the swamps, pools and flow regime in the creeks;
- The adequacy of the water management facilities associated with mine operations to manage flow and water quality of any discharge from the pit-top facilities.

Accordingly, this review is structured as follows:

- **Section** Error! Reference source not found. reviews the surface water features, investigations and impact assessment relating to the Wonga East domain;
- **Section** Error! Reference source not found. reviews the surface water features, investigations and impact assessment relating to the Wonga West domain;
- **Section** Error! Reference source not found. provides an assessment of the water management systems for mine water, stormwater, water supply and wastewater treatment or disposal.

2 Wonga East

2.1 Catchment and Creek Characteristics

The Wonga East mine area is located mainly in the catchment that drains to Cataract Creek with a small proportion within the catchment of Cataract River and Bellambi Creek, all of which drain to Cataract Reservoir.

2.1.1 Cataract Creek

The *Surface Water Modelling* report describes Cataract Creek as being a fourth order stream with a total catchment of 5.2 km^2 that extends approximately 5.5 km upstream from Cataract Reservoir. The creek channel commences at an elevation of about 340 m AHD and has two distinctly different sections; a gradient of 4.2% for about 500 m in the headwaters with the remaining having a slope of about 0.5%.

The *Stream Assessment* describes the section of Cataract Creek downstream of Mount Ousley Road as comprising a series of long elongated pools that are constrained by low (<0.5 m high) rock bars, which predominate in the upper to mid-section, along with occasional gravel sized riffle sections. A limited number of rock bar constrained pools are present towards Cataract Reservoir with two moderate sized, <1 - 2 m deep pools located significant bends located near the edge of Longwall 8. These features are identified on Figure 11, a copy of which is provided as **Figure 2.1** on the next page.

The figure would benefit from greater detail to show:

- The extent of the pools;
- Which pools have been instrumented for water level monitoring since November 2010 (CC3, CC4 and CC9);
- Which pools are proposed to be instrumented in the future (CC6, CC7 and CC8)

In terms of impacts from previous mining, the report states:

> *No evidence of stream bed cracking, flow loss or adverse effects on pool levels has been observed in Cataract Creek in the areas undermined by the Bulli, Balgownie or Wongawilli workings.*

The *Stream Assessment* (Table 16) lists a total of 15 '*stream monitoring sites*' within the Cataract Creek catchment of which 10 are located on the creek channel, three at locations where water drains from upland swamps, one downslope of a shallow piezometer and one within Cataract Reservoir. These sites are described as being "*installed*" from August 2008 onwards. However it is apparent from the text that continuous water level measurement equipment has only been installed to measure pool water level at four sites, three on the main creek and one on a tributary; while two others are noted as "*Additional sites are currently being installed*" as at the time of preparation of the report (November 2012). Presumably, the other sites are locations at which only water quality monitoring has been undertaken to date.

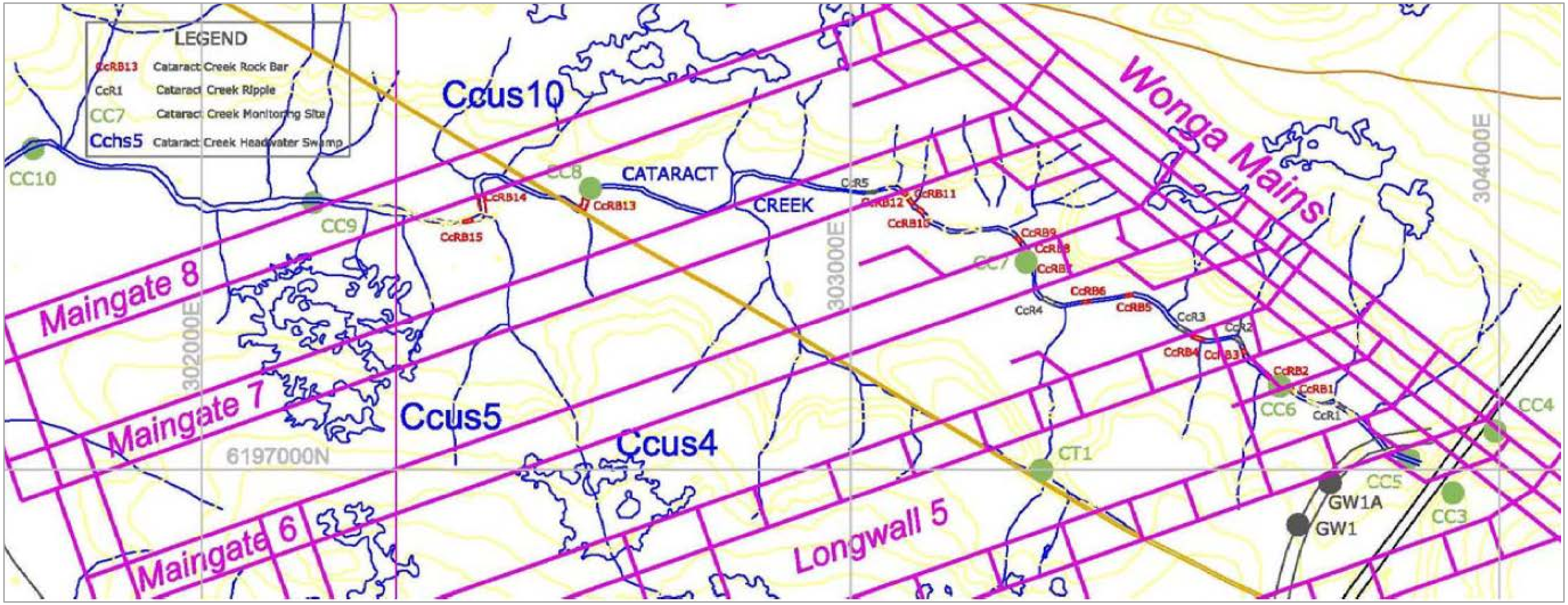


Figure 2.1: Cataract Creek Wonga East Area 2 Stream Monitoring Sites

(Source: *Stream Assessment* Figure 11)

2.1.2 Cataract River

Cataract River is a larger stream than Cataract Creek with a total catchment of 11.6 km^2. The river channel extends about 6.7 km upstream of Cataract Reservoir commencing at an elevation of about 430 m AHD where the gradient is about 17% progressively grading to about 1% at about 1.5 km from the headwaters and 0.5% for the remainder of the creek downstream of about 3 km from the headwaters.

The *Stream Assessment* describes detailed mapping of the channel of Cataract Creek from the full supply level of Cataract Reservoir to Mount Ousley Road, which crosses the creek about 2.5 km upstream of the reservoir. This mapping identified 15 rock bars and five riffle zones. Most of the rock bars are described as having shallow upstream pools (<0.5 m deep) while two have deeper pools (<1 – 2 m deep). The locations of these features are only shown on a small scale map and the report does not provide chainage distances or MGA co-ordinates.

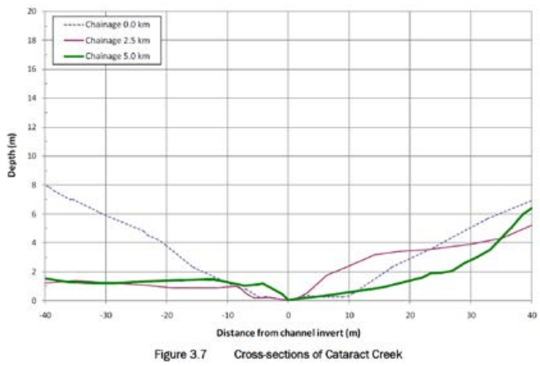
The *Stream Assessment* (Table 17) lists four monitoring locations along Cataract River at which "*Stream flow, height and water quality monitoring installations were installed in April 2012*". Three of these are located along the main creek, with the fourth being at a location which is inundated when the Cataract Reservoir is at full supply level (approximately 290 m AHD). Two of the sites on the main creek are intended to provide flow measurement once sufficient data has been obtained from manual stream gauging to develop a rating curve. Presumably these sites have been selected to be on rock bars which provide a fixed flow cross section. One of the sites on the main creek is located at a weir installed by the SCA. However it is not apparent from the text whether this site has an established rating curve.

The *Stream Assessment* acknowledges that no information has yet been obtained on the channel characteristics of the Cataract River adjacent to the Wonga East mining area:

> "*The Cataract River catchment has not been fully inspected to date as the proposed longwalls are not predicted to undermine or impact on the creek bed, and therefore a detailed assessment has not yet been conducted on the geomorphology of the reach between the freeway and the reservoir*".

2.1.3 Creek Cross Sections

Figure 2.2 is a copy of figures from the *Surface Water Modelling* report which shows representative cross sections of Cataract Creek and Cataract River at the headwaters (chainage 0), the middle reaches and the lower reaches. The sections show that, while the channels are more incised at the headwaters end (side slopes in the range 20-30%), the side slopes are generally flatter downstream, particularly on Cataract Creek.



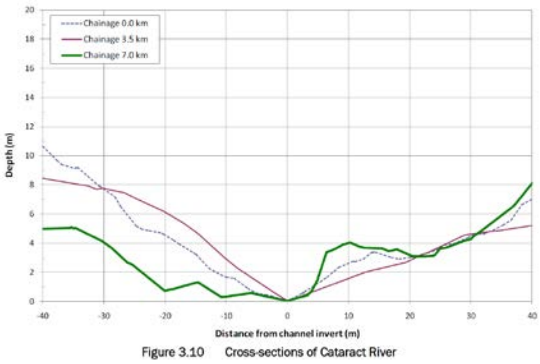


Figure 2.2: Cross Sections of Cataract Creek and Cataract River
(Source: *Surface Water Modelling* Figures 3.7 and 3.10)

The text does not indicate the orientation of the cross sections (facing upstream or downstream). In addition, the text and various figures in the *Stream Assessment* and the *Surface Water Modelling* report use different conventions for measuring along the stream. The *Stream Assessment* adopts chainage zero at an indeterminate point in Cataract Reservoir (approximately 800 m downstream of the top water level) while the *Surface Water Modelling* report adopts an arbitrary zero at the headwaters end. For consistency of reporting, a common system should be adopted and used for all references to features within the creek such as rock bars, pools and riffle zones.

2.2 Hydrology

The available surface hydrology data comprises:

- Flow records from SCA monitoring on headwater streams flowing into Cataract Reservoir from two catchments in relatively close proximity to the Wonga East area;
- Water level data from three pools on Cataract Creek, three pools on Cataract River and one pool on a tributary to Cataract Creek.

The data from the SCA monitoring sites has been used to calibrate a rainfall runoff model which was subsequently used to estimate the flow regime in the creeks within the mining area and to assess the potential effects of assumed losses due to the impacts of subsidence. Further commentary on this aspect of the impact assessment is contained in **Section 2.2.1** below.

Records of water level from the pools within the creeks in the Wonga East domain have not been used as part of the hydrologic analysis because of:

- The limited duration of the records (since November 2010 on Cataract Creek and since April 2012 on Cataract River); and
- The absence (to date) of sufficient flow gauging to develop rating curves for each of the rock bars which control the discharge from the pools.

2.2.1 Rainfall - Runoff Estimation

Daily streamflow records were obtained from two flow monitoring stations operated by the SCA:

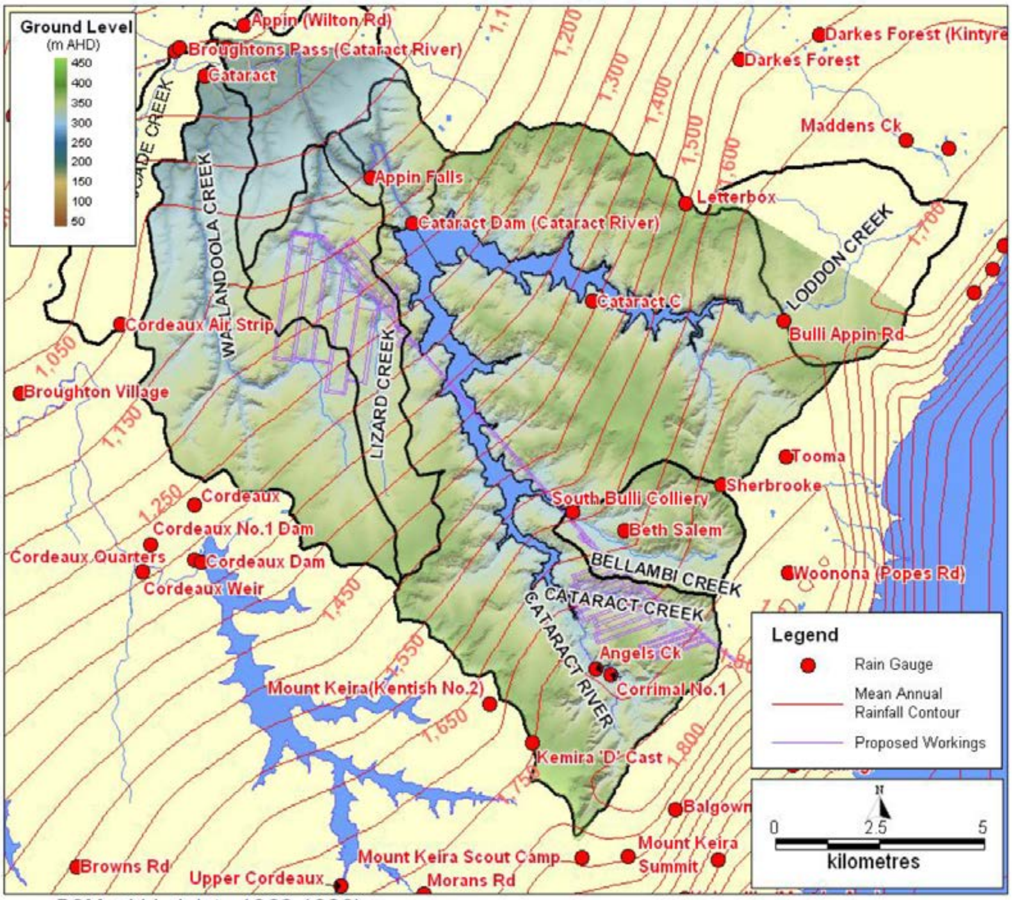
- Bellambi Creek at South Bulli No. 1 which has a catchment area of 9.3 km^2 and records from 1 January 1991 to 3 September 1995 (<5 years);
- Loddon River at Bulli Appin Road which has a catchment area of 917.6 km^2 and records from 1 January 1991 to 8 November 2009 (<19 years).

From the 1:25,000 topographic map it can be seen that both these catchments contain areas of upland swamps, but the proportion of the swamp area in each catchment has not been documented.

The *Surface Water Modelling* report states that the streamflow records from these two gauges show similar responses to rainfall– with persistent baseflow being a notable feature, but contributing a relatively small proportion total runoff. However, the flow data in the report indicates that for the period of common record (1991 – 1995), runoff from the Loddon River catchment was about 90% greater than that from the Bellambi Creek catchment. This is attributed to differences in rainfall on the catchments and the presence of a small dam on Bellambi Creek. Given the fact that both catchments experience similar average rainfall (as shown in a copy of **Figure 4.4** below) this assertion requires further justification. A comparison of the runoff as a percentage of rainfall attributable to each catchment would help justify this explanation.

The flow duration curves in Figure 5.3 of the *Surface Water Modelling* report are expressed in terms of ML/day. In order to distinguish any differences in runoff characteristics it would be helpful for the flow duration curves for the two catchments to be expressed in terms of mm/day.

A further possibility would be to examine the relative proportion of landscape types, particularly upland swamps in each catchment. From a casual inspection using GoogleEarth, it would appear that the Loddon River catchment has large areas of upland swamps.



(Source: BOM gridded data 1969-1990)

Figure 2.3: Mean Annual Rainfall Distribution
(Source: *Surface Water Modelling* report, Figure 4.4)

For assessment purposes, the recorded streamflow data was utilised as follows:

- Derivation of model parameters for each catchment for the AWBM rainfall:runoff model (which is widely used for daily rainfall:runoff modelling and is entirely appropriate for this application);
- Use of the derived model parameters to estimate flows for the catchments draining to Cataract Reservoir for the period 1976 to 2010 based on rainfall data from various daily rain gauges within and surrounding the catchment area;
- Use of these flows in a separate water balance model for Cataract Reservoir which also took account of recorded releases and overflows from the reservoir (provided by the SCA). This analysis provides a level of validation that the rainfall:runoff model gives reasonable estimates of total catchment runoff;
- A further model validation by comparing modelled and recorded flows at Broughtons Pass weir for a number of periods between August 1986 and January 2000 when there was no release of water from Cataract Reservoir;

- Use of the AWBM model to assess the effects of various assumed baseflow losses on reservoir yield and stream health.

As with any modelling, the model results are heavily dependent on the modelling assumptions and the input data. Aspects of the modelling that warrant further justification or consideration are:

- The validity of the calibrated model parameters to characterise the daily flow regime is expressed in terms of daily and monthly statistics for the Nash Sutcliff coefficient. In both cases, the coefficient indicates reasonable agreement between observed and modelled data for daily and monthly runoff. However, it appears that the statistic has been calculated by comparing the model output against that data actually used to derive the parameters. It is hardly surprising, therefore, that the Nash Sutcliff coefficient indicates reasonable agreement between the runoff data and modelled values. This does not constitute an independent validation of the models. More appropriate methods to validate the AWBM model would be to either separate the available data into two and use one as the calibration period and one as the validation period or to separate the data into separate years and use the 'leave-one-out cross validation' procedure.
- As noted previously, although the Loddon River and Bellambi Creek appear to have similar physical features and average rainfall, the runoff data appears to show much higher runoff from the Loddon River catchment. Given that the derived runoff characteristics from each catchment are subsequently applied to different parts of the landscape, the magnitude of the difference in runoff warrants further investigation and explanation.
- **Figure 2.4** is a copy of the observed and modelled flow duration curves for Bellambi Creek and Loddon River for the respective model calibration periods. These flow duration curves indicate that:
  - The model parameters derived for Bellambi Creek tend to over-estimate the low flows (<1 ML/day);
  - The model parameters derived for Loddon River tend to under-estimate the lower flow range (<10 ML/day).

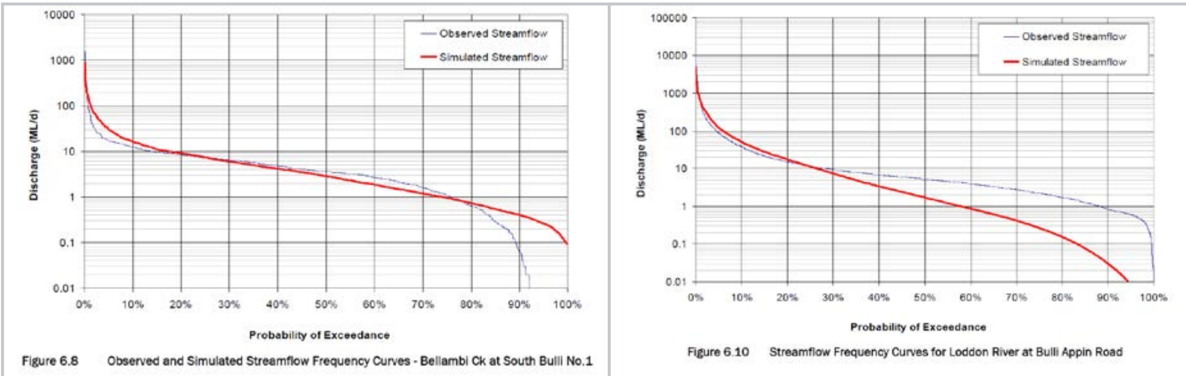


Figure 2.4: Flow Duration Curves for Bellambi Creek and Loddon River
(Source: *Surface Water Modelling* report, Figures 6.8 and 6.10)

- In general, the modelling of stored water volume in Cataract Reservoir for the period 1976 – 2010 shows good agreement with the volume recorded by SCA with the exception of a period from February 2000 to May 2003. The good agreement over the majority of the period provides evidence that the AWBM model is a reasonable model for the assessment of reservoir yield. However, when discussing potential consequences of subsidence, Section 7.2.1 of the *Surface Water Modelling* report notes that

"During higher flow events, where there was a large discrepancy between the modelled and observed inflow, the modelled inflow was modified to achieve an improved fit to observed volumes.

This statement calls into question what other 'modification' to the modelled flows was necessary during the validation modelling reported in Section 6.5 of the *Surface Water Modelling* report.

- The validation of the AWBM model for the creeks that drain to Cataract River between Cataract Dam and Broughtons Pass Weir is limited to a number of periods when there was no release from Cataract Dam. The graphs (in Appendix B to the *Surface Water Modelling* report) that compare observed and modelled flows at the weir lack sufficient detail to justify the conclusion that, "*the model appears to be reasonably representative of catchment runoff during these times.*" This conclusion provides the justification for adopting the AWBM model parameters from the Loddon River to model the flow regime in Lizard Creek and Wallandoola Creek.

Although there is some uncertainty about an 'modification' of modelled flows during periods of high inflow to the reservoir, the modelling of the water balance for Cataract Reservoir indicates that the AWBM model developed for the study area provides a reasonable basis for assessing the overall long term water balance of the reservoir.

However, the discrepancy between the observed and modelled flows in the low flow range indicate that the current AWBM model does not provide a reliable basis for assessing the potential impacts of subsidence on the lower flow range that is relevant for stream health. In particular, the Loddon River data indicates persistent baseflow, which may be attributable to the contribution from swamps (rather that hard rock aquifers) associated with the apparent large area of upland swamps within the catchment (see above). However, this persistence is not represented in the AWBM model which may lead to an underestimation of baseflow losses in catchments such as Lizard Creek and Wallandoola Creek (which are based on the parameters for the Loddon River). This issue is commented on further in **Section 3.2**.

2.2.2 Potential Impacts on Cataract Reservoir

The AWBM and Cataract Reservoir water balance models that were previously used to validate the AWBM model were used to assess the impact that various assumed baseflow losses would have on the available water in the reservoir. Although the text of the *Surface Water Modelling* report (Section 7.3.1) makes reference to modelling for the period since 1976, Figure 7.3 (reproduced as **Figure 2.5** below) only shows the period 1996 to 2007 during which the reservoir experienced two significant periods of drawdown.

The assumed baseflow losses attributable to subsidence effects were 0.5, 1, 5 and 10 ML/day. These losses were assumed to be the combined effects of losses from Cataract Creek and Cataract River. Although not explained, it appears that the modelling assumed that the loss was subtracted from the combined total daily flow from Cataract Creek and Cataract River. This approach to sensitivity analysis appears reasonable. However, as noted above, there appears to have been some 'modification' to the modelled flow for higher flow events, which calls into question the validity of the modelling.

The modelling shows that maximum reduction in stored volume occurs in mid-2007 and ranges from 940 ML for a loss rate of 0.5 ML/day to 1,385 ML for a loss rate of 10 ML/day. The assessed minimal impact of this range of losses is hardly surprising given the fact that the catchments of Cataract Creek and Cataract River represent only 25% of the total catchment contributing to the reservoir and are assumed to have much lower runoff than the Loddon River and other catchments with similar characteristics, which comprise 70% of the contributing catchment.

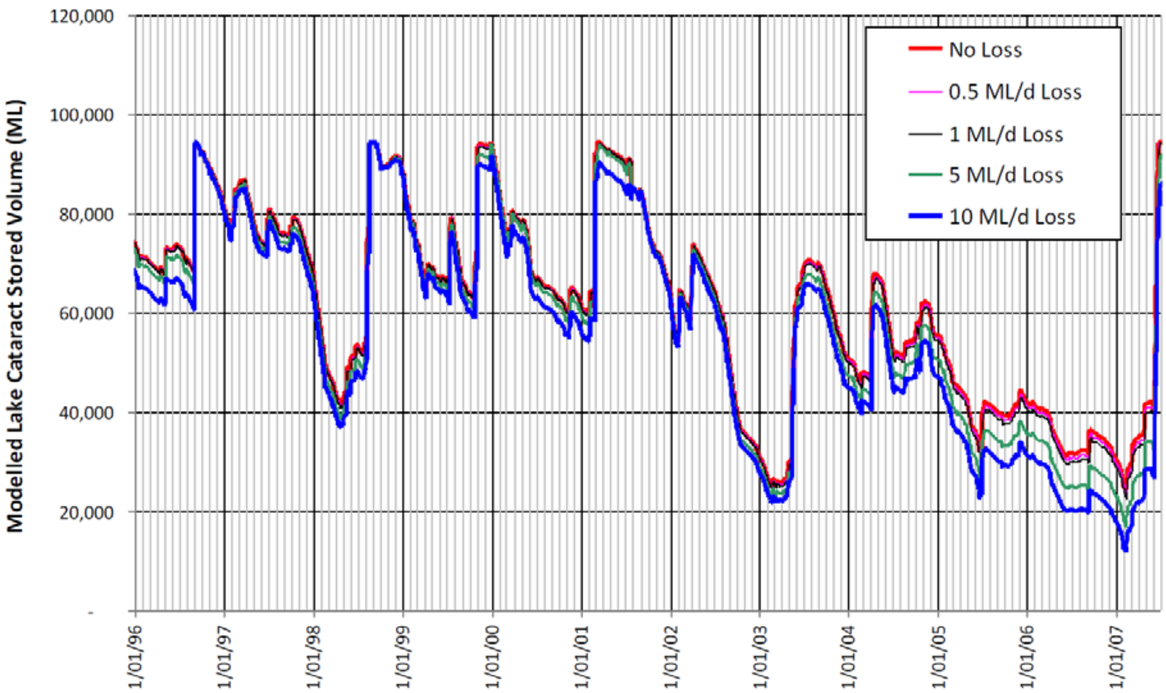


Figure 2.5: Impact of Catchment Loss on Cataract Reservoir Dry Period Stored Water Volume
(Source: *Surface Water Modelling* report, Figure 7.3)

Notwithstanding the aspects of the analysis noted above, it is apparent that subsidence induced cracking is unlikely to have a significant impact on the water stored in Cataract Reservoir unless connective cracking occurs between the workings and surface, particularly in the vicinity of Longwalls 9 (WE-A2-LW9) and 10 (WE-A2-LW10) in the Wonga East area where the *Stream Assessment* report notes:

> *"In addition, monitoring following prolonged rain in early 2012 observed that Cataract reservoir backed up in Cataract Creek to just upstream of site CC9, which means that an approximately 100m long reach over WE-A2-LW10 and up to 300m over WE-A2-LW9 could lie underneath Cataract reservoir."*

2.2.3 Baseflow from Swamps

The calibrated parameters for the rainfall:runoff models for the Loddon Rover and Bellambi Creek both have base flow indices of about 0.3 which infers that about 30% of the flow from these catchments exhibits a relatively long period of flow recession characteristic of the slow release of groundwater into the watercourse. In this instance, however, the 'baseflow' has two potential sources which are subject to different potential impacts from underground mining:

- Seepage from swamps which is potentially subject to reduction due to shallow sub-surface cracking leading to alternative flow paths, and
- Release of groundwater from the sandstone aquifers which is potentially subject to reduction due to lowering of the local water-table (see below).

Because these sources of baseflow are subject to different processes, it would be useful for quantify the relative contributions in a manner that is consistent between the surface water assessment and the groundwater assessment.

2.2.4 Groundwater Baseflow

The only reference to the estimated groundwater contribution to flow in the water courses in the Wonga East area are contained in Table 10 in the *Groundwater Assessment* (reproduced below).

Table 2.1: Modelled Cataract Creek Stream Flow Changes

	Creek Catchment Area (km^2)	Creek Flow Loss (ML/day)	Creek Flow Gain (ML/day)	Net Result (ML/day)	Change Due to Proposed Mining Compared to Current Stage (ML/day)
Current	5.2	-0.03	+0.36	0.33 (gaining)	
End of Mining Wonga East	5.2	-0.04	+0.31	0.27 (gaining)	0.06 (0.0115 ML/km^2/day) or 0.5% loss
End of Mining Wonga West	5.2	-0.04	+0.30	0.26 (gaining)	0.07 (0.0135 ML/km^2/day) or 0.6% loss

(Source: *Groundwater Assessment*, Table 10)

The data in **Table 2.1** indicates that, in the main, Cataract Creek is a 'gaining' stream but there is a small section which is a 'losing' stream. However, no details are provided to indicate where the gaining and losing sections are located.

Neither the *Stream Assessment* nor the *Surface Water Modelling* provide a flow duration curve or statistics for Cataract Creek for the period adopted for modelling of the water balance of Cataract Reservoir. It is therefore not possible to assess the estimated groundwater flow contribution quoted in **Table 2.1** relative to the contribution of 'baseflow' from the swamps or estimated surface runoff. The *Stream Assessment* (Section 13.5.2), quotes the average daily flow of Cataract Creek as being 11.73 ML/day but the source of this figure cannot be found in the *Surface Water Modelling* report.

Further details are required to allow a full assessment of the groundwater baseflow contribution including:

- Statistics and a flow duration graphs for Cataract Creek and Cataracts River for the period 1976 to 2010 (adopted for purposes of water balance assessment of Cataract Reservoir);
- Groundwater baseflow estimates for Cataract River comparable to those in **Table 2.1**. (The current text in the *Stream Assessment* makes no mention of groundwater baseflow losses from Cataract River. However the groundwater modelling results in **Table 2.1** indicate that groundwater drawdown effects from extraction in the Wonga West area would have some influence on groundwater baseflow in Cataract Creek. By analogy, it could be expected that the groundwater drawdown associated with extraction in the Wonga East area would affect Cataract River as well as Cataract Creek.)

2.3 Pools

2.3.1 Distribution

Figure 11 in the *Stream Assessment* identifies 15 rock bars in Cataract Creek between Mount Ousley Road and Cataract Reservoir. The detailed mapping describes the creek as

> "*. . . a series of long elongated pools that are constrained by low (<0.5m high) shallow rock bars, which predominate in the upper to mid section,*' and

> "*A limited number of rock bar constrained pools are present between CC7 and CC9, although two moderate sized, <1-2m deep pools have developed at significant bends at rock bars CcRB13 and CcRB14 as shown in Figure 11.*"

Whilst Figure 11 identifies the locations of the rock bars, the figure does not provide sufficient information regarding the size and importance of the various pools. It also appears that there is no intention to monitor the deeper pools listed as CcRB13 and CcRB14 which are located on the edge of Longwall 8 (and would apparently be at greater risk of cracking due to the strains).

Whilst the subsidence impacts on the Cataract River are predicted to be minor, nevertheless, continuous water level monitoring was established in three pools in April 2012. As noted previously, detailed mapping of the creek has not yet been undertaken.

2.3.2 Pool Water Levels

Pool water levels have been monitored at a number of locations on the watercourses in the Wonga East area:

- Three sites on Cataract Creek which have been continuously monitored since November 2010;
- One site on a tributary Cataract Creek which drains from the area being undermined by Longwalls 4 and 5. This site has been continuously monitored since April 2012;
- Three sites on Cataract River, one of which is an SCA weir. These have been continuously monitored since April 2012.

In addition, the *Stream Assessment* report states that, at the time of writing (November 2012), a further three sites were being instrumented for continuous water level monitoring on Cataract Creek. The report also states that there is an ongoing program of flow gauging or the use of temporary weirs that will be used to derive flow rating curves for each location that relate flow rate to water level. Once this has been done, the historic water level recordings will be converted to volumetric flow rates.

Once flow rating curves have been developed for each monitoring site, the pool water level records will provide a useful means for monitoring for loss of flow due to subsidence impacts. However, prior to the preparation of the rating curves, the pool water levels themselves are only of relevance in circumstances when the pool level drops below the crest of the confining rock bar. Unfortunately the pool level records are all quoted as "*Pool Water Level (mm Above Logger)*" without the level of the logger being specified. All that can be concluded from the pool water level records in the *Stream Assessment* report is that the water levels vary significantly over time and respond very rapidly to rainfall.

2.4 Waterfalls

No waterfalls are recorded in the Wonga East area.

2.5 Swamps

2.5.1 Distribution

The boundaries of the upland swamps identified in the *Upland Swamp Assessment* have been reproduced on various drawings located at the end of the *Stream Assessment* report. By close inspection of the drawings and reference to the naming of the swamps it is possible to determine the approximate location of the catchment divide. To assist in understanding the hydrologic context, it would be helpful if any updated drawings could include lines defining the catchment boundary.

In the Wonga East area all identified swamps are headwater swamps that are generally located in close proximity to the catchment divide. By reference to Figure 11 in the *Stream Assessment* report (copy in **Figure 2.1**), a significant number of small watercourses have been identified that, in most instances drain from the various headwater swamps. (This detail is not apparent on the 1:25,000 topographic maps or the drawings which use the photographic maps as a background). To assist in gaining an understanding of the relationship between the drainage network and the swamps it would be helpful for the level of detail depicted in Figure 11 (drainage lines, rock bars, riffle zones, etc.) to be provided on a map (or two) that encompass the whole of the Wonga East area and reproduced the colour coding for the swamp vegetation shown on Figures 4 an 5 in the *Upland Swamp Assessment*.

Table 2.2 summarises the data from Appendix 2 of the *Upland Swamp Assessment* which identifies 34 swamps in the Wonga East area that have been undermined by prior mining, the majority by bord and pillar methods which are considered to provide a low risk of subsidence impacts. There are, however, 11 swamps which have been affected to some extent by longwall mining in the Balgownie Seam.

While **Table 2.2** identifies a total of 34 swamps, the *Stream Assessment* only refers specifically to ten of these that have the potential to be affected by extraction in the Wonga East area:

- Swamps Ccusl and 2 which were both undermined by Bulli Seam first workings in the early 1900's and subsequently by Bulli seam pillar extraction and the Balgownie longwalls. The *Stream Assessment* reports no observable adverse effects on stream/swamp flow, water quality or ecosystem health.
- Swamps Ccus3, 4, 5 and 6 were undermined by Bulli Seam first workings in the early 1900's and subsequently by Bulli seam pillar extraction and the Balgownie longwalls. Ccus6 was also recently undermined by Longwall 4 in the Wongawilli Seam. The *Stream Assessment* reports no observable adverse effects on stream/swamp flow, water quality or ecosystem health.
- Swamps Ccus10, 11 and 12 were undermined by Bulli Seam first workings, but not by Bulli seam pillar extraction or the Balgownie longwalls. The *Stream Assessment* quotes the *Upland Swamp Assessment* as reporting no observable adverse impacts from subsidence.
- Swamp Crus1 was undermined by Bulli Seam first workings, but not by Bulli pillar extraction or the Balgownie longwalls. The *Stream Assessment* reports no observable adverse effects on stream/swamp flow, water quality or ecosystem health.

Given that many of these swamps were undermined decades ago, and there do not appear to be any contemporaneous records of swamp conditions at the time, the claim that there were "*no observable adverse effects on stream/swamp flow, water quality or ecosystem health*" needs to be recognised as a judgement based on current conditions rather that before and after observations. This assessment precludes the possibility that some of the swamp ecosystems have evolved to accommodate changes in the hydrologic regime.

Table 2.2: Wonga East Swamps Previously Affected by Mining

Swamp Name	Size (ha)	Previously Subsided by
Bellambi Creek		
Bcus 2	0.89	Bulli bord and pillar
Bcus 3	0.12	Bulli bord and pillar
Bcus 4	2.2	Bulli bord and pillar
Bcus 5	0.96	Bulli bord and pillar
Bcus 6	1.37	Bulli bord and pillar
Bcus 7	0.62	Bulli bord and pillar
Bcus 8	0.66	Bulli bord and pillar
Bcus 9	0.27	Bulli bord and pillar
Bcus 10	0.41	Bulli bord and pillar
Bcus 11	0.26	Bulli bord and pillar
Cataract Creek		
Ccus 1	4.81	Balgownie Longwall, Bulli bord and pillar
Ccus 2	1.21	Bulli bord and pillar
Ccus 3	0.55	Balgownie Longwall, Bulli bord and pillar
Ccus 4	1.77	Balgownie Longwall, Bulli bord and pillar
Ccus 5	3.45	Balgownie Longwall (partial), Bulli bord and pillar
Ccus 6	2.05	Balgownie Longwall, Bulli bord and pillar (partial)
Ccus 7	1.32	Bulli bord and pillar
Ccus 8	0.46	Bulli bord and pillar
Ccus 9	0.76	Balgownie Longwall, Bulli bord and pillar
Ccus 10	1.63	Balgownie Longwall,, Bulli bord and pillar
Ccus 11	0.34	Bulli bord and pillar
Ccus 12	1.84	Bulli bord and pillar
Ccus 13	0.26	Bulli bord and pillar
Ccus 15	0.06	Bulli bord and pillar
Ccus 16	0.07	Balgownie Longwall, Bulli bord and pillar
Ccus 18	0.05	Bulli bord and pillar
Ccus 19	0.04	Bulli bord and pillar
Ccus 20	0.55	Balgownie Longwall, Bulli bord and pillar
Ccus 21	0.05	Balgownie Longwall, Bulli bord and pillar
Ccus 22	0.31	Bulli bord and pillar (partial)
Ccus 23	1.44	Balgownie Longwall, Bulli bord and pillar
Cataract River		
Crus 1	9.84	Bulli bord and pillar
Crus 2	3.12	Bulli bord and pillar
Crus 3	3.42	Bulli bord and pillar

2.5.2 Potential Impacts

Table 2.3 summarises various data from the *Upland Swamp Assessment* for swamps located above longwalls in the Wonga East area and which are either of ecological significance or are located above the proposed Wongawilli longwalls.

Table 2.3: Swamps Located Above Mining or of Potential Significance in the Wonga East Area

Swamp Name	Size (ha)	Located Above Longwall	Predicted Subsidence	Tensile Strain (mm/m)	Compressive Strain (mm/m)	Tilt (mm/m)	Ecologically Significant	Risk of Impacts
Bellambi Creek								
Bcus 4	2.2	Area 1 LW11	-0.81	4.24	-6.48	17.43	No	
Bcus 11	0.26	Area 1 LW11	-0.88	4.14	-7.43	17.07	No	
Cataract Creek								
Ccus 1	4.81	Area 1 LW3	-0.40	2.65	-6.79	11.38	Yes	Significant
Ccus 2	1.21	Area 1 LW1, LW2	-0.39	2.77	-6.59	11.42	No	
Ccus 3	0.55	Area 2 LW5	-0.99	4.52	-8.04	20.31	No	
Ccus 4	1.77	Area 2 LW6	-1.00	4.63	-8.03	21.04	Yes	Low
Ccus 5	3.45	Area 2 LW7, LW8	-1.00	4.74	-8.03	21.30	Yes	Significant
Ccus 6	2.05	Area 2 LW4	-1.02	4.79	-8.05	21.95	No	
Ccus 10	1.63	Area 2 LW9	-1.00	4.60	-8.74	21.39	Yes	Low
Ccus 11	0.34	Area 2 LW10	-0.47	4.37	1.61	17.58	No	
Ccus 12	1.84	Area 2 LW11	-0.88	4.24	-7.47	17.50	No	
Ccus 23	1.44	Area 2 LW5	-0.99	4.41	-8.04	20.04	No	
Cataract River								
Crus 1	9.84	Area 2 LW6	-0.89	4.34	-7.20	17.51	Yes	Low
Crus 2	3.12	No	0.00	0.0	0.00	0.00	Yes	Negligible
Crus 3	3.42	No	0.00	0.0	0.00	0.00	Yes	Negligible

On the basis of this data, the *Stream Assessment* concludes that the main risks of negative environmental consequences relate to swamps Ccus1 and Ccus5, while swamps Ccus4 (wrongly reported as Ccus5 in the text) and Ccus10 have low risk of negative environmental consequences. None of the swamps in the Bellambi Creek or Cataract River catchments are specifically mentioned. The *Stream Assessment* concludes:

> *"However, it is considered that the risk of swamp drainage, reduction of discharge to downstream gullies and adverse effects on water quality are low, and that the total volume of water entering Cataract Creek from the headwater swamps will not be observably affected."*

In view of the observed significant width of cracking on the edge of Longwall 4, this conclusion appears optimistic. As noted by Krogh (2012) in a review of the impacts associated with longwall mining at the nearby Dendrobium mine:

> *"If the relatively impermeable base of upland swamps is fractured, then any perched aquifer is likely to drain downwards into the fracture network, thereby altering natural groundwater levels within the swamp and leading to increased desiccation. The similarity of impacts in*

Dendrobium Swamps 12 and 15b to impacts measured in Kangaroo Creek swamp on the Newnes Plateau as a result of longwall mining (DECCW 2011) reveal some consistent patterns of longwall mining impacts on swamps. Not only is the absolute level of the aquifer being affected (ie loss of permanent perched aquifer), but the groundwater level recessions in response to rainfall after undermining are very abrupt when compared to recessions prior to undermining. Vegetation changes have also been identified in some impacted swamps.

Also, it is apparent that the swamp impact assessment provided in the *Stream Assessment* is restricted to those swamps considered to be of ecological 'special significance', and ignores other swamps that may be hydrologically significant in providing baseflow to downstream drainage lines even if the swamps themselves are not classified as being of special ecological significance. The assessment of the risk of subsidence impacts needs to take account of the hydrologic as well as ecological significance of the swamps.

2.6 Water Quality

Sections 10.5.3 and 10.5.4 of the *Stream Assessment* provide an overview of the water quality monitoring program including locations and periods over which monitoring has occurred. In general it appears that water quality monitoring has occurred bi-monthly rather than the usual practice of monthly monitoring. No explanation is provided for this.

The monitoring program includes:

- Bi-monthly monitoring of four sites on Cataract Creek upstream of Mount Ousley Road and one immediately downstream since August 2008;
- Bi-monthly monitoring of one site within Cataract Reservoir since August 2008;
- Progresive expansansion of the monitoring on Cataract Creek to include an additional six sites on Cataract Creek and one of its tributaries since July 2010;
- Commencement of monitoring outflow from thre swamps and one piezometer since March 2012.

The *Stream Assessment* provides graphs of the longitudinal profiles of median values of pH, conductivity, iron (total and filtered) and manganese (total and filtered) as well as graphs of the variability of pH and conductivity over time.

- pH shows a slight increasing trend from a median of about 5.6 at the upstream monitoring point to 6.3 upsteram of Cataract Reservoir;
- Conductivity declines from a median of about 145 μS/cm at the upstream monitoring point to about 120 μS/cm just upsteram of Cataract Reservoir;

The assessment of overall water quality is summarised in the following quotations:

"In general, enhanced rainfall in the catchment has the effect of reducing salinity, marginally raising pH, increasing dissolved oxygen, diluting ferruginous discolouring (or deposition), diluting major metals and generally increasing nutrients, with the degree of change relating to the degree and duration of rainfall runoff dilution in the stream."

"Hydrous ferruginous seeps are relatively common in Cataract Creek, although their exact inflow location has not yet been identified as ferruginous precipitation is relatively ubiquitous in the creek both upstream and downstream of the freeway.

> *Due to the lack of pre mining data, it is not possible to ascertain whether the ferruginous seeps are caused by, or related to, historic mine subsidence."*
>
> *"In summary, monitoring to date indicates the creek is within the acceptable range for potable water, however is generally outside the ANZECC 2000 South Eastern Australia Upland Stream Criteria for pH. It is generally the case that the stream pH is more acidic as it discharges out of the humic / fulvic acid dominated swamp areas, then becomes more alkaline as it flows down the main stream, with no significant acidification downstream of upwelling seepage re-entry locations in the streams."*

The water quality in the Creek can also exceed the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for aluminium, filtered zinc, filtered copper, total phosphorus and total nitrogen depending on the flow conditions at the time of sampling.

It is apparent that baseline water quality data has been collected for range of relevant analytes. This data should provide an appropriate basis for establishing baseline water quality for purposes of identifying any water quality impacts as a result of mining. However a full list of the analytes monitored and tables showing the key statistics are necessary to provide a complete picture of the water quality characteristics for assessment purposes. Further analysis of the water quality statistics should also be provided along with justification for any proposed water quality 'trigger' levels that differ from the default values in the ANZECC Guidelines.

3 Wonga West

3.1 Catchment and Creek Characteristics

The proposed Wonga West domain is located within the catchments of Lizard Creek and Wallandoola Creek, both of which drain to the Cataract River downstream of Cataract Dam.

3.1.1 Lizard Creek

The *Surface Water Modelling* report describes Lizard Creek as being a fourth order stream within the proposed extraction area. The creek extends approximately 10 km upstream from the confluence with Cataract River (about 4.5 km downstream of Cataract Dam) and has a total catchment area of 17.1 km^2 (derived from inspection of Figure 6.18 but not stated in the catchment description). The creek channel commences at an elevation of about 360 m AHD and has a highly variable profile with four distinct sections:

1. From the headwaters to chainage 4,600 m (measured from the headwaters) the channel progressively grades from about 2% to 1%;
2. A waterfall, almost 30 m high, is located at about chainage 4,600 m;
3. For a further 4,500 m the channel has a gradient of about 1%;
4. The channel then increases in gradient to about 3% before a second waterfall just upstream of the Cataract River.

Figure 3.1 in the *Surface Water Modelling* report shows that the section of the creek adjacent to the proposed extraction zone extends from chainage 3,500 m to 7,000 m where the gradient is predominantly about 1% apart from the 30 m waterfall. The data derived from the figure is inconsistent with the text which states that, "*The proposed Wonga West workings are located between Chainage 5,300m and Chainage 7,800m*."

The *Stream Assessment* describes four general channel forms along both Lizard and Wallandoola Creeks:

1. Valley fill upland swamps with an indistinct channel;
2. Narrow indistinct overgrown channels;
3. Rock platforms of variable width;
4. Incised channels in sandstone.

Table 12 in the *Stream Assessment* identifies nine monitoring sites on Lizard Creek and five on tributary creeks which have been monitored for various periods of time with the earliest record starting in July 2006.

In contrast to Cataract Creek and Cataract River, Lizard Creek has a series of valley fill swamps and pools extending for over 2 km. This section of the creek is described as having, "*pool levels are supported behind exposed sandstone rock bars, often with less than a 0.5 m drop between pools which range up to approximately 500 m long*". These details are not apparent from the mapping in Drawing 3 which shows the outline and designation of various swamps, but not the pools which are shown in various aerial photographs (which lack any scale) in Appendix C. The description of the characteristics of the creek is further confused by the fact that some of the referenced swamps (e.g. Lcus4) are not labelled on Drawing 3.

Downstream of the minor valley fill swamp (Lcus4) the channel is described as,

> "*The stream bed can be dry for a stream reach of approximately 750m between the downstream termination of valley fill swamp Lcus4 and the approximately 200m long, orange discoloured permanent pool upstream of Waterfall L1.*"

Subsequent text in reference to pool depths and flow notes that,

> *"Accurate stream flow monitoring for use in comparing upstream and downstream catchment volumetric flows is logistically difficult to achieve in Lizard Creek for the following reasons;*
>
> - *lack of sites where all stream flow is present as overland flow due to;*
>   - *natural diversions through fissures, joints and washed out bedding planes in the sandstone, or*
>   - *diversion underneath the stream bed through subsidence cracks that developed over the Bulli Seam longwalls."*

In addition, Figure 8 has a dotted line '*stream diversion*' in this vicinity. However, it is not apparent whether the observed dry section of the creek downstream of swamp Lcus4 is attributable to natural diversions through fissures and joints or subsidence cracking from previous mining.

Downstream of the waterfall, the channel is described as running through a sequence of elongated pools, rock bars, boulder fields. From Drawing 3 this zone appears to be about 650 m in length and leads into a further 1,3oo m section which is also described as an "*area of sequential pools, rock bars, boulder fields and sandy sediment based pools*". This latter section is reported to have been observed to dry out after extended low rainfall periods and is shown on Figure 8 as an area where it is assumed that stream diversion occurs. In common with the reach of the creek downstream of swamp Lcus4, it is not apparent whether this diversion is attributable to natural diversions through fissures and joints or subsidence cracking attributable to previous mining. However it is notable that, in neither instance is any mention made to observed cracking attributable to mining as observed elsewhere on tributaries of Lizard Creek.

3.1.2 Wallandoola Creek

Wallandoola Creek is a third order stream in the sections adjacent to the proposed Wonga West extraction area, becoming a fourth order stream about 1.5 km downstream. The creek extends approximately 15.5 km upstream from the confluence with Cataract River (about 10 km downstream of Cataract Dam) and has a total catchment area of 33.2 km^2 (derived from inspection of Figure 6.18 but not stated in the catchment description). The creek channel commences at an elevation of about 370 m AHD and has a highly variable profile with four distinct sections similar to Lizard Creek:

1. From the headwaters to chainage 5,000 m (measured from the headwaters) the channel progressively grades from about 4% to 0.5%;
2. A series of three waterfalls, drop the bed level by over 40 m in a reach of 2,000 m which includes a section if almost 1,500 m with a gradient of only 0.4%;
3. For a further 3,000 m the channel has a gradient of about 0.5%;
4. The channel then increases in gradient to about 2% before increasing to about 3% immediately upstream of the confluence with the Cataract River.

Table 9 in the *Stream Assessment* identifies five monitoring locations along Wallandoola Creek that extend over about 3 km, starting about 1.5 km upstream of the area adjacent to the proposed Wonga West longwalls. An additional monitoring site has also been established on one of the tributaries. Key features of the creek include:

- A long pool upstream of a rock bar that defines the first monitoring site (WC1) on the eastern headwater tributary. From Drawing 3, it appears that this pool is located within a valley fill swamp. (N0te that the first four of the aerial photographs for Wallandoola Creek, which show this pool are missing from Appendix C of the *Stream Assessment*.);

- Further extension of the valley fill swamp about 900 m downstream of WC1 to a point where the western headwater tributary joins the creek. (Based on Drawing 3, this tributary also has an extensive valley fill swamp);
- A 1.25 km long pool that is controlled by a rock bar;
- A further series of sections of valley fill swamp and pools which include a "*distinctly iron hydroxide orange coloured pool*" that terminates at a rock bar;
- A further 1.7 km long pool followed by a sharp drop into a short 'plunge pool' which is controlled by a rock bar at site WC4. This site is described as "*constrained by a rock bar with evident cracking located approximately 100m upstream of Waterfall W1, where the pool level and extent is affected by enhanced drainage of the pool through the downstream cracked sandstone streambed.*"

The relationship between the various features of the creek is unclear. Drawing 3 shows the waterfall W1 as being located upstream of monitoring site WC4. However the text (page 35) describes site WC4 as being located 100 m upstream of the waterfall. On the other hand, Figure 7 shows site WC4 as being located approximately 300 m upstream of the waterfall.

Figure 8 has a dotted line '*stream diversion*' extending from downstream of site WC4 to mid-way down waterfall W1. It appears that this is intended to represent an interpretation of the observation that, "*The waterfall is also affected by cracking in the sandstone, as the stream has not been observed to flow over the falls during 'dry' periods*". However, it is unclear whether there are any direct observations of cracks or seeps; or whether the cracking is simply inferred by the lack of flow over the falls and the observation that "*Downstream of the waterfall, the plunge pool containing Site WC5 maintains a consistent pool, with a distinctly orange ferruginous colour*." – presumably taken as an indication of seepage.

3.1.3 Channel Cross Sections

Figure 3.1 is a copy of figures from the *Surface Water Modelling* report which shows representative cross sections of Lizard Creek and Wallandoola Creek at the headwaters (chainage 0), the middle reaches and near the confluence with the Cataract River. In contract to the cross sections in **Figure 2.2**, these sections show significant change in cross section with the channel becoming increasingly incised downstream.

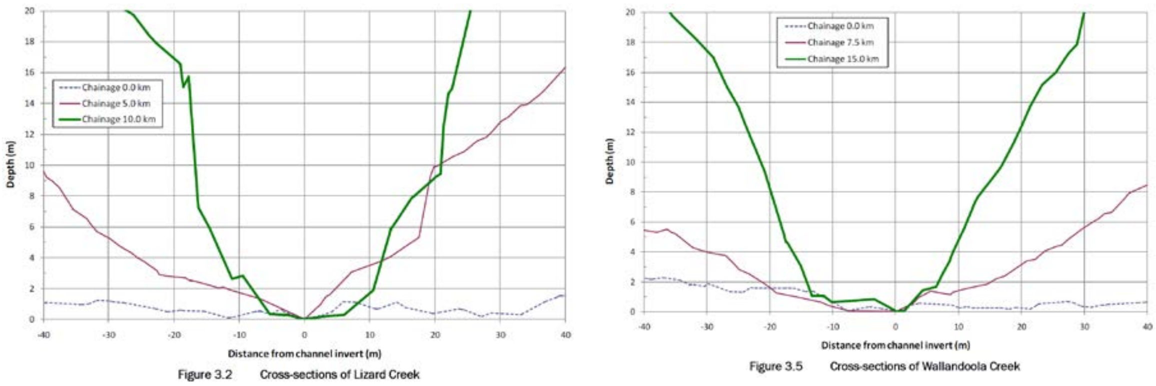


Figure 3.1: Cross Sections of Lizard Creek and Wallandoola Creek
(Source: *Surface Water Modelling* Figures 3.2 and 3.5)

3.1.4 Comment

The *Stream Assessment* would benefit significantly from the provision of an overall map showing the all surface water related features along Lizard Creek and Wallandoola Creek, including:

- channel type (as referenced on page 32 of the *Stream Assessment*);
- pool type (as referenced on page 32 of the *Stream Assessment*);
- other stream features such as rock bars, cracked rocks, swamps, riffle zones, etc.;
- chainages (using a common starting point to that adopted in *Surface Water Modelling* report);
- monitoring locations (distinguishing continuous flow monitoring from water quality sampling);
- delineation of the reaches referred to in the impact assessment.

3.2 Climate and Hydrology

The regional climate and the approach to modelling of the flow regime in the creeks are set out in **Section 2.2** above.

3.2.1 Surface Runoff

The modelling of flow for Lizard Creek and Wallandoola Creek is based on adopting the parameters derived from calibration of the AWBM model against the flow records from the Loddon River. The justification for using these parameters appears to be based on the comparison between the modelled flow hydrographs and the flows recorded at Broughtons Pass. These hydrographs (in Appendix B of the *Surface Water Modelling* report) show similarities in terms of the timing of flows and the relative magnitude of the flows, but the report lacks any statistical analysis of the flow duration or peak flows. However the *Surface Water Modelling* report does not provide any firm justification for adopting parameters from the Loddon River, rather than from Bellambi Creek in terms of:

- Comparison of catchment characteristics in Lizard Creek and Wallandoola Creek catchments with those of the Loddon River catchment, particularly the proportion of the catchment covered by upland swamps;
- Validation of the AWBM model parameters using the flow records from Lizard Creek at site LC3. Figure 5.13 of the *Surface Water Modelling* report shows some gaps in the record between October 2009 and February 2011, but apparently complete record thereafter until August 2012. Although this record is unlikely to provide sufficient basis for calibration of a set of parameters specific to Lizard Creek and Wallandoola Creek, the record could be compared to the model predictions using parameters derived from both Bellambi Creek and Loddon River.

The *Stream Assessment* quotes the following average daily flows from Lizard Creek and Wallandoola Creek to the Cataract River (referenced as being from WRM Water & Environment, 2012):

- Lizard Creek 17.0 ML/day
- Wallandoola Creek 33.0 ML/day.

However, these figures do to appear in the *Surface Water Modelling* report (prepared by *WRM*) and there is no reference to any reports by WRM quoted in the *Stream Assessment.*

3.2.2 Baseflow from Swamps

As noted in **Section 2.2.3**, the calibrated parameters for the rainfall:runoff models for the Loddon Rover and Bellambi Creek both have base flow indices of about 0.3 which infers that about 30% of the flow from these catchments exhibits a relatively long period of flow recession characteristic of the slow release of groundwater into the watercourse, but does not distinguish between seepage from swamps and the release of groundwater from the sandstone aquifers. Because these sources of baseflow are subject to different impacts from mining, it would be useful for quantify the relative contributions in a manner that is consistent between the surface water assessment and the groundwater assessment.

3.2.3 Groundwater Baseflow

The *Stream Assessment* describes Lizard Creek and Wallandoola Creek as varying from being 'losing disconnected streams' in the headwaters to 'gaining' streams where the creeks are incised into Hawkesbury Sandstone downstream of the waterfalls. However, the report acknowledges that this behaviour has not been directly observed.

The assessment of the 'losing' and 'gaining' behaviour of different sections of the creeks is supported by the groundwater modelling results reported in the *Groundwater Assessment* and reproduced in **Table 3.1**. Interestingly, despite their similar longitudinal profiles, Lizard Creek is currently assessed as being a net 'losing' stream while Wallandoola Creek is a net 'gaining' stream.

Given the magnitude of the predicted gains, such flows would be difficult to measure in a natural stream unless the groundwater inflows were concentrated in a short section of the creek and there was a rock bar at the downstream end if the gaining section with a very confined low flow channel.

Table 3.1: Modelled Lizard and Wallandoola Creek Stream Groundwater Baseflow Changes

	Creek Catchment Area (km^2)	Creek Flow Loss (ML/day)	Creek Flow Gain (ML/day)	Net Result (ML/day)	Change Due to Proposed Mining Compared to Current Stage (ML/day)
Lizard Creek					
Current	17.1	-0.50	+0.31	-0.19 (losing)	
End of Mining Wonga East	17.1	-0.49	+0.32	-0.17 (losing)	0.02 (0.0012 ML/km^2/day) or 0.1% gain
End of Mining Wonga West	17.1	-0.52	+0.23	-0.29 (losing)	0.10 (0.0058 ML/km^2/day) or 0.6% loss
Wallandoola Creek					
Current	33.2	-0.70	+0.90	+0.29 (gaining)	
End of Mining Wonga East	33.2	-0.76	+0.90	+0.14 (gaining)	0.06 (0.0018 ML/km^2/day) or 0.2% gain
End of Mining Wonga West	33.2	-0.70	+0.65	-0.05 (losing)	0.25 (0.0075 ML/km^2/day) or 0.8% loss

(Source: *Groundwater Assessment*, Table 11)

3.2.4 Potential Impacts of Mining

In the Lizard Creek and Wallandoola Creek catchments, there are three potential mechanisms by which longwall mining could affect streamflow:

- Further tensile cracking of rocks in the bed of the creeks near the edge of the longwall panels due to tensile stress. Depending on the depth of cracking and the proximity of the collapsed zone above the goaf, this cracking could lead to redirection of flow through lateral bedding planes or drainage to the workings;

- Tensile cracking of rocks in the base of swamps leading to redirection of flow or loss to the goaf in a similar manner to losses from creeks;
- Reduced groundwater baseflow due to lowering of the regional groundwater as set out in **Table 3.1**.

The *Stream Assessment* notes that subsidence induced cracking has the potential to affect streamflow in the reaches overlying and downstream of the proposed workings. The assessment of the potential impacts provided in the *Stream Assessment* relies on "*other investigations*" that are "*reported to have concluded that these impacts would normally be restricted to short reaches, where flow infiltrates into cracks in the bed, then remerges further downstream*". Because this mechanism is such an important aspect of the stream assessment, it warrants further justification and discussion relating to the findings of the '*other investigations*'.

Because the occurrence of the first two mechanisms is unknown, the potential impacts have been assessed in the *Surface Water Modelling* report by a sensitivity analysis that assumed a range of losses from each of the creeks at a location immediately downstream of the 20 mm subsidence zone. This was achieved by subtracting a uniform daily loss from the modelled stream flows generated by the AWBM modelling.

The report contains a discrepancy between the text describing the analysis (which lists flow losses of 1, 5 and 10 ML/day in Section 7.2.2) and the results (that refer to losses of 0.1 and 0.5 ML/day). From an inspection of the results (reproduced in **Figure 3.2**), it appears that the earlier reference to 1, 5 and 10 ML/day is a typographical error.

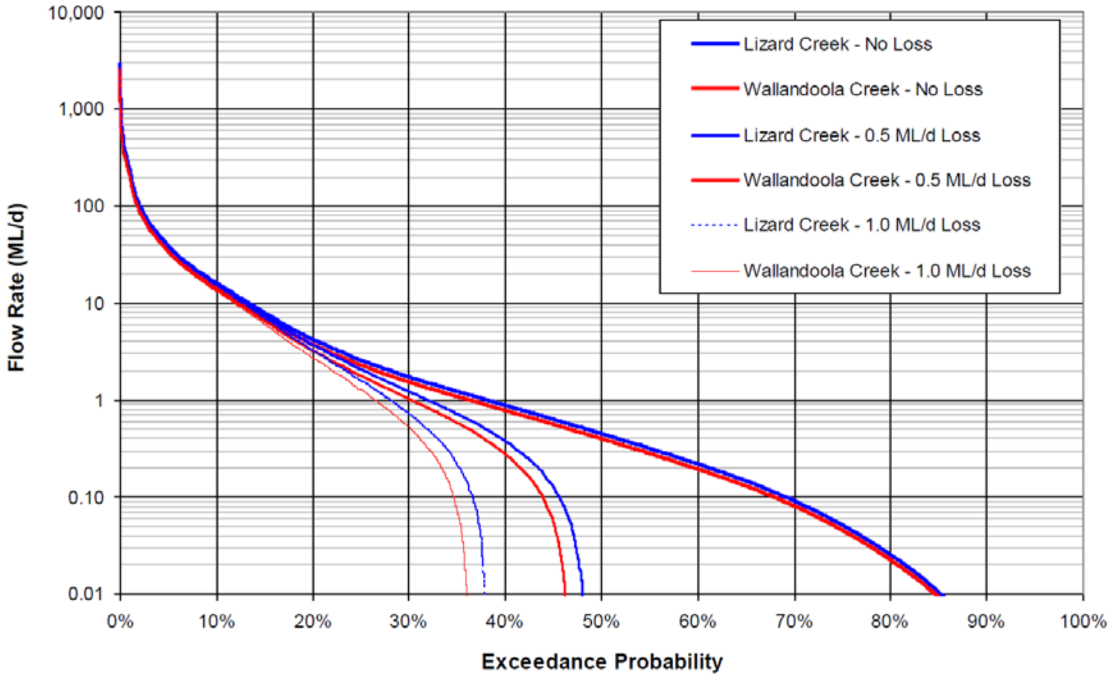


Figure 3.2: Impact of Losses on Flow Frequency Curve – Lizard Creek and Wallandoola Creek
(Source: *Surface Water Modelling* Report, Figure 7.5)

For more explicit understanding of the potential impact of the assumed losses on the low flow regime, **Table 3.2** shows the frequency of flow greater than either 0.5 or 1 ML/day. The results show that losses of the order of 0.5 or 1 ML/day would significantly increase the proportion of time that the creek would dry up or have limited flow in those sections affected. However, as noted in the *Surface Water Modelling* report, the overall effect of these losses downstream would depend on the nature of the cracking. The *Surface Water Modelling* report notes:

> *"It should be noted that if flow losses occurred from a reach of the affected streams, it is thought that the flow would return to the channel further downstream. The impacts described above are therefore likely to affect only limited portions of the affected streams."*

Table 3.2: Effect of Assumed Baseflow Loss on Flow Frequency in Lizard Creek and Wallandoola Creeks

	Creek Catchment Area (km^2)	Frequency of Flow Greater than Nominated	
		0.5 ML/day	1.0 ML/day
Lizard Creek			
Current	13.8	69%	38%
Loss of 0.1 ML/day	13.8	46%	32%
Loss of 0.5 ML/day	13.8	37%	28%
Wallandoola Creek			
Current	10.7	67%	37%
Loss of 0.1 ML/day	10.7	44%	30%
Loss of 0.5 ML/day	10.7	34%	27%

(Source: *Surface Water Modelling*, Section 7.3.2)

The results in **Table 3.1** show that, as a result of the predicted lowering of the groundwater due to longwall mining in the Wonga West area, the creeks are predicted to suffer the following loss of groundwater baseflow:

- Lizard Creek 0.12 ML/day;
- Wallandoola Creek 0.19 ML/day.

Note that these losses have been assessed for the creeks at the confluence with the Cataract River and are not directly comparable with the results in **Figure 3.2** and **Table 3.2** which relate to the downstream boundary of the 20 mm subsidence zone. Notwithstanding the differences in catchment area, the flow frequency results in **Figure 3.2** provide a useful basis for a more discriminating assessment of groundwater baseflow losses than is provided in the *Stream Assessment* which relates the losses to the average flow in each creek. While the groundwater baseflow losses represent a very minor loss as a percentage of the average flow (0.7% and 0.6% respectively), it can be seen that in respect of the flow regime shown in **Figure 3.2**, these losses would significantly affect the low flow regime in both creeks. This aspect has not been adequately assessed.

3.3 Pools

3.3.1 Distribution

The descriptions of Wallandoola Creek and Lizard Creek in Sections 10.1.1 and 10.1.2 in the *Stream Assessment* provide a general description of the various pools along each creek but lack a simple table summary of the size of each pool and the hydraulic control in each case.

3.3.2 Pool Water Levels

Water level monitoring has been installed on:

- Four pools along Lizard Creek which have been monitored since late 2009;
- Three pools along Wallandoola Creek, two of which have been monitored since late 2009 and the third since late 2010.

For one of the pools on Lizard Creek (site LC3) a flow rating has been developed to allow the water level records to be converted to volumetric flow. The *Stream Assessment* reports the intention to develop flow rating curves at the sites that already have water level measurements as well as at three additional sites on Lizard creek and its tributaries and two on Wallandoola Creek.

The assessment of the pool level data is limited to the following general comments:

Lizard Creek: "*The effect of enhanced pool drainage is apparent at, and between, Sites LC5 and LC6 over the Bulli 300 series longwalls.*"

Wallandoola Creek: "*Sites WC1 and WC3 do not show an enhanced pool drainage rate, whereas WC4 has enhanced pool level reduction as it is in a pool that is hydraulically connected to the subsidence cracked Waterfall W1.*"

In both instances the basis for these conclusions is not obvious and further explanation of the basis for these statements is required. It would also be desirable for estimates the rate of loss rates to be prepared.

3.3.3 Subsidence Impacts

Notwithstanding the observed effects of previous subsidence on pools within Lizard Creek, Lizard Creek tributaries and Wallandoola Creek (as set out in Sections 11.2 – 11.4 of the *Stream Assessment*) it is surprising that the report does not contain an analysis for each pool similar to the analysis provided for each swamp in the *Upland Swamp Assessment*.

3.4 Waterfalls

A number of significant waterfalls are located close to the proposed Wonga West extraction panels:

Waterfall L1 on Lizard Creek. This waterfall is described as being about 26 m high and to exhibit significant seepage, some of which is ferruginous. Because this waterfall is located in an area of Bulli Seam first workings, which would have given rise to low subsidence, the seepage is attributed to naturally occurring bedding planes and joints.

This waterfall is located about 240 m east of Longwall 1 in the Wonga West area and predicted to be subject to less than 0.12 m subsidence and 3.5 mm/m strain. Accordingly, the Stream Assessment concludes that the waterfall is "*predicted to have a low risk of subsidence related cracking and a low risk of enhanced stream bed throughflow*." The evidence for this prediction is not presented and there is no analysis of the consequences if the prediction is incorrect and cracking does occur.

In the absence of any adverse subsidence effects due to previous mining the *Assessment of Mining Impacts on Cliffs and Steep Slopes* (SCT, 2012) considered Waterfall L1 to qualify for 'special significance'.

Waterfall W1 on Wallandoola Creek. This waterfall is described as comprising two major steps of 11 and 16 m "*for a total drop of 30 m over a 1.1 km reach*". This description seems at odds with the stream profile shown in Figure 7 of the *Stream Assessment* which shows the distance as about 560 m. Although the creek profile in Figure 3.4 of the *Surface Water Modelling* report identifies the two steps as individual waterfalls rather than one, its shows the overall distance for a total drop of 30 m as being little more than 500 m. During dry periods the waterfall is reported not to flow. Although the *Stream Assessment* notes that, "*The waterfall is also affected by cracking in the sandstone*" and later makes reference to "*the subsidence cracked Waterfall W1*", it is not clear precisely where cracking has been observed.

Waterfall W1 is located about 270 m south of Longwall 5 in the Wonga West area and is located outside the 20 mm predicted subsidence zone. Because the waterfall is predicted to be subject to minimal levels of subsidence and strains, no adverse impacts are expected.

Because flow at Waterfall W1 has been affected by previous subsidence, the *Stream Assessment* does not consider it qualifies for "special significance" in terms of stream connectivity. However, the *Assessment of Mining Impacts on Cliffs and Steep Slopes* (SCT, 2012) considered Waterfall W1 to be of 'special significance' as a cliff structure.

3.5 Swamps

3.5.1 Distribution

The boundaries of the upland swamps identified in the *Upland Swamp Assessment* have been reproduced on various drawings located at the end of the *Stream Assessment* report. While the Appendix 2 of the *Upland Swamp Assessment* differentiates between headwater swamps and valley fill swamps, this hydrologic distinction is not reflected in any of the mapping or the naming convention.

In the Wonga West area there are is mixture of valley fill and headwater swamps, with the largest number being headwater swamps, but the largest area being valley fill (about 85% of the total).

The *Stream Assessment* notes that forty five swamps which meet the definition of the Coastal Upland Swamp Endangered Ecological Community are located within 600 m of the proposed workings at Wonga West. Of these, thirty six lie within the predicted 20 mm subsidence zone with eight of these being assessed in the *Upland Swamp Assessment* as being of 'special significance' according to the NSW Office of Environment and Heritage criteria (OEH, 2012).

Table 3.3 summarises the data from Appendix 2 of the *Upland Swamp Assessment* which identifies 35 swamps in the Wonga West area that have been undermined by prior longwall mining. Whilst the *Stream Assessment* provides an assessment of the locations where previous mining has affected rock bars, no analysis has been undertaken to assess which swamps, if any, may have been affected by prior longwall mining which could provide a benchmark for interpretation of the potential impact of longwall mining in the Wongawilli Seam.

Table 3.3: Wonga West Swamps Previously Affected by Mining

Swamp Name	Size (ha)	Type[1]	Previously Subsided by
Lizard Creek			
Lcus 1	129.89	HW / VF	Cordeaux LW Bulli LW
Lcus 2	0.74	HW	Bulli LW
Lcus 4	0.83	HW	Bulli LW
Lcus 5	0.60	HW	Bulli LW
Lcus 6	3.74	HW / VF	Bulli LW
Lcus 7	0.41	HW	Bulli LW
Lcus 8	2.09	HW / VF	Bulli LW
Lcus 9	0.20	HW	Bulli LW
Lcus 10	2.71	HW	Bulli LW
Lcus 11	0.35	HW	Bulli LW
Lcus 12	1.68	HW	Bulli LW
Lcus 13	0.22	HW	Bulli LW
Lcus 14	0.91	HW	Bulli LW
Lcus 15	0.43	HW	Bulli LW
Lcus 16	0.06	HW	Bulli LW
Lcus 17	1.16	HW	Bulli LW
Lcus 18	2.53	HW	Bulli LW
Lcus 19	0.21	HW	Bulli LW
Lcus 20	0.24	HW	Bulli LW
Lcus 21	0.11	HW	Bulli LW
Lcus 25	3.34	HW	Bulli LW
Lcus 28	1.00	HW	Bulli LW
Lcus 29	0.34	HW	Bulli LW (partial)
Lcus 33	0.35	HW	Bulli LW
Wallandoola Creek			
Wcus 1	36.16	VF	Cordeaux LW Bulli LW
Wcus 3	0.71	HW	Bulli LW
Wcus 4	11.08	HW / VF	Bulli LW
Wcus 5	0.23	HW	Bulli LW
Wcus 6	0.55	HW	Bulli LW
Wcus 7	1.97	VF	Bulli LW
Wcus 8	0.24	HW	Bulli LW
Wcus 9	0.27	VF	Bulli LW
Wcus 10	0.21	HW	Bulli LW
Wcus 11	2.79	HW	Bulli LW
Wcus 12	0.82	HW	Bulli LW

Note1: HW = Headwater Swamp, VF = Valley Fill Swamp. Predominant type listed first

3.5.2 Potential Impacts

Table 3.4 summarises various data from the *Upland Swamp Assessment* for swamps located in the Wonga West area and which are either of ecological significance or are located above the proposed Wongawilli longwalls. Of the eight (only seven referenced in the *Stream Assessment*) which are of ecological significance because of their size or ecological features, the *Upland Swamp Assessment* identifies only two, predominantly valley fill swamps, as being at moderate risk from longwall mining impacts. Both these swamps (Wcus 4 and Wcus7) are located within the Wallandoola catchment.

Table 3.4: Swamps Located Above Mining or of Potential Significance in the Wonga West Area

Swamp Name		Type[1]	Size (ha)	Located Above Longwall	Predicted Subsidence	Tensile Strain (mm/m)	Compressive Strain (mm/m)	Tilt (mm/m)	Ecologically Significant	Risk
Lizard Creek										
Lcus	1	VF / HW	129.89	No	-0.87	0.00	0.00	0.00	Yes	Negligible
Lcus	6	VF / HW	3.74	No	-0.96	0.00	0.00	1.93	Yes	Negligible
Lcus	8	VF / HW	2.09	Area 3 LW1	-2.66	2.75	-2.64	9.15	Yes	Low
Lcus	9	HW	0.20	Area 3 LW1	-3.29	-3.88	-4.81	5.09	No	
Lcus	12	HW	1.68	Area 3 LW1	-3.02	3.95	-4.59	9.51	No	
Lcus	13	HW	0.22	Area 3 Mainroad	0.12	0.00	0.00	0.00	No	
Lcus	14	HW	0.91	Area 3 Mainroad	-0.05	0.00	0.00	0.00	No	
Lcus	15	HW	0.43	Area 3 Mainroad	0.03	0.00	0.00	0.00	No	
Lcus	17	HW	1.16	Mainroad	-0.77	0.00	0.00	1.70	No	
Lcus	18	HW	2.53	Area 3 LW2	-3.30	4.04	-3.43	4.45	No	
Lcus	19	HW	0.21	Area 3 LW3	-3.33	-4.04	-5.56	11.99	No	
Lcus	20	HW	0.24	Area 3 LW4	-2.18	4.13	-1.39	4.69	No	
Lcus	21	HW	0.11	Area 3 LW4	-3.29	-3.64	-3.97	1.86	No	
Lcus	25	HW	3.34	Area 3 LW4 and 5	-3.30	9.98	-7.29	13.57	No	
Lcus	27	HW	1.04	No	0.00	0.00	0.00	0.00	Yes	Negligible
Lcus	28	HW	1.00	Area 4 Mainroad (partial)	-1.85	4.71	1.76	9.15	No	
Lcus	33	HW	0.35	Area 3 Mainroad	-0.19	0.00	0.00	0.00	No	
Wallandoola Creek										
Wcus	1	VF	36.16	No	-0.72	0.00	0.00	0.00	Yes	Negligible
Wcus	4	HW / VF	11.08	Area 3 LW2	-3.35	5.03	-6.97	10.58	Yes	Moderate
Wcus	7	VF	1.97	Area 3 Mainroad	-2.19	5.45	-0.01	10.70	Yes	Moderate
Wcus	11	HW	2.79	Area 3 LW2	-3.27	5.35	-3.81	8.02	Yes	Low
Wcus	12	HW	0.82	Area 3 LW4	-3.22	4.50	-2.74	4.07	No	

Note1: HW = Headwater Swamp, VF = Valley Fill Swamp. Predominant type listed first

The *Stream Assessment* notes that the following significant swamps are at moderate risk of adverse subsidence related effects:

- Wcus4 headwater swamp complex, which overlies longwall LW2;
- Wcus7 valley fill swamp to the south of longwall LW4

All other ecologically significant swamps in the Wonga West area are deemed to be of low or negligible effect of subsidence related effects. However, the impact assessment in the *Upland Swamp Assessment* focusses on swamps that are deemed to be ecological significance. As noted in **Section 2.5.2** the assessment overlooks the potential hydrologic significance of swamps that are subject to similar subsidence impacts as the swamps of ecological 'special significance.

In relation to the potential effects of subsidence on upland swamps in the Wonga West area, the *Stream Assessment* concludes:

> "*However it is considered that the risk of swamp drainage, reduction of discharge to downstream gullies and adverse effects on water quality are low, and that the total volume of water entering Lizard Creek will not be observably affected.*" and;
>
> "*However it is considered that the risk of swamp drainage, reduction of discharge to downstream gullies and adverse effects on water quality are low, and that the total volume of water entering Wallandoola Creek from the headwater swamps, or from the valley fill swamps will not be observably affected.*"

In view of the observed significant bedrock cracking resulting from previous longwall mining, these conclusions appear optimistic and hard to justify in light of the experience at other mines such as Dendrobium (quoted in **Section 2.5.2** above).

3.6 Water Quality

Water quality monitoring has been undertaken at a range of sites in the Wonga West area:

- Nine locations on Lizard Creek commencing at various dates between July 2007 and November 2009;
- Five locations on Lizard Creek tributaries commencing in July 2006 or august 2008;
- Five locations on Wallandoola Creek commencing at various dates between July 2007 and November 2009;
- One location on a tributary of Wallandoola Creek (date of commencement not specified).

The Stream Assessment does not specify the frequency of monitoring, but from the number of data points in some of the graphs, it appears that monitoring events occurred between two and three months apart, with an average of about 2.5 months on both creeks. For both creeks, the dataset appears to include about 24 samples which would provide a reasonable basis for establishing site specific water quality trigger levels in accordance with the procedures set out in the ANZECC guidelines. Any seasonal variation effects would be better represented if further monthly monitoring occurred prior to mining being undertaken. In addition to the water quality monitoring, water level and volumetric flow monitoring are also undertaken as a limited number of sites as set out in **Section 3.3.2**.

The *Stream Assessment* provides graphs of the longitudinal profiles of median values of pH, conductivity, iron (total and filtered) and manganese (total and filtered) as well as graphs of the variability of pH and conductivity over time.

- In Lizard Creek median pH and EC show a slight increasing trend from upstream to downstream, which is not exhibited in Wallandoola Creek. No explanation is provided for these differences which may be due to there being fewer sites on Wallandoola Creek spread over a shorter length of creek;

- In Wollondoola Creek both median pH and EC show a marked reduction at sites WC3 and WC 5. A reduction in both filtered and total manganese also occurs at at site WC3. However the *Stream Assessment* provides no analysis of these water quality variations in relation observed bedrock cracking or observed ferruginous discharge/precipitation that might be attributed to the consequenced of previous longwall mining.

- For both creeks the graphs showing variation of pH and EC over time show considerable vaiation between sites and over time, with no apparent pattern.

In addition to pH, EC, iron and manganese, it is apparent that a range of other analytes are monitored including nitrogen, phosphorus, aluminium, copper, zinc and sulphates. The *Stream Assessment* provides only a very general summary and no supporting statistics. Notwithstanding, the key features of the water quality in Lizard and Wallandoola Creeks are:

- pH shows an increasing trend downstream except for areas of inferred groundwater seepage, but exceeds the ANZECC default trigger values for upland streams in south-east Australia;
- Water quality occasionally exceeds the 95th percentile for freshwater ecosystem protection for filtered aluminium, copper, nickel and zinc. For purposes of monitoring the impacts of mining, further assessment may be required to establish relevant trigger levels for further investigation;
- Nitrogen and phosphorus levels have, on occasions exceeded the ANZECC default trigger values for upland streams. Given the undeveloped nature of the catchment, these exceedances seem anomalous and may require further investigation to identify the source.

It is apparent that baseline water quality data has been collected for range of relevant analytes. This data should provide an appropriate basis for establishing baseline water quality for purposes of identifying any water quality impacts as a result of mining. However a full list of the analytes monitored and tables showing the key statistics are necessary to provide a complete picture of the water quality characteristics for assessment purposes. Further analysis of the water quality statistics should also be provided along with justification for any proposed water quality ‘trigger’ levels that differ from the default values in the ANZECC Guidelines.

4 Water Management at Mine Facilities

The mine facilities that will be required for the NRE No 1 Colliery project comprise:

- The existing pit-top facility at Russell Vale;
- The No 4 Shaft site located approximately 10 km north-west of the Russel Vale site.

4.1 Russell Vale

4.1.1 Overview

The Russell Vale site (about 38 ha) is located on the lower slopes of the Illawarra escarpment at elevations between approximately 30 m AHD and 140 m AHD. The site contains all the usual mine site facilities including the mine portal, workshops, laydown areas, coal conveyor and stockpile, and separate water management systems for:

- Water supply and effluent disposal;
- Mine water management;
- Stormwater (four classes).

The water management facilities on site include various interconnections, particularly the treatment of 'dirty' stormwater for re-use in site operations.:

4.1.2 Stormwater Management

The stormwater management system at the Russell Vale pit-top area attempts to segregate and manage stormwater from four separate sources which are shown on **Figure 4.1**:

- 'Clean' runoff from the escarpment which is directed off site with minimal or no treatment;
- 'Clean' runoff from within the site which is directed off site with minimal treatment;
- Moderately dirty water which is subject to 'first flush' treatment;
- 'Dirty' water which is directed via sediment basins to a holding dam from where it is pumped for treatment and either re-use within the mine or discharge as 'clean' water.

The *Water Management Report* (Beca, 2011) and its appendix (*Gujarat NRE Stormwater Hydrology Review*, Beca, 2010) set out details of the existing catchments and proposed modifications to improve the performance of the system in terms of pollution and flood control. The main characteristics of the various sub-catchments and the proposed improvements are summarised in **Table 4.1**.

The main features of the proposed improvements to the stormwater management system are:

- Improved separation and control of conveyance of water from the different catchments;
- Upgrading of about 560 m of the Southern Stormwater Channel to ensure separation of 'clean' water from the site and up-slope from 'dirty' stormwater from the coal stockpile area (L2 on **Figure 4.1**);
- Construction of a stormwater energy dissipater and settlement area with a low flow outflow pit to control discharge from the Southern Stormwater Channel into Bellambi Gully.;

- Construction of a dry sediment basin to provide pre-treatment of stormwater from the coal stockpile area before it drains to the existing settling ponds;
- Cleaning out and reconfiguration of the existing settling ponds into a single pond.

Table 4.1: Summary of Catchment Characteristics and Proposed Stormwater Improvements

Catchment	Area (ha)	Water Quality	Catchment Conditions	Pervious (%)	Drains to	Proposed Improvements
Natural Escarpment						
U1	10.69	Clean	Natural escarpment	100%	Roadside swale drains to Southern Stormwater Channel	New diversion drain
U2	9.76	Clean	Natural escarpment	100%	Diversion drain to Southern Stormwater Channel	Clear diversion drain
U3	8.63	Clean	Natural escarpment	100%	Diversion drain - off-site to existing natural drainage to the north	-
Site Facilities with Minimal Pollutant Sources						
U4	0.50	Clean	Former power station	100%	Diversion drain - off-site to existing natural drainage to the north	-
U5	0.40	Clean	Natural escarpment	100%	Diversion drain - off-site to existing natural drainage to the north	Upgrade diversion drain
M2	1.28	Clean?	Office and car park	34%	M3 channel then to Southern Stormwater Channel	Bitumen car park
M3	3.31	Clean?	Vegetated batters and set-down area	100%	Swale, culvert and channel, then to Southern Stormwater Channel	Increase bund height. Raise down-slope road crest
M4	0.43	Clean?	Vegetated natural slope	100%	Southern Stormwater Channel	-
M5	3.34	Clean?	Steep vegetated batters and access roads	100%	Channel to join M6 channel then to Southern Stormwater Channel	Increase local grade. Increase bund height
M6	1.36	Clean?	Steep vegetated batters and access roads	100%	Channel to join M5 channel then to Southern Stormwater Channel	Increase local grade. Increase bund height. Conveyor underpass concrete channel
M8	1.78	Clean?	Access road and vegetated corridor	95%	Roadside swale	Roadside piped drainage to existing clean water pipeline and settlement area
L1	4.84	Clean	Dam and batters to south of Southern Stormwater Channel	100%	Southern Stormwater Channel	Remove dam. Reconstruct channel. Construct outlet energy dissipater and low flow control pit
Moderate Pollution Potential						
M1	6.12	Dirty?	Workshop, hardstand and mine portal	55%	First flush to dirty water system. Overflow to Southern Stormwater Channel	Improve first flush
Dirty Water Catchments						
M7	1.73	Dirty	Conveyor belt portal	100%		Sealed access road then piped to stockpile area
L2	12.70	Dirty	Coal stockpile, truck loading	90%	Settling ponds then to Dirty Water Dam	Construct new sediment basin

Source: *Stormwater Hydrology Review*

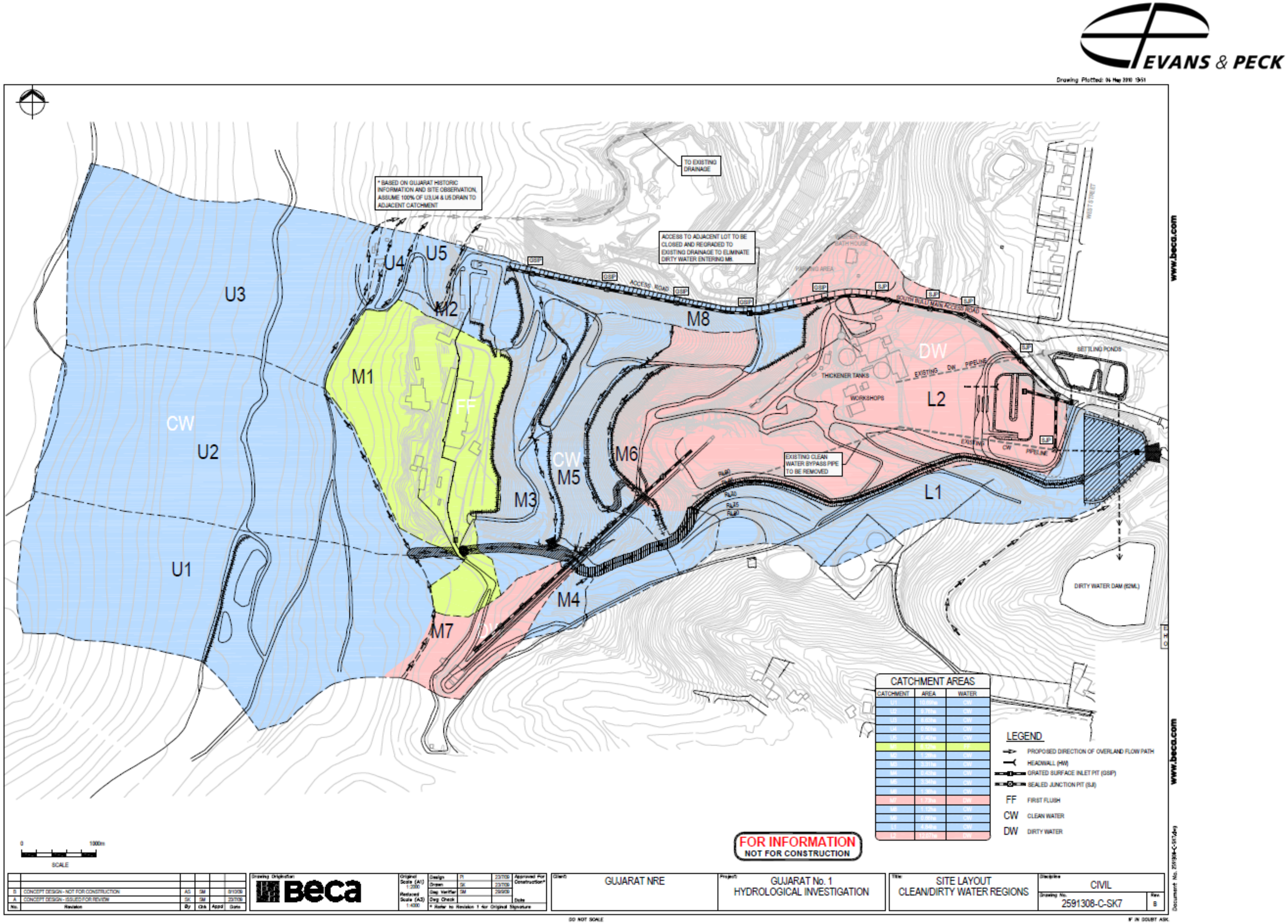


Figure 4.1: Catchment Designations within the Russel Vale Site

Source: *Stormwater Hydrology Review*

A number of aspects of the existing and proposed stormwater management systems require further clarification:

- The contention that the mine portal and pit-top area (including the workshop) (catchment M1) can be considered to have only moderate potential for generation of polluted stormwater is questionable. The proposed method of treatment of this water is via a first flush system that directs the initial runoff into the dirty water capture system and the remaining runoff to the Southern Stormwater Channel. Further details are required to:
  - Justify why the runoff from this area should not be considered 'dirty' and all runoff directed to the dirty water management system;
  - Define and justify the first flush volume (expressed as mm of runoff) that would captured before any remaining runoff is directed to the Southern Stormwater Channel;
  - Demonstrate that the arrangement will operate as a genuine 'first flush' system.
- Large areas within the site are classified as 'clean' including the office, car park and large areas of constructed batters and laydown areas. Large parts of these areas are bare ground which has sediment generation potential. In addition, there does not appear to be any guarantee that materials stored on the laydown areas would not include potential sources of pollutants, such as fuel and oil. The stormwater management proposals for these areas seek to maintain separation of runoff from the various terrace levels, but does not provide any simple sediment control except via the 'energy dissipater and settlement area' at the end of the Southern Stormwater Channel;
- The proposed maximum operating level of the Dirty Water Dam (30 ML) is based on being able to retain runoff from catchments M7 and L2 for a 72 hour 10 year ARI storm while operating the water treatment system at a rate of 300 kL/hour (7.2 ML/day). The analysis underpinning this proposed maximum operating level appears to be based on a simple 'design storm' approach and does not adequately take account of the volumes of runoff that would be generated from longer duration storms that give rise to a total volume greater than that generated by the assumed 72hour 'design storm'. (Assuming that the water treatment system is operating at 7.2 ML/day and the Dirty Water Dam is drawn down to 30 ML at the start of a storm, the implied volume of runoff is 55.6 ML which equates to 385 mm of runoff or a runoff coefficient of 0.88 from catchments L2 and M7. Is this runoff coefficient realistic? How has the first flush and continuing runoff from catchment M1 been taken into account?) The preferred approach would be to examine the behaviour of the Dirty Water Dam using a daily water balance model (e.g. AWBM) to generate runoff from the catchment and test the required drawdown to achieve the required frequency of overflow.

4.1.3 Process Water Requirements and Supply

The main water requirements for the project will be the supply for the underground operations. At peak operation the daily requirement is estimated to be 4.2 ML/day. The proposed sources of supply for this water are:

- Raw water from Corrimal Springs (estimated to be 0.1 ML/day);
- Mine dewatering;
- Make-up from Cataract Dam.

This list does not appear to account for all the treated water from the thickener tank that is quoted as providing 1.7 ML/day (Section 3.3.2) and which, as noted above, is intended to provide up to 7.2 ML/day when the Dirty Water Dam is full.

Based on a report by Golder Associates (Appendix D to the *Groundwater Assessment*) the *Water Management Report* provides the groundwater inflow estimates set out in **Table 4.2** below.

Table 4.2: Modelled Groundwater Inflow Rates (ML/day)

Groundwater Source	Current Bulli Seam Workings	Last Phase of Mining Wongawilli Seam Workings	Last Phase of Mining Wongawilli and Bulli Seam Workings
Wonga East	0.2	1.2	1.4
Wonga West	0.9	0.8	1.7
Total	1.1	2.0	3.1

It is unclear how well the modelled groundwater inflow rates correlate with actual dewatering records from recent years. Figure 22 in the *Groundwater Assessment* (reproduced as **Figure 4.2** below) shows the pumping from one section of the workings which appears to show an average since 2010 of about 0.15 ML/day. Presumably there are other pumping records that could be used to support the estimates of current groundwater inflow.

One of the objectives of the graphs in Figure 22 of the *Groundwater Assessment* appears to be to demonstrate that there is no relationship between rainfall and groundwater make. The assertion that there is no relationship would be more apparent if the rainfall and inflow graphs were plotted as cumulative values against each other.

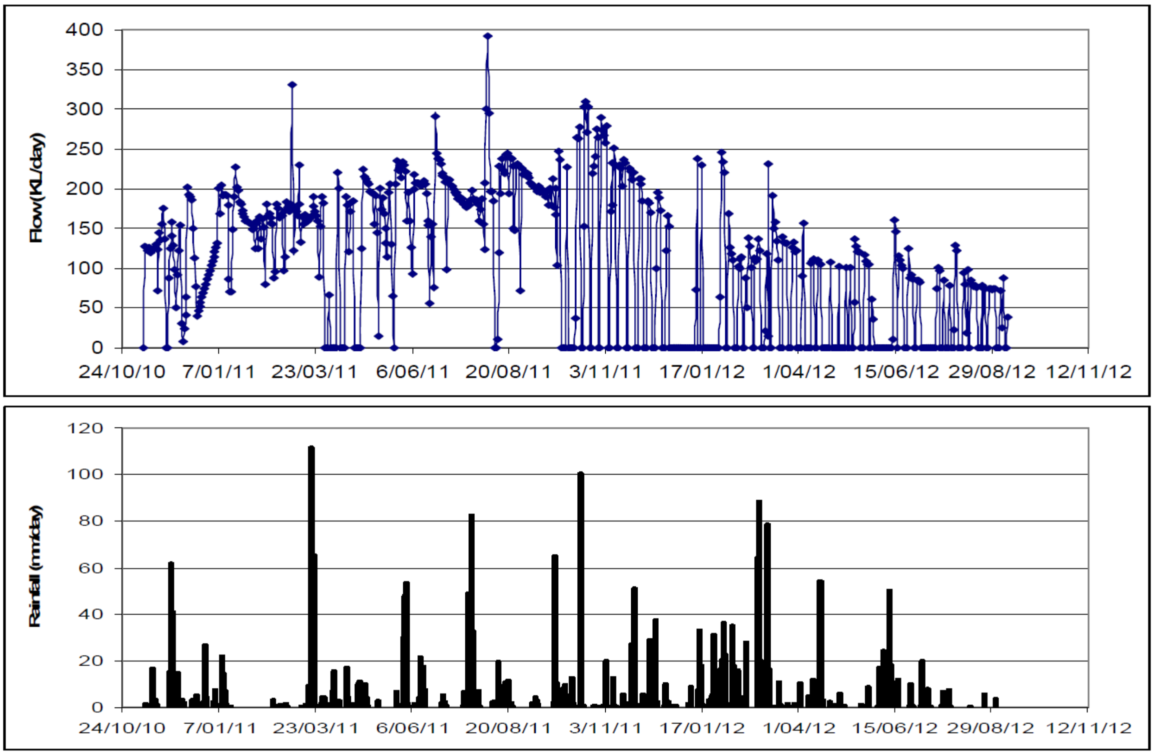


Figure 4.2: Wonga East (27 Cut through) Groundwater Extraction and Rainfall
Source: *Groundwater Assessment* Figure 22

With reference to a site water balance schematic diagram (Figure 10 in the *Water Management Report)*, the report notes that:

> *"10% of the water supplied to mine operations is assumed to be not recoverable or collectable to the new mine water storage tank/s and that this will be routed (as part of stream 17) through existing drains to Dam 1."*

The accompanying table shows the following numbers:

- Mine Water Supply 4.2 ML/day;
- Mine Water to Treatment 3.1 ML/day.

These numbers, taken together with the modelled groundwater inflow rates (in **Table 4.2** above) do not appear consistent.

- If 4.2 ML/day is supplied to the mine operations, about 0.65 would be required for above ground purposes (27 kL/h x 24 h from Section 4.3.1) leaving 3.55 ML directed underground;
- Assuming 10% of the supplied water is not recoverable, the recovered water would be 3.2 ML/day;
- Assuming groundwater inflow of 3.1 ML/day, the total water to be extracted from the mine would be 6.3 ML/day.

This does not appear to be reflected in the site water balance. If this analysis is correct, the mine would not require any supplementary supply from Cataract Dam.

4.1.4 Site Discharge

Stormwater leaves the site via four routes:

- Diverted 'clean' water from catchments U3, U4 and U5 drains to an existing drainage line to the north of the site;
- Diverted 'clean' runoff from the upslope catchments U1 and U2, together with 'clean' runoff from catchments M2 to M6, M8 and L1 drains to Bellambi Gully via the Southern Stormwater Channel and the proposed energy dissipater and settlement area;
- Treated water from the Dirty Water Dam is also discharged to Bellambi Gully;
- Overflow from the Dirty Water Dam would also discharge to Bellambi Gully.

The limited water quality monitoring in Bellambi Gully undertaken in 2010 (as quoted in *Water Management Report*) indicates that the water has elevated levels of total dissolved solids and is slightly more alkaline than in comparable creeks in the area.

Given the limited number of samples reported for Bellambi Gully (maximum three dates at any site) and the fact that the sampling was probably undertaken on a routine basis, the data is unlikely to fully represent the water quality in the creek, particularly during storm runoff.

4.1.5 Flow and Flooding

The operation of the water treatment system that takes water from the Dirty Water Dam means that the flow regime in Bellambi Gully is likely to have an artificially elevated baseflow.

Flooding downstream of the Russell Vale site has been experienced in the past. From the *Water Management Report* it is unclear the degree to which the flow was attributable just to flow from the Southern Stormwater Channel, or whether overflow from the Dirty Water Dam also contributed.

The text of the *Water Management Report* notes that the culvert under the Princes Highway has inadequate capacity to convey the flow from the 10 year ARI storm. However, there is no supporting analysis to confirm this or to identify the contribution that the Russell Vale site itself (as opposed to the steep escarpment above the site) makes to flood flows downstream in Bellambi Gully.

The proposed changes to the stormwater management system are designed to primarily address water quality issues. It is unclear how much these works would affect flood flows from the site. The *Stormwater Hydrology Review* indicates that the ILSAX rainfall:runoff component of DRAINS has been used to assess the peak runoff characteristics of the various sub-catchments (and presumably takes account of the differing times of concentration). The availability of this runoff modelling would allow a DRAINS model to be configured which represented the 'existing' and 'proposed' conditions in order to demonstrate how much these works would affect flood flows from the site.

4.2 No 4 Shaft

4.2.1 Overview

The No. 4 Shaft site provides access to the mine for workers and their equipment. No coal is taken out of the mine via the No 4 Shaft. The facilities at No. 4 Shaft site include winder, offices, bath-house, stores, workshop, car parking, water management facility, sewage treatment plant, electrical substation and explosives magazine.

The facilities at Shaft No. 4 are designed to accommodate approximately 1,000 persons, but have not been used anywhere near capacity in recent times. The proposed project would involve increased use of the No. 4 Shaft site, but it is unclear the likely number of personnel.

The main surface water management issue at this site relates to effluent treatment and disposal of treated effluent by irrigation.

4.2.2 Wastewater Treatment and Disposal

The site has two separate wastewater treatment systems:

- 'Grey' water from showers and hand basins is treated in a Pasveer ditch and the treated effluent is placed in the Main Collector Dam. This water is either used to maintain the fire water supply or is treated prior to underground use.
- 'Black' water from toilet flushing is treated in a second Pasveer ditch from which the effluent is directed into a series of two maturation ponds and a wet weather holding pond (total capacity 1.4 ML). The treated effluent is finally irrigated onto a designated area of about 0.25 ha in accordance with a protocol designed to ensure that runoff is not caused as a result of effluent irrigation.

Appendix D of the *Water Management Report* provides an analysis to demonstrate the adequacy of the available effluent storage capacity to cater for low evaporation in winter and/or prolonged wet weather. The analysis purports to be based on the DEC guidelines *Use of Effluent by Irrigation* (2004).

Although the facility exists and, presumably, does not form part of the current project application, a number of aspects of the facility and its operation require clarification and/or justification:

- The effluent irrigation is quoted in the *Water Management Report* as having an area of 0.25 ha (2,500 m^2). However the effluent balance analysis in Appendix D appears to be based on an area of 4,500 m^2.
- The analysis is based on an effluent flow of 7.4 kL/day. The basis of this assumed flow is not stated either in terms of the number of employees or the volume allowance per employee (which requires justification).
- The monthly water balance is appropriate for a single household but is an over simplification for a facility catering for a large number of people. A daily water balance should be used with an extended period (minimum 20 years) of local rainfall and evaporation data.
- The analysis in Appendix D uses monthly average rainfall for Picton. In view of the local rainfall variation (illustrated in **Figure 2.3** in this review), and as rainfall is a key factor in determining how much effluent can be irrigated, the use of Picton data requires justification.

Australia

Adelaide
Level 30, Westpac House
91 King William Street
Adelaide SA 5000
Telephone: +618 8113 5359

Brisbane
Level 2, 555 Coronation Drive
Toowong QLD 4066
Telephone +617 3377 7000
Fax +617 3377 7070

Melbourne
Level 15, 607 Bourke Street
Melbourne VIC 3000
Telephone: +613 9810 5700
Fax: +613 9614 1318

Perth
Level 6, 600 Murray Street
West Perth WA 6005
Telephone +618 9485 3811
Fax +618 9481 3118

Sydney
Level 6, Tower 2
475 Victoria Avenue
Chatswood NSW 2067
Telephone: +612 9495 0500
Fax: +612 9495 0520

Asia

Beijing
6/F Building A1
Beijing Electronic Technology Zone
No.9 Jiuxianqiao East Road
Chaoyang District, Beijing,
People's Republic of China
Telephone: +8610 5908 3000
Fax: +8610 5924 5001

Hong Kong
Level 32, 248 Queen's Road East
Wanchai, Hong Kong
Telephone: +852 2722 0986
Fax: +852 2492 2127

Kunming
Room B2901, Yinhai SOHO
612 Beijing Road
Kunming 650011
Telephone: +86 871 319 6008
Fax: +86 871 319 9004

Shanghai
C/- WorleyParsons, 8/f
No. 686 Jiujiang Road
Huangpu District Shanghai 200001
People's Republic of China
Telephone +86 21 6133 6892
Fax +86 21 6133 6777

Europe

London
Parkview, Great West Road
Brentford, Middlesex TW8 9AZ
United Kingdom
Telephone +44 (0)208 326 5347

EVANS & PECK

Evans & Peck Group Pty Ltd
ABN50 098 008 818
E: info@evanspeck.com