Appendix D

Groundwater Reports

Appendix D Groundwater Reports

GeoTerra

Groundwater Exploration Services

WOLLONGONG COAL LTD
RUSSELL VALE COLLIERY
UNDERGROUND EXPANSION PROJECT
PREFERRED PROJECT REPORT
WONGA EAST
GROUNDWATER ASSESSMENT

Bellambi, NSW

NRE1 – R1C GW

19 JUNE, 2014

NRE8 R1C GW (19 June 2014)

Wollongong Coal Ltd
PO Box 281
Fairy Meadow NSW 2519

Attention: Dave Clarkson

Dave,

RE: Russell Vale Colliery – Underground Expansion Project, Preferred Project Report, Wonga East Groundwater Assessment

Please find enclosed a copy of the above mentioned report.

Yours Faithfully

GeoTerra Pty Ltd	**GES Pty Ltd**
Andrew Dawkins	**Andy Fulton**
Principal Hydrogeologist (MAusIMM CP-Env)	Principal Hydrogeologist

Distribution: Original	Geoterra Pty Ltd / GES Pty Ltd	
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Position:	Principal Hydrogeologist / Principal Hydrogeologist

Date	Rev	Comments
20/05/2014		Draft
02/06/2014	A	Incorporate review comments
5/06/2014	B	Incorporate review comments
12/06/2014	C	Incorporate review comments

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1. INTRODUCTION

As part of the proposed Underground Expansion Project (UEP), Wollongong Coal Ltd (Wollongong Coal) proposes to extract coal from the Wongawilli Seam by longwall extraction from Longwalls 1 to 3 and Longwalls 6 to 11 in the Wonga East mining domain.

Longwalls 4 and 5 in the Wongawilli Seam at Wonga East were recently mined between April 2012 and January 2014.

The proposed workings are contained within Consolidated Coal Lease 745 (CCL745) and Mining Lease 1575 (ML1575), both of which are held by Wollongong Coal.

The proposed and historic workings are predominantly located within the Metropolitan Special Area as shown in **Figure 1**. The Metropolitan Special Area is a restricted area managed by the Sydney Catchment Authority.

The Study Area is located approximately 13km northwest of Wollongong and is defined as the area within the 20mm predicted subsidence zone (SCT Operations 2014) above the proposed Wongawilli Seam workings.

Potential Significant Feature Zones have been defined as 600m wide zones that extend from the edge of the secondary extraction footprint for the assessment of any potentially significant natural features (NSW Planning Assessment Commission, 2009).

In addition, Risk Management Zones have been defined with 400m wide (or 40^{o} angle of draw from the edge of the proposed underground workings) corridors that extend centrally from the creek centre line for the Cataract River, Cataract Creek and Bellambi Creeks.

Where either of these two zones extend outside the footprint of the 20mm subsidence zone, they have been incorporated in the Study Area for this assessment.

Within Wonga East, 1st and 2nd order tributary creeks drain into the 3rd, and subsequently 4th order catchment of Cataract Creek, downstream of the freeway, and the 3rd order catchments of Cataract River.

The Wonga East catchments drain directly into Cataract reservoir and subsequently, to Broughtons Pass weir. Cataract River subsequently drains downstream to the off-take to the Macarthur Water Treatment plant at Broughtons Pass Weir.

Cataract River is regulated by Cataract Dam, upstream of the Lizard Creek / Wallandoola Creek confluence, as well as by Broughton’s Pass Weir, downstream of their confluences with Cataract River.

The Study Area is focussed on the main channel of Cataract Creek, with Bellambi Creek on the northern periphery and Cataract River in the western region.

None of the main creek channels will be undermined by the proposed workings.

The Study Area contains steep gradient valleys that drain off the western slopes of the Illawarra escarpment to Cataract reservoir in the west.

The proposed Wonga East workings predominantly underlie the Cataract Creek catchment, and to a lesser degree, the Cataract River and Bellambi Creek catchments.

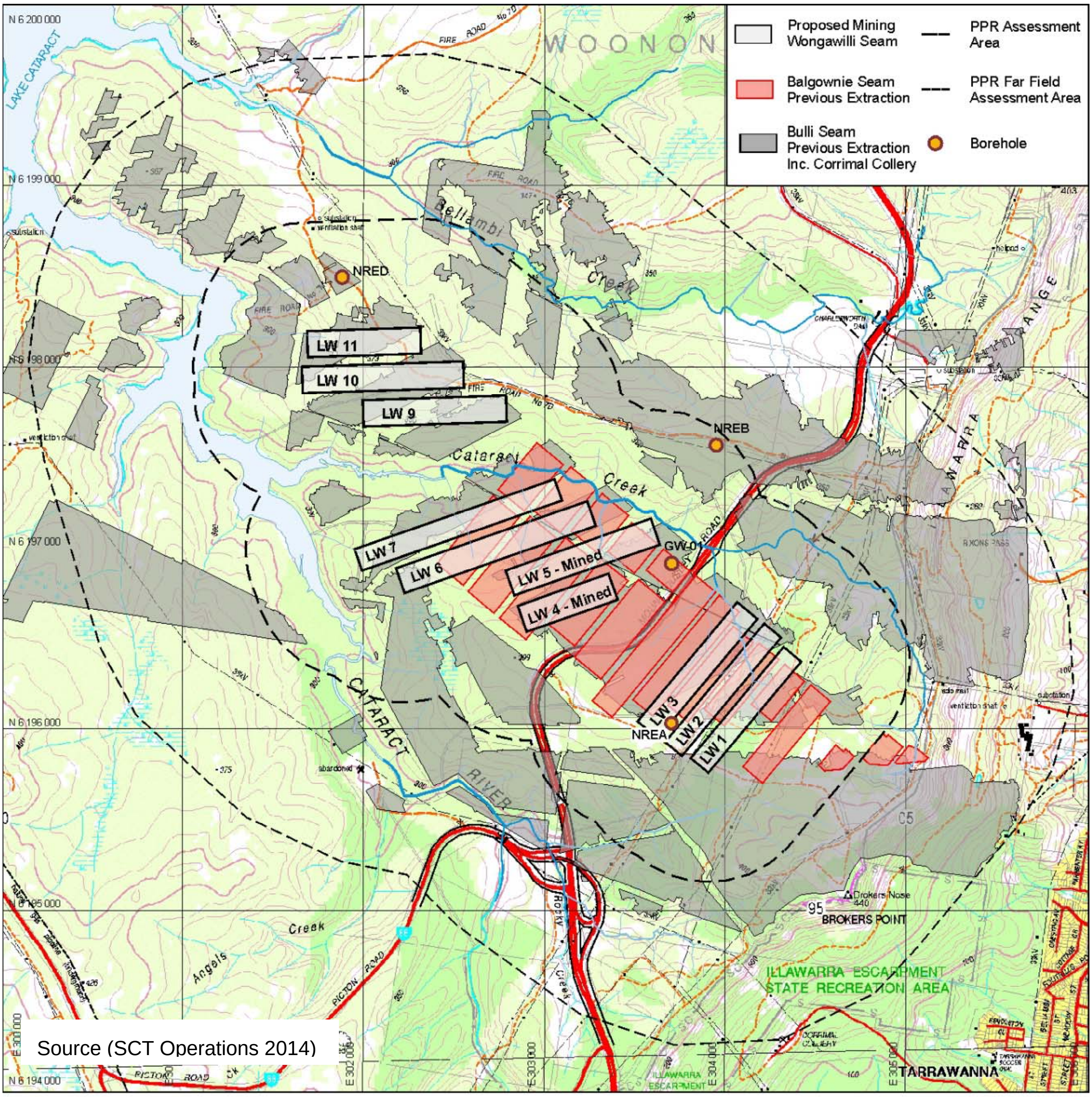


Figure 1 Wonga East Historic and Proposed Mining

Thirty nine upland headwater swamps that meet the definition of being a Coastal Upland Swamp Endangered Environmental Community are present in the Wonga East Study Area within the Cataract Creek, Cataract River and Bellambi Creek catchments (Biosis, 2014).

Land use within the Study Area generally consists of undeveloped bushland, including some limited fire access and power transmission access trails.

This study provides a baseline assessment of the current status of potentially affected groundwater systems within the proposed mining area in accordance with the Director-Generals Requirements (DGR's) for the project as well as subsequent Preferred Project

Report review correspondence by the relevant regulatory departments.

Office assessments, field monitoring, laboratory analysis and computer modelling studies have been used to prepare a baseline assessment of the shallow and deep groundwater systems, as well as perched upland swamp water levels, water quality and aquifer hydraulic parameters within the Study Area.

The study assesses the potential mining impact on the groundwater systems, as well as providing a potential indicative management and monitoring strategy that will be suitable to manage any potential adverse effects that may be caused by subsidence.

Related groundwater features within the Study Area include:

- a regional water table which has been intersected between 17m to 48m below surface within the Hawkesbury Sandstone. Where paired measurements are available, the regional aquifer has been shown to be hydraulically separated from the upland swamps by up to 15m of dry to unsaturated, weathered Hawkesbury Sandstone;
- shallow, perched, ephemeral aquifers within the upper (<20m deep) Hawkesbury Sandstone;
- headwater swamps within Cataract Creek, Bellambi Creek and Cataract River catchments;
- shallow (<1.9m deep) perched, ephemeral highly variable water level aquifers within the swamps, and;
- "Losing" streams, which predominate in the upper catchments, where stream water permeates into the regional Hawkesbury Sandstone aquifer, and "gaining" streams in incised sections, where groundwater seeps under gravity into the main creek channels.

Previous underground mining in and adjacent to the Study Area has been conducted through longwall mining of the Bulli Seam in Wollongong Coal's lease area to the west, east and beneath Cataract reservoir, as well as in BHP Billiton's (BHPB) Cordeaux and Corrimal lease areas to the south and the BHP Old Bulli workings to the north.

Multi seam mining has been conducted at Wonga East through:

- bord and pillar, as well as pillar extraction of the Bulli Seam at Wonga East, along with predominantly bord and pillar mining, and to a lesser degree, longwall extraction in the old Australian Iron and Steel (AIS) (subsequently BHPB) Bulli Colliery workings to the north and Corrimal colliery to the south of Wonga East.
- longwall extraction of the Balgownie Seam at Wonga East, and;
- extraction of Longwalls 4 and 5 in the Wongawilli Seam at Wonga East.

The proposed mine plan has been specifically designed to not directly undermine the main channels of Cataract and Bellambi Creeks, Cataract River or Cataract reservoir.

The proponent has committed to developing a closure based trigger system for managing impacts on the creek with the exact values to be determined based on the best available predictive models and assessment of existing closure data from LW 4 & 5. This will be undertaken in liaison with regulators as part of the development of management plans for Cataract Creek.

The stream assessment for the Study Area is discussed seperately in WRM Water and Environment (2014), whilst the swamp assessment is detailed in Biosis (2014).

1.1 Scope of Work

In accordance with the Director General's Requirements for Project Application 09_0013, (20/3/2009), the requirements for the groundwater component of the assessment are:

- *a description of the existing environment, using sufficient baseline data;*
- *an assessment of the potential impacts of all stages of the project, including any cumulative impacts, taking into consideration any relevant guidelines, policies, plans and statutory provisions and the findings and recommendations of the recent Southern Coalfield inquiry;*
- *a description of the measures that would be implemented to avoid, minimise, mitigate, rehabilitate/remediate, monitor and/or offset the potential impacts of the project, including detailed contingency plans for managing any potentially significant risks to the environment, and;*
- *a detailed assessment of the potential impacts of the project on the quantity, quality and long-term integrity of the groundwater resources in the project area, paying particular attention to the Upper Nepean River sub-catchment (Metropolitan Special Area)*;

This document also addresses submissions from the relevant regulators in response to the Underground Expansion Project Preferred Project Report provided by Gujarat NRE Coking Coal Ltd (now Wollongong Coal Ltd) to the Department of Planning and Infrastructure (DoPI), on 28 August 2013, as well as subsequent correspondence between Wollongong Coal, DoPI and its authorised representatives.

Geoterra Pty Ltd (Geoterra) and Groundwater Exploration Services Pty Ltd (GES) were commissioned by Wollongong Coal Ltd to address any potential groundwater impacts relating to the proposed extraction and associated subsidence of the Wongawilli Seam in the Wonga East mining area, as proposed for the UEP.

The groundwater investigation was conducted to assess the current and historic:

- standing water levels and / or hydrostatic pressures within formations overlying the existing and proposed workings;
- groundwater quality of the upland swamps, shallow and deeper Hawkesbury Sandstone units;
- hydraulic parameters of the upland swamps, Hawkesbury Sandstone and other formations overlying the proposed workings, and;
- any observed or inferred groundwater discharge zones into local streams.

In addition, the study aims to:

- identify potential groundwater dependent ecosystems;
- collate and review mine water management data;
- collate and review additional data from adjacent mines and government agencies;
- develop a conceptual groundwater model and represent the Study Area with a numerical MODFLOW SURFACT groundwater model to assess potential underground mining impacts on the local and regional groundwater system;

- provide a qualitative and quantitative assessment of cumulative impacts from adjacent existing and approved mines;
- assess post mining groundwater impacts in regard to groundwater level recovery;
- develop measures to avoid, mitigate and/or remediate potential impacts on groundwater resources, and;
- indicate groundwater monitoring measures that will measure any impacts on the local and regional groundwater system.

The study provides a baseline, pre-mining assessment of the potentially affected groundwater systems within the proposed mining area and has been conducted to satisfy the requirements for an Environmental Assessment

2. RELEVANT LEGISLATION AND GUIDELINES

The report has been prepared with reference to the following documents;

- Barnett et al, 2012, Australian Groundwater Modelling Guidelines, Water lines Report, National Water Commission, Canberra
- National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC);
- NSW State Groundwater Policy Framework Document (NSW Department of Land and Water Conservation [DLWC]);
- NSW State Groundwater Quality Protection Policy (DLWC);
- NSW Draft State Groundwater Quantity Management Policy (DLWC);
- NSW Groundwater Dependent Ecosystem Policy (DLWC);
- Murray-Darling Basin Commission Groundwater Quality Sampling Guidelines Technical Report No 3 (MDBC);
- Murray-Darling Basin Commission. Groundwater Flow Modelling Guideline (MDBC);
- Water Management Act 2000;
- Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 (NSW Office of Water – NOW); and
- NSW Aquifer Interference Policy (NOW).

2.1 State Groundwater Policies and Management Plans

The aquifers are covered, as appropriate, by the generic State Groundwater Policy (DLWC, 1997), Groundwater Quality Protection Policy (DLWC, 1998).

The Study Area lies within Groundwater Flow System 5 (GFS5) Hawkesbury Sandstone - South-East (Grey and Ross, 2003) which includes the catchment of Cataract Dam. As the area is within the Sydney Catchment Authority controlled Metropolitan Special Area, no groundwater supply work development is permitted as it is a protected area. As such, there are no private bores. GFS5 has a sustainable yield estimate of 58,000 ML/year (Grey and Ross, 2003).

The *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011* encompasses the Study Area. The Study Area is within the Sydney Basin Nepean Groundwater Source Area.

The water sharing plan annual rainfall recharge in the Sydney Basin Nepean Groundwater Source Area is assessed at 224,483ML/year. This volume is subdivided into consumptive pool water and environmental water, with 124,915ML/year of the long term annual average recharge being reserved as environmental water. The remaining volume is classified as a sustainable yield or long term average extraction limit of 99,568ML/year.

The current extraction limits and groundwater entitlement volumes do not include all water taken through aquifer interference activities such as mine voids (remnant or otherwise).

Reservation of environmental water aims to support the long term viability of the aquifers and their dependent ecosystems.

While it does not extend into the Study Area, there is currently an embargo on further applications for sub-surface water licences in the Southern Coalfield (ordered under section 113A of the Water Act, 1912), for areas covering the:

- Nepean Sandstone Water Shortage Zone GWMA 607 (gazetted 8 June 2007); and
- NSW Southern Highlands (gazetted 21 May 2004 and 16 December 2005).

2.2 Water Management Act 2000

The *Water Management Act 2000* allows for the development fo water sharing plans (WSPs). The rules of WSPs determine how water is to be allocated between water users and the environment. WSPs include extraction limits to ensure that there is sufficient water in the water source to maintain environmental health.

In regard to swamps, the Water Management Act provides for protection of groundwater dependent ecosystems (GDEs) in Sections 3, 5 and 9. GDEs are also protected through clauses 8(1) and 9 as well as Schedule 4 of the WSP.

Upland Swamps within the Study Area are not representative of the Temperate Highland Peat Swamps on Sandstone (THPSS) EEC listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The listing advice for the THPSS EEC (TSSC 2005) contains a number of criteria not met by the upland swamps within the Study Area.

It is understood that the Department of Environment (DoE) are currently reviewing the listing of upland swamps, and that the new listing advice is likely to cover swamps on the Woronora plateau, as outlined in Biosis (2012).

Notwithstanding, the upland swamps within the Woronara Plateau were considered to be significant by the Office of Environment and Heritage (OEH)in the Bulli PAC report.

2.3 Water Sharing Plan for the Greater Metropolitan Region Groundwater Water Sources 2011

The water sharing plan also includes rules aimed at protecting Groundwater Dependent Ecosystems consistent with the Groundwater Dependent Ecosystem Policy (DLWC, 2002). The policy includes wetlands, terrestrial vegetation and caves or karst systems. In the proposed plan, terrestrial ecosystems are protected by a 200m stand off for new bores from any sandstone escarpment where hanging swamps or base flow to rivers is supported by groundwater. It should be noted, however, that no extraction bores are proposed and there are no “hanging” swamps, as opposed to “Upland” swamps in the Study Area

The Project is located within the Sydney Basin Nepean Groundwater Source (Management Zone 2) under the WSP. The rules of the WSP that may be relevant to the proposed mining include:

- A commercial access licence under a controlled allocation order may be made in relation to any unassigned water in this water source

To minimise interference between neighbouring works

Clause 39 of the WSP states that no water supply works (bores) to be granted or amended within the following distances of existing bores:

- 400m from an aquifer access licence bore on another landholding, or
- 100m from a basic landholder rights bore on another landholding, or
- 50m from a property boundary (unless written consent from neighbour), or
- 1,000m from a local or major water utility bore, or
- 200m from a NSW Office of Water monitoring bore (unless written consent from NSW Office of Water).

To protect bores located near contamination

Clause 40 of the WSP states that no water supply works (bores) are to be granted or amended within:

- 250m of contamination as identified in the WSP, or
- 250m to 500m of contamination as identified within the plan unless no drawdown of water will occur within 250m of the contamination source,
- a distance greater than 500m of contamination as identified within the plan if necessary to protect the water source, the environment or public health and safety.

To protect water quality

Pursuant to clause 40 of the WSP, to minimise the impact on water quality from saline interception in the shale aquifers overlying Sydney basin sandstone, the bore being used to take groundwater must be constructed with pressure cement to seal off the shale aquifer as specified by the Minister.

To protect bores located near sensitive environmental areas

Clause 41 of the WSP provides that no water supply works (bores) to be granted or amended within the following distances of high priority Groundwater Dependent Ecosystems (GDEs) (non Karst) as identified within the plan:

- 100m for bores used solely for extracting water under basic landholder rights, or
- 200m for bores used for all other access licences.

The above distance restrictions for the location of works from high priority GDEs do not apply where the GDE is a high priority endangered ecological vegetation community and the work is constructed and maintained using an impermeable pressure cement plug from the surface of the land to a minimum depth of 30m.

The Project is not located near any high priority GDEs listed under the WSP.

No water supply works (bores) to be granted or amended within the following distances from these identified features:

- 500m of high priority karst environment GDEs, or
- a distance greater than 500m of a high priority karst environment GDE if the Minister is satisfied that the work is likely to cause drawdown at the perimeter of the high priority karst GDE, or
- 40m of a river or stream or lagoon (3rd order or above),
- 40m of a 1st or 2nd order stream, unless drilled into underlying parent material and slotted intervals commence deeper than 30m. (30m may be amended if demonstrate minimal impact on base flows in the stream.), or
- 100m from the top of an escarpment.

To protect groundwater dependent culturally significant sites

Clause 42 of the WSP states that no water supply works (bores) to be granted or amended within the following distances of groundwater dependent culturally significant sites as identified within the plan: ,

- 100m for bores used for extracting for Basic Landholder Rights, or
- 200m for bores used for all other aquifer access licences.

The Project is not located near any groundwater dependent culturally significant sites under the WSP.

Rules for replacement groundwater works

Clause 38 of the WSP states that a replacement groundwater work must be constructed to take water from the same water source as the existing bore and to a depth specified by the Minister.

A replacement work must be located within:

- 20 metres of the existing bore; or
- If the existing bore is located within 40 metres of the high bank of a river the replacement bore must be located within 20 metres of the existing bore but no closer to the high bank of the river or a distance greater if the Minister is satisfied that it will result in no greater impact

Replacement works may be at a greater distance than 20 metres if the Minister is satisfied that doing so will result in no greater impact on the groundwater source and its dependent ecosystem.

The replacement work must not have a greater internal diameter or excavation footprint than the existing work unless it is no longer manufactured. If no longer manufactured the internal diameter of the replacement work must be no greater than 110% of the existing work.

To manage bores located near contaminated sites

Under clause 44 of the WSP, the maximum amount of water that can be taken in any one year from an existing work within 500 metres of a contamination source is equal to the sum of the share components of the access licences nominating that work at commencement of the plan.

To manage the use of bores within restricted distances

Under clause 44 of the WSP, the maximum amount of water that can be taken in any one year from an existing work within the restricted distances to minimise interference between works, protect sensitive environmental areas and groundwater dependant culturally significant sites is equal to the sum of the share component of the access licence nominating that work at commencement of the plan.

To manage the impacts of extraction

The Minister may impose restrictions on the rate and timing of extraction of water from a water supply work to mitigate the impacts of extraction.

Available Water Determinations

The Available Water Determination (AWD) represents the volume of water that can be taken per unit share. The maximum allowable AWD is 1 ML per share. The AWD for aquifer access licences in the Sydney Basin Nepean Groundwater Source is currently 1 ML per share.

AWDs are prescribed by NOW and may change in response to climatic conditions or growth in use.

Trading Rules

Section 71Q of the WM Act allows the Minister to alter the assignment of shares between multiple water access licences. That is, part of the share component from one licence can be assigned to the other licence. Share components can only be re-assigned between water access licences in the same water source.

Clause 47 of the WSP states that assignment of shares between licences is prohibited under certain circumstances. Relevantly, within the Sydney Basin Nepean Groundwater Source, an assignment of share from Management Zone 2 to Management Zone 1 is prohibited if the trade will cause the total share component for Management Zone 1 to exceed the total share component at the commencement of the plan. Trading within management zones permitted subject to local impact assessment.

Conversion to another category of access licence

Clause 46 of the WSP prohibits the conversion of water access licences from one category to another within the water sources that are subject to the WSP.

2.4 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy was released in September 2012.

Under the policy, and the associated WM Act, an aquifer is a geological structure or formation that is permeated with water or is capable of being permeated with water. Groundwater is defined as all water that occurs beneath the ground surface in the saturated zone. For the purpose of the policy, the term “aquifer” has the same meaning as groundwater system.

The *Water Management Act 2000* defines an aquifer interference activity as the:

- penetration of an aquifer,
- interference with water in an aquifer,
- obstruction of the flow of water in an aquifer,
- taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations, and the;
- disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

A water licence is required under the *Water Management Act 2000,* unless an exemption applies or water is being taken under a basic landholder right, where any act by a person carrying out an aquifer interference activity causes the:

- removal of water from a water source;
- movement of water from one part of an aquifer to another part of an aquifer;
- movement of water from one water source to another water source, such as from an aquifer to an adjacent aquifer, an aquifer to a river/lake, or from a river/lake to an aquifer.

The AIP lists a number of activities that are deemed to be minimal impact aquifer interference activities. In terms of mining, activities considered as having a minimal impact include:

- sampling and coring using hand held equipment;
- trenching and costeaning;
- access tracks;
- leachate ponds and sumps if constructed, operated and abandoned in accordance with appropriate standards and guidelines as determined by the Minister;
- construction and ongoing use of tailings and ash dams if lined with an impervious layer providing these are carried out in accordance with their planning and other approvals;
- caverns, tunnels, cuttings, trenches and pipelines (intersecting the water table) if a water access license is not required;

The Aquifer Interference Policy also states that monitoring bores are deemed to be minimal impact activities if the bores are:

- required by a development consent under Part 4 or an approval under Part 5.1, of the Environmental Planning and Assessment Act 1979,
- required or undertaken as a result of an environmental assessment under Part 5 of that Act,
- required by a condition of an environment protection license under the Protection of the Environment Operations Act 1997, or where;
- core holes, stratigraphic (chip) holes, geo-environmental and geotechnical bores, works or activities intersecting the water table if they are decommissioned in such a way as to restore aquifer isolation to that which existed prior to the construction of the bore, work or activity and that the decommissioning is conducted within a period of 28 days following completion of the bore, work or activity;

The *Water Management Act 2000* includes the concept of ensuring "no more than minimal harm" for both the granting of water access licenses and the granting of approvals. Water access licenses are not to be granted unless the Minister is satisfied that adequate arrangements are in force to ensure that no more than minimal harm will be done to any water source as a consequence of water being taken under the license.

Where a water access licence has been applied for by a method consistent with a controlled allocation process then adequate arrangements are in force to ensure that no more than minimal harm will occur. This is because the controlled allocation process allows for the allocation of a proportion of the unassigned water within the relevant water source using a conservative approach. Furthermore, unassigned water can only occur where total water requirements within a water source are less than the long-term average annual extraction limit specified in the relevant water sharing plan.

Where water is to be taken from a water source that has no unassigned water or insufficient unassigned water to account for any inflows to the activity, either surface or groundwater, then water entitlements will need to be purchased from an existing licensed user.

Any access licence dealing requiring the Minister's consent will need to consider the requirements of section 71Y of the *Water Management Act 2000,* including the water management principles that require water sources to be protected and social and economic benefits to be maximised.

Aquifer interference activities may induce flow from adjacent groundwater sources or flow from connected surface water sources to compensate for the water taken from the aquifer in which the activity is occurring or to fill the void created in the aquifer.

Where an aquifer interference activity is taking water from a groundwater source, and this causes movement from an adjacent, overlying or underlying groundwater source, separate aquifer access licenses are required for the groundwater source and for any adjacent, overlying or underlying groundwater sources.

Where an aquifer interference activity causes movement of water from a connected regulated or unregulated river water source into the groundwater source, then an access license in the regulated or unregulated river water source is required to account for the take of water from that water source and another access license in the groundwater source is required for the remainder of the take.

Where an aquifer interference activity is incidentally taking water from a river it must be returned to that river when river flows are at levels below which water users are not permitted to pump.

It is the proponent's responsibility to ensure that the necessary licenses are held with sufficient share component and water allocation to account for all water take, both for the life of the activity and after the activity has ceased.

In determining what licenses are required and which water source(s) the activity will take water from, the following need to be considered;

- prediction of the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity and after closure of the activity. Where required, predictions should be based on modeling conducted in accordance with the Australian Groundwater Modeling Guidelines;
- how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources;
- how any relevant license exemptions might relate to the water to be taken by the

activity;
- whether the water is taken at a fixed or varying rate;
- whether sufficient entitlements and allocations are able to be obtained;
- consideration of water sharing plan rules;
- by what mechanism and license category the water will be obtained, consistent with any trading rules specified in either the Minister's access license dealing principles and/or relevant water sharing plans;
- the effect that activation of existing entitlement may have on future available water determinations for the proposed license category and entitlement volume;
- actions required both during operation and post-closure to minimise the risk of inflows to a mine void as a result of flooding. Set-back distances from rivers should be no less than that required to ensure structural integrity of the river bank during flooding events. Levee banks or landforms should also be constructed at the appropriate time to prevent at least a 1 in 100 year flood from entering the site either during or after operation, and;
- a strategy for accounting for any water taken beyond the life of the operation of the project, such as holding the appropriate entitlement or surrendering a component of the entitlement at the end of the project. Where a license or part of a license has been surrendered to the Minister, a security deposit or condition of consent under the EP&A Act may account for or require the upfront payment of fees and subsequently the license may be retained for the period of ongoing take of water or cancelled.

Where uncertainty in the predicted inflows may have a significant impact on the environment or other authorised water users, the applicant will need to report on:

- potential for causing or enhancing hydraulic connection between aquifers or between groundwater and surface water sources, and quantification of this risk;
- quantification of any other uncertainties in the groundwater or surface water impact modeling conducted for the activity; and
- strategies for monitoring actual and reassessing any predicted take and how changes will be accounted for, including analysis of water market depth and/or in situ mitigation and remediation options

Where there is ongoing take of water, the holder must retain a license until the system returns to equilibrium or surrender it to the Minister. Surrendering entitlements that adequately cover any likely future low available water determination periods is preferable.

The NSW Office of Water will assess the potential impacts of the aquifer interference activity against the minimal impact considerations, as well as any specific rules in a relevant water sharing plan

There are two levels of minimal impact considerations specified in **Table 1**.

Groundwater sources have been divided into "highly productive" and "less productive". Highly productive groundwater is defined as a source that is declared in the Regulations and:

- has total dissolved solids less than 1,500 mg/L, and
- contains water supply works that can yield water at a rate greater than 5 L/sec.

Highly productive groundwater sources are grouped into:

- Alluvial;
- Coastal sands;
- Porous rock;
    - o Great Artesian Basin - Eastern Recharge and Southern Recharge;
    - o Great Artesian Basin - Surat, Warrego and Central;
- other porous rock, and
- fractured rock

Less productive groundwater sources are grouped as:

- Alluvial;
- Porous rock, and;
- Fractured rock.

Table 1 Minimal Impact Considerations for Aquifer Interference Activities – Less Productive Porous Rock Groundwater Sources

Water Table	Water Pressure	Water Quality
LEVEL 1		
Less than or equal to 10% cumulative variation in the water table, allowing for typical post water sharing plan (WSP) variations, 40m from any: High priority groundwater dependent ecosystems, or High priority culturally significant site; listed in the schedule of the relevant WSP. A maximum of 2m decline cumulatively at any water supply work.	A cumulative pressure head decline of not more than 2m decline at any water supply work.	Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.
LEVEL 2		
If there is more than 10% cumulative variation in the water table, then appropriate studies will need demonstrate to the ministers satisfaction that the variation will not prevent the long term viability of the dependent ecosystem or significant site If more than 2m decline cumulatively at any water supply work then make good provisions should apply.	If there is more than a 2m pressure head decline, then appropriate studies will need to demonstrate to the ministers satisfaction that the decline will not prevent the long term viability of the water supply works unless make good provisions apply	If the above condition is not met, then appropriate studies will need to demonstrate to the minister's satisfaction that the change in groundwater quality will not prevent the long term viability of the dependent ecosystem, significant site or affected water supply works.

If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable.

Where an activity's predicted impacts are greater than Level 1, but they exceed it by no more than the accuracy of a robust model, then the project will be considered as having acceptable impacts, with monitoring, as well as potential mitigation or remediation required during operation.

If the predicted impacts exceed Level 1 by more than the accuracy of a robust model, then the assessment will need to involve additional studies, and if the impacts will not prevent the long-term viability of the water dependent asset, then the impacts will be considered acceptable.

A risk management approach to assessing the potential impacts of aquifer interference activities will be adopted, where the level of detail required is proportional to the likelihood of impacts occurring on water sources, users and dependent ecosystems and the potential consequences.

In addition to the volumetric water licensing considerations, a proponent will need to provide;

- baseline groundwater depth, quality and flow;
- a strategy for complying with any water access rules;
- potential water level, quality or pressure impacts on nearby water users, connected ground / surface water sources and groundwater dependent ecosystems;
- the potential for increased saline or contaminated water inflows to aquifers and highly connected river systems;
- the potential to cause or enhance hydraulic connection between aquifers;
- the potential for river bank instability, or high wall instability or failure to occur;
- the method for disposing of extracted water;
- contingency plans or remedial measures if impacts are outside of the licensing and approval requirements.

If a development consent under Part 4, Division 4.1 or Part 5.1 of the EP&A Act has been granted or for any approved mining or CSG production activity that was not subject to the Gateway process, the maximum predicted annual water quantities are to be licensed from the commencement of the activity.

Aquifer Interference Approval

Under the WM Act, an aquifer interference activity requires:

- The necessary volumetric WALs
- A separate aquifer interference approval.

An aquifer interference approval confers a right on its holder to carry out specified aquifer interference activities at a specified location or area.

Under section 91F of the WM Act, it is an offence to carry out an aquifer interference activity without an aquifer interference approval. An aquifer interference activity includes the penetration, interference or obstruction of flows within an aquifer or to take or dispose of waters from an aquifer.

However, section 91F of the WM Act does not currently apply. Section 88A provides that Part 3 of Chapter 3 (including section 91F) applies to each part of the State or each water source and each type or kind of approval that relates to that part of the State or that water source that is declared by proclamation. In essence, the AIP applies, however the approvals framework has not been finalised.

A framework for the implementation of the AIP was produced by NoW (October 2013) and this report addresses the key issues in this document.

Licences for Impacts on Stream Baseflow

Any reduction in baseflow as a result of depressurisation will also require a water access licence under the WSP for the unregulated rivers. The Project is located within the Upper Nepean and Upstream Warragamba water source under the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011*.

Any take of surface water / baseflow as a result of depressurisation of deeper aquifers will require a water access licence within this water source.

2.5 Environment Protection and Biodiversity Conservation Act 1999

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is the main Commonwealth environmental legislation that provides legal framework to protect and manage matters of environmental significance including nationally and internationally important flora, fauna, ecological communities and heritage.

The EPBC Act was amended to introduce a new matter of national environmental significance named the *"Protection of Water Resources from Coal Seam Gas Development and Large Scale Coal Mining Development".*

Pursuant to the EPBC Act, an action that has, will have, or is likely to have a significant impact upon Matters of National Environmental Significance (MNES) is declared a "controlled action" and requires the approval of the Commonwealth Minister for Environment.

Approval under the Commonwealth EPBC Act is in addition to requirements under NSW State legislation.

The EPBC Act lists Matters of National Environmental Significance (MNES) that must be addressed when assessing the impacts of a proposal.

Water resources are also an MNES and the potential impact of the Project must be assessed in accordance with the Independent Expert Scientific Committee's Information Guidelines for *Proposals Relating to the Development of Coal Seam Gas and Large Coal Mines where there is a Significant Impact on Water Resources* (IESC, February 2013) and the *Significant Impact Guidelines 1.3: Coal Seam Gas and Large Coal Mining Developments – Impacts on Water Resources* (Department of Environment, December 2013). The criteria are presented below for;

Hydrological Characteristics, covering changes in the:

- water quantity, including the timing of variations in water quantity;
- integrity of hydrological or hydrogeological connections, including substantial structural damage (e.g. large scale subsidence), and;
- area or extent of a water resource.

Water Quality, in regard to, if;

- there is a risk that the ability to achieve relevant local or regional water quality objectives would be materially compromised;
- a project creates risks to human or animal health or to the condition of the natural environment as a result of the change in water quality;
- a project substantially reduces the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality;
- a project could cause persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment;
- a project could seriously affect the habitat or lifecycle of a native species dependent on a water resource;
- there is a significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives), and if:
- high quality water is released into an ecosystem which is adapted to a lower quality of water

2.6 Southern Coalfields Inquiry, Metropolitan and Bulli Seam Operations Planning Assessment Commission

In addition to the policies and guidelines outlined in Section 2.0, the three following reports have also guided the current assessment:

- NSW Dept of Planning, 2008 Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield – Strategic Review;
- NSW Planning Assessment Commission, 2009 The Metropolitan Coal Project Review Report, and;
- NSW Planning Assessment Commission, 2010 Bulli Seam Operations PAC Report

The combined groundwater related issues highlighted in the above Planning Assessment Commission (PAC) reports that are addressed in this study are:

- the use of 3D groundwater numerical modelling that can adequately address high contrasts in hydraulic properties and steep hydraulic gradients in non-steady state flow domains
- aquifer numerical modelling used as a management tool for the ongoing prediction of impacts attributed to longwall extraction
- adequate density and duration of observations with respect to redirected surface flows and regional strata depressurisation, ideally with a minimum two years of baseline environmental data collected at appropriate frequency and scale
- the possibility of a fault or dyke, or other linear features providing a potential leakage conduit from surface to below the Bald Hill Claystone and development of a strategy to characterise the structure and determine the magnitude and extent of the leakage.

The reports indicate that groundwater monitoring regimes and impact assessments should be based on:

- shallow piezometers monitoring groundwater levels within significant upland swamps, drainages or connected alluvium with sufficient distribution to characterise the swamp with a high level of confidence in potentially affected areas. Water level measurements should be automated with daily or more frequent recording;
- sufficient piezometers in swamps and associated regional groundwater systems to verify perching and to monitor the underlying hardrock water table
- groundwater quality classification through regular sampling and analyses that can discriminate mining related impacts and ionic species attributable to new water/rock interactions;
- deep piezometer installations to monitor pore pressures in the natural rock strata with sufficient distribution to describe the distribution of deep aquifer pressures with a high level of confidence using automated daily or more frequent recording;
- strata porosity and permeability measurements used to calculate subsurface flows and presentation of a database to facilitate impact assessment using packer testing, variable head testing, test pumping, core analyses (matrix properties and defects inspections) and geophysical logging where appropriate; and
- a mine water balance (Beca, 2010) to confirm groundwater transmission characteristics of the coal seam, overburden and drainage characteristics of goaves and the overlying failure regimes. Use of a mine water balance can also indicate potentially anomalous mine water seepages that may be initiated by increased connectivity to surface drainage systems or in association with igneous intrusions. The water balance should account for water pumped into and out of the mine, coal moisture, ventilation moisture and any other exports. The capacity of the mine water management system to manage increased contributions from underground operations should also be addressed.
- use of airborne laser survey for detailed topographic mapping, GIS of groundwater systems assessment and management and consideration of data generated by other mine sites
- wireline geophysical logging (natural gamma; density (neutron), resistivity, sonic, acoustic scanner) to improve interpolation of measured permeability and porosity.

3. PREVIOUS GROUNDWATER RELATED STUDIES

Within the Wollongong Coal lease area, groundwater level and / or hydrostatic water pressure monitoring has been conducted for the Hawkesbury Sandstone and underlying lithologies over the 500 series Longwalls adjacent to the western side of Cataract reservoir (Singh, R.N. Jakeman, M. 2001).

Vibrating wire piezometers in open standpipe bores P501 and P502 were used to monitor groundwater levels since December 1992 and August 1993 over Longwalls 501 and 502 respectively and since November 1998 in an open standpipe piezometer P514 over Longwall 514.

Geoterra (2012) conducted a detailed groundwater model and impact assessment for both the Wonga East and Wonga West proposed mining domains as part of the original Underground Expansion Project Part 3A (Pt3A) application.

The extent of historic fracturing and depressurisation due to subsidence over previous Wollongong Coal workings was assessed in SCT Operations (2014) and the findings are discussed in subsequent sections of this report.

In addition, stream water quality, groundwater seepage and stream flow studies have been conducted since 2001, as outlined in Geoterra (2014A).

4. PREVIOUS AND PROPOSED MINING

4.1 Previous Mining

Three coal seams have been mined at Russell Vale Colliery.

The uppermost is the 2 - 2.5m thick Bulli Seam where most of the previous mining activity has occurred. The 1.3m thick Balgownie Seam is located 5 - 10m below the Bulli Seam, whilst the 7 - 9m thick Wongawilli Seam is located 18 - 26m below the Balgownie Seam. However, only the bottom 3 - 3.5m of the Wongawilli Seam has been mined.

4.1.1 Bulli Seam

The Bulli Seam was mined between the late 19th Century and about 1950, initially as a hand worked bord and pillar operation and then with some mechanized pillar extraction. Bulli Seam mining continued under and to the west of Cataract reservoir, initially as a continuation of Continuous Miner pillar extraction operations and then as a longwall mining operation until 2002.

4.1.2 Balgownie Seam

The Balgownie Seam was started in the late 19th Century in the Wonga East area using hand worked methods for a brief period. Mining restarted in the late 1960's with continuous miners, then from 1970 to 1982 as one of the first longwall operations in Australia. To the north, some additional mining in the Balgownie Seam included a first workings continuous miner bord and pillar thin seam mining operation between 2001 and 2003 in Gibson's Colliery (S Wilson, pers comm.).

4.1.3 Wongawilli Seam

Mining of the Wongawilli Seam mining access started in 2008 at Wonga East. This seam has been mined by Longwall 4 from 22/4/2012 to 23/09/2012 and by Longwall 5 between 15/01/2013 and 12/01/2014.

4.2 Proposed Mining

Wollongong Coal is proposing to mine additional longwall panels in an area referred to as the Wonga East mining area at Russell Vale Colliery.

After consideration of submissions from the community and government agencies to its earlier Underground Expansion Project Part 3A (Pt3A) application, Wollongong Coal (then Gujarat NRE Coking Coal) significantly modified the application through a Preferred Project Report (PPR). The Preferred Project does not include any mining in the Wonga West area.

The current proposal includes the extraction of Longwalls 6 and 7 in the Wongawilli Seam to the south of Cataract Creek, as well as Longwalls 9 to 11 to the north of Cataract Creek, between Mt Ousley Road and Cataract Reservoir, within the SCA managed land. Longwall 8 has been excluded from the Underground Expansion Project by the PPR.

To the east of Mt Ousley Road, on private land, Wollongong Coal proposes to extract Longwalls 1 to 3 in the Wongawilli Seam as shown in **Figure 1**.

4.3 Observed and Predicted Subsidence

The following section is a compilation of relevant findings from SCT Operations (2013) and SCT Operations (2014).

Previous mining in the Bulli and Balgownie Seams is estimated to have caused up to 1.9m of subsidence.

Maximum subsidence due to mining in the Wongawilli Seam is predicted to range from 1.5m over the slightly narrower LW7 to 2.6m over LW3 where the overburden depth is shallowest with overlying goaf in both seams.

Maximum tilts are anticipated to range from 24mm/m over LW10 through to 51 mm/m above LW3. The peak values are anticipated to occur at the goaf edges and with areas of higher change in topographic gradient. Across a panel, systematic tilts are likely to range from 50 - 90% of peak values.

Maximum strains are anticipated to range from peaks of 14mm/m over LW10 to 31mm/m over LW3. Tensile peaks are most likely to occur at topographic high points and compression peaks are most likely at topographic lows. More generally across the panel, systematic strains are likely to be 20 - 30% of the peak values.

The predicted closure across Cataract Creek ranges from 10 – 50mm adjacent to Longwalls 9 to 11, 400mm adjacent to Longwalls 6 and 7, with up to 650mm adjacent to Longwalls 6 and 7.

These estimates are provided as upper limit values as they are based on experience in deep gorges at high stress levels.

Monitoring to date has recorded closures that are much less than predicted maxima consistent with the local site conditions.

Table 2 summarises subsidence that has occurred in the area of extraction during mining in the Bulli Seam (estimated) and the Balgownie Seam (measured) as well as observed and predicted subsidence due to the proposed mining in the Wongawilli Seam.

Movements outside the goaf edge are expected to be essentially similar to the movements observed during mining of Longwalls 4 and 5. Vertical movements (of greater than 20mm) are expected to be substantially limited to within a distance of 0.7 times the overburden depth from the nearest goaf edge (equivalent to an angle of draw of 35°).

In areas where there has been previous mining in both the overlying seams, vertical subsidence at the goaf edge is expected to be up to 300 - 500mm and the goaf edge subsidence profile over the panel is expected to be generally steeper than in areas where the overburden strata has not been disturbed by previous mining. In areas where there is either solid coal or substantial coal pillars directly above the goaf edge, goaf edge subsidence is expected to be of the order of 100 - 200mm.

Potential pillar instability in the Bulli Seam may cause additional surface subsidence when the proposed longwall panels are mined in the Wongawilli Seam, but the area likely to be affected at the northern end of LW1 is likely to require special consideration.

Table 2 Historic and Predicted Subsidence

	Previous Bulli and Balgownie Seam Subsidence (m)	**Predicted and Measured Subsidence (m)**	**Predicted and Measured Tilt (mm/m)**	**Predicted and Measured Tensile Strain (mm/m)**	**Predicted and Measured Compressive Strain (mm/m)**	**Maximum Cataract Creek Closure (mm)**
LW1	1.3	2.1	40	12	24	650
LW2	1.1	2.1	40	12	24	610
LW3	1.3	2.6	51	15	31	350
LW4	1.9	2.1 **(1.6)**	35 **(30)**	10.5 **(7.5)**	21 **(14)**	N/A
LW5	0.9	1.9 **(1.8)**	36 **(30)**	10.8 **(6)**	22 **(12)**	**(49)** at closure site CC4
LW6	1.5	2.1	38	11	23	400
LW7	1.2	1.5	28	8	17	400
LW9	0.5	2.1	32	10	19	50
LW10	0.6	1.6	24	7	14	30
LW11	0.6	2.1	30	9	18	10

NOTE: There is NO proposed Longwall 8 **(measured parameters are in brackets)**
Valley closure survey site CC4 in not the same as stream flow / pool / geochem site CC4

For further details and a location plan of the closure monitoring lines CC1 to CC4, refer to (SCT Operations, 2013).

5. STUDY AREA DESCRIPTION

5.1 Wonga East Catchments and Topography

Stream water level monitoring in pools and at selected flow constriction sites in Cataract Creek and Cataract River have been conducted since November 2010, with volumetric stream flow assessment conducted as outlined in WRM Water and Environment (2014).

The following sections describe the individual catchments in the Wonga East study area.

5.1.1 Cataract Creek

Cataract Creek is a 4th order stream for most of its length and is approximately 5.5km long from its headwaters to the upstream reaches of the Lake Cataract storage.

Channel invert elevations fall from approximately 340m AHD to 285m AHD, with the channel being relatively gently sloping at a gradient of 0.9% for most of its length, except for a 0.5km reach in its headwaters, which slope at 2.5%.

Approximately 2.5km of the stream reach is located upstream, 2km within and 0.9km downstream of the predicted 20mm subsidence zone.

5.1.2 Cataract River

Cataract River is a 3rd order stream upstream of the Link Road crossing, and 4th order from the confluence near the crossing to the Lake Cataract backwater. It is approximately 6.7km long from its headwaters to the upstream reaches of the Lake Cataract storage.

Channel invert elevations fall from approximately 430m AHD to 285m AHD and the channel is relatively gently sloping at a gradient of 0.5%, for much of its length, except for a steep upstream 0.5km reach, which slopes at around 17%.

The proposed Wonga East workings do not underlie the Cataract River.

5.1.3 Bellambi Creek

Bellambi Creek is a 3rd order stream upstream for the first 5.5 km, then 4th order to the Lake Cataract backwater. It is approximately 6.4km long from its headwaters to the upstream reaches of the Lake Cataract storage.

Channel invert elevations fall from approximately 453m AHD to 286m AHD, with the channel being relatively gently sloping at a gradient of 0.6%, except for the first 1km upstream reach, which slopes at around 2.8%.

5.2 Climate

5.2.1 Rainfall

Daily rainfall has been recorded by the Bureau of Meteorology (BOM) and the SCA and its predecessors, and the nearest stations with the longest records are located at Cataract and Cataract Dam, with good quality records extending from 1883 to 1966 and 1904 to 2014 respectively.

The BOM's SILO data service has prepared Patched Point Datasets (PPDs) from the Cataract and Cataract Dam records. Gaps in the records are infilled with data interpolated from other nearby stations to provide continuous records between 1889 and the present day (WRM Water and Environment, 2014).

Annual rainfall at Cataract Dam between 1889 and 2013 varied from 480mm in 1944 to 2,293 mm in 1950, with a mean annual rainfall of 1,085 mm/a.

Cataract Dam rainfall is highest between January and June and lowest between July and December as shown in **Figure 2**.

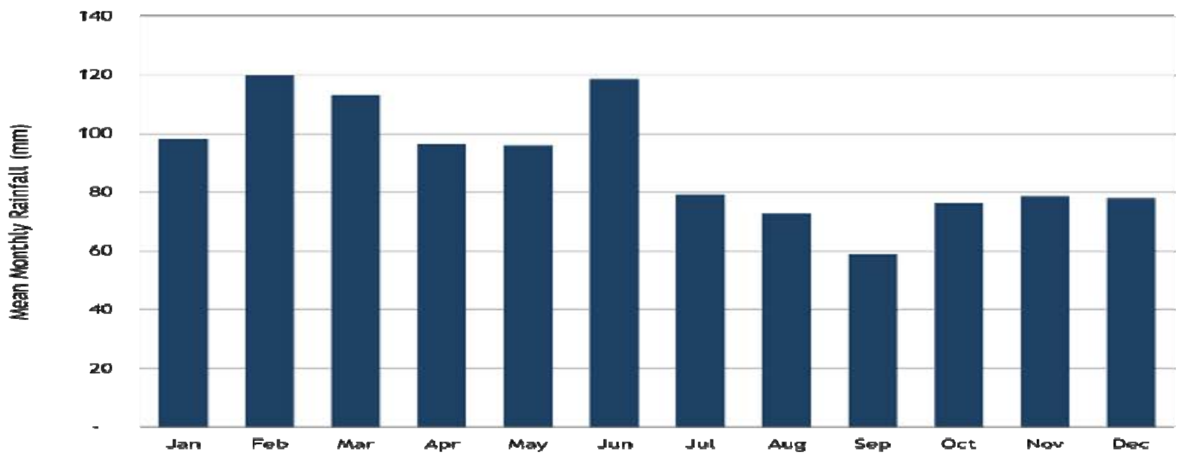


Figure 2 Variation in Mean Monthly Rainfall at Cataract Dam

Figure 3 shows a plot of cumulative rainfall residual at Cataract Dam for the period 1889 to 2013 that was prepared using the PPD. The raw data for the station is overlaid for comparison.

The cumulative rainfall residual shows departures from the long-term average (i.e. it has not been seasonally adjusted). Upward sloping lines indicate relatively wet periods, and downward sloping lines indicate relatively dry periods.

The figure shows that the period between 1905 and 1942, and the period since 1992 were relatively dry. The period from 1890 to 1900 and between 1950 and 1992 was generally relatively wet, with the exception of the late 1960s and the early 1980s. A plot of the SOI residual has been overlaid on the rainfall residual for comparison.

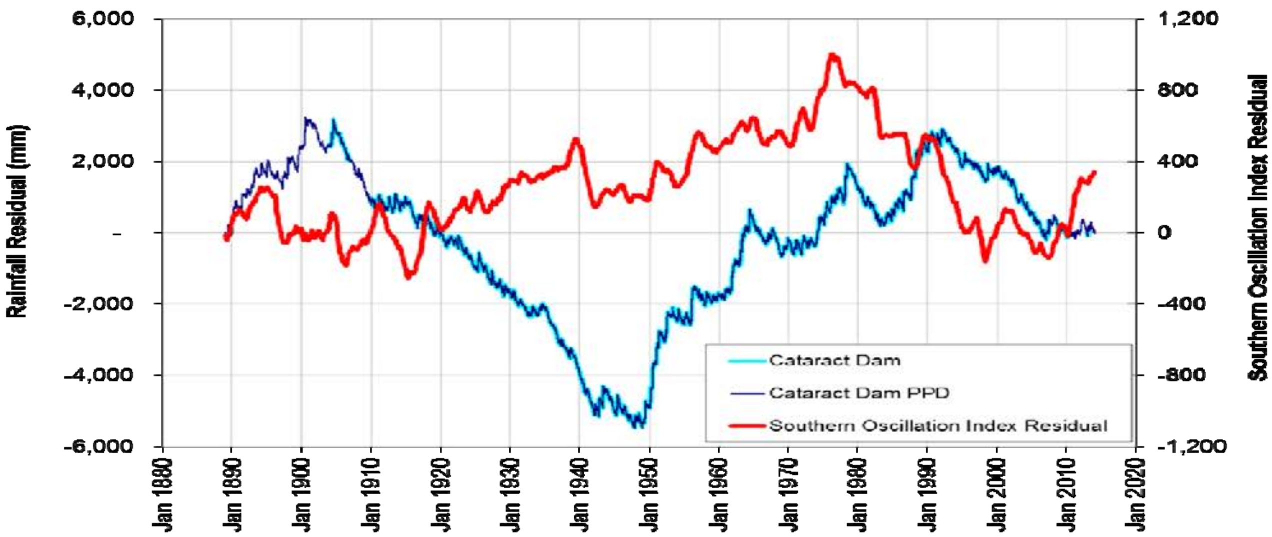


Figure 3 Rainfall Residual at Cataract Dam (1889 – 2013)

5.2.2 Evaporation

The mean annual pan evaporation at Cataract Dam is approximately 1420 mm/a as shown in **Figure 4**, and is highest in the summer months.

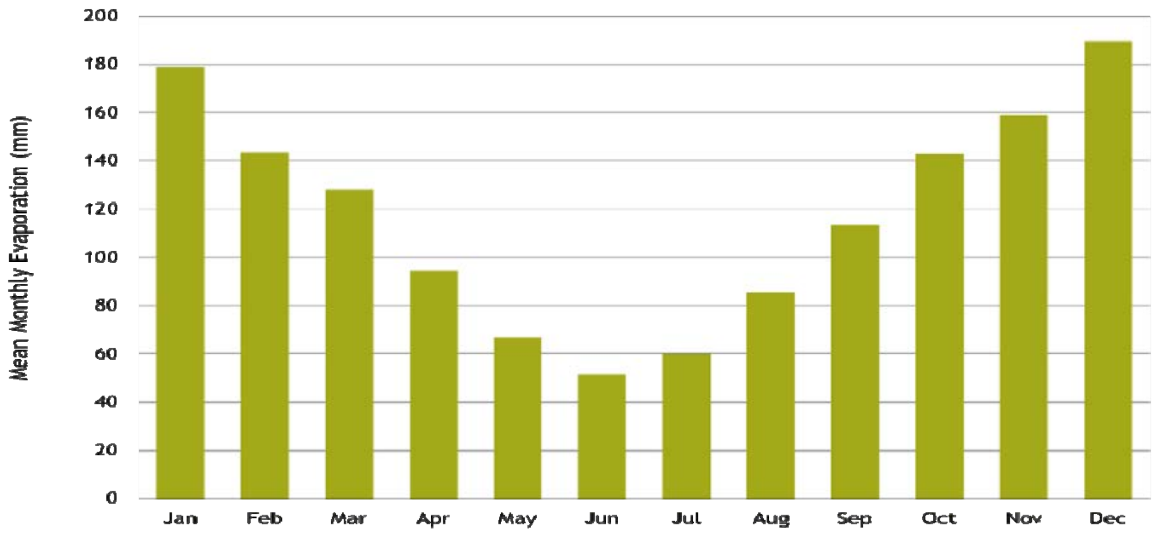


Figure 4 Monthly Pan Evaporation at Cataract Dam (PPD)

5.3 Geology

Russell Vale Colliery is situated at the southern end of the Permo-Triassic (225-270 million years) Sydney Basin within the Illawarra Coal Measures, which contains the Bulli, Balgownie and the Wongawilli seams.

The Study Area is predominantly covered by shallow hillslope-based colluvium, with very thin to no alluvial sedimentary deposits in the valley floors as shown in **Figure 5**.

Outside of the upland swamps, there are no alluvial deposits of any significance within the Wollongong Coal lease except for possibly within, or under, Cataract Reservoir.

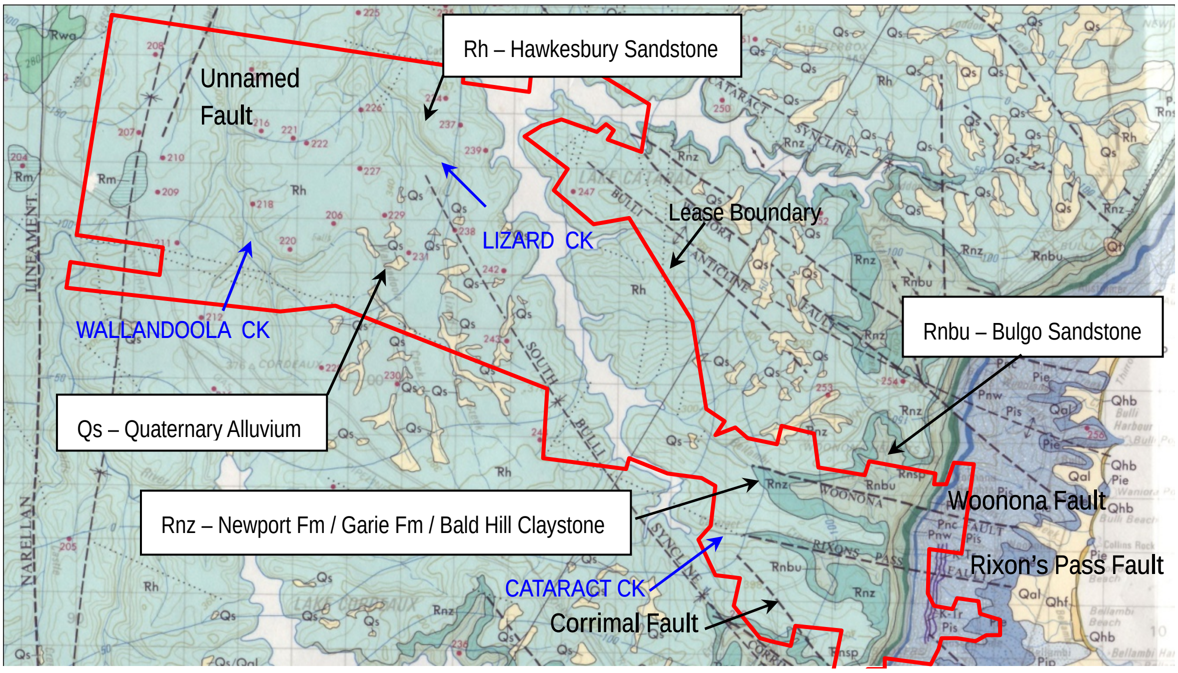


Figure 5 Published Regional Surface Geology

Quaternary unconsolidated alluvial and colluvial sediments are also present within both valley fill and headwater upland swamps, and are generally less than 2m thick, comprising humic sands and clayey sands overlying weathered Hawkesbury Sandstone.

The Quaternary sediments in the Wonga East area are, in turn, sequentially underlain by the:

Wianamatta Group (this formation is absent at Wonga East)

Hawkesbury Sandstone (absent to 181m thick) – the bedded to massive quartzose sandstone with grey shale lenses up to several metres thick is uppermost in the stratigraphic sequence in the majority of the Study Area except where it has been eroded in the headwater valleys of Cataract and Bellambi Creeks in the Wonga East area. Exposed Hawkesbury Sandstone is prevalent across the central and western areas of the lease. The Hawkesbury Sandstone also outcrops in the catchment headwaters of Wonga East, with the underlying Newport and Garie Formations, Bald Hill Claystone and Bulgo Sandstone being exposed in reaches of Cataract Creek.

It can contain up to 4% manganiferous siderite and up to 0.5% of iron sulfide (principally marcasite) with minor solid solution incorporation of nickel, zinc and manganese sulfides.

Narrabeen Group – the Narrabeen Group consists of the following units as described below.

- **Newport and Garie Formations** (4.6 - 36m thick) – The Newport Formation has interbedded grey shales and sandstones which has a variable thickness across the Study Area. The Garie Formation is generally around 3m thick and contains cream to brown, massive, characteristically oolitic claystone with a relatively constant thickness across the Study Area.

- **Bald Hill Claystone** (17 - 42m thick) – The unit is typically a chocolate brown to red brown kaolinitic marker bed claystone with silty and sandy grey and mottled grey - brown zones with a relatively constant thickness over the study Area. It predominantly consists of 50 - 75% kaolinite with hematite and siderite as accessories, which give it its distinctive colour.
- **Bulgo Sandstone** (113 - 154m thick) - thickly bedded, medium to coarse - grained lithic sandstone with occasional conglomerate and shale.
- **Stanwell Park Claystone** (15 - 26m thick) - greenish-grey mudstone and sandstone, with a general thickening of the claystone to the north west.
- **Scarborough Sandstone** (16 - 31m thick) - thickly bedded sandstone with shale and sandy shale lenses up to several metres thick.
- **Wombarra Claystone** (35 - 61m thick) – has a similar lithology to the Stanwell Park Claystone and generally thickens to the south east.
- **Coal Cliff Sandstone** (8 - 13m thick) - shales and mudstones contiguous with the underlying Bulli seam and varies from a quartzose sandstone in the east to a more shale/mudstone dominated unit in the west.

Illawarra Coal Measures – The Illawarra Coal Measures consist of interbedded shales, mudstones, lithic sandstones and coal seams, including the Bulli Seam, Loddon Sandstone, Balgownie Seam, Lawrence Sandstone, Eckersley Formation, Wongawilli Seam and Kembla Sandstone. The major coal seams in sequentially lower order are described below.

- **Bulli Seam** (2.0 - 4.7m thick) – Coal from the Bulli Seam has been worked extensively by both longwall as well as bord and pillar methods within and surrounding the Wollongong Coal lease area. The depth of cover to the Bulli Seam varies from 205 - 290m at Wonga East, with a seam dip to the north-west of approximately 1 in 30 with modification in the vicinity of the north west / south east trending South Bulli Syncline to the west of Cataract Reservoir, and a north south trending unnamed syncline to the west of Wallandoola Creek. A small scale north south trending syncline is present in the Bulli Seam workings. The Bulli Seam overlies the Balgownie Seam by 5.5 - 13.6m with a median 9.9m separation in the lease area.
- **Loddon Sandstone** (5 - 8m thick) – shale, mudstone, siltstone, sandstone with a sharp conglomeratic base
- **Balgownie Seam** (0.8 - 1.5m thick) – The Balgownie Seam has not been worked extensively in the southern coalfield, although limited longwall extraction has been conducted in the Wonga east area. The Balgownie Seam overlies the Wongawilli Seam by 10.6 - 24.7m with a median 18.7m in the lease area.
- **Lawrence Sandstone** (16 - 17m thick) – mudstone, siltstone to sandstone at the base
- **Cape Horn Seam** (0.1 - 0.4m thick) - a thin seam that is not mined commercially

- **Eckersley Formation and Hargraves Coal Member** (6 - 8m thick) – mudstone, claystone, siltstone and shales with the intercalated very thin (0.1 - 0.3m), uncommercial Hargraves Coal Seam
- **Wongawilli Seam** (6.2 - 10.5m thick) – comprised of up to 11 sub seams. It has predominantly been mined in the southern area of the Southern Coalfields, although has also been mined by Longwalls 4 and 5 in the Wollongong Coal lease. The depth of cover for Wongawilli Seam varies from 237 - 321m at Wonga East. In the lease area the Wongawilli Seam underlies the Bulli Seam by 24.1 - 36.4m with a median of 30.4m.

Lithologies underlying the Wongawilli Seam – the following units underlie the Wongawilli Seam:

- **Kembla Sandstone** (5 - 9m thick) – shale, siltstone and finer to coarse grained sandstone
- **American Creek Coal Member** (0.3 - 3.5m thick) – this seam has not been mined in the Southern Coalfields
- **Allens Creek Formation** (14 - 15m thick) – shale, siltstone and finer to coarse grained sandstone
- **Darkes Forest Sandstone** (5 - 9m thick) – fine to medium grained sandstone
- **Bargo Claystone** (10 - 12m thick) – mudstone, siltstone, shale
- **Tongarra Seam** (1.5 - 2.0m thick) – this seam was mined to a limited extent in the southern part of the Southern Coalfields
- **Wilton Formation** (minimum 4m thick) – claystone, siltstone and shale

5.4 Wonga East Geological Mapping

5.4.1 Outcrop Mapping

Outcrop mapping of the surface geology, faults and dykes in the Wonga East area was completed by Wollongong Coal geologists in 2013 (Gujarat NRE Coking Coal, 2014) as shown in **Figure 6**.

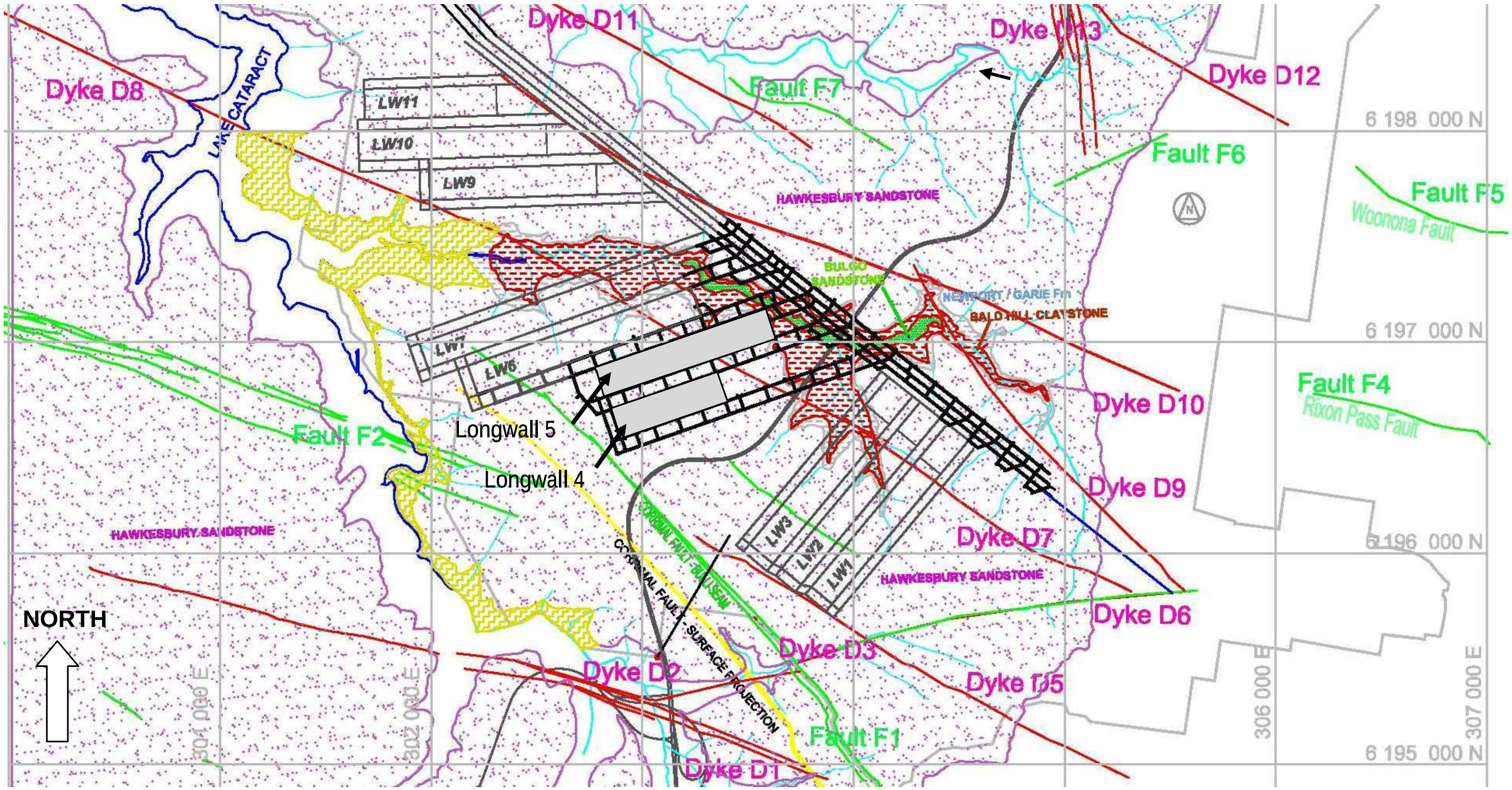


Figure 6 Wonga East Outcrop Geology and Structures

For a detailed discussion of the Wonga East outcrop geology, refer to Gujarat NRE Coking Coal (2013).

5.4.2 Underground Mapped Faults

There are no known major faults in the overburden above the proposed Wonga East workings, apart from the Corrimal Fault which has only been mapped in the Bulli workings in the western periphery of Wonga East as shown in **Figure 7**.

No known or observed groundwater inflows have been associated with any faults intersected by the workings at Wonga East in the Bulli, Balgownie or Wongawilli Seams.

At the Bulli Seam level, the Corrimal Fault has a 1.3 – 3.0m displacement in the vicinity of the proposed workings. The Corrimal Fault trends in a SE / NW direction, and is located to the west of Longwalls 1 to 3, as well as Longwalls 4 and 5. It then passes into the western ends of Longwalls 6 and 7, and phases out mid-way inside Longwall 7.

The maximum displacement of the Corrimal Fault within a 20m wide faulted zone is 28.7m, which reduces toward zero in the vicinity of the proposed LW7. It has not been mapped or interpreted to extend to the north of LW7, and is not interpreted to be present between LW7 and Cataract Reservoir.

A NW / SE trending splay off the Corrimal Fault (associated with Dyke D5) and a SW / NE fault (associated with Dyke D6) are located to the south of Longwalls 1 to 3, with the D6 fault crossing under Cataract River, to the west of the proposed Longwalls 1 to 3, outside of the 20mm subsidence zone.

The north-west south-east trending Rixon's Pass Fault is shown at surface on the 1:100,000 geological map to be sub-parallel to Cataract Creek, however, no trace of it has been identified in the Bulli or Balgownie workings.

Outside of the historic mine workings, the exact location, throw and inclination of the faulted zones are not known, and their potential position is extrapolated from drilling data and in-seam mapping.

5.4.3 Underground Mapped Intrusives

The proposed Wongawilli Seam workings are bound by:

- SE / NW trending dyke D5 (south of Longwalls 1 to 3)
- SE / NW trending dyke D9 (north of Longwalls 1 to 3)
- SE / NW trending dyke D10 (east of Longwalls 1 to 3, 5 to 7 and 9 to 11), and the
- E W trending dyke D6 (south of Longwalls 1 to 3)

The SE / NW trending Dyke D7 cuts through Longwalls 1 to 3, then phases into Dyke D8, which cuts through the eastern end of Longwall 5 and within Longwalls 6 and 7, before passing to the west of Longwalls 9 to 11. Limited in-seam silling has been mapped within the eastern end of Longwall 5, which significantly affected the extraction rate of LW5.

Dyke D8 underlies Cataract Creek between Longwall 7 and Longwall 9, but does not intersect Cataract reservoir until it is approximately 550m west of Longwall 10.

Dyke D8 has been mapped at surface as a highly weathered to illite / montmorillonite clay, or totally eroded feature of up to 0.5m wide and with up to 0.8m of displacement. It is associated with smaller first order SE / NW trending gullies over the Longwalls 1 to 3 as well as 4 to 7.

No diatremes have been identified within the proposed subsidence area, however a large sill is located to the east and north of Wonga East.

No groundwater inflows were observed when Dyke D8 (and its associated sill) was mined through by Longwall 5.

For further discussion of the Wonga East underground structures and intrusives, the reader is referred to Gujarat NRE Coking Coal (2014).

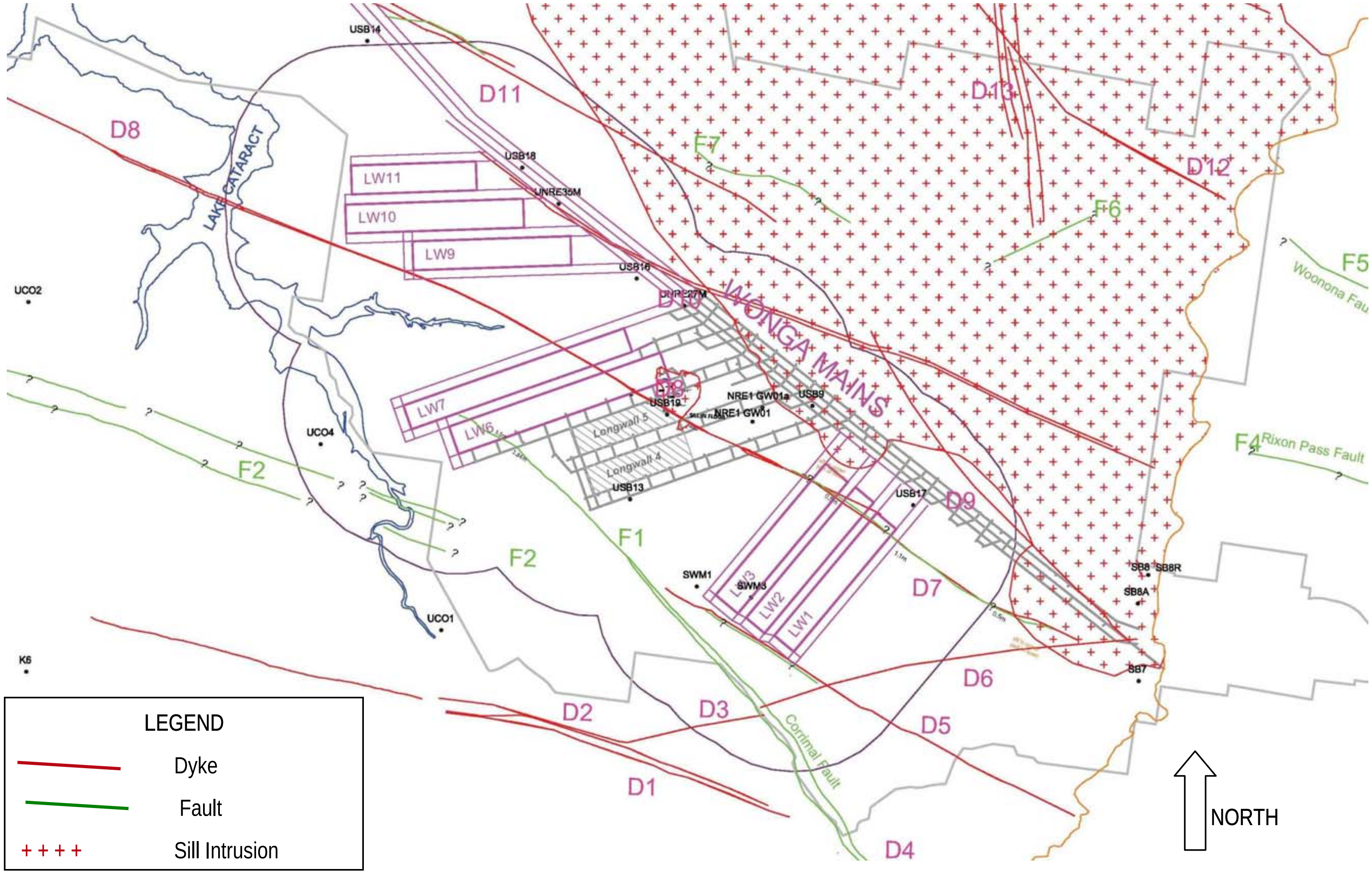


Figure 7 **Wonga East (Wongawilli Seam) Structures and Intrusives**

5.5 Basement Hydrogeology

Six general hydrogeological domains are present in the study area, including the:

- hydraulically disconnected (perched) upland swamps;
- hydraulically disconnected (perched), ephemeral weathered Hawkesbury Sandstone;
- deeper Hawkesbury Sandstone, which is hydraulically separated from the underlying Bulgo Sandstone and deeper lithologies by the Bald Hill Claystone, except where the claystone is fractured by subsidence or eroded away in the channel of Cataract Creek;
- Narrabeen Group sedimentary lithologies, the lower portions of which have already been locally fractured and depressurised above the existing workings and are interpreted to be fractured and/or depressurised over areas of triple seam mining, secondary extraction areas (including Longwalls 4 and 5 in the Wongawilli Seam) up to the shallow surficial strata, whilst areas only mined in the overlapping Bulli and Balgownie secondary extraction areas are interpreted to extend to the upper Bulgo Sandstone;
- Illawarra Coal Measures, which contains the Bulli, Balgownie and Wongawilli Seam aquifers that have also been fractured and depressurised to varying degrees by the existing workings and will be locally fractured and depressurised by the proposed workings, and the;
- sedimentary sequence underneath the Wongawilli Seam.

Due to the steep topography and limited alluvium within the Cataract Reservoir storage, there is no notable groundwater bearing stream based alluvium in the Study Area.

5.5.1 Hawkesbury Sandstone

Apart from aquifers in the coal seams, the main aquifer in the Study Area is the dual porosity (i.e interstitial pore space along with fractures and joint porosity) Hawkesbury Sandstone which, although having generally low permeability, can provide relatively higher groundwater yields compared to other lithologies in the area.

The Hawkesbury Sandstone outcrops over the majority of the lease area although it has been partially eroded in the central valley of Cataract Creek where the upper Bulgo Sandstone is exposed.

Regional water levels within the sandstone result from interaction between rainfall infiltration (recharge) through the shallow weathered zone into the underlying clastic rocks and with topography over geologic time. Rainfall infiltration elevates the water table whilst drainage channels incised through to the water table can provide seepage pathways that constrain groundwater levels to the elevation of stream beds through seepage into "gaining" streams.

Evapo-transpiration losses from deep and shallow rooted vegetation would also reduce the phreatic surface of the water table to varying degrees.

The low groundwater flow rates within the Hawkesbury Sandstone are primarily horizontal with minor vertical leakage due to the dominant horizontal bedding planes and bedding discontinuities interspersed with generally poorly connected vertical joints.

Ephemeral perched water tables within the upper 20m of the Hawkesbury Sandstone that are hydraulically disconnected from the underlying regional aquifer, can occur following extended rainfall recharge periods.

In rainfall recharge periods, water levels in shallow aquifers respond by rising, whilst in dry periods, levels are lowered through seepage to the local watercourses. During dry periods the salinity in surface drainages normally rises as the basement baseflow seepage proportionally increases.

Measured standing water levels in the Hawkesbury Sandstone range from to 12m to 39m below surface.

High yields of up to 30L/s have been identified outside of the local area by Sydney Catchment Authority in the Kangaloon and Leonay-Wallacia areas where the sandstone is distinctly affected by deep regional scale fracturing associated with igneous intrusions or a major regional lineament along the base of the Blue Mountains associated with the Lapstone Monocline (SCA, 2006).

These high yielding sandstones are not located in or near the Study Area.

Water quality in the Hawkesbury Sandstone generally has low salinity (81 - 420µS/cm) with relatively acidic pH (3.22-5.45) and can contain high iron levels up to 12.0mg/L in the Study Area.

5.5.2 Narrabeen Group

The Narrabeen Group lithologies have significantly lower yielding aquifers compared to the Hawkesbury Sandstone, with very minor productive supplies obtained in the Southern Coalfields due to its generally deeper elevation below surface and its very low permeability. The Bulgo Sandstone can contain salinities of up to 2300µS/cm (KBR, 2008) whilst the Scarborough Sandstone (Short et al. 2007) can average around 850µS/cm.

The Narrabeen Group is generally low yielding (<1.0L/sec), with its highest yields obtained from the coarser grained or fractured units.

The Narrabeen Group has generally low permeabilities, where the sandstones can provide porous storage with limited fracture flow and with low transmissivity, whilst mudstones, siltstones and shales effectively impede vertical flow. In some localities, groundwater flow may be enhanced by localised, secondary fracturing where faulting and/or jointing associated with bedding flexure or igneous intrusions can increase the hydraulic conductivity.

Hydraulic connection between the lithologies occurs through fractures and joints. Where vertical connectivity is present more laterally uniform pressure distributions are exhibited. Some local scale faults and dykes are present in the Study Area as shown in **Figure 7** although they are not anticipated to be large enough to enable loss of stream flow into the workings if dislocated by subsidence.

The Newport and Garie Formations, along with the underlying Bald Hill Claystone and the upper Bulgo Sandstone outcrop within the base of the headwater valleys within the Wonga East area would be directly recharged by stream flow leakage from Cataract Creek and Bellambi Creek.

The base of the Narrabeen Group is marked by the Wombarra Claystone which has very low permeability in its unsubsided state.

5.5.3 Illawarra Coal Measures

Water quality varies regionally both within and between coal seams and interburden in the Illawarra Coal Measures due to the complexity of groundwater flow, with the water being mostly brackish to saline.

The Balgownie, Bulli or Wongawilli Seams do not outcrop within the Study Area, although they outcrop along the lower section to the base of the Illawarra Escarpment. They would be recharged by vertical infiltration from overlying lithologies, and there is no direct connection between the seams and the surface creeks.

5.6 Registered Bores and Piezometers

There are no private bores or wells within the Study Area. The nearest private registered bore on the Woronora Plateau is a test bore at Appin Colliery, which is located approximately 4.9km to the north of the proposed workings.

At present, one monitoring piezometer P514 (GW102223) is recorded in the NSW Natural Resource Atlas database in the vicinity of the proposed workings.

No local data within the proposed extraction area is available on bore yields, as there are no production bores present there.

5.7 Geomorphology

The Study Area contains the regulated catchment of Cataract Creek, as well as portions of Cataract River and Bellambi Creek, upstream of Cataract Reservoir at Wonga East, which drain into Cataract Reservoir.

The catchments are described in detail in an associated report (WRM Water and Environment, 2014) to which the reader is referred for further discussion.

5.8 Stream Flow, Stream Water Quality, Rainfall and Land Use

The Study Area stream flow, stream water quality, rainfall and land use is described in detail in WRM Water and Environment (2014) and Geoterra (2014A) to which the reader is referred to for further discussion.

Based on drilling information and site observations, streams are interpreted to be “losing” in the Wonga East catchment headwaters and “gaining” near Cataract reservoir.

However, due to the lack of drill rig accessibility to install piezometers in the valley floors, there is insufficient data to map where the transition occurs on site.

Surface water drainage from the plateau to the local streams is through ephemeral first and second order gullies. The smaller gullies discharge into the major streams from elevated stream beds after sufficient rain, whilst the majority of rain would infiltrate into the plateau and swamp soils and weathered sandstone.

Recharge to the shallow, and subsequently the deeper regional groundwater system, would occur over an extended delay of months to years. It would occur after the meteoric water has soaked through the plateau's soil and bedrock, with the majority of water discharging from temporary seeps in the swamps and creek beds along the preferential horizontal flow regime in the Hawkesbury Sandstone.

The predominantly horizontal flow regime and restricted vertical recharge is essentially determined by the:

- horizontally bedded strata with preferential flow along bedded zones with coarser grain size,
- claystone/mudstone banding at the base and tops of sedimentary facies which restrict vertical migration and enhance horizontal flow at the base of the more porous unit,
- fracture zones enhancing horizontal flow through the strata, and;
- bedding planes or unconformities located immediately above finer grained sediments or iron rich zones.

Groundwater seepage to the local streams can occur at isolated iron stained seeps along the creek beds, where low volume and variable duration seeps discharge for a few days to weeks after significant rainfall. The seeps are generally located at the interface between coarser and underlying finer sandstone or shale/ sandstone interfaces which restrict vertical flow through the bedrock and enhance lateral flow. Most observed seeps in the local streams are anticipated to flow at less than 1L/sec.

The current interaction between surface water, perched and regional groundwater systems is postulated to be that pre-mining conditions prevail in that during wet periods there is a net contribution of groundwater to the surface system, while in dry conditions there is a net loss of surface water, with the resulting surface flow depending on the relative balance between seepage baseflow and stream outflow.

Mapping of the stream reach over the proposed workings indicates Cataract Creek is an ephemeral, "losing" stream in its first order headwater tributaries to approximately 25m downstream of the Longwall 1 tailgate edge, then becomes perennial downstream of that point where a seepage face is present in a 3m high sandstone rock face, down to its junction with Cataract Reservoir.

The surface water and shallow groundwater system is currently interpreted to be hydraulically isolated from the Bulli Seam workings in areas where only overlapping Bulli and Balgownie secondary extraction is present, although may not be separated where the overlapping workings of the Wongawilli Seam (Longwalls 4 and 5) have also been mined.

At present there are local scale aquifer systems at Wonga East over the subsided zone of the Bulli, Balgownie and Wongawilli Seam workings.

It is assessed an upper fractured unit is present from surface to approximately 20m below ground, which transitions into an elevated horizontal permeability zone caused by vertical bedding dilation, which does not necessarily contain a hydraulically connected, subsidence enhanced, vertical permeability component. This zone subsequently transitions into a sequentially higher permeability zone in the goafed and overlying deeper lithologies which can have a higher potential hydraulic connection to the Wongawilli Seam workings.

The Hawkesbury Sandstone and Bulgo Sandstone groundwater systems are not interpreted to be hydraulically separated in the valley of Cataract Creek where the Bald Hill Claystone is eroded through to the Bulgo Sandstone, downstream of the freeway. In addition, they may not be separated where the sandstone may have locally enhanced permeability due to its lack of lithostatic pressure where it has limited or no overburden, or where the Bald Hill Claystone has been fractured by subsidence.

The creeks and perched swamps are separated from the underlying regional groundwater system by a profile of unsaturated strata.

5.9 Groundwater Dependent Ecosystems and Upland Swamps

5.9.1 Groundwater Dependent Ecosystems

The proposed mining is located within the Sydney Basin Sedimentary Rock Groundwater System as described in the NSW State Groundwater Dependent Ecosystems Policy (SGDEP) (DLWC, 2002) which has its associated dependent ecosystems.

The SGDEP recognises four groundwater dependent ecosystems types in NSW, namely:

- Terrestrial vegetation;
- Base flows in streams;
- Aquifer and cave ecosystems; and
- Wetlands.

Groundwater dependent ecosystems present in the Study Area are:

- terrestrial vegetation, in terms of headwater upland swamps which are susceptible to changes in groundwater seepage inflow rates, the balance between rainfall and evaporation, the effect of bushfires and changes to the erosional regime; and
- baseflows in streams, which can be affected by changes in groundwater seepage inflow rates to a stream and the balance between rainfall and evaporation.

5.9.2 Upland Swamps

Biosis (2014) indicates that thirty-nine upland headwater swamps meet the definition of the Coastal Upland Swamp Endangered Ecological Community in the Wonga East Study Area.

No valley fill swamps are present at Wonga East.

The study highlighted the complexity and variability of the associated vegetation communities, with some swamps having a fully developed, saturated, humic sandy clay matrix up to 1.6m deep, through to essentially dry, shallow sandy clay locations with a high degree of shallow or subcropping sandstone and a thin weathered, colluvial, sandy clay soil profile.

Biosis (2014) identified that seven swamps in Wonga East are considered to be of 'special significance' using OEH criteria.

Field mapping, aerial photography and Lidar interpretation indicated that the Wonga East swamps are predominantly drier, shallower and less spatially continuous than a “typical” humic, saturated swamp (Biosis, 2014).

Upland headwater swamps in the Study Area have relatively small upstream catchments, with their saturation relying on rainfall recharge directly into the sandy sediments, seepage out of upslope Hawkesbury Sandstone and their organic (humic) content.

The storage and water transmission characteristics of the surrounding and underlying Hawkesbury Sandstone is critical in sustaining these environments.

The swamps occur in either headwater tributary valleys that are characteristically derived from colluvial sand erosion from Hawkesbury Sandstone dominated ridgelines or along the riparian zone of the major creeks. They are only located over Hawkesbury Sandstone which provides a low permeability base on which the swamp sediments and organic matter accumulate.

Regional groundwater flow within the Hawkesbury Sandstone is hydraulically beneath, and separated by approximately 15m from the surficial swamps.

Due to their gentle slope, only the larger swamps can contain small, shallow, poorly defined open channels, which are generally short and located at the downstream reaches, whilst ephemeral patches of saturated sediment can be present in the headwater sections.

The Wonga East swamps are not located near any cliff scarps, as is the case for “hanging” swamps in the Blue Mountains. As such there are no “hanging” swamps (by definition) in the Study Area, except possibly for swamp Ccus4 which is located upslope of a small, 3 - 4m high rock face.

The headwater swamps are predominantly located within gently sloping, shallow trough - shaped gullies, although they can partially extend onto steep slopes, benches or valley sides, where the plateau is not dissected by the Study Area creeks.

The central axes of the swamps are generally saturated after substantial recharge events, though the margins can comparatively dry out after extended dry periods.

The sand and humic material increases the swamp’s water holding capacity and subsequently discharges rainfall infiltration, groundwater seeps and low-flow runoff into the local streams. Rainfall saturates the swamp after storms and with a slow, delayed discharge due to the low slopes when the recharge exceeds evaporation.

Sediments below and laterally lensing into the humic material are variable in nature and can be composed of fine to medium grained sands that can contain clayey bands and comprise a grey to mottled red-orange colour due to insitu weathering.

Detailed impact assessment, including an initial risk assessment, comparative analysis, groundwater assessment, flow accumulation modelling and analysis of strains and potential for fracturing of bedrock, was undertaken on these 'special significance swamps (Biosis, 2014).

Further detailed information on the swamp structure, component lithologies, geomorphology, ecological diversity and terrestrial flora is provided in Biosis (2014).

6. PREVIOUS GROUNDWATER SYSTEM SUBSIDENCE EFFECTS

6.1 Adjacent Historical and Current Mines

6.1.1 Strata Depressurisation

Each of the existing or decommissioned adjacent underground mines have the potential to interact with the groundwater pressure regime within and adjacent to the proposed Russell Vale Colliery Wongawilli Seam workings.

Excavation of the adjacent underground mines has resulted in localised depressurisation of the Bulli Seam and overburden, which has altered regional groundwater flow toward each of the workings.

Combined pressure losses from the decommissioned, existing and proposed BHP Billiton (BHPB) operations (Appin, Westcliff and Northcliff) and Peabody's Metropolitan Colliery to the north of Cataract River were predicted in the revised groundwater model (Heritage Computing 2010A) to have the following potential drawdowns in the Wollongong Coal lease after 31 years of operation:

- negligible drawdown in the mid Hawkesbury Sandstone;
- 1 - 3m in the lower Hawkesbury Sandstone;
- 5 - 20m in the upper Bulgo; and
- 10m in the Bulli Seam.

The ultimate shape of the depressurised surface will be governed by the prevailing hydraulic properties of the coal measures, connectivity of strata through jointing and fracturing and the cumulative impacts of the regional mines.

The increased or decreased permeability changes along the fault trace that separates the BHP lease to the north and Wollongong Coal lease area to the south, together with the up to 90m lithological displacement may effectively compartmentalise the Wollongong Coal lease area from the BHPB workings, thereby reducing the cumulative depressurisation effect on the lease area.

After 31 years of mining, regional groundwater levels over the BHPB workings were modelled to recover at a rate depending on the remaining water held in storage in the coal measures, the hydraulic properties of subsided overburden, rainfall recharge and any seepage discharges to local streams (Heritage Computing, 2010).

6.1.2 Loss of Stream Flow

Due to the highly localised effects of subsidence on streams overlying subsided workings, there is anticipated to be no transmitted effects on streams within the Wollongong Coal lease from the adjacent BHPB workings as they are either down gradient of the lease, or are in a completely separate watershed on the northern side of the Cataract River.

6.1.3 Loss of Bore Yield

There are no private bores or wells registered with the NSW Office of Water (NOW) within the Study Area.

6.1.4 Changes in Groundwater Quality

No measureable change in groundwater quality has been reported, or is anticipated, within the Study Area as a result the existing, decommissioned or proposed underground workings adjacent to the Wollongong Coal lease.

The previous operators of Russell Vale Colliery, as well as the decommissioned BHPB Cordeaux and Corrimal Collieries to the south and the BHPB Bulli bord and pillar mine to the east have undermined the catchments of Lizard, Wallandoola, Cataract and Bellambi Creeks, as well as the Cataract River (upstream of Cataract reservoir).

Up to 1.3m of subsidence was generated by extraction of the Bulli Seam in the 200, 300, 500 series longwalls to the west of and beneath Cataract Reservoir (SCT Operations, 2014) in the Wonga West Area as shown in **Figure 8**.

Subsidence monitoring over the 200 series longwalls, which consisted of 190m wide panels and 35m wide chain pillars, was limited. However the same layout in the 300 series panels to the north resulted in 0.9m of subsidence. Longwall mining generated a maximum vertical subsidence of 1.1m for 155m wide longwalls with 30m wide pillars, whilst the up to 205m wide panels in Cordeaux Colliery with 30m wide chain pillars generated up to 1.3m of subsidence (SCT Operations, 2014).

No publicly available pre and post mining surveys of groundwater levels or groundwater quality are known to be available over the BHPBIC Cordeaux, Corrimal or Bulli mine workings.

6.2 BHP Bulli Colliery Short Walls

Three 80 - 86m wide short walls (1SW, 2SW, 3SW) with 67m wide pillars were mined in the Bulli Seam adjacent to and under Cataract Reservoir in the Bulli Colliery between 1983 and 1986 for a 230 - 340m depth of cover and 1.9 - 2.6m seam thickness.

A major NE-SW dyke zone with 2 x 5m wide doleritic dykes cutting across the workings corresponded to a pronounced surface lineament, however no evidence of the dyke was seen at surface. The dykes typically had minimal associated seepage into the workings.

During mining the workings were typically “dry” (Holla, L. Barclay, E. 2000).

Monitoring of two piezometer arrays installed to the base of the Bulgo Sandstone and the Bulli Seam near the workings indicated that the vertical permeabilities[a] were generally very low (Bulgo Sandstone horizontal hydraulic conductivity of 7.5×10^{-8} – 1.2×10^{-9}m/s) and that the extraction did not have a significant effect on the vertical permeability of the overburden with the maximum subsidence of 127mm and strains being less than 2.25mm/m.

An upper perched aquifer zone in the Hawkesbury Sandstone showed no response to subsidence, whilst the Bald Hill Claystone and upper Bulgo Sandstone showed a slow response to panel extraction, whilst the lower Bulgo Sandstone showed a pronounced response (Reid, P. 1991).

[a] Considered here to be synonymous with hydraulic conductivity

6.3 Russell Vale Colliery 500 Series Longwalls

The 500 Series Panels were part of the last area mined within the Bulli Seam in Wonga West. Three monitoring locations where installed over the 500 series panels as shown in **Figure 8**.

P501, which is a multi-level vibrating wire array that was installed using a single bore for each VWP intake, and P502, which was installed using nested VWP intakes in one borehole and grouted single vibrating wire piezometers were installed over Panel 502.

P501 and P502 are located over Panels 501 and 502 respectively, whilst P514 is located over Panel 514. All three piezometers are adjacent to Cataract Reservoir.

Regular monitoring of P501 and P502 began in December 1992 and August 1993 respectively, whilst P514 began in November 1998. The piezometer locations are shown in **Figure 8**.

Figure 8 Vibrating Wire Piezometer P501, P502 and P514 Locations

Studies over Longwall panels 501 and 502 by Singh R. N. and Jakeman, M. (2001) indicated that for the 115m wide longwalls with 65m wide pillars and 400 – 440m depth of cover, seepage from the walls or overlying goaf was too small to measure. It should also be noted that the eastern portion of the panels underlie Cataract Reservoir and that the Bellambi West Colliery at the time was referred to as a “dry” pit.

A combined study over Longwall 514 at Bellambi West in 1998 using micro seismic monitoring (CSIRO, 2000) and an open standpipe piezometer indicated that the majority of fracturing was concentrated in the Coalcliff and Scarborough Sandstones, to approximately 100m above the Bulli Seam. Vibrating wire piezometer monitoring between

Longwalls 501 and 502 indicates that the hydraulic integrity of the Bulli Seam and the Hawkesbury Sandstone was not adversely affected (Seedsman, R,W. & Kerr, G, 2001).

P501 is a 338m deep multi-level vibrating wire piezometer array that was installed with intakes in the:

- Hawkesbury Sandstone at 110mbgl;
- Bulgo Sandstone at 174mbgl, 228mbgl and 274mbgl; and
- Scarborough Sandstone at 328mbgl (0m AHD).

However, only data from a single Bulgo Sandstone at 228mbgl (100m AHD) and Scarborough Sandstone at 328mbgl (0m AHD) were available for this study.

This VWP array was installed using sand filters surrounding the transducer intakes with cement grout placed between intakes zones. Commentary from the time of installation (R Byrnes, pers comm.) suggests that bridging of the mid section sand intakes may have occurred during grouting and that the cables were placed under load and had dropped most likely as the sand and grout settled. It is suspected that this led to seals between Bulgo and Scarborough sandstones being compromised.

This is important to note as the VWP water levels within the Scarborough Sandstone overlying 501 Panel prior to extraction are equivalent to the overlying Bulgo Sandstone. This was noted when longwall extraction had occurred immediately to the west in the 200 and 300 series Longwall Panels (**Figure 8**) during the mid to late 1980's and immediately to the east in Longwall Panels 1 – 9 which were mined earlier effectively leaving the 500 series panels as an island surrounded by undermined areas..

The initial rise in pressure before each piezometer is undermined is due to overburden compression that occurs ahead of the retreating longwall. The overburden initially deforms in compression just before subsidence fracturing occurs, which then causes a sudden drop in groundwater pressure heads as the system re-equilibrates to the secondary porosity generated by the fracturing. The effect of rising pressure heads is generally more prevalent at the start of a longwall panel and reduces as the panel advances.

As shown in **Figure 9**, intake P5, which is installed at 226m below surface (100m AHD) in the Bulgo Sandstone, initially had its head pressure fall as the intake equalised with the hydrostatic and lithostatic pressures in the overburden to approximately 277m AHD following installation. As the panel approached the piezometer, the pressure gradually increased then fell sharply to around 263m AHD as the piezometer was undermined Pressures continued to fall slightly due to continued mining of the area to a low of 248 m AHD in September 1996. Since September 1996, pressures have recovered slightly and then have remained relatively static around 255 to 260m AHD.

As the panel approached P501, pressures within the vibrating wire transducer in the Scarborough Sandstone (P2) initially dropped in excess of 120m to 165m AHD. Just after undermining, the Scarborough Sandstone in P501 indicated a 20m rise in head which was attributed to compression of the strata ahead of the longwall face. Pressure heads then dropped to approximately 0m AHD within the Scarborough Sandstone which effectively became depressurised to at least the depth of the VWP instrument.

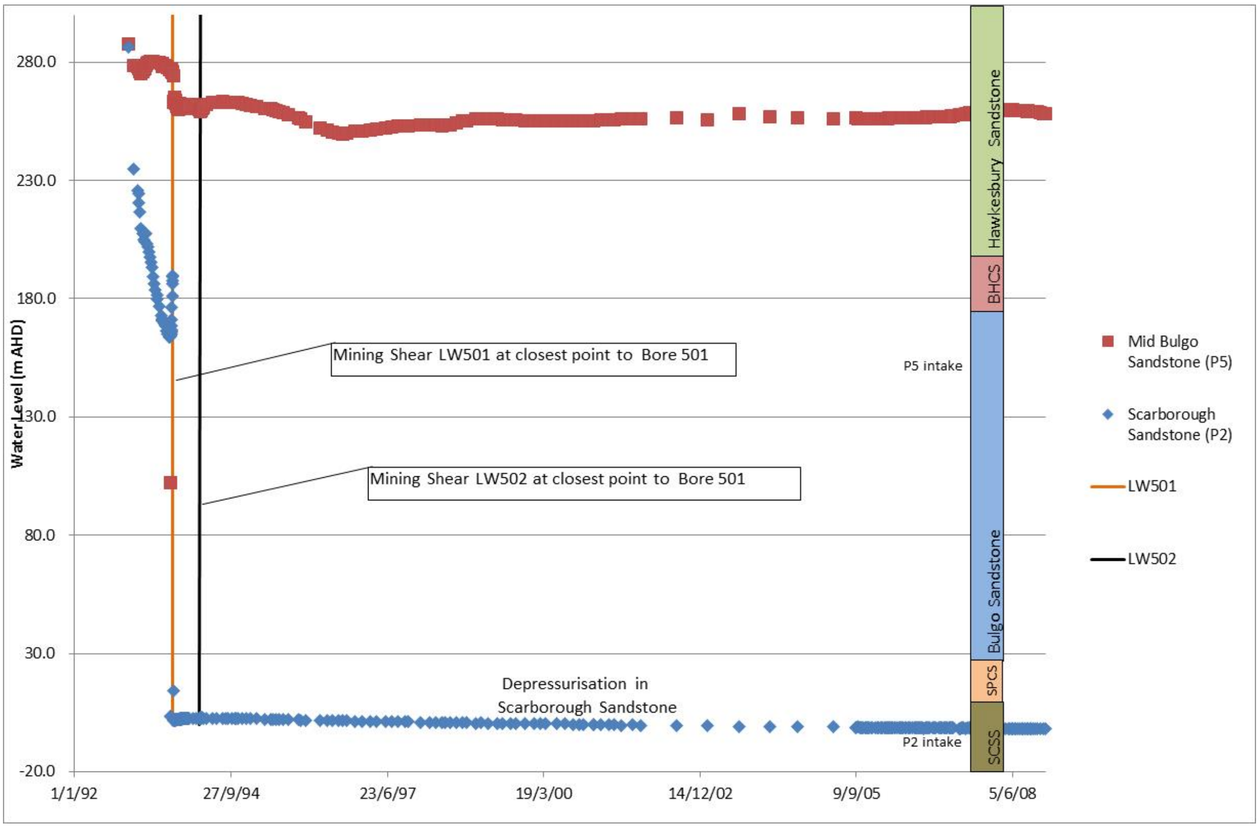


Figure 9 Longwall 501 Water Pressures

At P502, 5 piezometers (P11, P12, P13, P14 and P15) are installed in individual bores in a nested arrangement. The intakes for P12 and P13 were installed 240m above the base of the Bulli Seam in the Upper Bulgo Sandstone. When the piezometers were undermined, groundwater pressures in this piezometer fell by around 18m to 20m around March 1994, to approximately 258m AHD. P13 then recovered up to around October 1996 to approximately 280m AHD. Piezometer P12 stopped functioning after it was undermined.

Since October 1996, as shown in **Figure 10**, water pressures indicated by P13 in the Upper Bulgo Sandstone have varied between 280 and 290m AHD which is similar to the pressures in the overlying Hawkesbury Sandstone until they responded to the rainy period around April / May 2007.

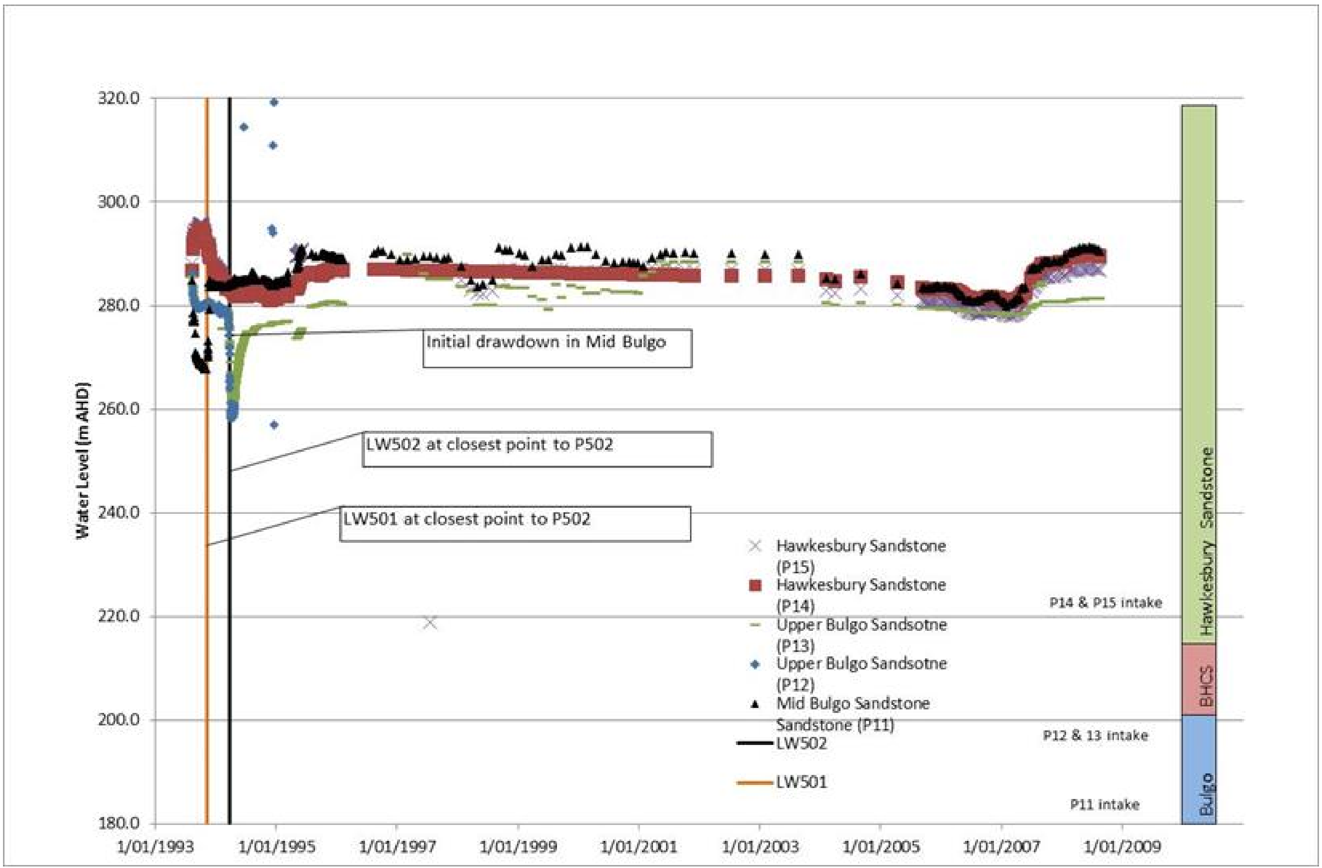


Figure 10 Longwall 502 Water Pressures

Intakes P14 and P15 were installed at 100m below surface in the Hawkesbury Sandstone. When the piezometers were undermined with the progression of LW501, both piezometers fell by around 10m between October 1993 and April 1994 to approximately 282m AHD, then P15 recovered up until around October 1996 to approximately 286m AHD.

Both P14 and P15 responded with falling pressures during the drought then rising pressures after the rainy period began in April 2007.

Piezometer P11 was installed within the Bulgo Sandstone and showed slightly different reactions to the longwall progression. P11 falls 18m to 268m AHD as LW501 passed its closest point and then the core casing appeared to fail. Water levels recovered to 284m AHD similar to P14 and P15. P13 survived the Panel 501 progression and water levels fell approximately 8m, tracking identically to that of the underlying Bulgo Sandstone (P12). P13 levels then drop by approximately 20m to 258m AHD prior to the bore casing appearing to fail. Water levels then recover to eventually mimic other Hawkesbury Sandstone piezometers. Water levels have remained essentially static, ranging between approximately 282m and 288m AHD, with a rise in pressures following the start of the rainy period around April 2007.

Monitoring over the 110m wide Panels 501 to 509, indicated a maximum subsidence of 202mm, with maximum tensile / compressive strain of 0.8mm/m and 0.4mm/m.

Groundwater pressure monitoring indicated that over Panels 501 and 502, vertical interconnected fracturing extended for less than 153m above the Bulli Seam, with a low permeability connection from the lower Bulgo Sandstone to the Bulli Seam goaf. It was interpreted that linked vertical fracturing was unlikely to have extended up into the mid Bulgo Sandstone, however it was potentially affected by horizontal bed separation (Seedsman Geotechnics, 1998).

The open standpipe piezometer P514 (GW102223) was installed to 191m below surface with an intake between 160-188mbgl in November 1998 within the lower Hawkesbury Sandstone and the Newport Formation over the 150m wide, 310-380m deep Panel 514.

As shown in **Figure 11**, since installation, P514 had a wavering water level between approximately 19m and 34m below surface, then essentially fell from 21 to 30m below surface between April 2001 and March 2007 due to the drought.

The standing water level then rose following the start of the rainy period around April 2007 by approximately 10m from 30m to 20m below surface.

The P514 piezometer became blocked between July and August 2009 and was no longer able to be used for equipment access to the water table.

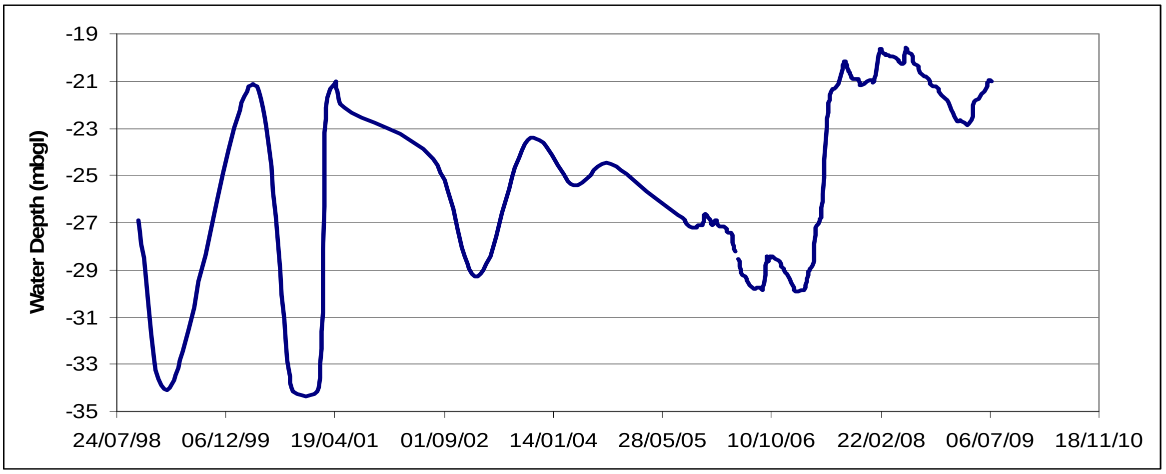


Figure 11 Piezometer 514 Groundwater Levels

6.4 Russell Vale Colliery Wongawilli Seam Longwalls 4 and 5

A vibrating wire piezometer array (GW1) and an open standpipe piezometer (GW1A) were installed adjacent to LW4 and LW5 in late September 2012. GW1 is located 190m east of LW4 and 175m south of LW5, whilst GW1A is located 280m east of LW4 and 125m south east of the LW5 secondary extraction area.

The piezometers are in an area where the Bulli seam has previously been mined by Bulli Seam bord and pillar, as well as pillar extraction, Balgownie Seam longwall extraction.

GW1 was drilled to 170.1mbgl into the Scarborough Sandstone, whist GW1A was drilled to 27m into the Bulgo Sandstone, with numerous fractures observed in GW1.

Neither bore intersected the Hawkesbury Sandstone or Bald Hill Claystone in their upper strata.

Eight vibrating wire piezometers were installed in GW1, with its location shown in **Figure 12.**

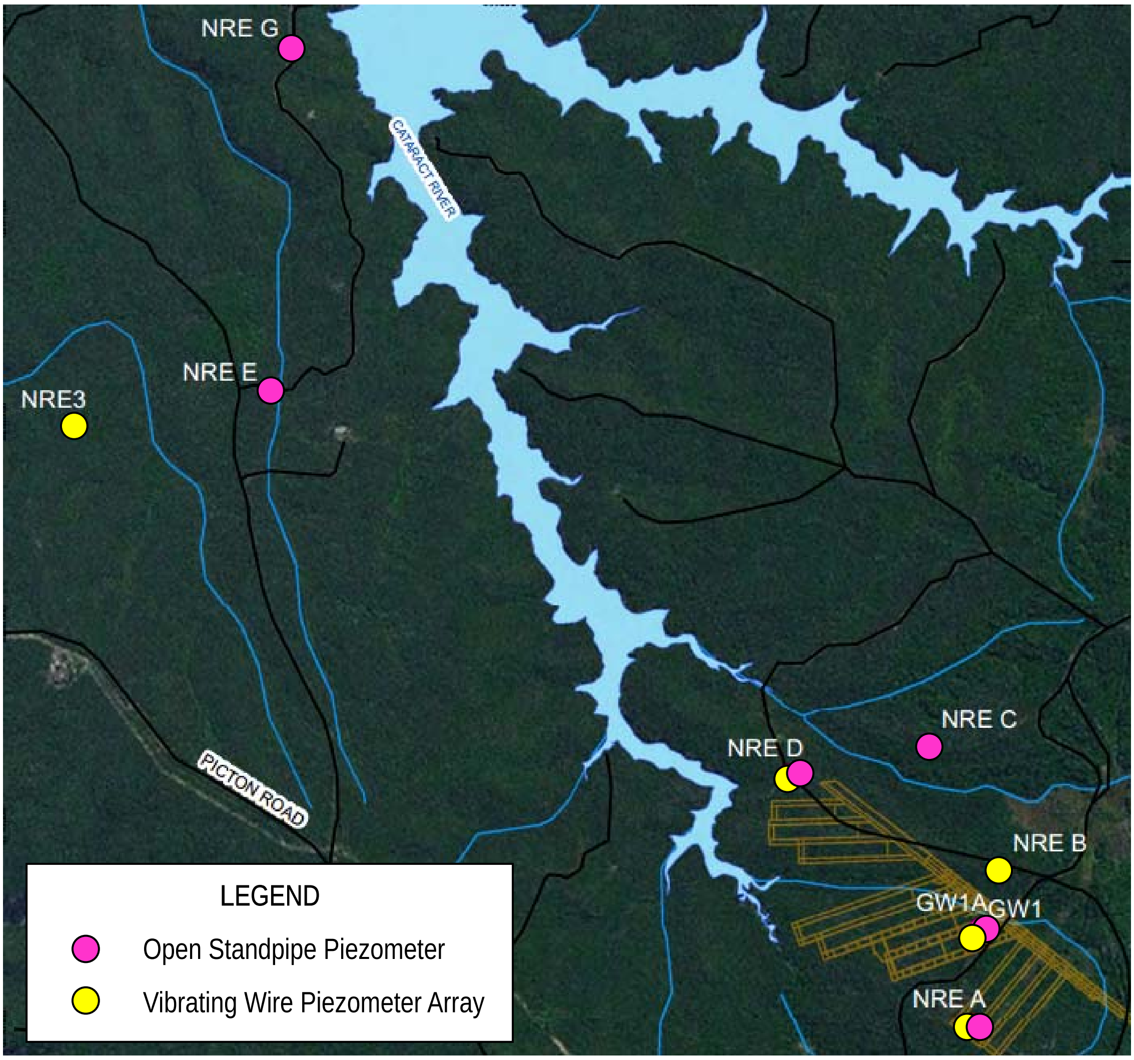


Figure 12 Russell Vale Colliery Piezometer Locations

The results indicate there is a restriction to downward flow in the upper Bulgo Sandstone.

Below the third VWP (45mbgl), the pressure gradient diverges from hydrostatic, which is consistent with low level downward flow. At approximately 140mbgl a reduction in pore pressure was observed with increasing depth consistent with the top of a more hydraulically connected fracture network above the Balgownie Seam longwall goaf.

A hydrostatic pressure gradient represents the rate of increase in water pressure that would be expected in a connected body of water where there is no vertical flow. A pore pressure gradient that is reduced below hydrostatic indicates downward flow, with the rate being dependent on the hydraulic conductivity of the strata.

The pressure profile indicates that the vertical flow rate is likely to be relatively insignificant in comparison with rainfall recharge, but the magnitude of downward flow indicated by this profile depends on the hydraulic conductivity of the overburden strata.

Packer testing in GW1 indicates the Bulgo Sandstone has regionally elevated hydraulic conductivities due to the previous mining related subsidence fracturing in the area, along with gradually reducing permeability with depth, where the strata has not been subsided, whilst the Stanwell Park Claystone has lower permeability than the overlying Bulgo Sandstone or the underlying Scarborough Sandstone (SCT Operations, 2012) as shown in **Figure 13**.

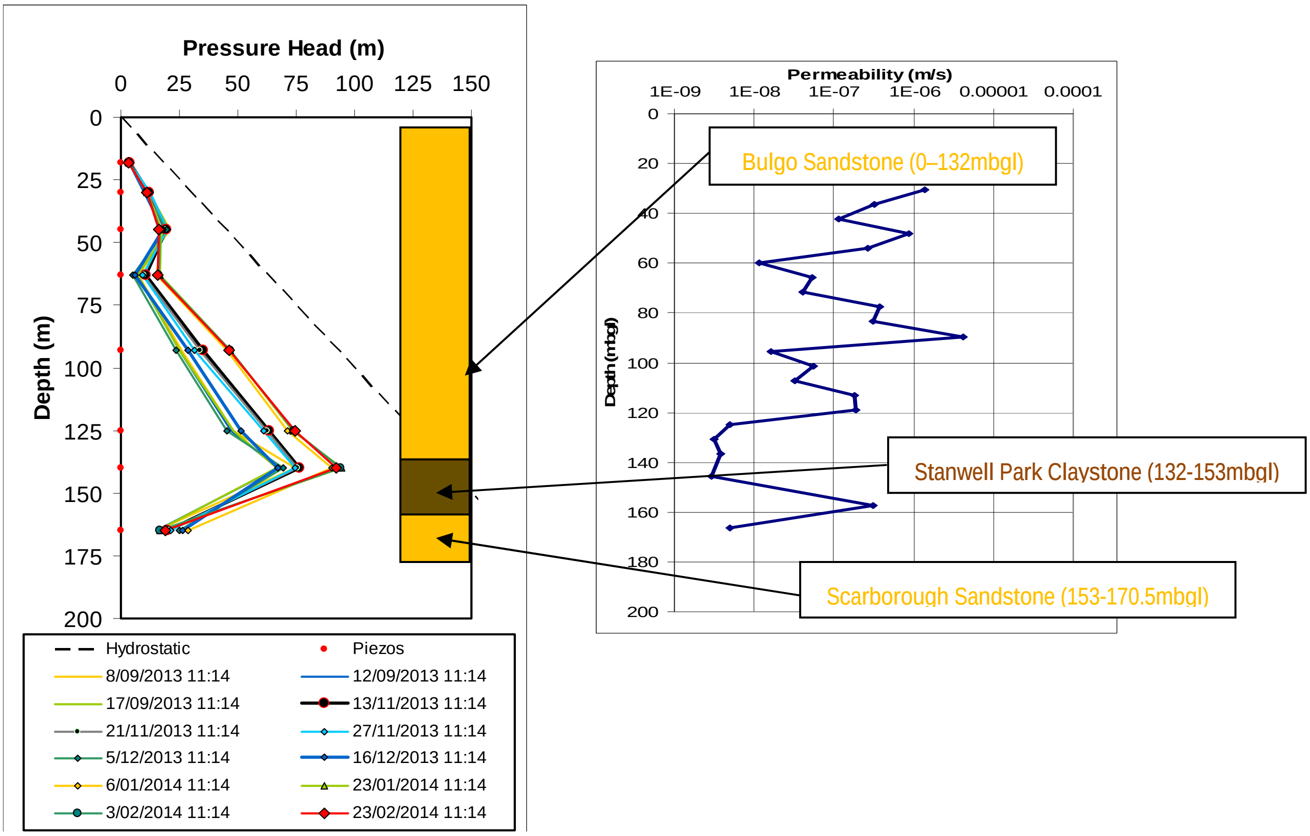


Figure 13 GW1 Pressure Head and Packer Test Data

The phreatic surface through NRE-A, GW1 and GW1A to Cataract Creek indicates the groundwater surface essentially mimics the ground surface, and that the creek has a "losing" relationship to the regional groundwater in its upper headwaters or during extended dry periods.

It should also be noted that the <1.0m wide, highly weathered dyke D8, which is located between GW1 and Longwall 4 does not appear to be acting as a groundwater flow barrier.

The following sections are a compilation of relevant findings from a groundwater and mine water balance study conducted by SCT Operations (2014).

6.4.1 GW1

Vibrating wire piezometer GW-1 was installed in September 2012 after completion of Longwall 4 and is located above the goaf of Longwall 7B in the Balgownie Seam where the Hawkesbury Sandstone has been completely eroded.

The bore is approximately 175m from Cataract Creek, 345m from the northern end of Longwall 4 and 125m from the finishing corner of Longwall 5.

The piezometric pressure profile in GW-1 indicates there are two groundwater systems in the LW4 / LW5 area, with a near surface perched water table and a second deeper groundwater system, both within the Bulgo Sandstone with a possible limited vertical hydraulic connection between the two.

Figure 14 shows that the phreatic surface of the perched water table, as indicated by the 18mbgl intake, is close to, although above the level of Cataract Creek (approximately RL300m).

The 30mbgl intake is near the level of Cataract Creek (RL300m) whilst the 45mbgl intake is below the creek, between 298.9 and 289.3mAHD.

During the period of monitoring to date only the lower two piezometers have correlated responses to rainfall and the effect has not been strong.

There is a slight reduction in the level of the phreatic surface in all three shallow piezometers which commenced soon after Longwall 5 started and continued throughout the period of mining LW5. The long term downward trend from the start of LW5 is considered to be a result of mining and the reactivation of a possible basal shear plane at or below the level of Cataract Creek and extending into the hillside that may have originally been natural, although may have been reactivated or formed during previous mining in the Balgownie Seam and LW4.

The approach of LW5 appears to have caused a reduction in the level of the phreatic surface that is still nominally above the level of Cataract Creek at 18m below the surface (RL300m) but is lower than the creek at 30m and 45mbgl. The effect of mining LW5 appears to have been to slightly elevate the horizon separating a flow gradient toward Cataract Creek from the flow gradient toward the mine, in effect increasing slightly the potential for flow from Cataract Creek toward the mine via the deeper strata. The surface strata is still indicated as having a flow gradient toward the creek in the 18mbgl intake VWP, but this gradient has been reduced slightly by mining LW5.

The uppermost piezometer at 18m below the surface does not change significantly over time or show much response to rainfall but this may be because it is operating at very low pressures and is close to dry.

The 30m piezometer is steady prior to the start of LW5, possibly because of an extended dry period prior to installation, but coincident with the start of LW5 and an intense rainfall event. There is a clear response to rainfall that continues afterwards.

The phreatic surface indicated by the 30m piezometer was initially several metres higher than the RL300m level of the nearest location in Cataract Creek, but with the mining of LW5, the phreatic surface indicated is 299.5m or about half a metre below the level of the nearest point on Cataract Creek. In other words, at the 30m depth horizon in GW-1 (about 12m below the level of Cataract Creek) the hydraulic gradient is slightly away from Cataract Creek toward the mine.

The deepest of the three shallow piezometers at 45m shows a more muted response to rainfall but shows the strongest decline in head of the three with a 9.6m fall since the start of mining LW4.

The relative water levels indicated by each of the piezometers indicates a slight downward gradient, suggesting downward flow into the lower groundwater system and the change in gradient indicates the downward gradient has increased during the period of mining LW5.

The shallow water levels may be hydraulically connected to Cataract Creek, possibly via a horizontal shear horizon located just below the level of Cataract Creek.

The hydraulic conductivity of this connection is such that rainfall recharge from the surface is able to flow back into Cataract Creek but mining increased the gradient toward the mine, particularly in the deeper strata.

Figure 14 also shows that the deeper groundwater table has clearly responded to the later stages of mining LW5. As the longwall approached within about 400m of the piezometer, there was a drop in pressure that was greater with depth below surface.

Mining then ceased for a period, recommenced and then the longwall finished. Each time the longwall advance was halted, the pore pressure recovered to pre-mining levels. Following the completion of LW5, the pore pressures recovered to higher than pre Longwall 5 levels.

This is thought to be due to mining slightly increasing the strata pore space, causing the pore pressure to be temporarily reduced. Inflow from above and possibly laterally allowed the pore pressures to recover to above pre-LW5 levels, possibly as a result of enhanced vertical connectivity caused by mining induced ground movements.

The volumes involved in this process are likely to be transitory but may have caused a temporary period of increased recharge from Cataract Creek.

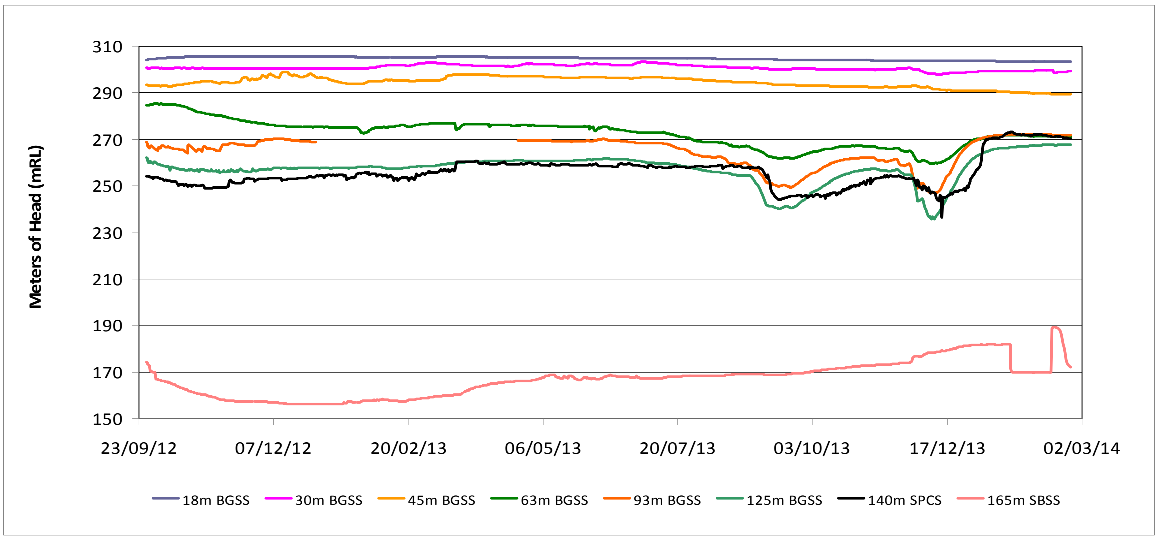
There is still a downward hydraulic gradient toward the mine evident throughout the Bulgo Sandstone but the flows appear to be of a low magnitude based on mine inflow records. The low flow would be consistent with the low hydraulic conductivity of only slightly disturbed strata.

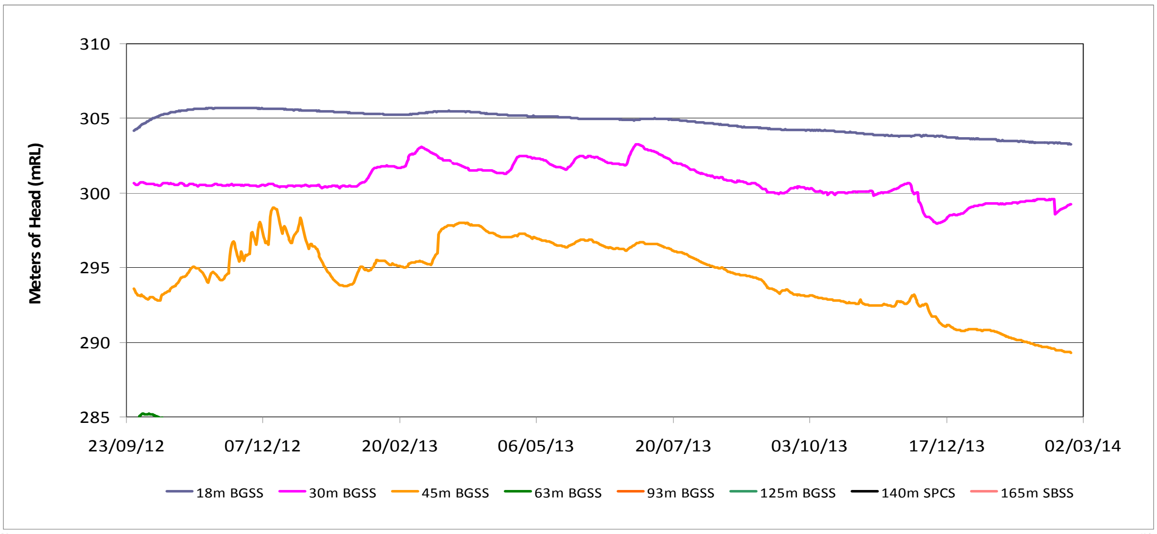
The piezometric profile in GW-1 shows the height above the mining horizon where there is depressurisation below hydrostatic. By implication, the vertical height above an existing mined void is where there is sufficient downward flow into the mine that the pressure profile can no longer be maintained. Extrapolation indicates that the point of zero pressure has been inferred at a depth of approximately 170m below surface in the Scarborough Sandstone (SCT Operations, 2014A).

The Bulli Seam is nominally 2.2m thick but mining in this area did not involve full extraction.

It is possible that the effective height of mining in both seams could be 2.0m and that the Tammetta (2012) approach could provide a basis to estimate the height of depressurisation above the most recent panel mined if the combined mining height is assumed.

Further measurements in a multi-seam mining environment are planned to confirm this single data point.





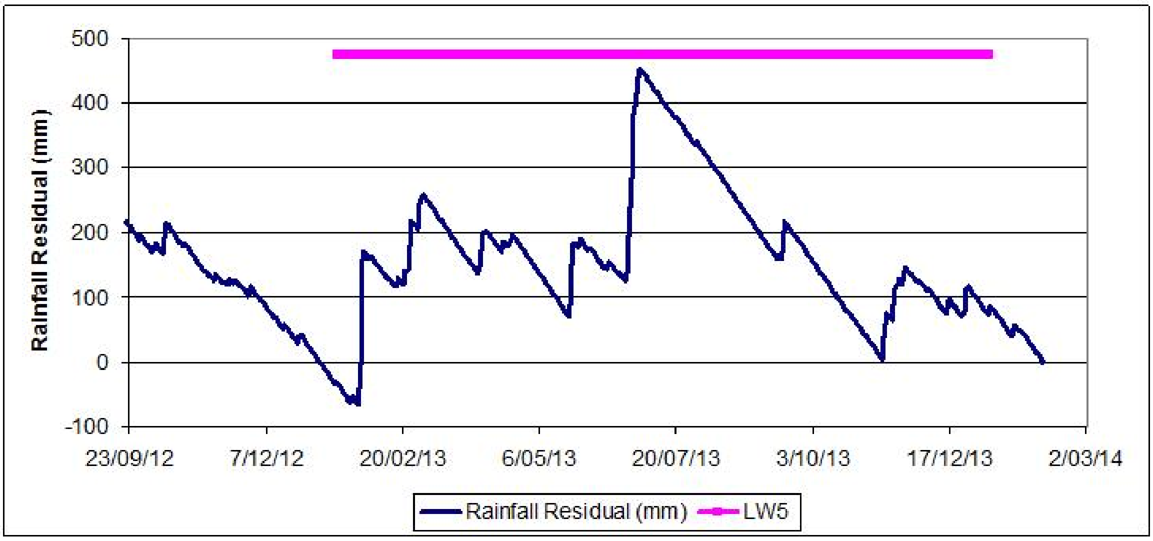


Figure 14 GW1 Groundwater Levels and Rainfall Residual Curve

6.4.2 Open Standpipe Piezometer GW1A

Open standpipe piezometer GW-1A was installed to a depth of 27m in September 2012 after completion of Longwall 4. It is located above the goaf of Longwall 7B in the Balgownie Seam where the Hawkesbury Sandstone has been completely eroded and is installed at the same stratigraphic depth in the Bulgo Sandstone as the 30m intake in the vibrating wire piezometer array in bore GW1.

The bore is located between the VWP piezo (GW1) and Cataract Creek, which is approximately 105m to the north east, 400m from the northern end of LW4 and 485m from the finishing corner of LW 5.

The piezometric pressure profile in GW1A is essentially the same as the 30mbgl VWP intake water level within the Bulgo Sandstone.

Figure 15 shows the water level in GW1A is near the level of Cataract Creek (RL300m) with a correlated, although not strong, similarity to rainfall recharge.

There is a slight reduction in the phreatic surface which commenced soon after LW5 started and continued throughout the period of mining LW5. The long term downward trend from the start of LW5 is considered to be a result of mining and the reactivation of a possible basal shear plane at or below the level of Cataract Creek and extending into the hillside that may have originally been natural, although may have been reactivated or formed during previous mining in the Balgownie Seam and LW4.

The approach of LW5 appears to have caused a reduction in the phreatic surface coincident with the start of LW5 and an intense rainfall event. There is a clear response to rainfall that continues afterwards.

The phreatic surface was initially several metres higher than the RL300m level of the nearest location in Cataract Creek, but with the mining of LW5, the phreatic surface indicated is 299.5m or about half a metre below the level of the nearest point on Cataract Creek. In other words, at the 30m depth horizon in GW-1 (about 12m below the level of Cataract Creek) the hydraulic gradient is slightly away from Cataract Creek.

The water in GW1A may be hydraulically connected to Cataract Creek, possibly via a horizontal shear horizon located just below the level of Cataract Creek.

The hydraulic conductivity of this connection is such that rainfall recharge from the surface is able to flow back into Cataract Creek.

Figure 15 GW1A Groundwater Levels and Rainfall Residual Curve

7. POTENTIAL STRATA DEFORMATION AND ASSOCIATED GROUNDWATER EFFECTS

7.1 Horizontal Strata Shear Zone Formation

Based on studies conducted in the Southern Coalfield at the BHPB Appin Colliery, Sandy Creek waterfall (Walsh R.W, et al 2014), Waratah Rivulet at the Peabody Coal Metropolitan Colliery (Mills, K.W. 2007) and the Wollongong Coal Wonga East study area, SCT Operations Pty Ltd (2014) have inferred that lateral movement of hillsides in toward the valley floor and associated horizontal to sub-horizontal shearing of the strata is possible.

The lateral shear mechanism occurs naturally in valleys, however it may be exacerbated by dilational hillslope shearing movement from the hillslopes toward the valley floor associated with mining induced subsidence as shown in **Figure 16**.

This mechanism is inferred to occur where lateral shear movement, which is not necessarily associated with pre-existing bedding plane or strata discontinuities, is mobilised following periods of intense rainfall.

At Russell Vale, the horizontal shearing of pre-existing natural bedding planes and vertical joints is inferred to have occurred in association with mining induced subsidence and hillslope dilational movement following extraction of the Balgownie and Bulli Seams.

The inferred shear (or shear planes) may have been re-mobilised following extraction of Longwalls 4 and 5 in the Wongawilli Seam, particularly after the heavy rain period in early to mid 2014.

SCT Operations (2014) infer that the main shear plane may be located between 6 – 10m below the valley floor and may extend from the creek bed, under the subsided hillslope within the zone of subsidence for up to approximately 400-450m away from the creek.

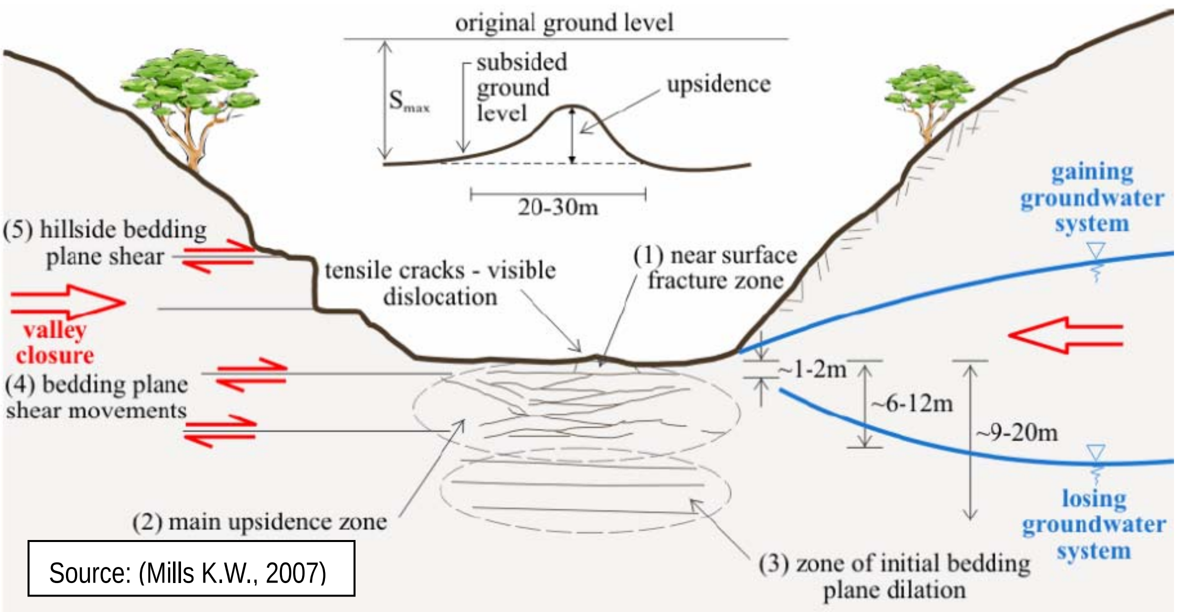


Figure 16 Conceptual Valley Closure Shearing

A definitive assessment of the location, presence and complex nature of the potential shear zone/s is not possible with current field / drilling data at Russell Vale in the valleys overlying subsided areas at Wonga East.

7.2 Tammetta (2012) Theory of Strata Depressurisation

A method for the potential empirical estimation of the height of depressurisation over the centre of single seam longwall panels, for ordinary situations, has been developed by Tammetta (2012). However, its applicability to multiple seam extraction situations has not been defined as yet.

The method and empirical estimation of depressurisation has been modified for use in the current assessment, as a base case scenario, by applying the geometry of the most recent mined panel and the combined thickness of all seams that have been mined.

The empirical equation (Tammetta, 2012) for the height of complete groundwater drainage above centre panel for continuously sheared longwall panels given by *H* (in meters) is:

$H = 1438 \ln(4.315 \times 10^{-5}u + 0.9818) + 26$

where $u = wt^{1.4}d^{0.2}$, and:

t = extracted seam thickness (m)

w = width of the secondary extraction workings (m)

d = overburden thickness (m).

In the equation, *H* depends only on the geometry of the mine opening (*w* and *t*) and the overburden thickness (*d*).

Overburden strata geology appears to play no role in the empirical equation (Tammetta, 2012) however other practitioners question this assumption (Seedsman, R.W. pers comm.).

The value of *H* is a maximum over the centre of a panel and decreases toward the chain pillars, where it is up to 70% smaller, and may reduce to zero in some circumstances, which is facilitated by the lower hydraulic conductivity over the chain pillars compared to the centre of the panel.

The value of *H* in the following situations is smaller than maximum *H* for ordinary locations for various reasons and is inappropriate for use in estimating maximum *H* above:

- chain pillars of continuously sheared panels, with either a panel on one side only or panels on both sides;
- the centre line of pillar extraction being undertaken in room and pillar panels; and
- above the centre line of continuously sheared panels under flowing rivers or saturated high-permeability alluvium.

From a groundwater perspective, the longwall caving process creates two distinct zones above a continuously sheared panel: the collapsed zone and the disturbed zone.

According to Tammetta (2012), the collapsed zone is interpreted to be parabolic in cross section and reaches from the mined seam to a maximum height equal to *H* over the centre of a panel as shown in **Figure 17**.

Tammetta (2012) interpreted this zone to be severely disturbed and drained to atmospheric groundwater pressure as a result of overburden caving and is subsequently unable to maintain a positive pressure head and behaves as a drain while the mine void is kept dewatered.

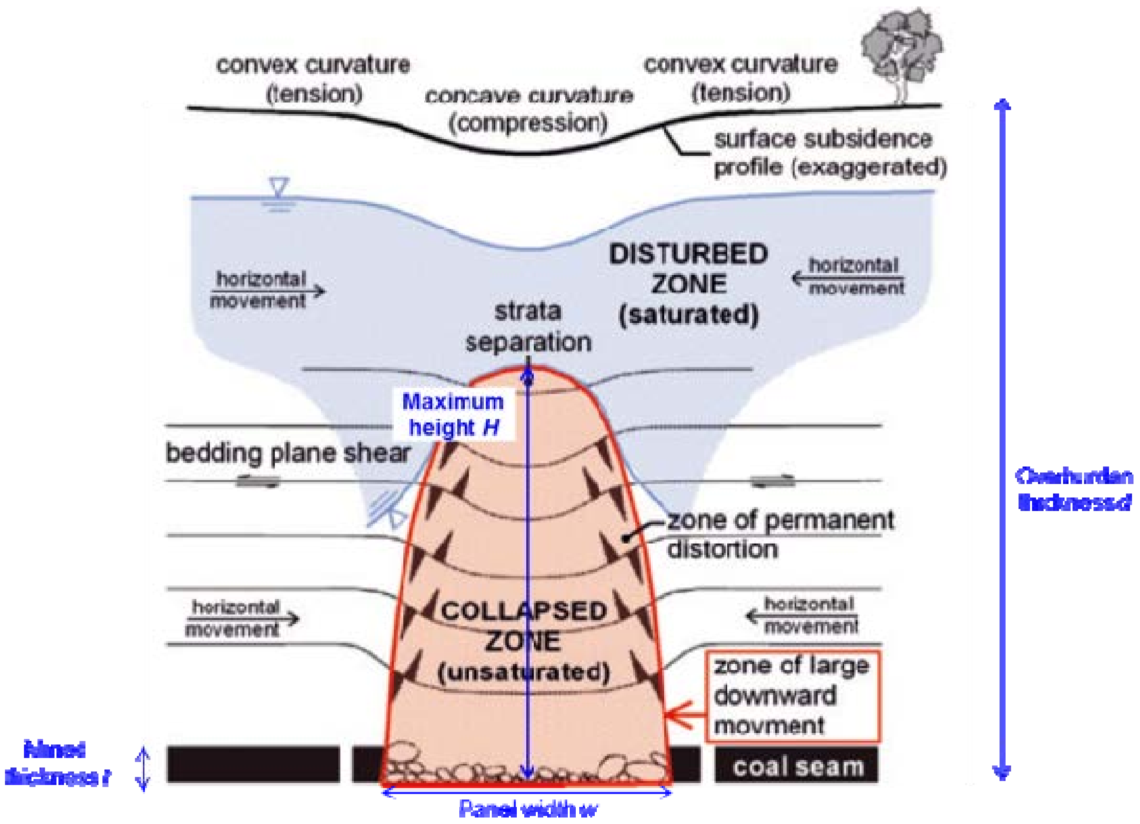


Figure 17 Conceptual Ground Deformation (Tammetta, 2012)

Within this zone, the matrix of rock blocks may continue draining for extended periods, however, the defects will immediately transport this water downward to the mine void.

Groundwater flow will not be laminar and Darcy's equation is unlikely to be obeyed.

The disturbed zone overlies the collapsed zone, where positive groundwater pressure heads are maintained over most of the zone. Limited data for long-term groundwater behaviour in this zone suggest that hydraulic heads remain relatively stable, except for immediate lowering associated with drainage of lower strata and minor increases in void space after caving. Groundwater flow will be laminar, and Darcy's equation is likely to be obeyed.

De-saturation in the disturbed zone occurs above the chain pillars. Here, *H* is smaller than over the centre of a panel and may reduce to zero if the pillar is flanked by one panel only. *H* above the pillars is likely to be more strongly dependent on *d* than for the centre panel and will probably also be dependent on the pillar width.

The Bald Hill Claystone is not anticipated to act as a semi-confining layer between the Hawkesbury Sandstone and Bulgo Sandstone aquifers where it is partially eroded in the mid valley of Cataract Creek, to the east of Cataract Reservoir over the proposed Wonga East workings, or where subsidence fracturing and associated depressurisation has passed through the Bald Hill Claystone.

8. HYDROGEOLOGICAL INVESTIGATIONS

Drilling, piezometer installation, low flow pump out tests, falling head tests, packer tests and installation of open standpipe and vibrating wire piezometers, as well as groundwater level and water chemistry monitoring were conducted within the Study Area from 1992 to the present.

The majority of drilling and monitoring conducted after July 2009 was used to provide input data for the development of a groundwater model and assessment of the hydrogeological characteristics of the:

- upland swamps;
- Hawkesbury Sandstone,
- Narrabeen Group lithologies, and
- Illawarra Coal Measures.

To date, groundwater investigation in the Study Area has involved the installation of:

- 8 open standpipes, and;
- 7 vibrating wire array piezometers,

as shown in **Figure 18**, with drilling extending to 335m below surface.

Drilling was contained within the Wollongong Coal lease area, although the groundwater model domain extends out to include the adjacent BHPB lease areas and current / decommissioned / proposed workings as well as peripheral areas within the major watersheds outside of the lease.

Details of relevant open standpipe piezometers are presented in **Table 3**, whilst geological logs and piezometer construction details were outlined in Geoterra (2012).

Under clause 18 and Schedule 5 of the *Water Management (General) Regulation 2011*, which was gazetted on 30 June 2011, an access licence is not required for monitoring bores.

Piezometers installed prior to that date were licensed by Wollongong Coal.

All relevant approvals from the Sydney Catchment Authority were obtained prior to drilling.

Discussions with the DoPI appointed reviewer for this assessment have indicated the groundwater data utilised is suitable for the groundwater modelling conducted for this study (Tammetta, P. pers comm.)

Table 3 Hawkesbury Sandstone Open Standpipe Piezometer Hydraulic Parameters and Standing Water Levels

Bore	Install. Date	E	N	Collar RL mAHD	Mining Domain	Total Depth (m)	Screen Interval (mbgl)	Standing Water Level (mbgl)
NRE-A (VWP)	21/11/09	303692	6196033	376.18	Wonga East	47	24 - 47	19.21 – 22.37
NRE C	3/12/09	303233	6198797	362.72	Wonga East	24	18 – 24	12.82 – 14.31
NRE D	6/11/09	301870	6198509	348.83	Wonga East	52	40 - 52	27.21 – 30.73
NRE E	23/10/09	296727	6202286	329.24	Wonga West	29	17 - 29	11.57 – 11.91
NRE G	20/10/09	296949	6205678	363.03	Wonga West	53	36 - 53	29.63 – 30.51
NRE3	5/12/09	294803	6201954	359.27	Wonga West	60	48 - 60	39.22 – 39.34
P514	1/11/98	297917	6204280	308.23	Wonga West	191	160 - 188	20.0 – 34.0
GW1A	22/8/12	303742	6196983	311.7	Wonga East	27	21 - 27	24.0

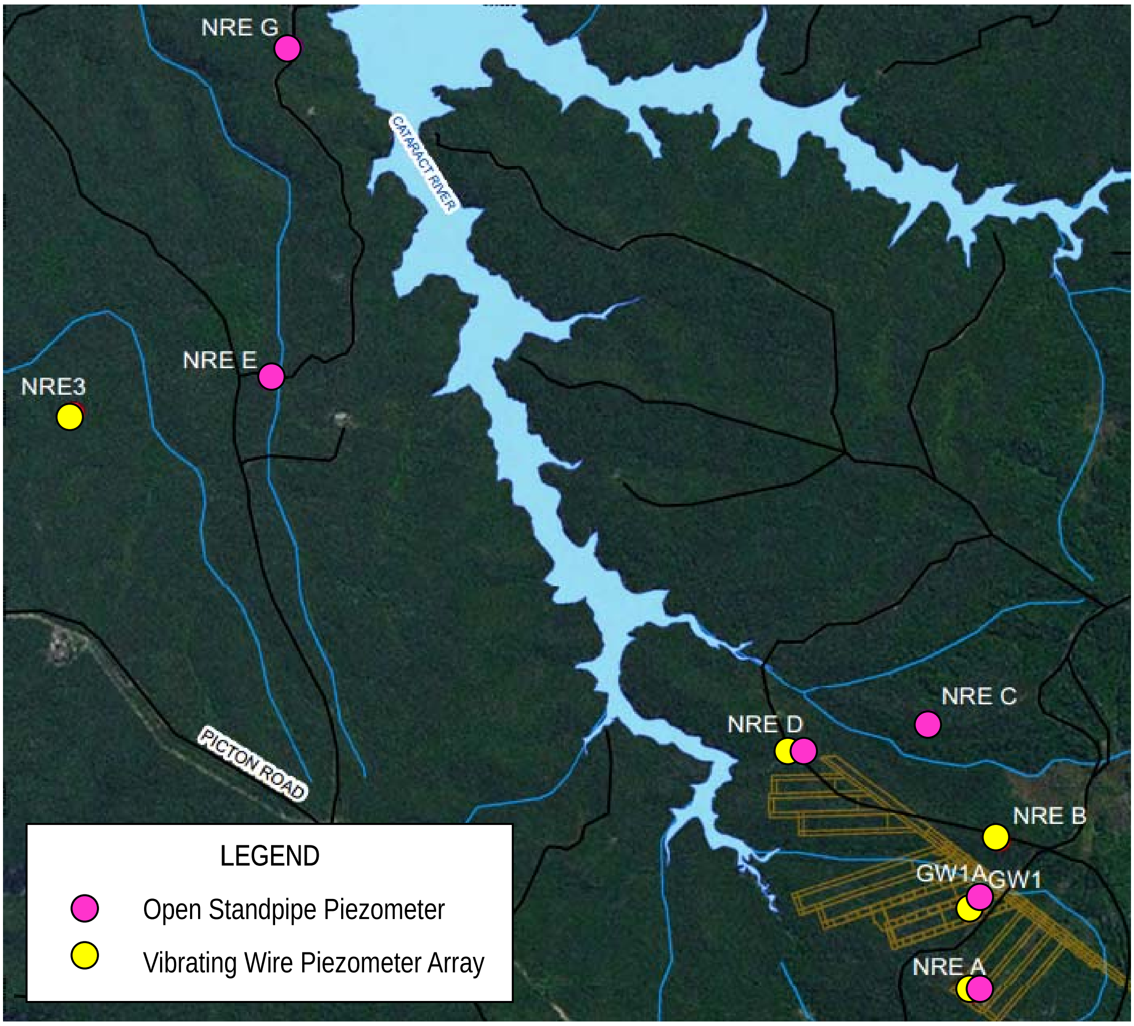


Figure 18 Russell Vale Colliery Piezometer Locations

It should be noted that where VWP arrays are installed, as shown in **Table 4**, the bores were sealed to surface with cement / bentonite.

Table 4 Vibrating Wire Piezometer Bores

Piezometer	E	N	Collar RL (mAHD)	Total Depth (mbgl)	Intakes (mbgl)
NRE-A VWP	303680	6196034	376.23	153	45(mid HS) 60(low HS) 75(up BS) 140(mid BS)
NRE B	303939	6197567	372.69	170	27.5(low HS) 43(up BS) 63(mid BS) 168(SPCS)
NRE D VWP	301875	6198493	348.0	176	33(mid HS) 60(low HS) 73(BHCS) 135(mid BS)
NE3	294794	6201945	360.23	281	100(mid HS) 130(low HS) 155(NP) 255(low BS)
P501	298771	6201855	326.18	335	110(HS) 174(up BS) 226(mid BS) 274(low BS) 325 (SS)
P502	298598	6202049	319.32	218	90(P14 & P15 low HS) 167(P12 & P13 up BS) 218(P11,mid BS)
GW1	303693	6196913	318.2	165	18 (BS) 30 (BS) 45 (BS) 63 (BS) 93 (BS) 125 (BS) 140 (SPCS) 165 (SS)

NOTE: HS - Hawkesbury Sandstone NP - Newport Formation BHCS - Bald Hill Claystone BS - Bulgo Sandstone SPCS - Stanwell Park Claystone SS - Scarborough Sandstone

8.1 Basement Hydraulic Properties

Low flow (<0.16L/sec) pump out tests of less than 45 minutes duration were conducted in all open standpipe piezometers seated in the upper to middle Hawkesbury Sandstone as outlined in Geoterra (2012).

Packer tests over 5.5m intervals were conducted in 6 bores to 281m below surface (SCT Operations, 2009).

As detailed in (Geoterra, 2012), the average packer test hydraulic conductivity of the Hawkesbury Sandstone varies from 0.01m/day in the upper section to 0.0003m/day in the mid section and 0.0008m/day in the lower horizon.

The Bald Hill Claystone averages 0.03m/day whilst the upper Bulgo Sandstone averages 0.007m/day and the mid Bulgo Sandstone averages 0.0004m/day (Geoterra, 2012).

Based on a combination of on-site tests as well as assessment of regional studies (Heritage Computing, 2010) hydraulic conductivities in the BHPB Bulli Seam proposed workings region vary from 0.03m/day to 1E-6m/day, whilst the western region around Tahmoor (Geoterra, 2009) ranges from 9.3E-6m/day to 1.6E-9m/day. The Dendrobium workings range from 8.6E-1m/day to 8.6E-5m/day (GHD, 2007).

Site specific test work, as well as reference to adjoining field and modelling groundwater studies in the Southern Coalfields, were used as hydraulic parameter inputs to the Study Area groundwater model.

Figure 19 shows the range of hydraulic conductivities available from the Study Area and adjoining Southern Coalfield study sites.

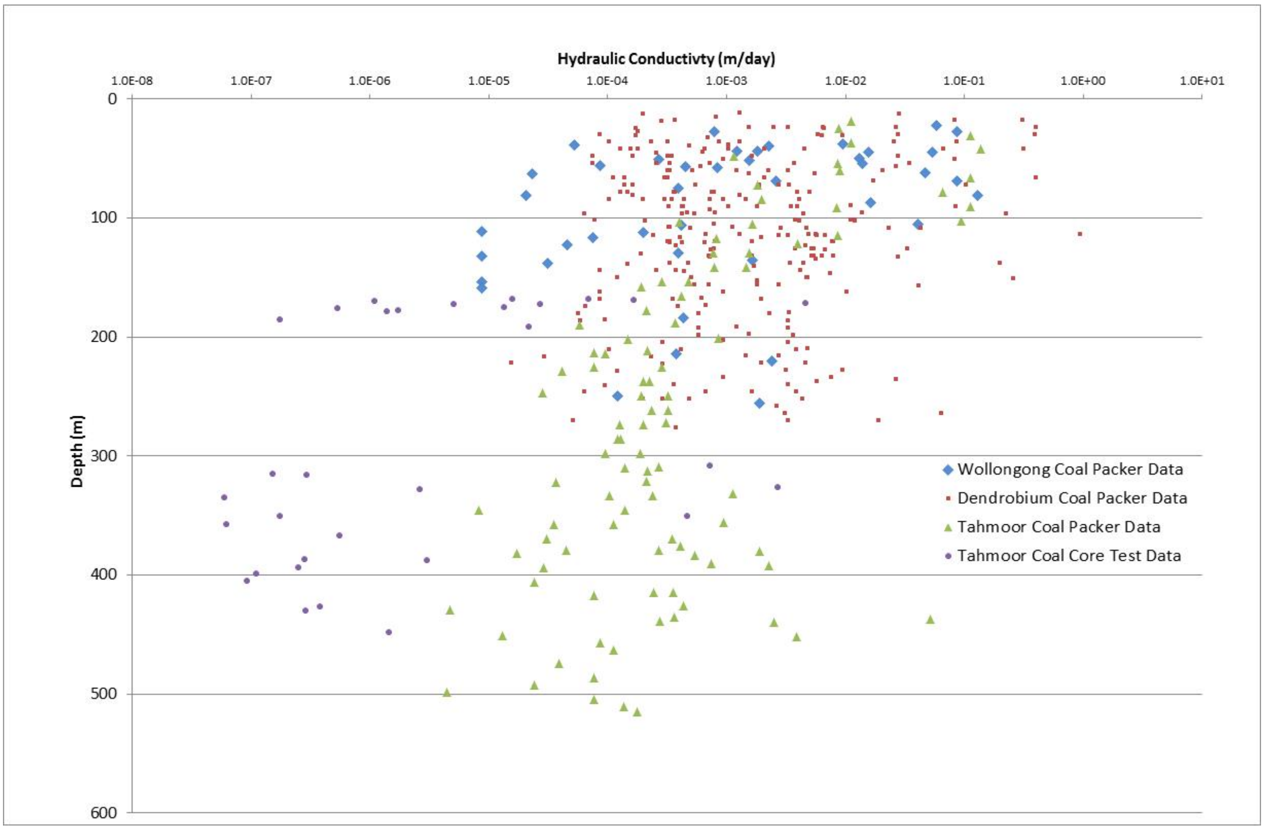


Figure 19 Selected Southern Coalfield Hydraulic Conductivities

8.2 Hawkesbury Sandstone Open Standpipe Water Levels

Water level variability has been measured in open standpipe piezometers that were installed in the upper Hawkesbury Sandstone as shown in **Figure 13** and **Table 5**.

Table 5 Open Standpipe Piezometer Water Level Variability

Piezometer	Drilling First Water Intercept (mbgl)	Water Level Range (mbgl)	Water Level Variability (m)
Wonga East			
NRE-A (VWP)	24.0	1.25 – 21.68	20.43
NRE C	18.0	6.32 – 13.06	6.74
NRE D	40.0	1.99 – 10.5	8.51
GW1A	24.0	6.97 – 13.6	6.63
Wonga West			
NRE E	17.0	10.41 – 11.63	1.22
NRE G	36.0	25.86 – 30.51	4.65
NRE3	48.0	6.97 – 39.55*	35.28*

NOTE: NRE3 piezo appears to not be correctly sealed

The monitoring data indicates that the Wonga East piezometers are generally more responsive to rainfall than at Wonga West, as shown in **Figure 20** with the variability principally due to the degree of subsidence and overburden fracturing that has occurred over the Wonga East workings.

Note that the high water level variability in NRE3 is unusual, and is probably due to incomplete sealing of the surface casing annulus, which allows overland surface water runoff to enter the casing and “artificially” raise the standing water level in the piezometer.

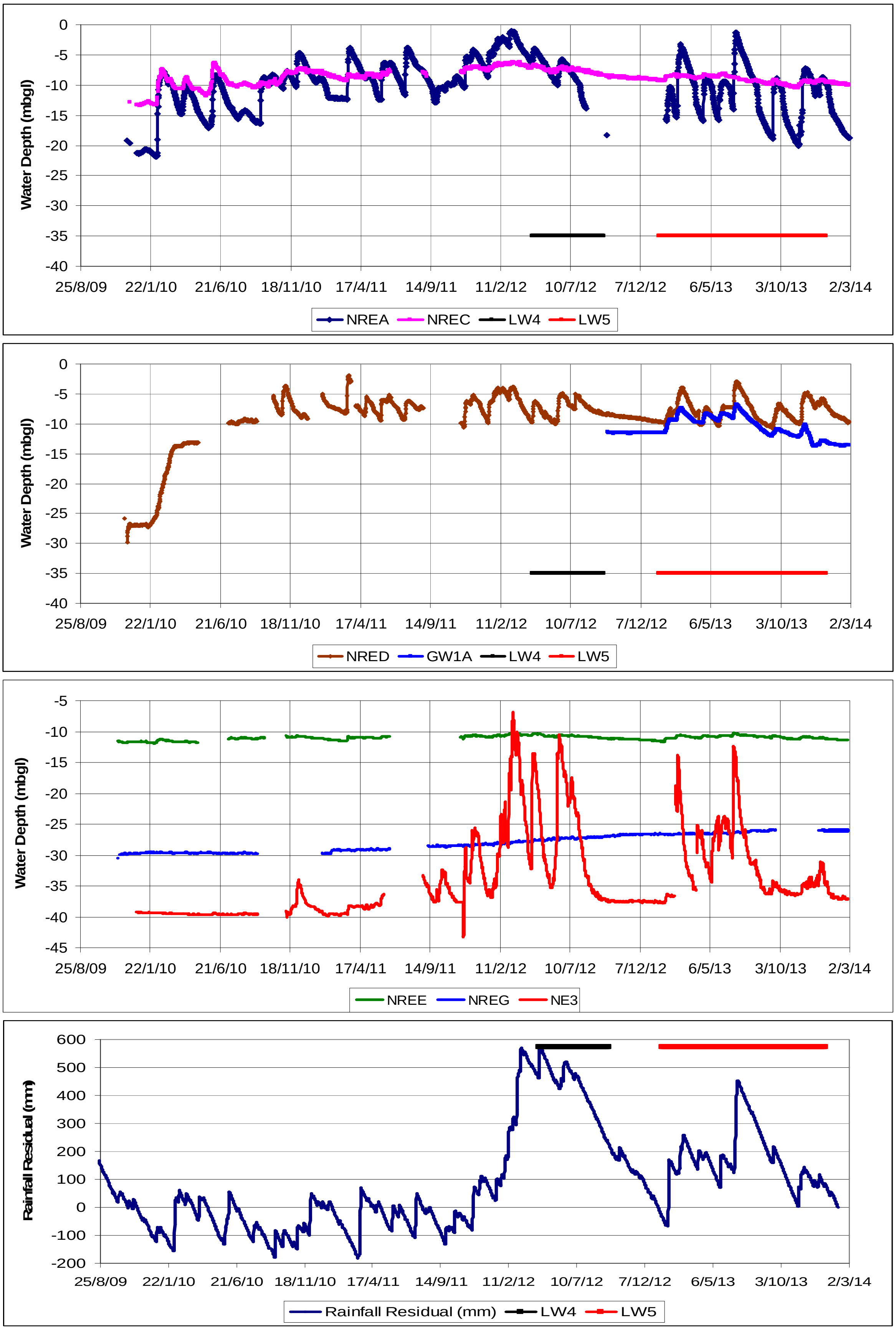


Figure 20 Shallow Sandstone Water Levels, Rainfall Residual and Longwall Extraction

8.3 Multi Level Piezometers

Multi level piezometers have been installed at selected depths between the Upper Hawkesbury Sandstone and the Stanwell Park Claystone since July 2009 in four bores at Wonga East and one at Wonga West as summarised in **Table 6**.

Table 6 Vibrating Wire Piezometers

Piezometer Intake Depth (mbgl)	Location / Formation	Piezometer Intake Depth (mbgl)	Location / Formation
NRE-A (VWP)	**(Wonga East)**	**NRE-B**	**(Wonga East)**
45	Mid Hawkesbury Sandstone	**27.5**	Lower Hawkesbury Sandstone
60	Lower Hawkesbury Sandstone	**43**	Upper Bulgo Sandstone
75	Upper Bulgo Sandstone	**63**	Mid Bulgo Sandstone
140	Lower Bulgo Sandstone	**168**	Stanwell Park Claystone
NRE-D (VWP)	**(Wonga East)**	**NRE-3**	**(Wonga West)**
33	Mid Hawkesbury Sandstone	**100**	Mid Hawkesbury Sandstone
60	Lower Hawkesbury Sandstone	**130**	Lower Hawkesbury Sandstone
73	Bald Hill Claystone	**155**	Newport Formation
135	Mid Bulgo Sandstone	**255**	Lower Bulgo Sandstone
GW1 (Wonga East)			
18	Upper Bulgo Sandstone	**93**	Mid Bulgo Sandstone
30	Upper Bulgo Sandstone	**125**	Lower Bulgo Sandstone
45	Upper Bulgo Sandstone	**140**	Stanwell Park Claystone
63	Mid Bulgo Sandstone	**165**	Scarborough Sandstone

NOTES: mbgl metres below ground level

Vibrating wire piezometers arrays were also installed in 1992 as part of an investigation of the 500 series longwall subsidence and groundwater response in piezometers P501, P502 and 514 (Singh R.N, Jakeman, M. 2001). These earlier piezometer arrays augment the latter VWP installations at Wonga East and Wonga West.

A contour plot of the regional upper Hawkesbury Sandstone piezometric surface based on data from the open standpipe and upper vibrating wire piezometer intakes as well as assumed water levels in the base of valleys and along Cataract Reservoir is shown in **Figure 21**.

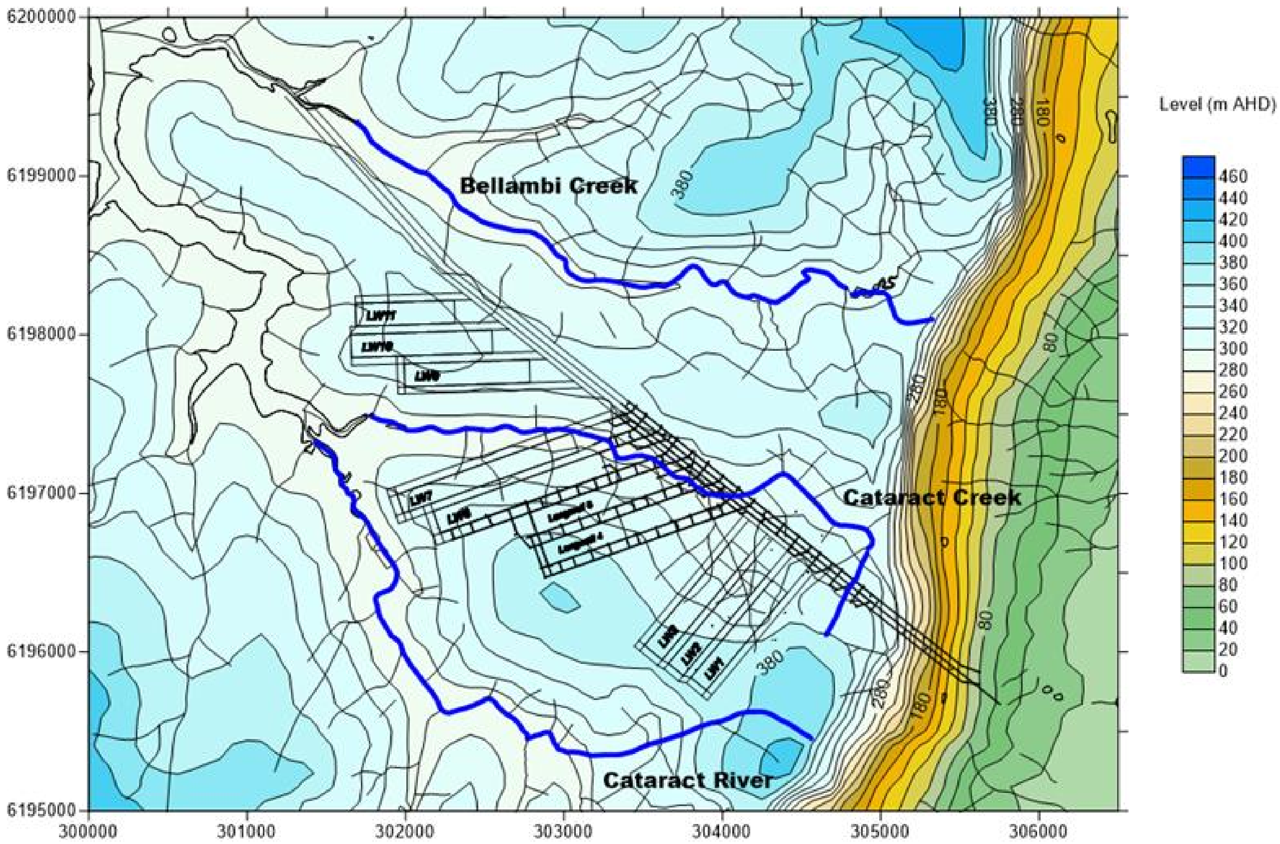


Figure 21 Russell Vale Colliery Phreatic Surface Groundwater Contours

The plot indicates a general flow at Wonga East from the escarpment to the Cataract Reservoir.

8.3.1 Comparison of Observed to Predicted Height of Strata Depressurisation

Comparison of the observed vibrating wire piezometer strata pressure profiles shown in **Figure 22**, to the predicted extent of the zone of depressurisation, according to the adapted Tammetta (2012) empirical method, indicates the method overestimates the observed height of depressurisation at Wonga East in GW1, as summarised in **Table 7**.

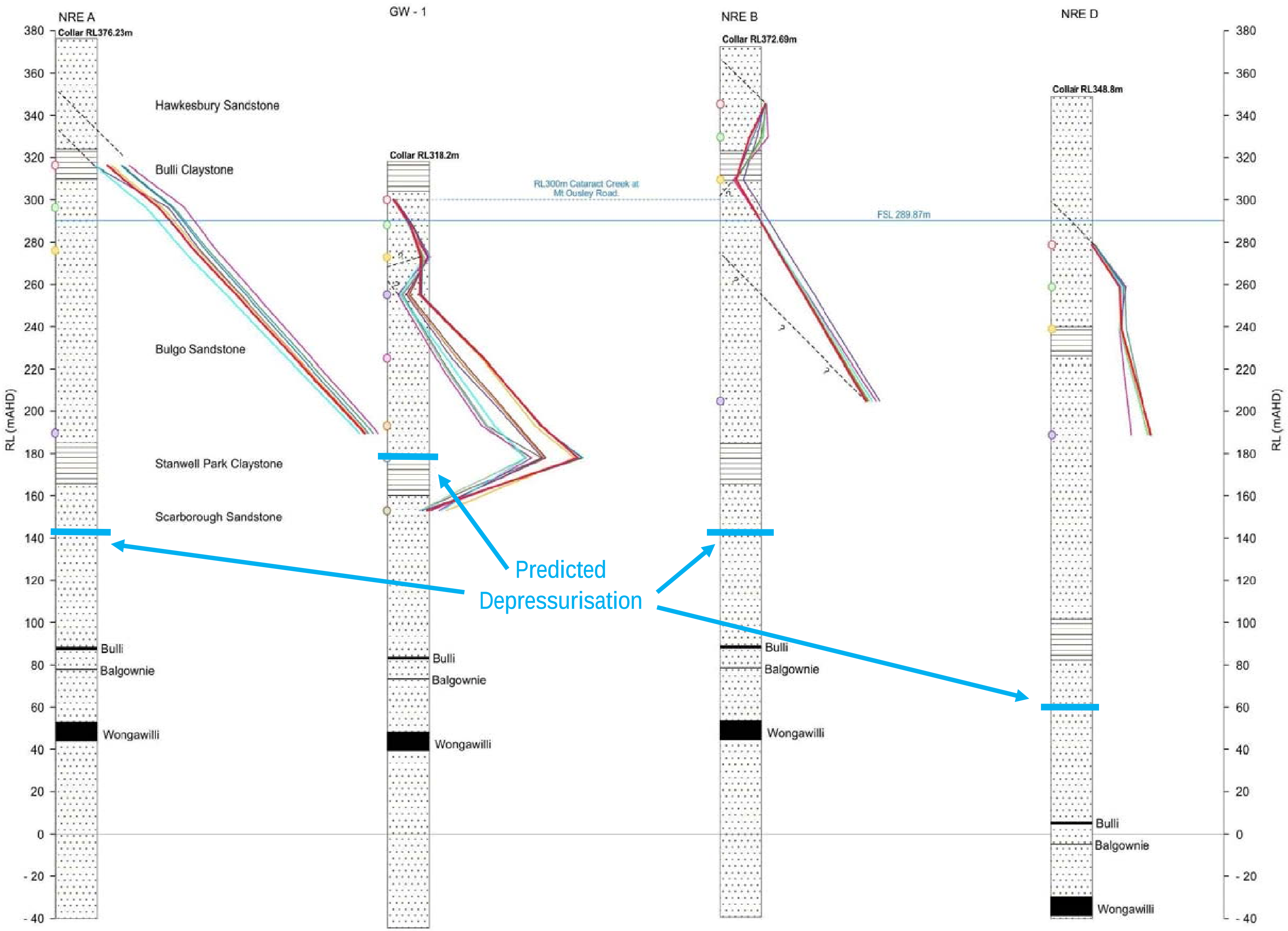


Figure 22 Wonga East Stratigraphy, Vibrating Wire Piezometer Installations and Head Pressures

It should be noted, however, that only GW-1 has been installed deep enough into the overburden to assess the height of depressurisation and that, as it is located approximately 500m off to the side of Longwall 4 and 250m from the edge of Longwall 5, use of this VWP data does not fulfil a tacit assumption in the Tammetta (2012) theory.

The theory assumes the depressurisation prediction location is directly over the centre of the subject secondary extraction workings.

Nevertheless, the available site data indicates the Scarborough Sandstone remains saturated, whereas the strata underlying the Bulli and Balgownie Seams have been dewatered due to earlier mining activities.

Table 7 shows that comparison of the theoretical versus actual height of depressurisation can not be ascertained in NRE-A, B and D as the lowest VWP transducer in each bore is not deep enough to measure the actual top of the "depressurisation" zone.

Comparison of the predicted versus actual depressurisation height is also complicated by the observation that although a VWP array may not directly overlie the centre of secondary extracted workings, most of the installed VWPs lie in close proximity to the edge of extracted workings and the depressurisation "halo" from the subsided strata over those workings affects the monitored overburden strata pressures in the VWPs.

GW1 however, does have deep enough instrumentation in the Scarborough Sandstone, and can be used to estimate the predicted "depressurisation" zone as a result of mining Longwalls 4 and 5 in the Wongawilli Seam.

Groundwater pressures have partially recovered in GW1 since the completion of LW5 and the Scarborough Sandstone remains saturated at least to the depth of the installed vibrating wire transducer.

Table 7 Comparison of Predicted and Observed heights of Depressurisation

Piezometer	Mining Height (Bulli / Balgownie / Wongawilli) Total (m)	Mining Width (Bulli / Balgownie / Wongawilli) Maximum (m)	Overburden Thickness From Top of Lowest Mined Seam (m)	Observed Height of Depressurisation Above Top of Lowest Mined Seam (m)	Predicted Height of Depressurisation Above Top of Lowest Mined Seam (m)
NRE-A*	0	0	295	<110	n/a
NRE-B**	2.2	100	285	<115	56
NRE-D**	2.2	100	345	<185	57
GW-1***	2.5	190	275	100 - 130	136

NOTES * NRE-A does not directly overly any workings, but is within close proximity to the edge of extraction in the Bulli and Balgownie secondary extraction areas

** NRE-B and NRE-D directly overly Bulli Seam extraction only

***GW-1 directly overlies Bulli + Balgownie Seam extraction, although is in close proximity to triple seam extraction from LW4 and LW5

The commentaries in the following sections on vibrating wire piezometer monitoring observations are an adaptation from the text, and also relate to the diagram in SCT Operations (2014) shown in **Figure 22.**

8.3.2 Wonga East NRE-A (VWP)

Piezometer NRE-A (VWP) is located on a ridge in the Hawkesbury Sandstone in an area where there are only first workings in the Bulli Seam (approx 285 mbgl), nearby longwall mining in the Balgownie Seam and no nearby mining in the Wongawilli Seam.

Figure 22 shows the pressure profile measured on the four piezometers installed in the bore indicate a hydraulic gradient that is close to hydrostatic with the indicated phreatic surface varying from 15m to 30m below surface (RL360m to RL345m).

The hydrograph in **Figure 23** indicates a response to short term rainfall trends consistent with the full column being vertically connected through the Hawkesbury Sandstone, the Bald Hill Claystone and approximately 75m into the Bulgo Sandstone as a result of mine subsidence.

There is some slight muting of the pressure response at 140m below surface in the Lower Bulgo Sandstone, but the immediacy of the response in all the piezometers indicates there is a high degree of vertical connectivity and that the Bald Hill Claystone is not acting to reduce vertical downward flow at this location.

Figure 23 **NRE-A VWP Water Levels, Rainfall Residual and Longwall Advance**

The individual piezometers indicate approximately the same response to rainfall recharge, with a slight trend of decreasing head with depth consistent with downward flow gradient from the surface toward the mining horizons. Given the high vertical conductivity indicated by the rainfall response, the presence of a downward hydraulic gradient indicates a strong potential for this area to be a source of inflow into the mine, particularly if the height of depressurisation above the mining horizon interacts with the zone of elevated vertical connectivity from the surface.

Although it is possible that the piezometer array was not properly sealed and the borehole annulus may contribute to the vertical conductivity, the downward trend with pressure does not support this. It should also be noted that NRE-A (VWP) is located on the same topographic ridge where horizontal stretching on the surface of Mount Ousley Road and open cracks in the adjacent terrain have been observed.

There were also pre-existing tension cracks close to the site of NRE-A (VWP) during mining of Longwall 3 in the Balgownie Seam. The high level of vertically connected cracking and consequently a high level of vertical conductivity observed in NRE-A (VWP) is considered to be a result of the presence of vertical fractures and opening of existing joints caused by horizontal tensional stretching of the shallow overburden (SCT Operations, 2014).

A second piezometer is proposed in this area in the near future and will help confirm the depth of elevated vertical conductivity.

The elevation of the phreatic surface at the NRE-A (VWP) site ranges from RL340m to RL360m which is at the level of the upper headwaters of Cataract Creek near the site and is likely to be contributing to an intermittent to perennial base flow into Cataract Creek.

Although there is a vertical hydraulic gradient downward toward the mine at NRE-A (VWP) and by implication some flow, there is also lateral flow into Cataract Creek, which is the primary control on the phreatic surface.

A significant observation from NRE-A (VWP) is that with the high level of vertical connectivity associated with tensional (stretching) movements caused by subsidence to a depth of at least 140m, the potential for downward flow into the mine is likely to be greatest directly below the tensional zone along the ridge top.

This piezometer string was installed well before the commencement of Longwall 4 on 22/4/12 and so there is a relatively long baseline of rainfall events prior to a series of high intensity rainfall events in early 2012 and the commencement of mining Longwall 4.

There is a clear reduction in piezometric pressure response after the start of mining Longwall 4 and this has continued through into Longwall 5. Close examination of the step change in the correspondence between rainfall and piezometric head change shows that rainfall prior to the start of Longwall 4 may have contributed to the inferred initial lateral hillside movement toward Cataract Creek.

The effect of the inferred lateral hillside movement, which was induced by a combination of high rainfall as well as previous historical and recent mining activity in the Wongawilli Seam, has been to reduce the head of the background phreatic surface by about 5 - 10m after March 2012.

Rainfall events appear capable of recharging the phreatic surface to pre - 2012 levels, but the level drops back more quickly to baseline levels. The volume of water stored in several large cracks observed during routine subsidence monitoring on the ridge above

Longwalls 4 and 5 soon after the start of mining Longwall 5 may be sufficient to account for the additional inflow volumes into the mine soon after the start of Longwall 5.

8.3.3 Wonga East (NRE-B)

As shown in **Figure 18**, piezometer NRE-B is located on a ridge to the north of Cataract Creek in an area where there has been secondary workings in the Bulli Seam but no mining in the Balgownie or Wongawilli Seams.

The piezometric profile at monitoring location NRE-B as shown in **Figure 22** indicates a perched water table under the ridge that is drawn down to zero at an elevation above Cataract Creek. It is difficult to draw many conclusions from the single pressure reading at 168m depth below surface in the Bulgo Sandstone, but this single value is consistent with a groundwater level at about 100m below the surface or 30m below the base of Cataract Creek. The upper two piezometers in the Hawkesbury Sandstone respond slightly to long term rainfall trends (**Figure 24**), but the correlation is much less clearly evident in NRE-B compared to NRE-A (VWP).

Although there has been some mining below this site in the Bulli Seam, extraction of coal has been much less systematic compared to the southern side of Cataract Creek where eleven longwall panels were mined in the Balgownie seam. Pore pressures in the Hawkesbury Sandstone are perched well above the level of Cataract Creek and the Cataract Reservoir.

The pore pressure in the Bulgo Sandstone is below the 289.87mAHD Full Supply Level (FSL) of Cataract Reservoir.

The NRE-B data indicates that there is a downward hydraulic gradient, but that the hydraulic properties of the intact strata are sufficiently low in the undisturbed strata so that there is almost no vertical downward flow component.

The response to long term rainfall trends even at relatively shallow depths within the Hawkesbury Sandstone is muted and only varies around a long term average by a few metres. There is a slow downward trend evident in the lower Hawkesbury Sandstone at 43m and the Bulgo Sandstone at 168m from about July 2011, but there is not clear a reason for this trend and it is not replicated in the piezometer located vertically between the two that are trending downward.

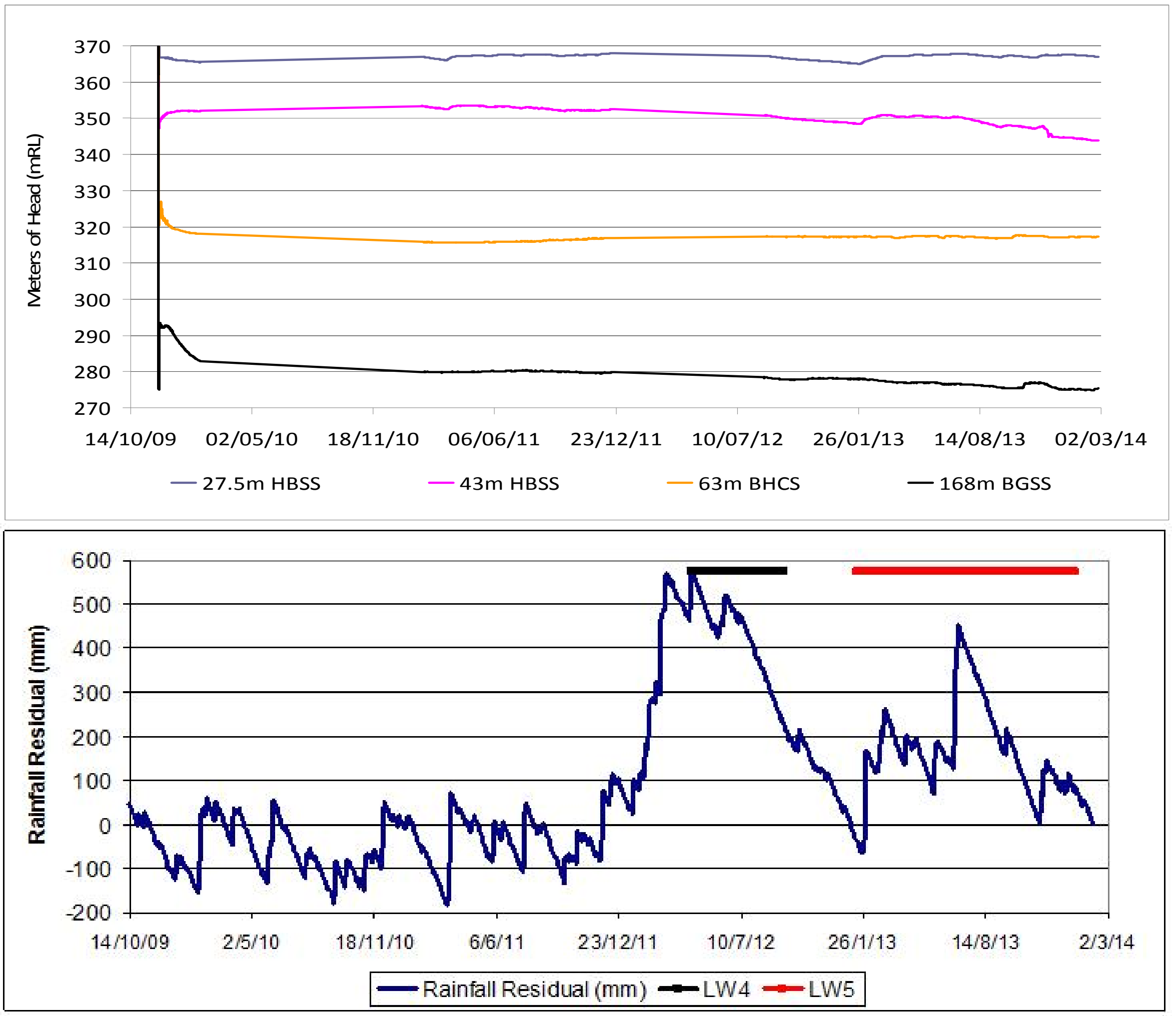


Figure 24 NRE-B VWP Water Levels, rainfall Residual and Longwall Advance

8.3.4 Wonga East NRE-D (VWP)

The vibrating wire piezometer array in bore NRE-D (VWP) is located approximately 540m to the east of Cataract Reservoir.

As shown in **Figure 18**, the borehole is located further west along the ridge to the north of Cataract Creek from NRE-B. The strata dips to the west so the equivalent geological units are about 75m lower at NRE-D (VWP) compared to NRE-B. There have been some limited secondary workings in the Bulli Seam but no mining in the Balgownie or Wongawilli Seams.

The piezometric profile at NRE-D as shown in **Figure 22** indicates the phreatic surface in the Hawkesbury Sandstone under the ridge is only slightly above the Full Supply Level (FSL) of Cataract Reservoir (RL289.87m). The pore pressure in the Bald Hill Claystone is drawn down 20m below FSL and the pore pressure in the Bulgo Sandstone is drawn down about 60m below FSL.

This profile indicates a downward hydraulic gradient, however, the mine pump-out records indicate there is very limited vertical flow down into the Bulli Seam workings so the in-situ vertical hydraulic conductivity appears to be limiting the downward flows to the low levels observed underground.

The graph also shows there is a positive head from the VWP intake at NRE-D 70HS and the open standpipe piezometer intake (NRE-D).

The piezometric pressure in the Bald Hill Claystone and Bulgo Sandstone that are below hydrostatic and below the level of Cataract Reservoir indicates there is a downward hydraulic gradient towards the mine in these units. The possible correlation with the changes in water level in Cataract Reservoir indicates there may be a connection between NRE-D (VWP) and the reservoir even at a distance of 540m.

The VWP array responses show a slight correlation with long term rainfall, particularly in the lower two intakes as shown in **Figure 25**.

In addition to the low rainfall deficit correlation, there may be an indistinct correlation with the level of Cataract Reservoir and the Bald Hill Claystone intake (NRE-D 110BHCS).

The possible correlation indicates that there may be limited lateral connectivity between the reservoir and NRE-D vibrating wire piezometer, potentially along a horizontal to sub-horizontal shear plane at a level just below the base of Cataract Reservoir (estimated in this area to be at about RL282m).

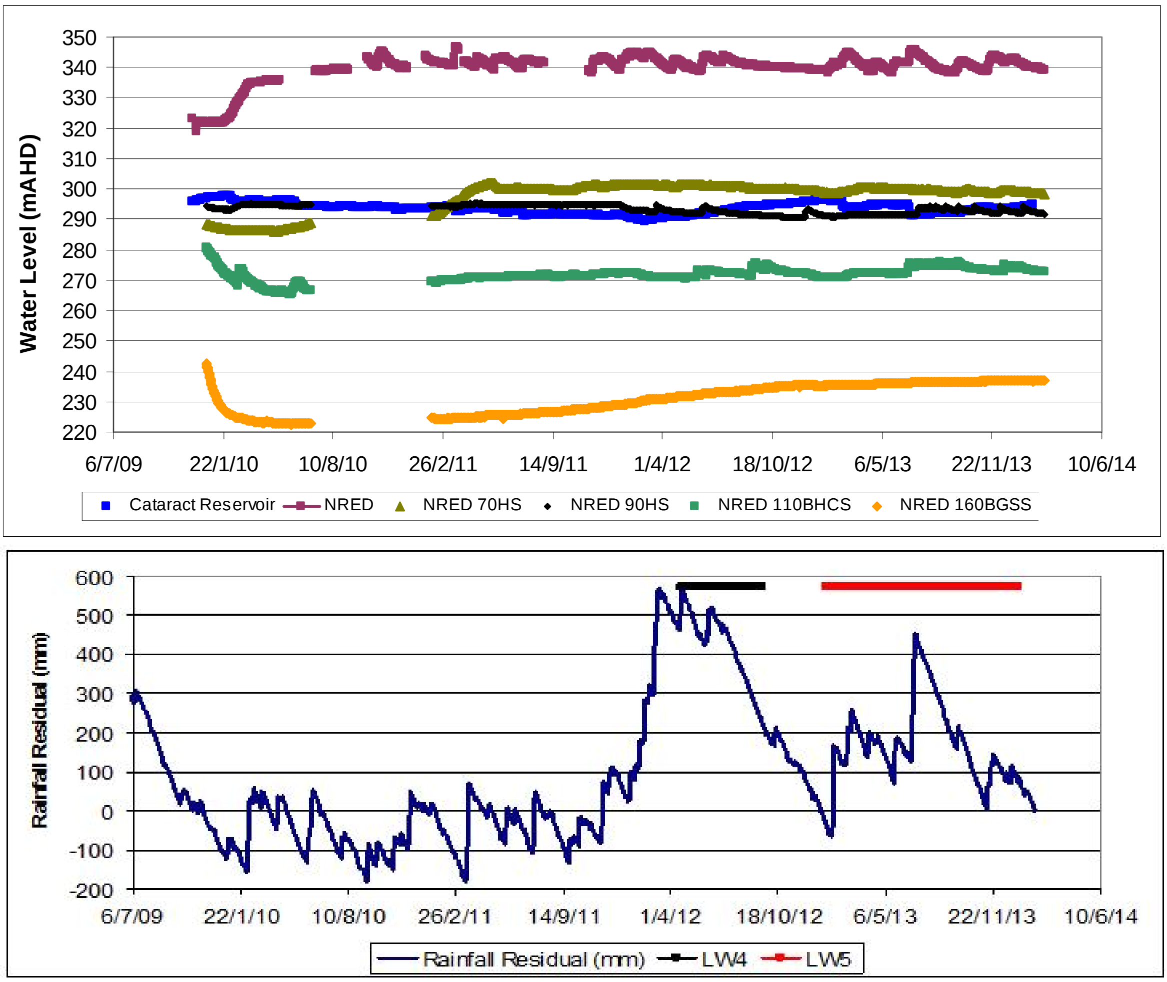


Figure 25 **NRE-D Water Levels, Rainfall Residual, Cataract Reservoir Level and Longwall Advance**

There is a hydraulic gradient away from the mine towards the reservoir in the Hawkesbury Sandstone and a hydraulic gradient from the reservoir back toward the mine at the Bald Hill Claystone and Bulgo Sandstone horizons.

The very low levels of inflow observed into the Bulli Seam indicate the hydraulic conductivity of the strata must be sufficiently low to limit any significant inflows into the mine to low levels despite this apparent possible connection.

8.3.5 Wonga West (NRE-3)

The head pressure vertical profile for NRE3 as shown in **Figure 26**, which is located at Wonga West near the southern lease boundary, indicates essentially hydrostatic pressure gradient from 100mbgl (Upper Hawkesbury Sandstone) to 155mbgl (Lower Hawkesbury Sandstone), with a decrease away from hydrostatic from 155mbgl to the Bulgo Sandstone at 255mbgl, which has not stabilised and is gradually reducing further.

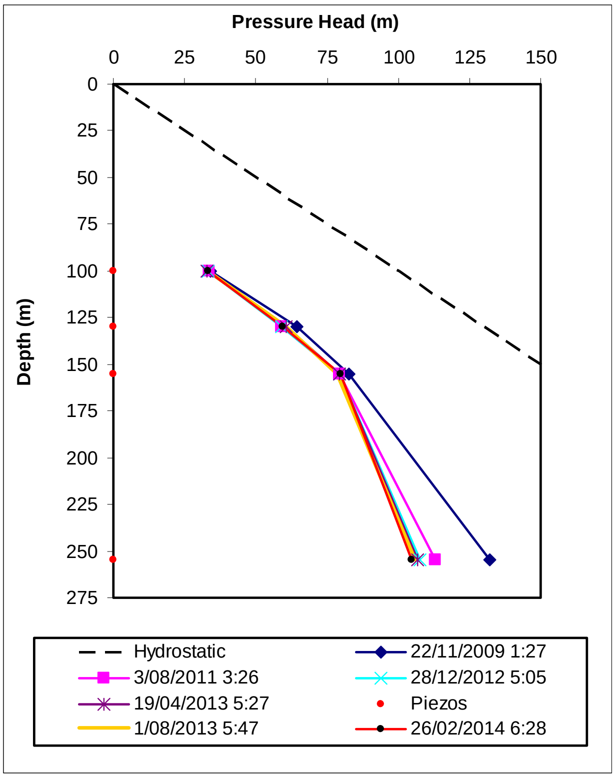


Figure 26 Wonga West NRE-3 VWP Head Pressure Profile

As shown in **Figure 27**, NRE-3 has limited response to rain events, with relatively stable pressures noted in the mid and lower Hawkesbury Sandstone (100 and 130mbgl) and in the Newport Formation (155mbgl), whilst the lower Bulgo Sandstone (255mbgl) is gradually depressurising presumably due to ongoing depressurisation associated with the historic mining of the Bulli Seam that has occurred to the west of cataract reservoir.

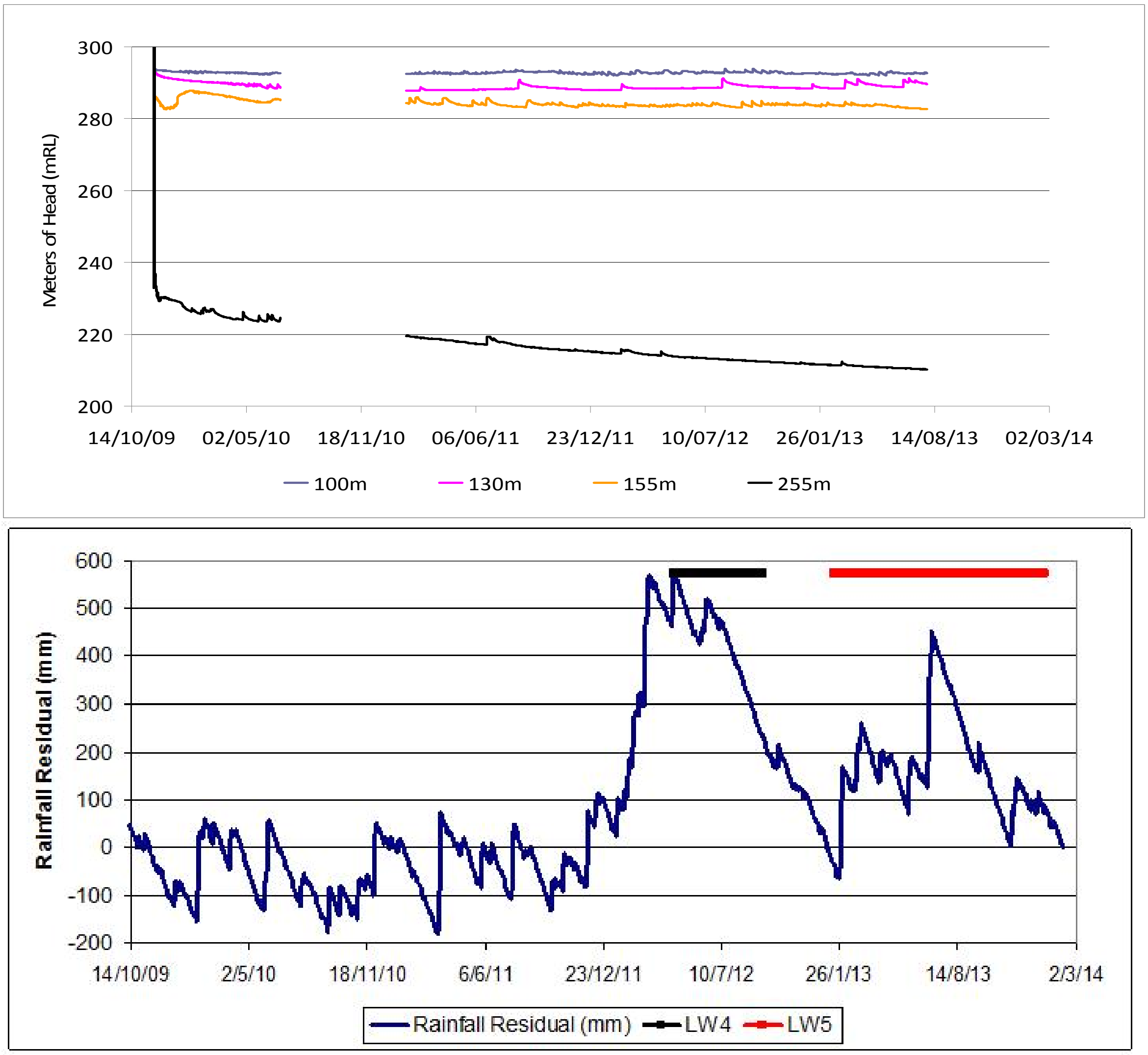


Figure 27 Wonga West NRE-3 VWP Water Levels, Rainfall Residual and Longwall Advance

8.4 Mine Water Pumping

This section outlines an adaptation of a mine water balance and groundwater assessment conducted by SCT Operations (2014).

All three seams dip to the west towards a low point in the 200 series longwall panels.

The natural pathway for water flow underground is from the outcrop on the Illawarra Escarpment down to the low point in the 200 series longwall panels. However, because of the irregular nature of the lease boundaries and the various panels within the mine, there are numerous underground storages created where water is impounded behind coal barriers within the mine and between mines.

Water flowing from up dip flows into these underground storages until they become full and overtop allowing flow to continue down into the lowest point in the mine. Over time, all the storage areas have filled up and so any additional flow occurs through a chain-of-ponds along each of the barriers. A similar process is occurring in the adjacent Old Bulli and Corrimal Collieries.

The current groundwater make from the Wongawilli Seam workings at Wonga East is approximately 1.05ML/day (383.3ML/year) as shown in **Figure 28**.

Based on considerations of how this flow has developed over time and where it has reported to in the mine, the current water make is estimated to comprise:

- 0.3ML/day from pre LW4 mining development headings in the Wongawilli Seam.
- 0.2ML/day for pre LW4 up dip inflow from upgradient adjacent workings in the Bulli and Balgownie Seams.
- 0.1ML/day additional inflow from mining Longwall 4.
- 0.5ML/day from mining Longwall 5.

8.4.1 200 and 300 Series Longwalls West of Cataract Reservoir

It is assessed there is no free drainage through the Bald Hill Claystone at Wonga West, as the existing workings are currently depressurised and essentially dry, although ponded water is present in a syncline in the central, southern section of the 200 series longwalls near as well as within the BHPB Cordeaux workings (S Wilson, pers comm.).

Monitoring of mine water pump-out from workings to the west of Cataract Reservoir, along with observations from underground supervisors (SCT Operations, 2014) indicate there is no short term increase in mine water make from the current workings following significant rain in the Lizard and Wallandoola Creek catchments.

Monitoring of water level trends in piezometers over the 200 and 300 series longwalls indicates the upper Hawkesbury Sandstone does not have an enhanced response to rainfall recharge.

8.4.2 Current Workings East of Cataract Reservoir

It is assessed there is no free drainage into the existing workings to the east of Cataract Reservoir as they are currently depressurised and essentially dry apart from a few small ponding areas at the down dip end of the old workings where the dewatering pump is not able to extract the water, until it “spills” into a downgradient section of the workings (SCT Operations, 2014).

Monitoring of water pump-out from the Wonga East workings indicates there is no observed associated short term increase in mine water make from the current Wonga East workings following significant rain in the Cataract Creek, Cataract River or Bellambi Creek catchments.

Based on available mine water balance records, the average daily groundwater inflow extracted from Russell Vale Colliery was 0.2 ML/day prior to extraction of LW4 and 1.05ML/day after extraction of LW5.

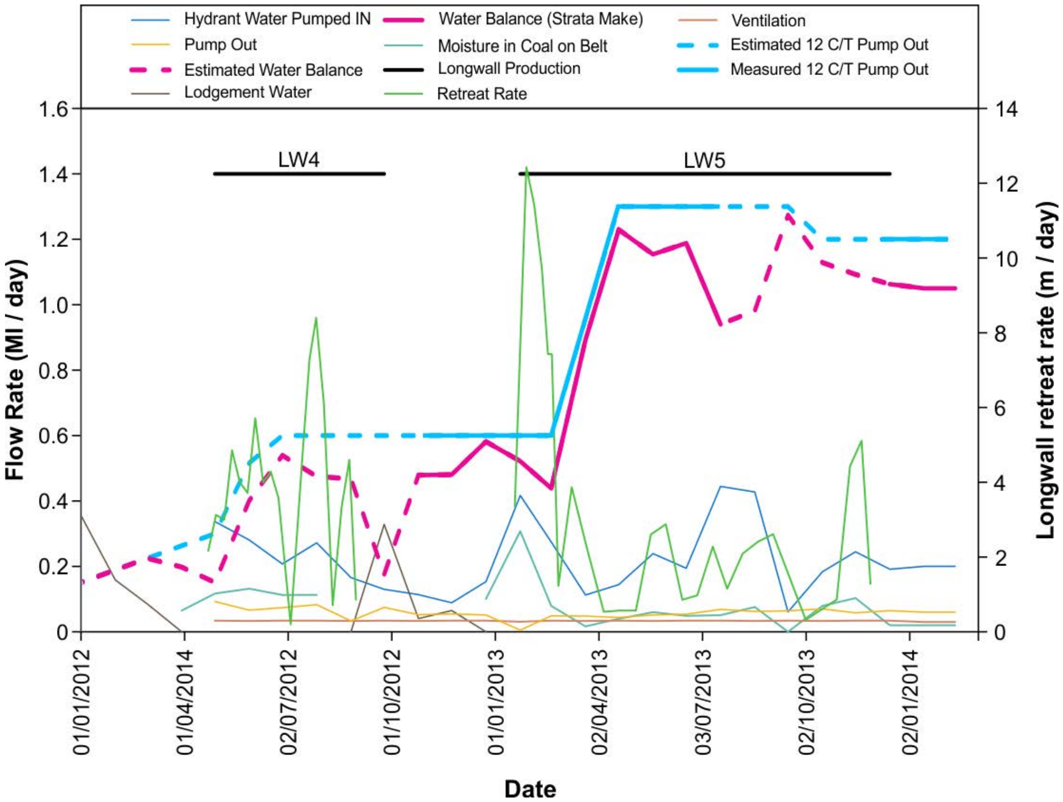


Figure 28 Russell Vale Colliery Groundwater Extraction and Rainfall

8.5 Groundwater Chemistry

Groundwater in the Hawkesbury Sandstone at Wonga East ranges from 76 - 776µS/cm with a pH from 3.2 – 6.8 as shown in **Figure 29**.

The moderate pH acidification and low salinity indicate meteoric rainfall recharge into the Hawkesbury Sandstone, with the salinity and pH range being typical of similar lithologies in the Southern Coalfields.

On the basis that the shallow groundwater discharges through seeps into the local streams, monitoring indicates the groundwater salinity is generally within the acceptable range for potable water, however it is predominantly outside the ANZECC 2000 South Eastern Australia Upland Stream criteria for pH and can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for:

- filtered copper, lead, zinc and aluminium (where the pH exceeds 6.5, which rarely occurs), as well as;
- total nitrogen and total phosphorus.

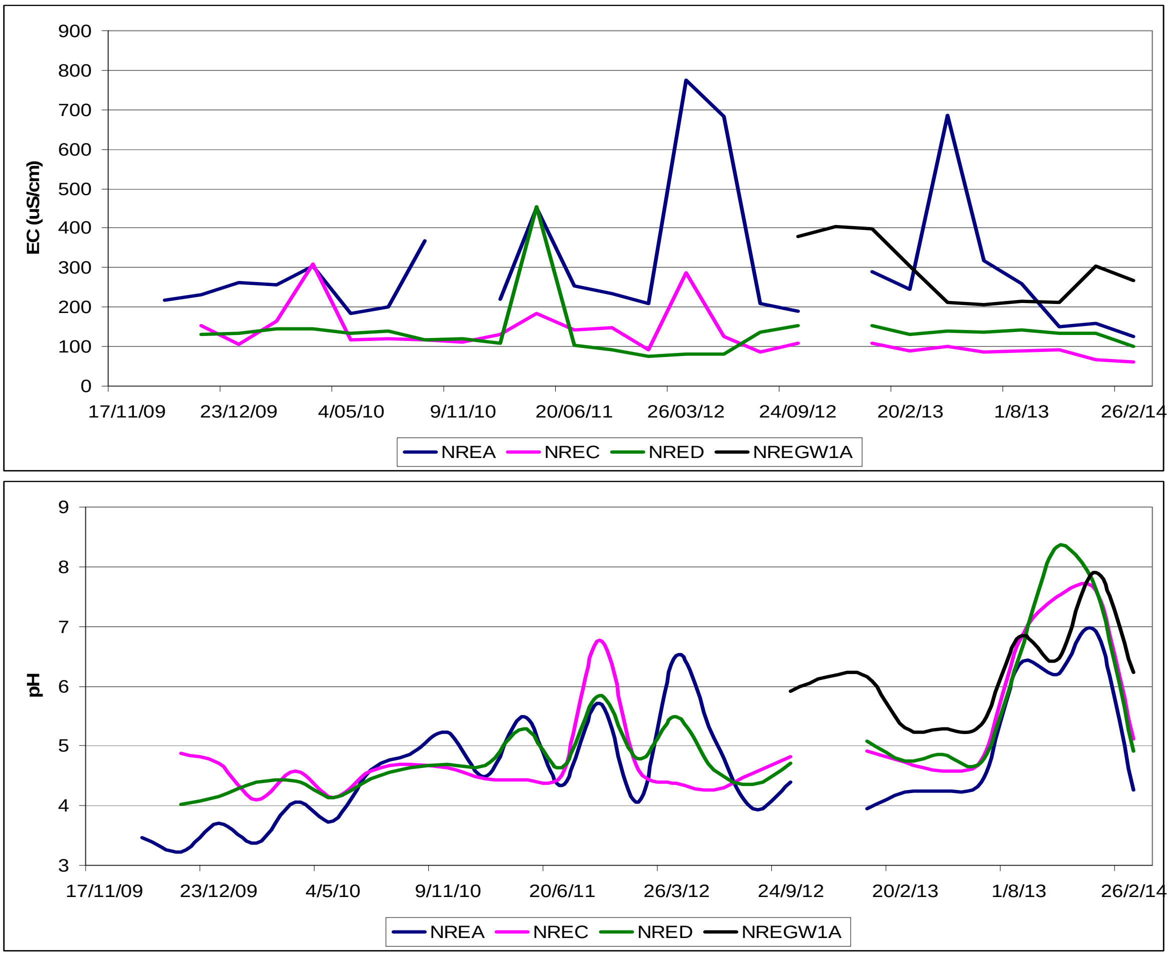


Figure 29 Wonga East Hawkesbury Sandstone Salinity and pH

Further detailed analysis of groundwater chemistry in the Wonga East area is contained in Geoterra (2014A).

9. GROUNDWATER MODELLING

Assessment of the current and potential mining related impacts due to extraction of the proposed Wonga East Wongawilli Seam longwalls on groundwater systems involved a revised conceptualisation of the local groundwater flow processes, measurement of hydraulic parameters in the field, and revised simulation using computer based mathematical modeling with MODFLOW SURFACT, imposition of changes brought about by the proposed extraction and assessment of the resulting impacts.

A previous FEFLOW based groundwater model and associated interpretation was reported in Geoterra (2012B). The previous report assessed the proposed mining in both the Wonga West and Wonga East areas, prior to revision of the mine plan to the current PPR.

The current MODFLOW SURFACT modelling was conducted to incorporate more recent drilling results and groundwater monitoring and to focus on the revised mine layout in the PPR Wonga East mining domain.

The model structure, modelling approach and simulations generated by Groundwater Exploration Services (GES) in association with Geoterra Pty Ltd and SCT Operations Pty Ltd are detailed in the following sections, with the potential groundwater impacts summarised in **Section 10.**

The groundwater model is of Moderate Complexity (under the MDBC Guidelines) with a Class 2 Confidence Level (under the NWC guidelines). It provides an assessment of the existing groundwater system status and predicts the potential effects from extraction of the proposed workings.

The key objective of this groundwater model is to simulate the current and proposed mining activities within the Wongawilli Seam in the Wonga East area and to understand the effects to groundwater and surface water environment in a local and regional context. There is extensive pre-existing depressurisation from the existing workings at Russell Vale, as well as the adjoining Cordeaux, Corrimal and Bulli mines resulting from mining activities over many decades. This includes the area immediately surrounding the Wong East proposal and also in a regional context. There has been a long period of hiatus in terms of mining activities in the Wonga East area with the extraction of the Balgownie Seam at Wonga East occurring in the 1970's.

There is also very little in the way of groundwater level data which show mining related impacts prior to Wongawilli Seam development given the amount mining activities which have historically occurred. The only known data available related to Wonga West Bulli Seam mining activities particularly in the 500 series panels. It was the monitoring of impacts of these panels in 1993 which led to the development of the model to begin transient modelling early enough to incorporate this data.

Hence the model includes stress periods which include the period in the Wonga West workings where the 500 series panels were active and monitored from early 2003 (Year 0), up to the current period, then after the end of extracting Wonga East, then up to 100 years after mining has finished in Wonga East.

Some uncertainty is present due to the lack of direct field measurement of post subsidence hydraulic conductivities applied to represent sedimentary formations above the existing workings, except at the vibrating wire piezometer bore site GW1 where packer tests were conducted.

In addition, assumptions were incorporated regarding the interactive effect of adjoining mines and workings within the overall Study Area.

The spatial relationship of the proposed and the existing workings within the model domain are shown in **Figure 30.**

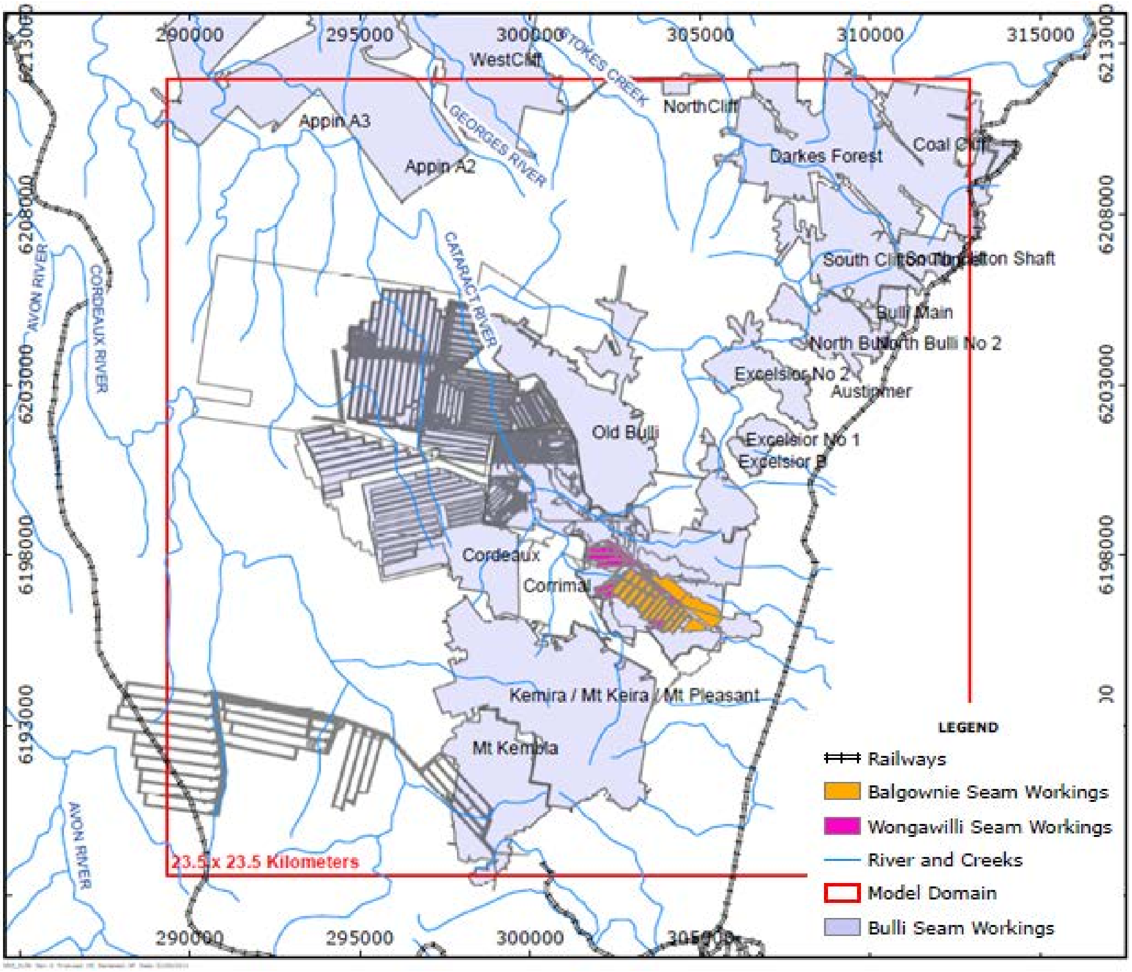


Figure 30 Russell Vale and Adjoining Mining Areas

It should be noted that the modelling requires simplification of the groundwater system in regard to lithological thicknesses, their hydraulic properties and applied stresses including previous subsidence, rainfall infiltration, creek leakage and underground seepage.

It is also challenging, within the model limitations, to represent steep hydraulic gradients above the mine workings and the potential for zero pore pressure horizons.

9.1 Conceptual Hydrogeological Model

A conceptual model of the Study Area hydrogeological regime has been developed based on a review of existing hydrogeological data as described in **Section 8** and shown in **Figure 31**, and was based on the Southern Coalfield 1:100,000 geology mapping, mine seam mapping and geological drill logs that are available from within the Russell Vale lease area.

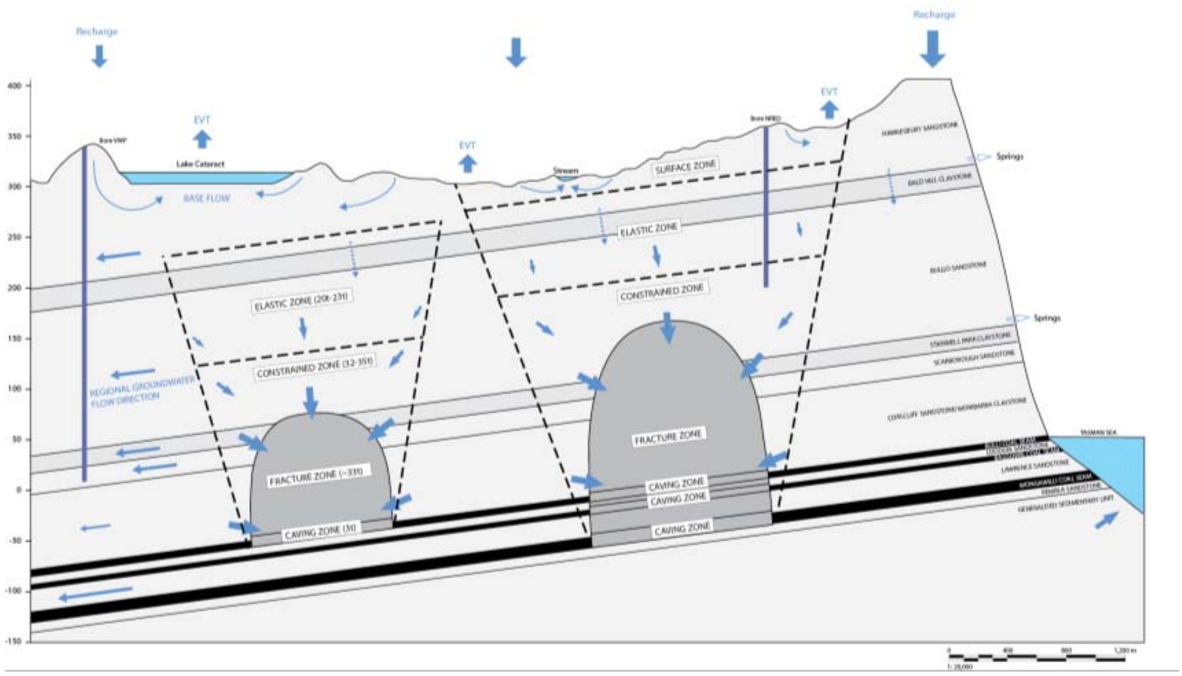


Figure 31 Conceptual Groundwater Model

Input data has also been gathered from geological and hydrogeological assessments undertaken for the Appin, West Cliff, Dendrobium and other Southern Coalfield mine lease areas.

Lithological layer depths and thicknesses within the Russell Vale lease area were based on in-situ piezometer and coal exploration drilling results within the Russell Vale lease area and from drilling data sourced from other projects.

Six conceptual groundwater sub-domains are present:

- intermittent to ephemeral, hydraulically disconnected (perched) upland swamps which provide baseflow to the local streams ;
- a perched, ephemeral weathered Hawkesbury Sandstone profile which provides baseflow to the local streams.
- the deeper Hawkesbury Sandstone, which is hydraulically separated from the overlying Quaternary sediments and weathered sandstone perched aquifers as well as from the underlying Bulgo Sandstone at Wonga West, although not at Wonga East, both before and after subsidence. Following mining, as has been observed in the piezometers to the east of the reservoir, the water levels exhibit a heightened response to recharge, or increased recharge due to the higher porosity, as well as interconnected permeability of the aquifer;
- the Narrabeen Group sedimentary lithologies which have already been locally fractured and depressurised above the existing workings up to the mid to lower Bulgo Sandstone, and are anticipated to be fractured and partially depressurised over the proposed Wongawilli Seam longwall workings up to the mid to upper Bulgo Sandstone;

- the Illawarra Coal Measures, containing the Bulli, Balgownie and Wongawilli Seam aquifers, which have also been fractured and depressurised by the existing workings and will be locally fractured and depressurised by the proposed workings, and;
- the sedimentary sequence underneath the Wongawilli Seam.

The model was set up with 18 layers to represent both the existing lithological and Bulli / Balgownie Seam subsidence affected areas, and to account for the anticipated change in hydraulic properties following extraction of the proposed workings within the Wongawilli Seam.

The existing Russell Vale Colliery workings within the model in the Bulli seam were assumed to be partially flooded in the central southern section of the longwalls to the west of Cataract Reservoir, as well as in the Cordeaux workings, and partially in the Bulli Colliery bord and pillar workings.

This is based on reported ponded areas within the Bulli Seam in the Wonga West area and estimated ponding levels within the Corrimal workings. Drain cell stages were limited to elevations above the seam for allowing ponding to occur. Wonga West drains were limited to -140m AHD and Corrimal was limited to -95m AHD. This has led to minor ponding within the seam and has removed dry cells from these areas. However, the levels are marginally higher than the base of the layers and have not led to wholesale flooding in any area.

Where the workings were dry they were modelled with seepage boundaries with head levels set to the elevation of the mine floor to simulate atmospheric pressure.

The adjoining Cordeaux and Bulli workings were assumed to be separated from Russell Vale Colliery by at least a 40m wide intact coal barrier.

9.2 Model Layers

Eighteen layers are conceptualised for the purpose of numerical modelling as shown in **Table 8**.

The major sandstone formations (Hawkesbury and Bulgo) are split into multiple layers in order to reproduce natural or mining-induced vertical hydraulic gradients.

In the mid-reach of Cataract River, the Hawkesbury Sandstone and underlying Newport / Garie Formation and the Bald Hill Claystone have been eroded away within drainage channels to enable exposure of the Bulgo Sandstone. Where this occurs, the appropriate hydraulic parameters have been propagated into overlying layers where each unit outcrops.

As a result, although Layer 1 is dominated by the upper Hawkesbury Sandstone, it also contains the Newport / Garie Formation, Bald Hill Claystone and upper Bulgo Sandstone in the eroded reach of Cataract Creek.

Similarly, but to a sequentially lesser degree, the mid and lower Hawkesbury Sandstone in Layers 2 and 3 are also eroded in the reach of Cataract Creek near the freeway, so these layers also contain the Newport / Garie Formation, Bald Hill Claystone and upper Bulgo Sandstone.

Layer 4, which predominantly contains the Bald Hill Claystone, can also contain the upper Bulgo Sandstone in the eroded reach of Cataract Creek.

All subsequent underlying layers contain only one lithology.

Table 8 Model Layers

Layer	Unit
1	Upper Hawkesbury Sandstone + NGF + BHCS +UBS
2	Mid Hawkesbury Sandstone + NGF + BHCS +UBS
3	Lower Hawkesbury Sandstone + NGF + BHCS +UBS
4	Bald Hill Claystone +UBS
5	Upper Bulgo Sandstone
6	Mid Bulgo Sandstone
7	Mid Bulgo Sandstone
8	Lower Bulgo Sandstone
9	Stanwell Park Claystone
10	Scarborough Sandstone
11	Wombarra Claystone
12	Coal Cliff Sandstone
13	Bulli Seam
14	Loddon Sandstone
15	Balgownie Seam
16	Lawrence Sandstone
17	Wongawilli Seam
18	Kembla Sandstone and Below

NOTE: NGF = Newport / Garie Formation BHCS = Bald Hill Claystone UBS = Upper Bulgo Sandstone

9.3 Boundary Conditions

The model areal extent has been chosen so that the peripheral boundary conditions are of a sufficient distance from the proposed Wonga East mining domain to significantly reduce the potential for a change in flow conditions across the model boundaries as a result of the Project.

The boundary conditions at the periphery of the model consist of:

- constant head boundaries representing active mining areas in the Wongawilli Seam including Appin (to the north) in the Bulli Seam and Dendrobium to the south;
- general head boundaries representing the coast line to the east of the escarpment and coastal plain;

- no-flow boundaries at topographic divides representing the western boundary of the model domain;
- historic mining areas, principally within the Bulli Seam, as represented by the Drain Package in MODFLOW SURFACT, have been conceptualised to remain as regional hydrogeological sinks, and;
- drainage channels which were simulated using the River Package. River stages were set 1m above base of surficial layer to allow the package to act as drainages, with their conductance set to $5m^2$/day to allow the aquifer hydraulic properties to control leakage to and from the model. Sydney Catchment Authority reservoirs, Lake Cataract and Lake Cordeaux were also simulated utilising River Package with levels set at 290m AHD and 305m AHD respectively.

The Cataract and Cordeaux reservoirs were represented with static (Steady State) River Package boundary cells.

Groundwater pressures or standing water level data from piezometers within the Study Area were used as a basis for initial conditions, whilst groundwater levels over the Cordeaux and Bulli workings were approximated, as no direct data was available.

Direct measurements of hydraulic parameters from bores within the Wollongong Coal lease were used, and where data was unavailable, approximated parameters were sourced from studies over the BHPB workings to the north (Heritage Computing, 2010).

Underground dewatering was represented by inclusion of the proposed mine voids in the Bulli, Balgownie and Wongawilli Seams through the use of drains as well as incorporating the associated changes in overburden hydraulic parameters in the overlying sedimentary units due to subsidence.

9.4 Recharge and Evapotranspiration

Recharge was set at 2% of rainfall from Woonona station data across elevated terrain west of the escarpment and to 4% over the escarpment and coastal plain, as was used in the Bulli Seam Operations modelling (Heritage Computing, 2010).

Evapotranspiration was applied uniformly to the model with rate of 0.005 m/d and an extinction depth of 4m.

9.5 Grid

A variable cell size is employed across the model domain.

A grid size of 250 x 250m occupies the periphery of the model domain, reducing to 100m x 100m nearer to the Wollongong Coal lease area, then to 50m x 50m over most of Wollongong Coal Lease area.

The grid was further reduced to 50m x 25m in an east – west alignment that overlies the main channel of Cataract Creek.

While the potential impacts from the mining activities relate to regional scale effects, experience has shown that providing more detailed grid discretisation has no significant impact on predicted mine inflows or groundwater levels as long as a mine plan can be appropriately represented.

However, the adopted grid refinement allowed for improved detailing of the mine plan scheduling and increased accuracy surrounding the baseflow effects in creeks overlying the Project.

The changes in grid size obeyed the 50% convention rule regarding changes between grid size between rows and columns with minimum ratio of cell size change being 0.75 (Environmental Simulations Inc. 2009).

9.6 Mining Schedule

The adopted mining schedule for development and the extraction of the panels within the Bulli and Wongawilli seams is shown in **Table 9**.

The model start date is 1/1/1993, whilst the calibration period is from 1/1/1993 to 28/2/2014. This includes the 500 series panels in Wonga West within the Bulli seam in 1993 and the initial mine development in the Wongawilli Seam at Wonga East, which began in early 2011. The interim period included a large hiatus where no significant mining activities occurred.

The period of predictive analysis occurs from 28/2/2014 to 28/8/2018 with the completion of LW3. The recovery period includes the subsequent 200 years to 1/1/2220.

Detailed time stepping has been used to simulate the Wongawilli Seam development and mining progression in the Wonga East area is shown in **Figure 32**.

In order to investigate the incremental effects of mining, the predicted operational mining impacts and the post mining recovery have been assessed in accordance with the adopted schedule.

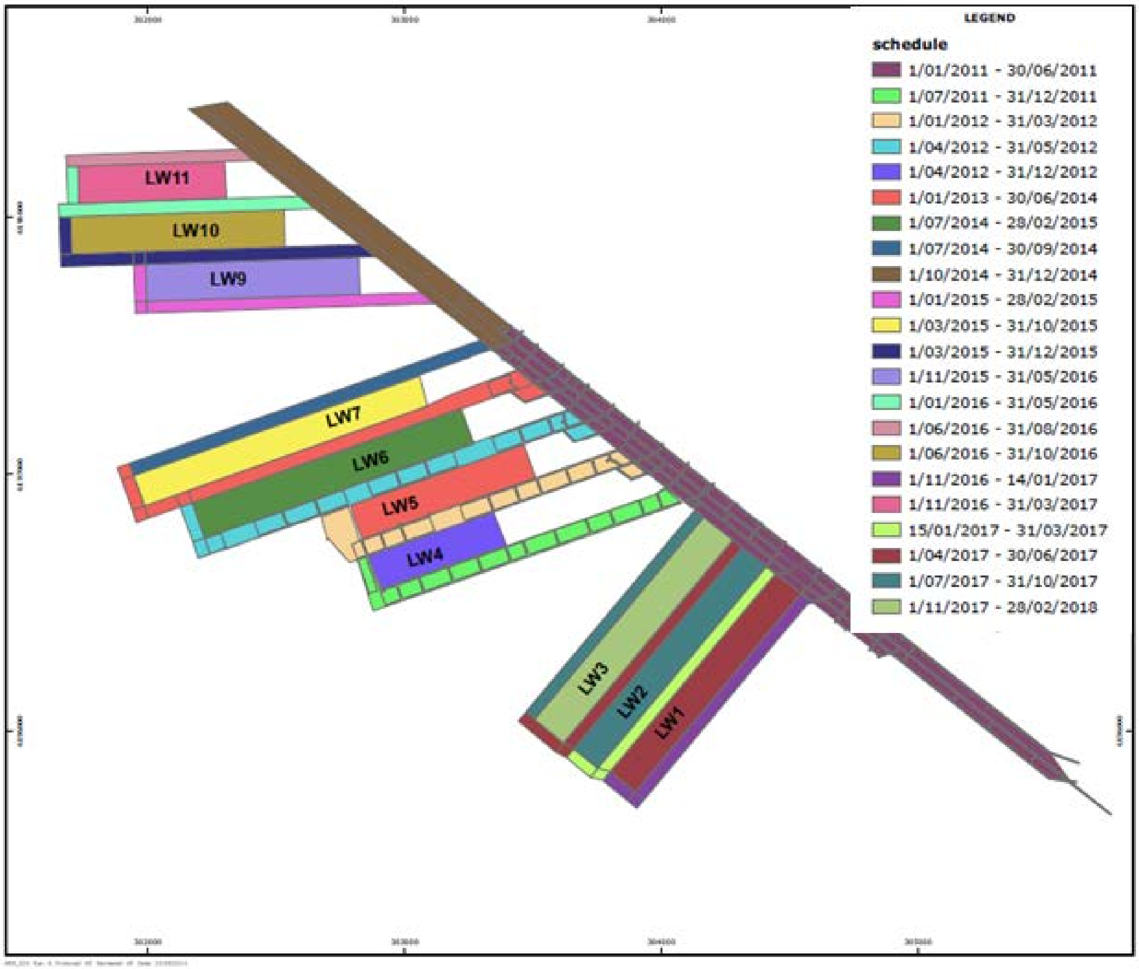


Figure 32 Mining Schedule in Wongawilli Seam

Table 9 Mine Schedules Used for the Impact Assessment

						MINING AREAS / LONGWALLS			
Model Type	**Purpose**	**SP**	**SP_START**	**SP_END**	**SP Length (DAYS)**			**Wonga West**	All Other Bulli Seam Mines
Steady State	'PRE-MINING'	1	01-Jan-91	31-Dec-92	731				
Transient Calibration	HISTORIC	2	1/01/1993	11/07/1993	192				modelled as constant
	HISTORIC	3	12/07/1993	13/12/1993	155			501	
	HISTORIC	4	14/12/1993	18/05/1994	156			502	
	HISTORIC	5	19/05/1994	28/09/1994	133			503	
	HISTORIC	6	29/09/1994	6/02/1995	131			504	
	HISTORIC	7	7/02/1995	19/06/1995	133			505	
	HISTORIC	8	20/06/1995	26/11/1995	160			506	
	HISTORIC	9	27/11/1995	16/08/1996	264			507	
	HISTORIC	10	17/08/1996	25/05/1997	282			508	
	HISTORIC	11	26/05/1997	31/12/1997	220			509	
	HISTORIC	12	1/01/1998	31/12/1998	365			no mining	
	HISTORIC	13	1/01/1999	31/12/1999	365				
	HISTORIC	14	1/01/2000	31/12/2000	366				
	HISTORIC	15	1/01/2001	31/12/2001	365				
	HISTORIC	16	1/01/2002	31/12/2002	365				
	HISTORIC	17	1/01/2003	31/12/2003	365				
	HISTORIC	18	1/01/2004	31/12/2004	366				
	HISTORIC	19	1/01/2005	31/12/2005	365				
	HISTORIC	20	1/01/2006	31/12/2006	365				
	HISTORIC	21	1/01/2007	31/12/2007	365				
	HISTORIC	22	1/01/2008	31/12/2008	366				
	HISTORIC	23	1/01/2009	31/12/2009	365				
	HISTORIC	24	1/01/2010	31/12/2010	365				
	HISTORIC	25	1/01/2011	31/03/2011	90	Mains			
	HISTORIC	26	1/04/2011	30/06/2011	91	Mains			
	HISTORIC	27	1/07/2011	31/12/2011	184	MG4			
	HISTORIC	28	1/01/2012	31/03/2012	91	TG4			
	HISTORIC	29	1/04/2012	31/05/2012	61	TG5			
	HISTORIC	30	1/06/2012	31/07/2012	61				
	HISTORIC	31	1/08/2012	31/08/2012	31		LW4		
	HISTORIC	32	1/09/2012	31/10/2012	61				
	HISTORIC	33	1/11/2012	31/12/2012	61				
	HISTORIC	34	1/01/2013	14/02/2013	45				
	HISTORIC	35	15/02/2013	31/03/2013	45				
	HISTORIC	36	1/04/2013	31/05/2013	61		LW5		
	HISTORIC	37	1/06/2013	31/07/2013	61				
	HISTORIC	38	1/08/2013	14/08/2013	14				

	HISTORIC	39	15/08/2013	31/08/2013	17				
	HISTORIC	40	1/09/2013	14/09/2013	14	TG6			
	HISTORIC	41	15/09/2013	30/09/2013	16				
	HISTORIC	42	1/10/2013	14/10/2013	14				
	HISTORIC	43	15/10/2013	31/10/2013	17				
	HISTORIC	44	1/11/2013	14/11/2013	14				
	HISTORIC	45	15/11/2013	30/11/2013	16				
	HISTORIC	46	1/12/2013	14/12/2013	14				
	HISTORIC	47	15/12/2013	31/12/2013	17				
	HISTORIC	48	1/01/2014	28/02/2014	59				
Prediction	IMPACT	49	1/03/2014	30/06/2014	122				
	IMPACT	50	1/07/2014	30/09/2014	92	TG7			
	IMPACT	51	1/10/2014	31/12/2014	92	Mains	LW6		
	IMPACT	52	1/01/2015	28/02/2015	59	MG9			
	IMPACT	53	1/03/2015	30/06/2015	122	TG9	LW7		
	IMPACT	54	1/07/2015	31/10/2015	123				
	IMPACT	55	1/11/2015	31/12/2015	61	TG9			
	IMPACT	56	1/01/2016	29/02/2016	60		LW9		
	IMPACT	57	1/03/2016	31/05/2016	92	TG10			
	IMPACT	58	1/06/2016	14/07/2016	44				
	IMPACT	59	15/07/2016	31/08/2016	48	TG11	LW10		
	IMPACT	60	1/09/2016	31/10/2016	61				
	IMPACT	61	1/11/2016	14/01/2017	75	MG1	LW11		
	IMPACT	62	15/01/2017	31/03/2017	76	TG1			
	IMPACT	63	1/04/2017	30/06/2017	91	TG2	LW1		
	IMPACT	64	1/07/2017	31/10/2017	123	TG3	LW2		
	IMPACT	65	1/11/2017	28/02/2018	120		LW3		
	RECOVERY	66	1/03/2018	31/12/2019	671	**Turn off DRN**	**Turn off DRN**		
	RECOVERY	67	1/01/2020	31/12/2029	3653				
	RECOVERY	68	1/01/2030	31/12/2069	14610				
	RECOVERY	69	1/01/2070	31/12/2119	18261				
	RECOVERY	70	1/01/2120	31/12/2169	18263				
	RECOVERY	71	1/01/2170	1/01/2220	18262				

9.7 Model Implementation

The underground mining and dewatering activity is defined in the model using drain cells within the mined coal seams, with modelled drain elevations set to 0.5m above the base of the Bulli Seam (Layer 13), Balgownie Seam (Layer 15) and Wongawilli Seam (Layer 17).

These drain cells were applied wherever workings occur and were maintained as constant within the Bulli and Wongawilli Seam and implemented in line with mine progression in the Wongawilli Seam. Mining prior to the transient modelling period was simulated as steady state within the Bulli Seam (Layer 13) and Balgownie Seam (Layer 15).

The model set-up involved changing the parameters with time in the goaf and overlying fractured zones directly after mining of each panel, whilst simultaneously activating drain cells along all development headings. The development headings were activated in advance of the active mining and subsequent subsidence. Although the coal seam void should be dominated by the drain mechanism, the horizontal and vertical permeabilities were raised to 10 m/day to simulate the highly disturbed nature within the caved zone.

9.8 Existing Mine Workings

Extensive abandoned mine workings occur regionally within the Bulli seam and extend the length of the escarpment within the model domain as shown in **Figure 30**.

Adjacent to the proposed Project, there are large areas of abandoned Bulli workings to the north and immediately to the south of the Wollongong Coal lease boundary as well as the combined Corrimal / Cordeaux complex to the south in the Bulli seam. The model maintains active sinks using drain cells with invert levels 0.1m representing Bulli Seam workings at the following decommissioned operations:

- Old Bulli;
- Excelsior 1, 2 and B;
- North Bulli;
- South Clifton Tunnel;
- Darkes Forest;
- Coal Cliff;
- Corrimal;
- Cordeaux, and;
- Mt Kembla.

Drain cell invert levels were set at 0.1m above the seam floor and were maintained throughout transient modelling with the exception of small areas in Wonga West at Russell Vale, where drain cell invert levels were raised slightly to mimic reported ponding in some areas. No flooding was indicated in any of these areas as the levels of ponding are not reported to be extensive.

The degree of hydraulic connectivity between the Corrimal / Cordeaux complex and the older mine workings adjacent to the Wollongong Coal lease area is currently unknown and has been assumed in the model to be constrained by hydraulic conductivities of the host strata.

Active mining within the Bulli Seam is occurring in the northern periphery of the model in the form of the BHPB Appin workings. Additionally, active mining is occurring within the Wongawilli seam at Dendrobium at the southern boundary of the model area.

9.9 Fracture and Depressurisation Zone Implementation

The post Wongawilli Seam extraction subsidence parameter distribution was based on a conceptual understanding of longwall mine subsidence geomechanics and fracture development as detailed in SCT Operations (2013).

Layer definition within the model has allowed primary mined coal seams to be represented individually. It also allows the overburden to be subdivided into multiple layers and therefore allows subsidence caving and fracturing effects to be simulated to various heights above each mined seam so that the impact of progressive caving and fracturing associated with the mining is adequately represented.

The fractured zone was simulated with horizontal hydraulic conductivity enhanced by a factor of two, and with vertical hydraulic conductivity enhanced according to a function which varied the vertical hydraulic conductivity field within the deformation zone overlying coal extraction areas and “weighted” the permeability changes based on layer thickness.

Limits for the variability were governed by the predicted fracture height, based on Tammetta (2012) and the pre-determined upper and lower bounds of hydraulic conductivity. These were manipulated to allow the height of depressurisation which follows an empirical equation based on historical data for single seam mining environments to be followed in this multiple seam mining environment.

9.9.1 Height of Fracturing and Associated Zone of Depressurisation

Based on in-situ monitoring, the hydraulic characteristics of strata overlying or adjacent to the extracted Bulli, Balgownie and Wongawilli Seam secondary workings have been altered due to subsidence that may have generated atmospheric depressurisation up to the lower Bulgo Sandstone following extraction of Longwalls 4 and 5 in the Wongawilli Seam.

Where mining in all three seams has occurred, or will occur, there is a potential for interaction between surface water features and the top of the depressurised groundwater zone that is recharged from rainfall and adjacent creeks. The potential may be enhanced if there is interaction between the hillslope basal shear plane that may have been re-activated by subsidence and the top of the zone of depressurisation above each longwall panel.

There is considered to be some potential for interaction between the zone of depressurisation and the basal shear planes in the shallower areas at the northern ends of Longwall 2 and 3 as well as at the northern end of Longwall 7. At the northern end of Longwall 7, the area where three seams have been mined is limited in extent and the height of depressurisation may be less as a result. Further monitoring is planned and has been applied for approval by the SCA to establish the height of depressurisation when all three seams have been mined.

Further in-situ field assessment via installation of additional vibrating wire piezometer arrays is planned in the short term to determine the height of depressurisation above the southern end of Longwall 4, which has also been planned and applied for approval by the SCA, where all three seams have been mined.

To date, the multi-seam estimated height of depressurisation is limited to the one location (GW-1), which is not located over the centre of a Wongawilli Seam longwall (SCT Operations, 2014).

Based on mine water balance monitoring and rainfall observations, free drainage through vertically connected fracturing from the surface streams and in the overall catchment is not apparent over the existing workings at Wonga East (SCT Operations, 2014).

In the groundwater model, it was assumed that the enhanced hydraulic conductivity after extraction of the proposed longwalls could enable free drainage within the goaf and overlying fractured strata, with vertical connective fracturing to the Upper Bulgo Sandstone / Lower Hawkesbury Sandstone.

Plastic deformation with bed delamination, without significantly enhanced vertical hydraulic connectivity was interpreted to be present from the mid / upper Bulgo Sandstone to 20m below surface where overlapping triple seam extraction was not present.

Due to limitations of the model setup capability and the scale of the model, it was not possible to represent any changes in hydraulic conductivity of the thin (<2m) Quaternary alluvial / colluvial and upland swamp profiles in the upper section of model Layer 1.

The predicted height of the depressurisation zone above the lowest mined seam, using the adapted Tammetta (2012) empirical equation, with linear addition of the extracted seam heights, is shown in **Figure 33** for the Wollongong Coal lease area, and for Wonga East in **Figure 34.** The height of separation between the predicted top of the depressurisation zone and the ground surface is shown in **Figure 35**.

It should be noted that although the adapted Tammetta (2012) method indicates the potential height of complete "depressurisation", and the figures indicate the theoretical separation distance from this zone to surface, strata depressurisation can not transgress through unsaturated strata between the surface water system and the underlying, separated, groundwater system. Therefore, the streams and swamps are hydraulically separated from the underlying "depressurisation" zone within the regional groundwater system.

This means that although depressurisation (which is associated with subsidence related fracturing) may be "predicted" to reach the surface, based on the theoretical Tammetta (2012) methodology, the streams and swamps will not necessarily be adversely affected by subsidence, unless connected, enhanced vertical conductivity strata are generated due to subsidence, and extend to the base of the swamps or stream beds.

The partial "depressurisation" zone generally extends higher up into the subsided strata than the "fractured", vertically connected, enhanced hydraulic conductivity zone.

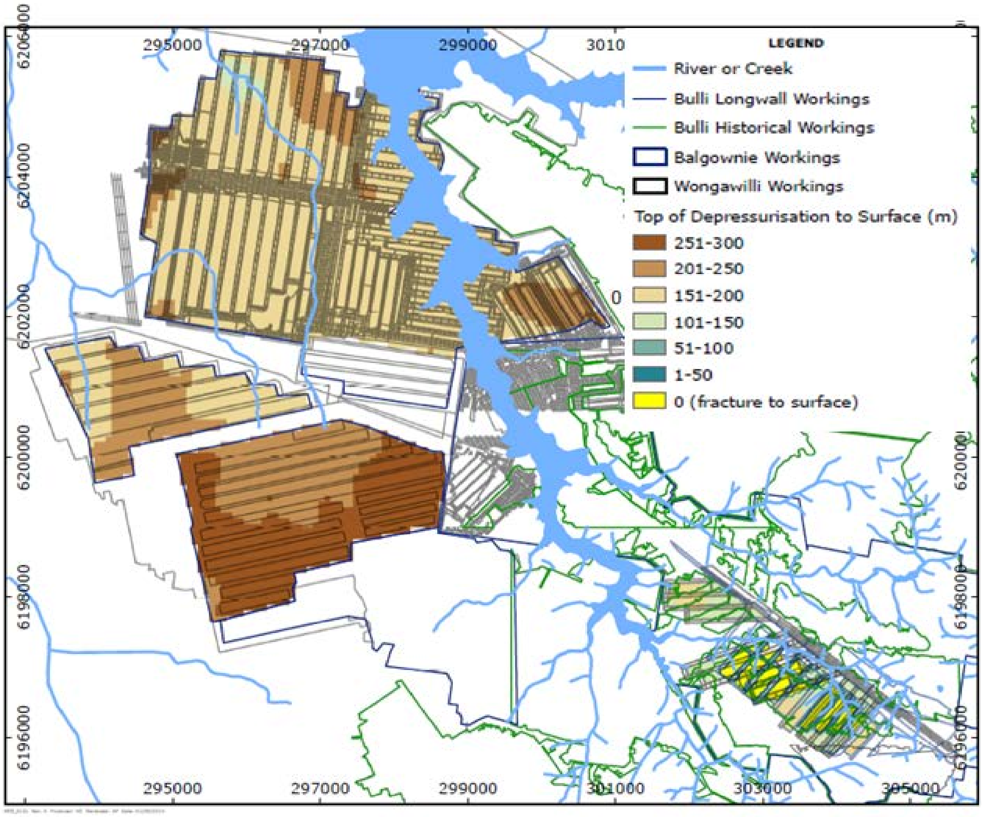


Figure 33 Predicted Height of Russell Vale Colliery Depressurisation Zone above the Lowest Mined Seam

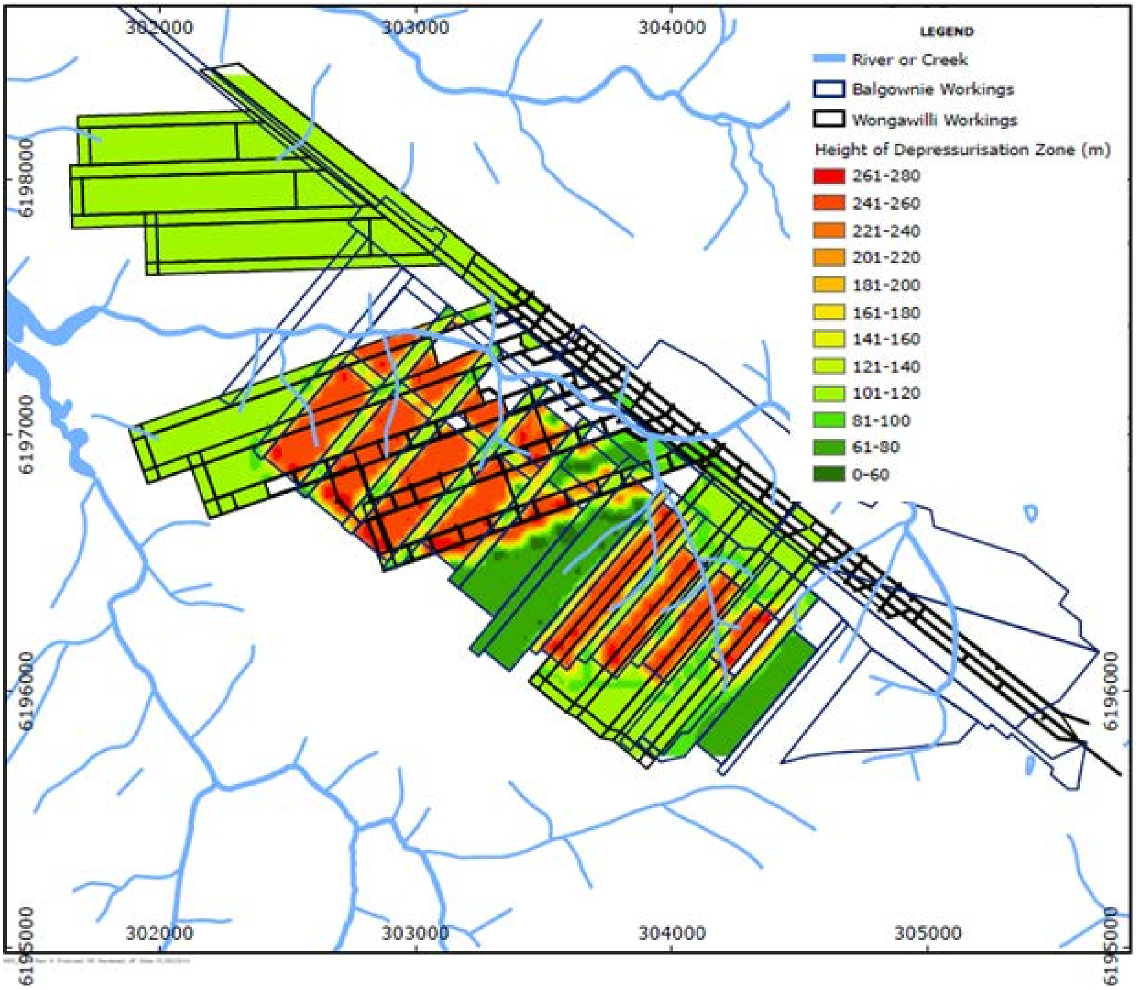


Figure 34 Predicted Height of Wonga East Depressurisation Zone above the Wongawilli Seam

Figure 35 indicates that, based on the inherent assumptions in the Tammetta (2012) empirical method and the adaptation of this equation to multi-seam mining, the depressurisation zone may reach the ground surface over the already extracted Wongawilli Seam Longwalls 4 and 5.

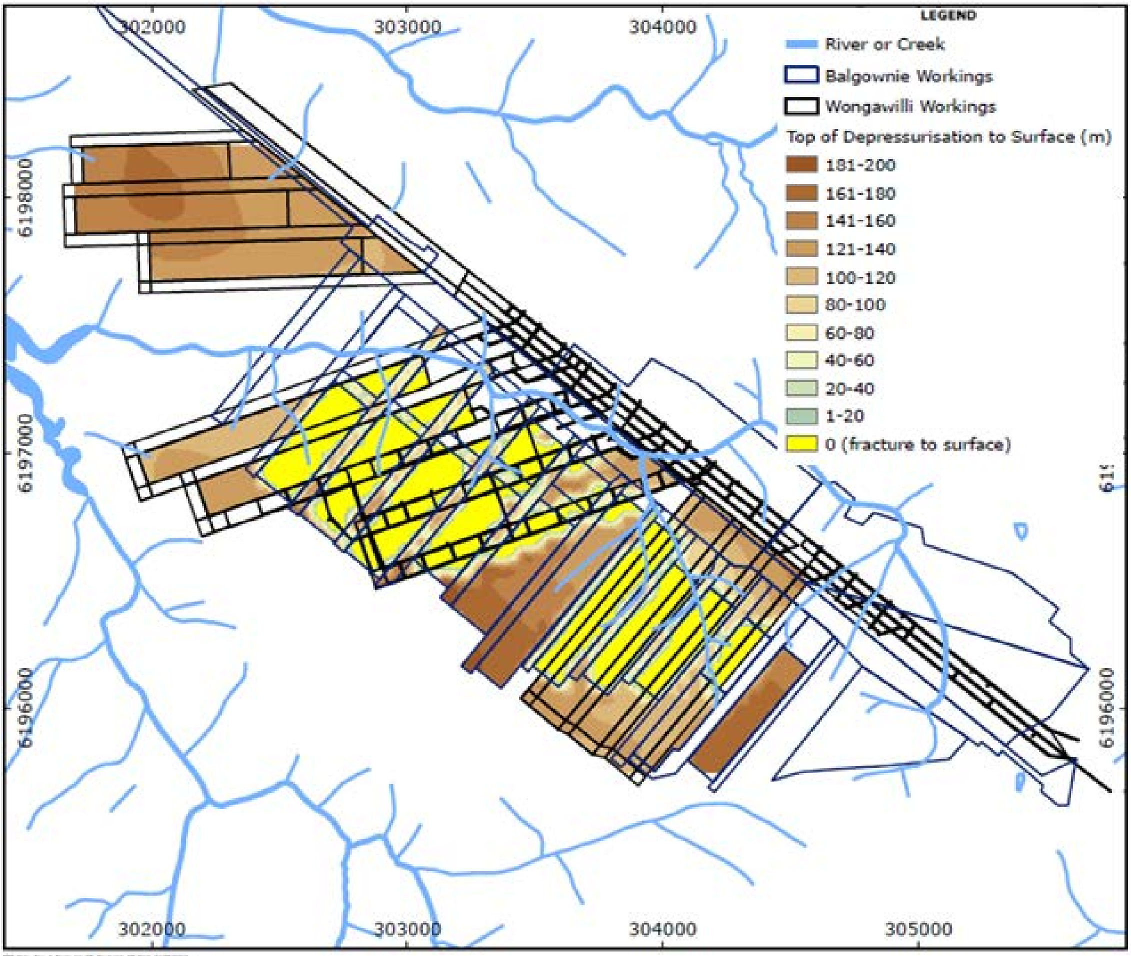


Figure 35 Predicted Height of Separation Between the Top of the Predicted Depressurisation Zone and the Ground Surface

The depressurisation "zone" may also potentially reach the ground surface over the eastern and central sections of Longwalls 6 and 7, but not over Longwalls 9 to 11 (due to the absence of triple seam mining at that location).

The depressurisation zone may also reach the ground surface over the eastern and central sections of Longwalls 1 to 3, where there are stacked, overlying, Bulli, Balgownie and Wongawilli secondary extraction workings.

It should be noted that the adapted Tammetta (2012) method is a conservative assessment of the potential height of depressurisation, and that, although the "atmospheric pressure" depressurisation zone may extend to surface, that does not mean the vertically connected, enhanced permeability, fractured strata will cause a "full" direct connection of surface waters to the mine workings to the degree where total loss of stream flow or swamp water occurs.

This is supported by the observation that although "surface to seam" depressurisation has potentially occurred over the extracted Longwalls 4 and 5 in the Wongawilli Seam (according the adapted empirical Tammetta (2012) model), the overlying swamps have not been observably drained, there are no observable changes to flow or pool levels in Cataract Creek and the mine inflows after Longwall 5 equate to 1.05 ML/day (383.3ML/year).

Of the measured 1.05ML/day mine inflow, 0.1ML/day of inflow is assessed to have occurred due to mining Longwall 4, with 0.5ML/day coming from mining Longwall 5. However the make up component of the inflows from stream flow losses and strata depressurisation is not known.

9.10 Model Calibration

Model calibration involves comparing predicted (modelled) and observed data and making modifications to model input parameters where required, within reasonable limits defined by available data and sound hydrogeological judgment, to achieve the best possible match.

Model calibration performance can be demonstrated in both quantitative (head value matches) and qualitative (pattern-matching) terms, by:

- Contour plans of modelled head, with posted spot heights of measured head;
- Hydrographs of modelled versus observed bore water levels;
- Water balance comparisons; and
- Scatter plots of modelled versus measured head, and the associated statistical measure of the scaled root mean square (SRMS) value.

Due to the complex interactive depressurisation effects of the existing subsidence and adjacent workings on groundwater levels and the predominantly “dry” nature of the Russell Vale workings, model calibration focussed on matching observed and modelled groundwater levels and mine inflows particularly during periods where mining impacts can be observed.

The scaled RMS value is the RMS error term divided by the range of heads across the site and it forms a quantitative performance indicator. Given uncertainties in the overall water balance volumes (e.g. it is difficult to directly measure evaporation and baseflow into the creeks), it is considered that a 10% scaled RMS value is an appropriate target for this study, with an ideal target for long term model refinement suggested at 5% or lower. This approach is consistent with the best practice Australian groundwater modelling guidelines (SKM, 2012).

Calibration was conducted initially as steady state (i.e. calibration to assumed long-term equilibrium conditions) and subsequently transient (i.e. calibration to the impacts of time-dependent stresses such as pumping and or climatic variation).

Steady state calibration was used to compare assumed long term average groundwater levels with groundwater levels prior to the transient calibration period (1993 – 2013).

Subsequent transient or “history match” calibration was conducted using the steady state model to determine initial conditions. The transient calibration period included underground mining in the Bulli Seam in the 500 Series panels in the Wonga West area and more recently in the Wongawilli Seam.

Transient calibration was to a degree restricted by the lack of monitoring locations within Permian aquifers. Attention was placed on achieving a level of inter-connection of underground mining areas to match the assessed drawdown response seen, particularly in the monitoring points over the 500 series longwall panels.

9.10.1 Calibration Targets

The model compares target values against model results and interpolates results in both space and time to compute an error or residual. A total of 32 groundwater monitoring locations including standpipes and multi-level vibrating wire piezometers have been used for steady state calibration. A total of 24 monitored horizons from 11 monitoring locations provided a total of 2328 temporal head targets which were included in the transient calibration.

The available monitoring based target points are distributed through the upper overburden layers, with no monitoring present below the Scarborough Sandstone.

Transient groundwater levels were taken from all records at each borehole where data was available. A full list of the calibration targets, including the Layers monitored and a comparison of actual versus modelled groundwater heads is included in Appendix A.

Groundwater inflows to active mining areas provide a valuable calibration measure and are critical for achieving a robust calibration. Historically, water balance records and, particularly mine inflow records for the Russell Vale Mine lease and other adjacent mining operations, have not been well recorded.

Considerable effort has recently been undertaken by SCT Operations (2014) to better understand water balance variables from data available from which a review of inflows has led to revised water make estimates. It is this data for mine inflows which was utilised during the calibration process.

9.10.2 Steady State Calibration

Steady state (or baseline ‘long term’) calibration was carried out as the first stage of the calibration process.

Given that the hydrogeological environment in this region is highly impacted from historical mining activities, achieving pre-mining steady state conditions was not the focus of the initial steady state modelling, rather it was focused on attaining realistic starting head conditions for transient calibration was the primary objective.

The steady state calibration allowed for initial head distributions in the model layers to be generated and to check assumptions on the conceptual hydrogeological processes.

It is acknowledged that steady state target heads were gathered from monitoring data that has considerable temporal range. However, the limited availability of monitoring data meant this was the best achievable option. Target heads were derived from numerous monitoring periods including 1992 – 1998 and 2007 – 2011. While the appropriateness of this may be questioned, the lack of any monitoring data with sufficient spatial distribution prior to the calibration period provided little opportunity to derive starting heads with any confidence and hence monitoring data with a range of dates was used to derive initial heads.

The steady state model was calibrated to groundwater levels as close as possible to the beginning of 1991, assuming these to be close to long term average groundwater levels.

Figure 3 shows that this year had a stable climate and preceded a period of drought.

In the Wonga East area, transient mining stresses had not occurred since completion of the Balgownie Seam extraction, which was completed in the 1980’s, and hence groundwater levels were assumed to have reached a relatively stable position particularly within shallower stratigraphy where most of the monitoring network is screened.

The pre-mining water levels in all bores have, to some extent, been influenced by the surrounding mining operations over an extended period of time. With this in mind, the steady state model calibration was principally used to provide an acceptable set of starting conditions for the transient calibration model.

Prior to undertaking transient calibration, these models were run in a "pseudo steady state" whereby the steady state model was run in a transient mode for a period of 10,000 days with no transient stress boundary condition variability. This was undertaken to assess the impact of changes to water levels and mine inflows etc. from the influence of storage and potential instability through transition of the hydrographs from steady state to transient model types.

9.10.3 Transient Calibration

Transient calibration against groundwater levels was carried out for the period 1993 to 2013 inclusive, utilising 24 target locations comprised of single screen standpipes and multi-level vibrating wire piezometers.

Although this period covers an extended time where limited to no significant secondary extraction occurred in the Wollongong Coal mine lease (1998 – 2010), it covers two periods where groundwater hydrographs show a response to mining influences.

Following completion of mining in the 500 series panels, apart from some limited areas of pillar extraction, no longwall mining was undertaken within the Wonga West area.

Mining was re-started in the Wonga East area, with development of first workings in the Wongawilli Seam in 2011 followed by extraction of Longwalls 4 and 5 commencing in April 2012.

All mines were represented using conventional drain cell representation.

The RMS value for the calibration period is 5.7m, whilst the scaled root mean square (SRMS) error is 2.6% (within the target range of 10%). The SRMS value is the RMS value divided by the range of heads across the site, and forms the main quantitative performance indicator. This result is consistent with the relevant groundwater modelling guideline (SKM, 2012).

The scatter diagram of measured versus modelled potentiometric head targets is plotted in **Figure 36** and it can be seen that the model is reasonably well balanced against the targets (i.e. there is no systematic under or over prediction). However, there are some significant departures from the matching curve and these can be attributed to bore failures during mining progression.

However, to some degree, this statistical measure is positively influenced by the transient data points in the GW1 VWP that is screened within the Scarborough Sandstone. This is the case even with its poor match due to the low elevation of the piezometer relative to other target monitoring elevations, and its effect in increasing the elevation range of the targets data.

Removal of GW1 from the calibration data set has a positive impact of the calibration statistics although it not overly dramatic. The RMS value for the calibration period would drop to 4.9m if GW1 were excluded.

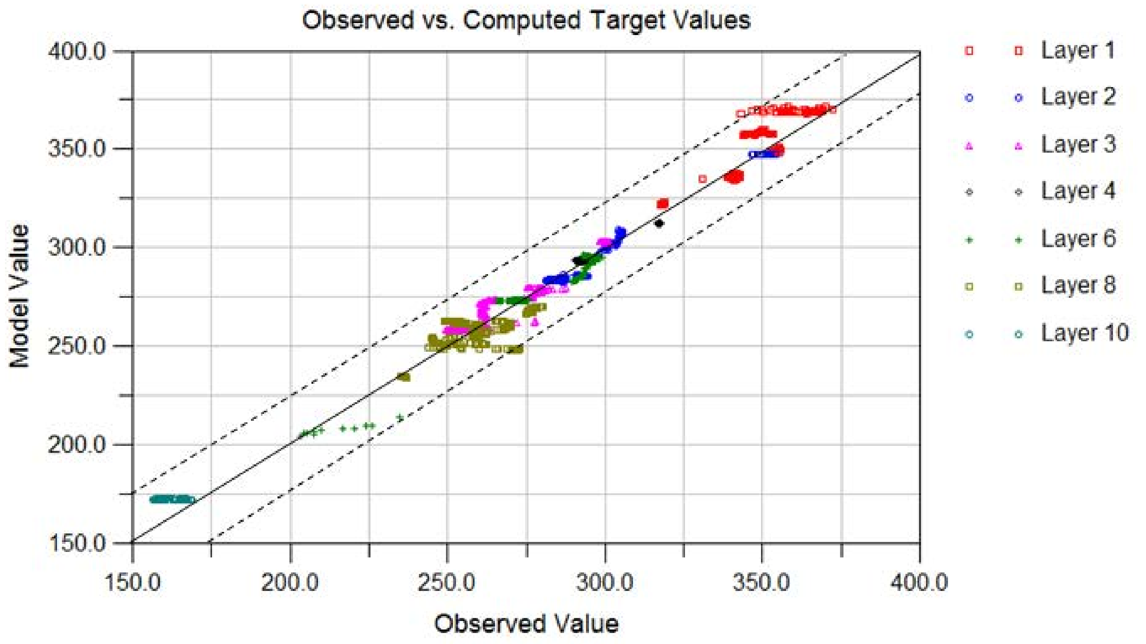


Figure 36 Measured Vs Modelled Potentiometric Head Targets

9.10.4 Calibrated Hydraulic Properties

Table 10 summarises the calibrated hydraulic properties of the modelled layers.

Table 10 Calibrated Hydraulic Properties

Layer	Stratigraphic Unit	Host (kx)	Ss [1/m]	Sy	Fracture Zone (Kz)	Wonga West (Kz)	Wonga East Historic Workings Bulli Seam (Kz)	Wongawilli Longwalls (Kz)
1	Upper Hawkesbury Sandstone	3.00E-02	1.0×10^{-3}	1.0×10^{-2}	1.62E-02			
1	Layer 1 (Coastal Plain)	3.03E-01	1.0×10^{-4}	2.0×10^{-2}	9.58E-02			
2	Upper Hawkesbury Sandstone	5.00E-04	1.0×10^{-4}	1.0×10^{-2}	1.00E-05			
3	Lower Hawkesbury Sandstone	5.55E-04	1.0×10^{-4}	1.0×10^{-2}	6.86E-05			5.00E-04
4	Bald Hill Claystone	2.00E-05	1.0×10^{-7}	1.0×10^{-2}	9.88E-06			2.00E-04
5	Upper Bulgo Sandstone	6.00E-04	1.0×10^{-6}	1.0×10^{-2}	1.00E-04			2.20E-03
6	Upper Bulgo Sandstone	5.00E-04	1.0×10^{-6}	1.0×10^{-2}	2.00E-05			9.00E-04
7	Lower Bulgo Sandstone	9.00E-04	1.0×10^{-6}	1.0×10^{-2}	3.00E-05			1.00E-04
8	Lower Bulgo Sandstone	9.28E-04	1.0×10^{-6}	1.0×10^{-2}	5.00E-06			4.50E-02
9	Stanwell Park Claystone	1.47E-04	1.0×10^{-7}	1.0×10^{-2}	3.00E-06			3.82E-04
10	Scarborough Sandstone	8.00E-04	1.0×10^{-7}	1.0×10^{-2}	1.00E-05			9.72E-03
11	Wombarra Claystone	1.68E-05	1.0×10^{-6}	1.0×10^{-2}	1.50E-06	7.00E-06	4.00E-05	3.14E-03
12	Coal Cliff Sandstone	6.92E-06	1.0×10^{-6}	1.0×10^{-2}	1.00E-06	3.96E-05	3.00E-04	2.36E-03
13	Bulli Seam	3.00E-02	1.0×10^{-6}	1.0×10^{-2}	1.00E-03	0.1		0.1
14	Interburden	1.19E-05	1.0×10^{-6}	1.0×10^{-2}	1.00E-06			0.1
15	Balgownie Seam	1.00E-02	1.0×10^{-6}	1.0×10^{-2}	6.29E-03			1
16	Interburden	2.32E-05	1.0×10^{-6}	1.0×10^{-2}	5.00E-06			1
17	Wongawilli Seam	1.00E-02	1.0×10^{-6}	1.0×10^{-2}	5.00E-03			10
18	Basement	5.32E-06	1.0×10^{-6}	1.0×10^{-2}	1.09E-06			

9.11 Water Balance

There are numerous opportunities for groundwater to discharge from and recharge to the groundwater system and into / out of the groundwater model. Those implemented in the model include:

- baseflow to major streams (represented by the river cells in MODFLOW);
- outflow / inflow to the eastern margin boundary representing the coastline, the northern margins representing the Appin mining area within the Bulli Seam and southern margin representing the Dendrobium mining area in the Wongawilli Seam (general heads in MODFLOW); and
- mine inflows to active mining areas and the sinks caused by historical mining areas.

The average water balance across the calibration period for the transient calibration model across the entire model area is summarised in **Table 11**.

The total inflow (recharge) to the aquifer system into the model domain is approximately 28ML/day, comprising rainfall recharge (approximately 52%), inflow from the head dependent boundaries on the margins (approximately 0.5%), and leakage from streams into the aquifer (approximately 42%). The remaining 5.5% is accounted for with changes in storage.

It is assumed that any water carried by the limited extent and duration of flow in ephemeral streams would have a negligible contribution to groundwater recharge via leakage from the stream bed.

Table 11 Simulated Water Balance at End of Transient Calibration

	Inflow (ML/d)	Outflow (ML/d)
Storage	2.82	2.26
Constant Head	0.09	0.03
Drains (Outflow = Groundwater Entering Mine Workings)	0.00	5.01
Recharge (Direct Rainfall)	27.46	6.04
Et (Evapotranspiration)	0.00	33.48
River (Leakage/Baseflow)	22.57	6.22
Head Dependent Boundary (GHB)	0.19	0.09
Total	53.13	53.12
% Discrepancy	-0.01%	

9.12 Effect of Structures

Due to the limitations and constraints inherent with the model set up and model code, as well as uncertainty in the location, stratigraphic persistence and hydraulic properties of geological structures in the Study Area, they are not simulated in the model.

It has been observed that faults encountered within the three levels of extraction have not encountered water make with any faults or dykes in the workings (Gujarat NRE Coking Coal, 2014).

10. POTENTIAL SUBSIDENCE EFFECTS, IMPACTS AND CONSEQUENCES

10.1 Stream Bed Alluvium and Plateau Colluvium

There are no anticipated subsidence effects on stream bed alluvium or plateau colluvium as there is no significant accumulation of Quaternary sediments within the Study Area.

The presence of alluvial sediments is limited to the upland swamps, which have been measured up to 1.6m deep.

Where the swamps are absent in the lower catchment, the stream beds are dominated by either exposed sandstone or boulder reaches without significant alluvial deposits.

10.2 Upland Swamps

Due to limitations of the MODFLOW SURFACT code and the regional scale model set up, the effect of subsidence on the small thickness (<2m) of perched groundwater in the upland swamps, with limited and variable spatial extent, was not assessed in the simulation.

Further discussion of the potential effects on swamps is contained in Biosis (2014).

10.3 Basement Groundwater Levels

Figures 37 to **42** show north - south and east – west cross sections of the overall modelled hydraulic head (m) for modelled initial conditions at the end of the calibration period (i.e. the end of LW5 extraction) and at the end of proposed mining at Wonga East.

Figure 37 and **Figure 38** show initial conditions and de-saturated areas underlying the escarpment in the south eastern area of the model. Zero pressures also extend into the Bulli Seam and overburden due to pre-existing mining voids from the lengthy period of mining in the region prior to the model simulation period.

Figure 39 and **Figure 40** show the same cross sections following the end of the calibration period after completion of LW5. Here early fracture zone implementation over LW4 and LW5 has caused a vertical propagation of the zero pressure contour. This does not propagate through to surface but positive pressures are maintained in the Upper Bulgo Sandstone. The fracture zone developed within the model is pushed into the Lower Hawkesbury Sandstone and a decline in head within the Hawkesbury sand stone is also evident.

Figure 41 and **Figure 42** show these cross sections following completion of mining in the Wongawilli seam. Here, the fracture zone has fully developed and this has led to a zero head contour breaking through to surface.

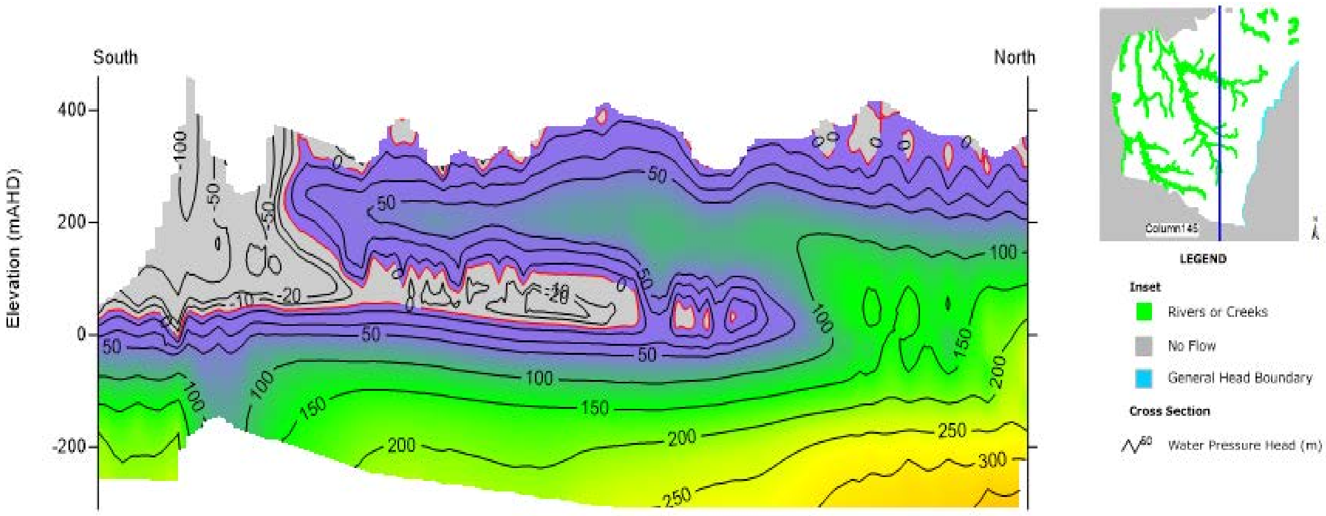


Figure 37 Predicted Pressure Head Initial Conditions at Wonga East (North – South Cross Section on Easting 303000)

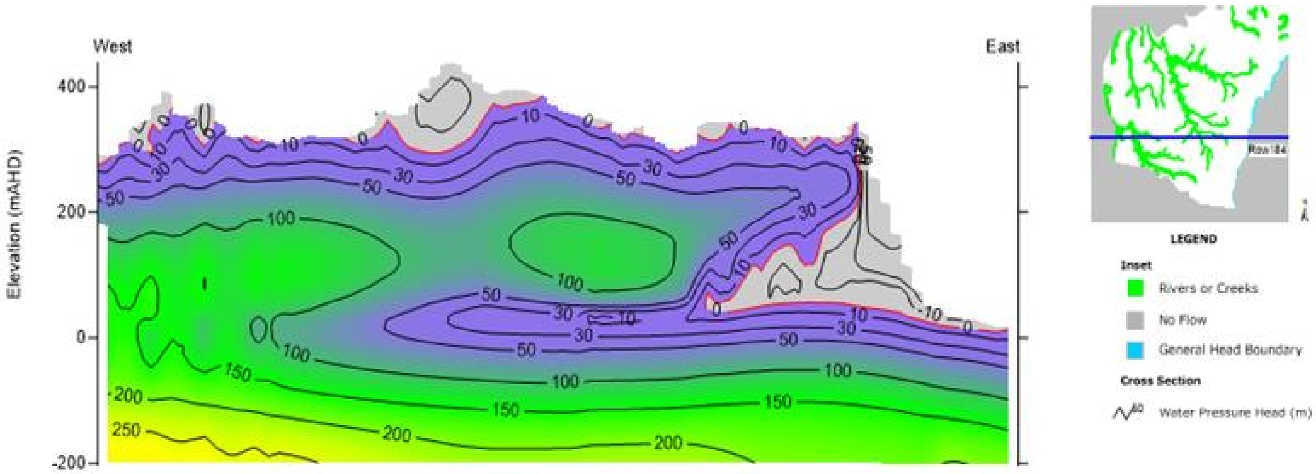


Figure 38 Predicted Pressure Head Initial Conditions at Wonga East (East – West Cross Section on Northing 6196895)

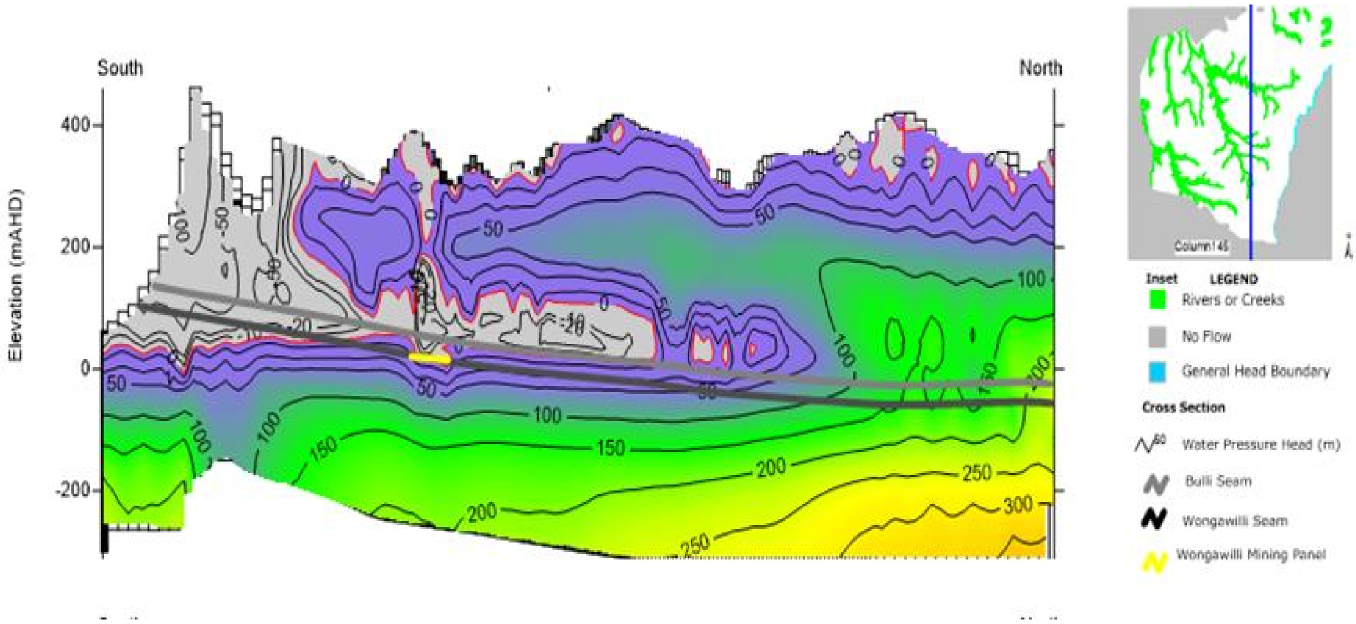


Figure 39 Predicted Pressure Head at Wonga East at the End of LW5 (North – South Cross Section on Easting 303000)

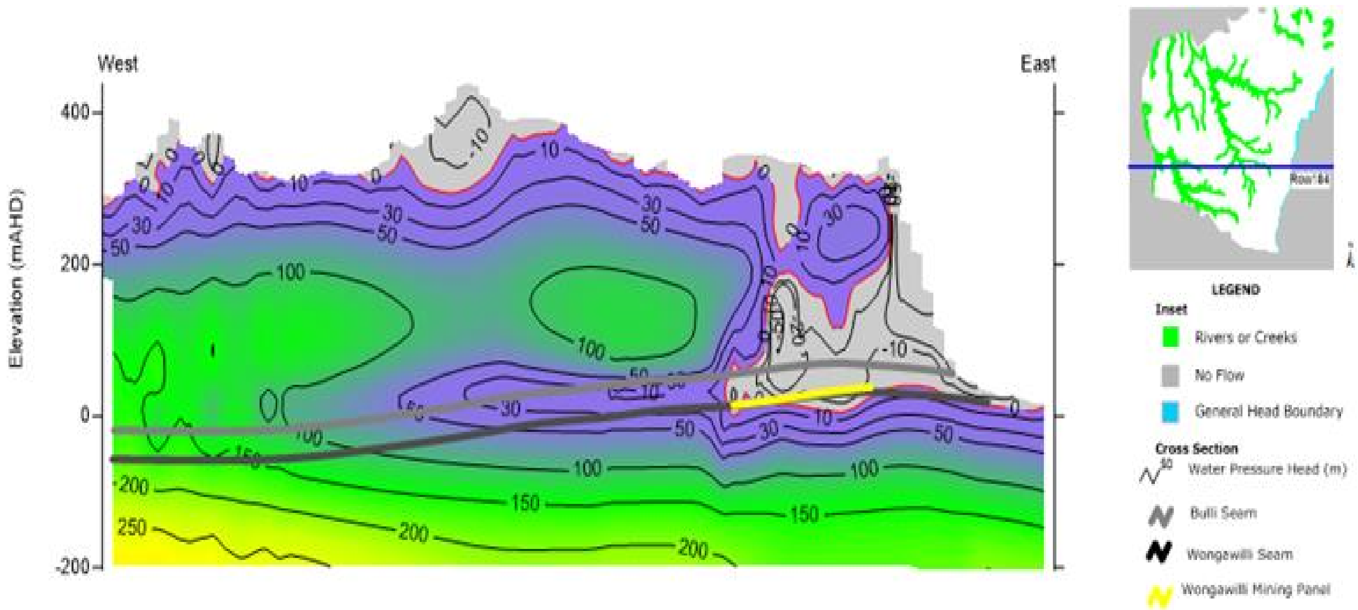


Figure 40 Predicted Depressurisation at Wonga at the End of LW5 (East – West Cross Section on Northing 6196895)

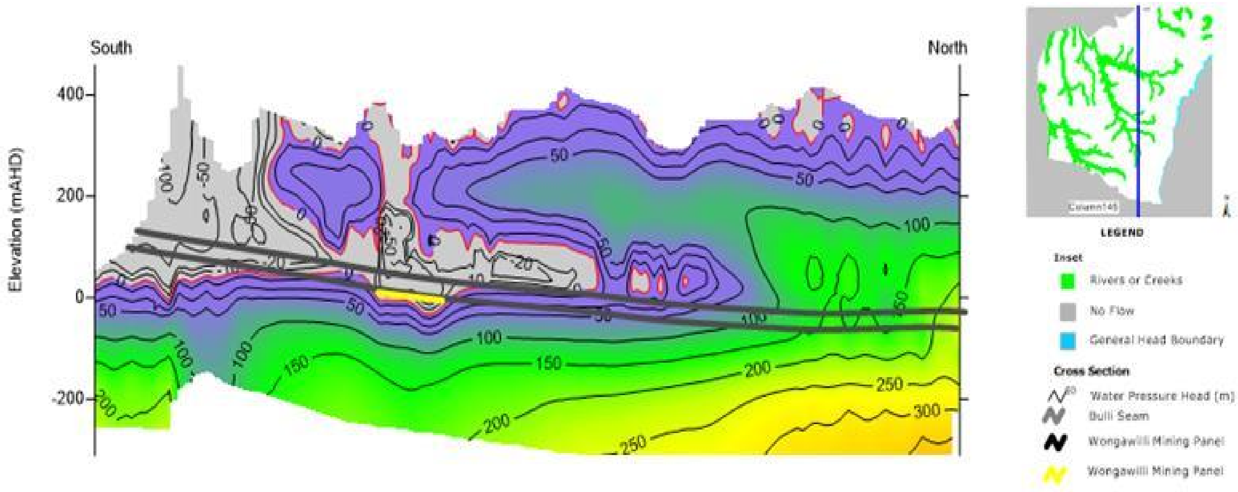


Figure 41 Predicted Depressurisation at Wonga East at the End of Mining (North – South Cross Section on Easting 303000)

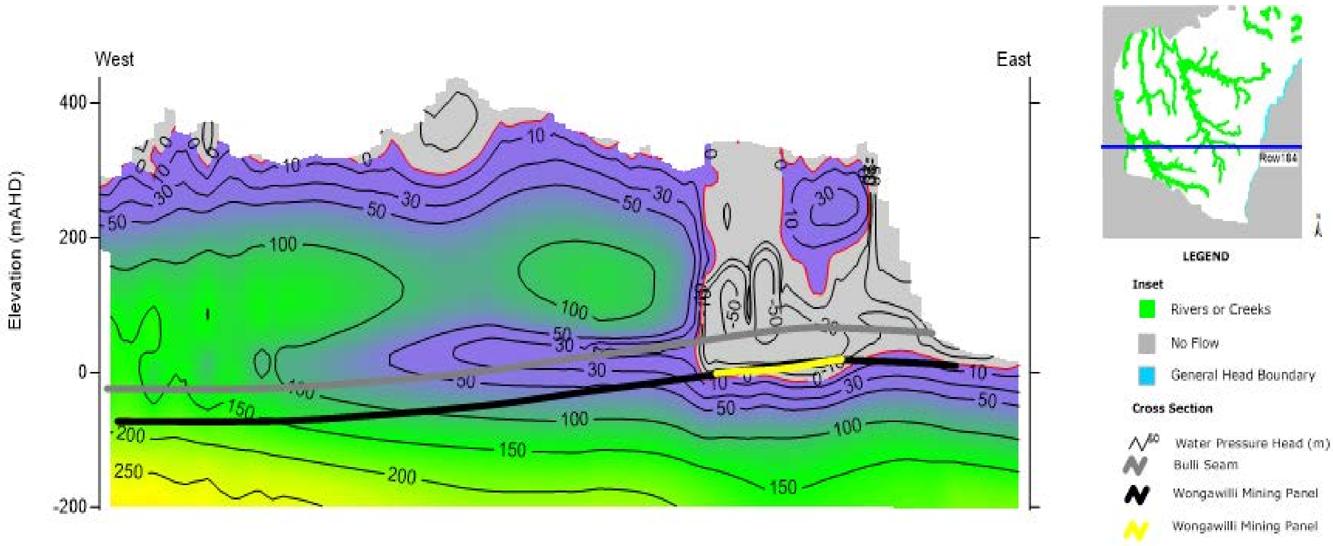


Figure 42 Predicted Depressurisation at Wonga East at the End of Mining (East – West Cross section on Northing 6196895)

10.3.1 Shallow, Perched, Ephemeral, Hawkesbury Sandstone

Perched, ephemeral, shallow groundwater within the upper Hawkesbury Sandstone (Layer 1) could undergo a water level reduction over the proposed workings after subsidence.

However, as the "ephemeral" shallow Hawkesbury Sandstone aquifers dissipate after extended dry periods, the effect on the mostly disconnected, perched aquifers with limited extent was not modelled. However, it is logical to conclude that fracturing of the upper, shallow strata would enhance the leakage rate from the perched aquifers into underlying strata over subsided areas, as well as enhancing the rainfall recharge and subsequent seepage rate from these perched aquifers into local streams or the underlying aquifers.

Subsidence of Layer 1 is not anticipated to have a significant overall effect on stream baseflow or stream water quality where the temporary aquifers seep into local catchments. However, temporary, localised effects may be observed.

10.3.2 Upper Hawkesbury Sandstone

The upper Hawkesbury Sandstone aquifer extends across the Study Area, with piezometer data indicating phreatic water levels ranging from 1 – 20m below surface in Wonga East.

It should be noted that the monitored water level is affected by semi-confined head pressures, whereas the first drilling water intercept, which indicates the upper bound of the aquifer varied from 17 – 48m below surface in Wonga East.

Once the piezometer is completed, subsequent water level measurements indicate a combination of head pressure in the aquifer, variability of recharge or other factors.

Based on past experience in the Southern Coalfields, the upper regional Hawkesbury Sandstone water levels can rise by up to 2m ahead of a piezometer being undermined, then reduce by up to 15m after development of cracking and additional secondary void space (porosity) in the aquifer. Apart from GW1, all of the piezometers installed by Wollongong Coal have monitored the post mining period in the Bulli and / or Balgownie mining phases. GW1 was installed after Longwall 4 in the Wongawilli Seam was extracted and observed water level reduction of up to 25m, with subsequent recovery of up to 31m due to extraction of Longwall 5.

The reduced water level generally recovers over a few months, depending on rainfall recharge in the catchment and the post subsidence outflow seepage rate, if it occurs, to local streams. Re-establishment of the pre-mining water level generally occurs, although the water levels may not necessarily fully recover.

Modelling of Layer 1 (which can include the Hawkesbury Sandstone as well as the Newport / Garie Formation, Bald Hill Claystone or Upper Bulgo Sandstone in eroded creek bed locations) after the end of mining in Wonga East indicates up to 1m of drawdown as shown in **Figure 43** in comparison to pre Wongawilli Seam development.

Figure 44 shows drawdown after mining is completed in comparison to post LW5 (currently approved) groundwater levels.

As shown in **Figure 45** and **Figure 46,** 50 and 100 years respectively after mining has been completed in Wonga East, water level reduction is generally less than 1m in comparison to pre-mining levels. These show that at 100 years, no further extension of a drawdown cone occurs and there is a slight reduction in impacted area in comparison to 50 years following completion of mining.

A drawdown of up to 3m is predicted for a small area overlying LW3.

10.3.3 Lower Hawkesbury Sandstone

Modelling of Layer 3 (Lower Hawkesbury Sandstone, as well as the Newport / Garie Formation, Bald Hill Claystone or Upper Bulgo Sandstone in eroded creek bed locations after the end of mining at Wonga East indicates up to 30m of drawdown as shown in **Figure 47** in comparison to pre Wongawilli Seam development. **Figure 48** shows drawdown after mining is completed in comparison to post LW5 (currently approved) groundwater levels. The main difference between these two drawdown periods is the drawdown over LW4 and LW5.

Figure 49 and **Figure 50** indicate that 50 years after mining, a further 5m reduction in groundwater pressures in comparison to initial conditions occurs, and at 100 years after completion of mining, water pressures remain static in comparison to the previous 50 years. This suggests that the peak impact is achieved prior to 50 years although no effective recovery is seen until after 100 years.

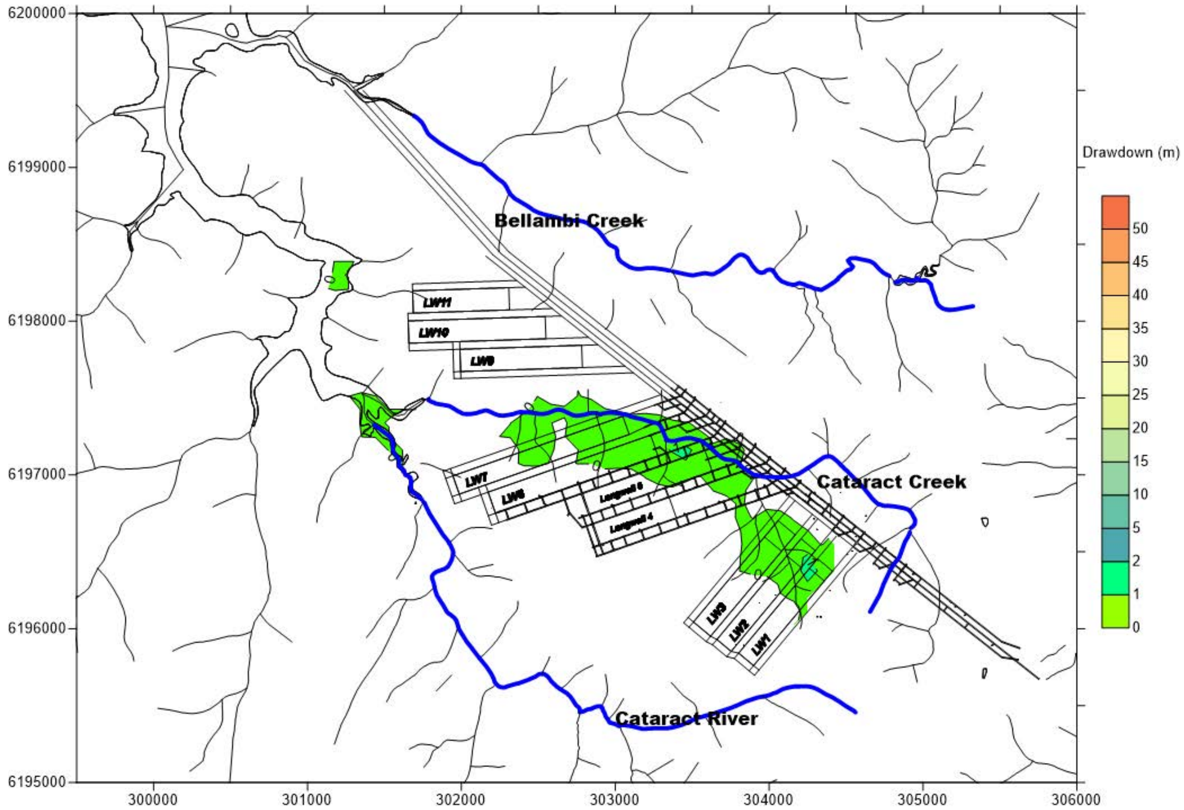


Figure 43 Layer 1 Drawdown after Mining at Wonga East Relative to Start of Mining in Wongawilli Seam.

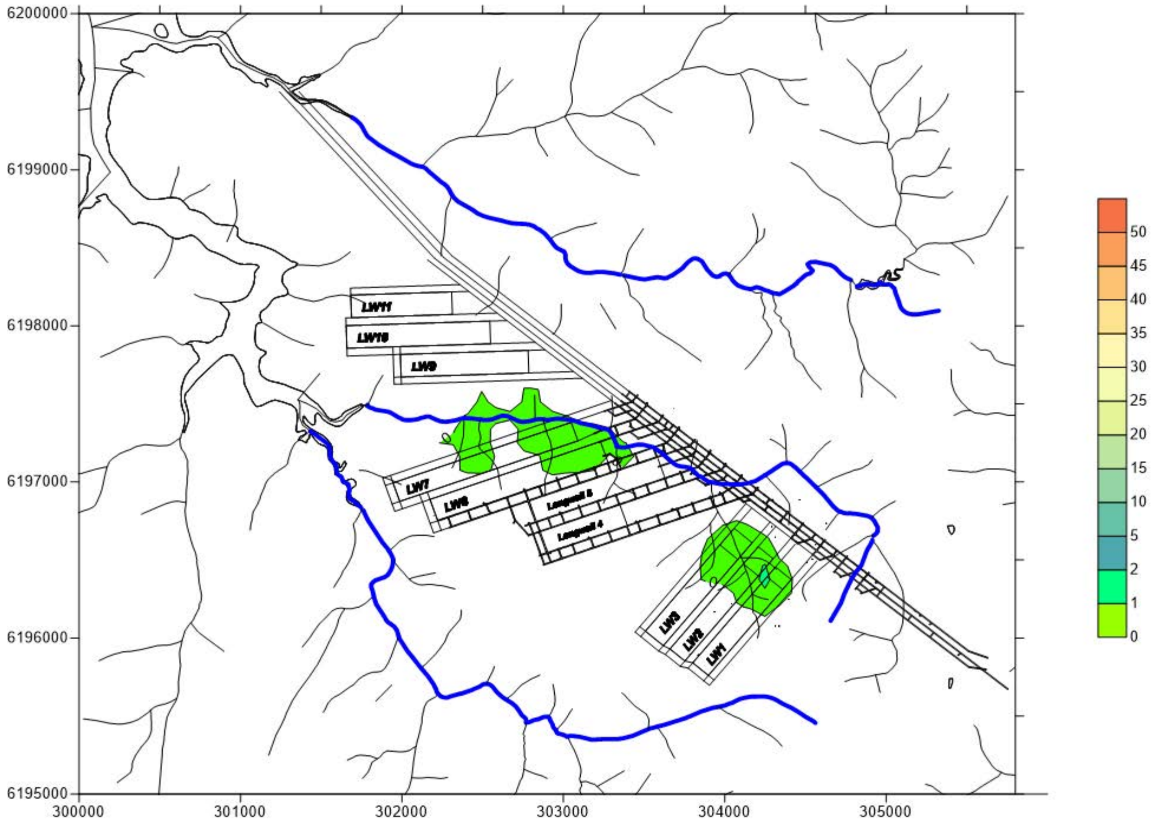


Figure 44 Layer 1 Drawdown after Mining Longwalls 4 and 5 at Wonga East Relative to End of LW5

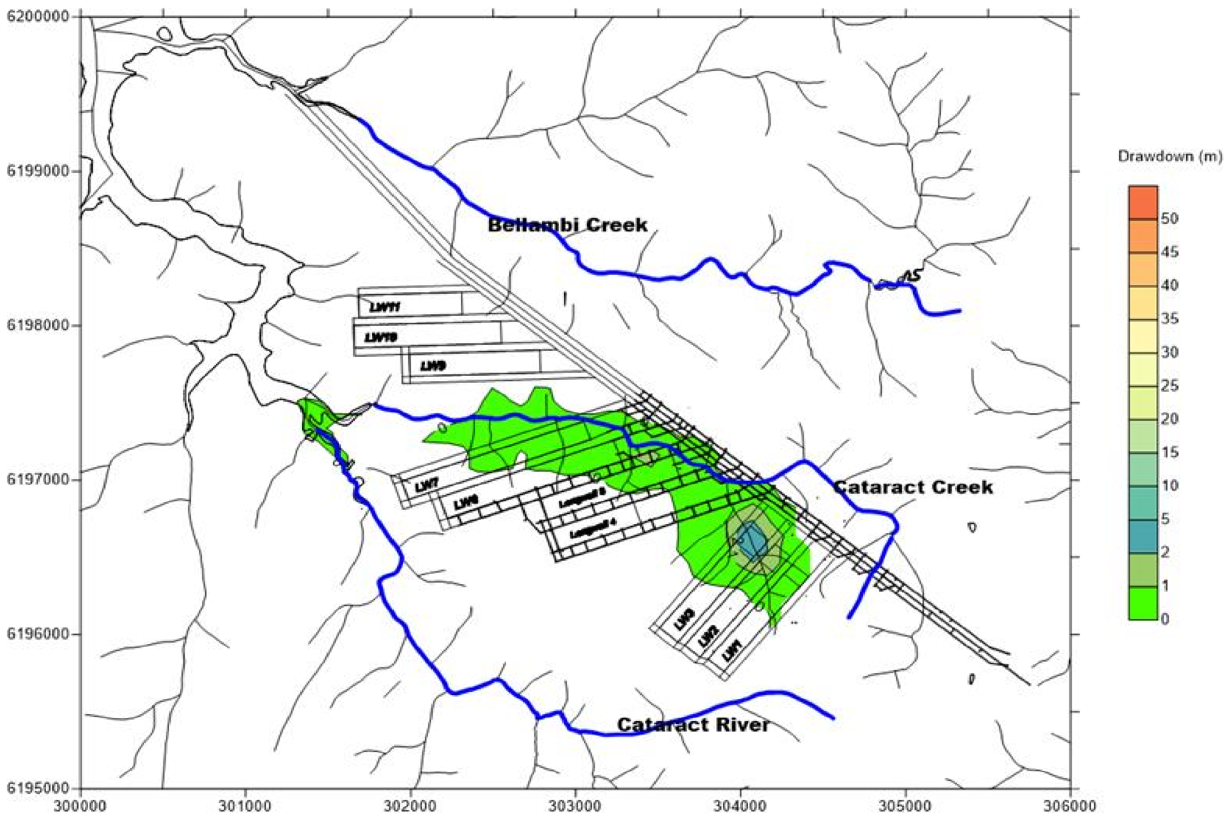


Figure 45 Layer 1 Recovery 50 Years After Mining at Wonga East

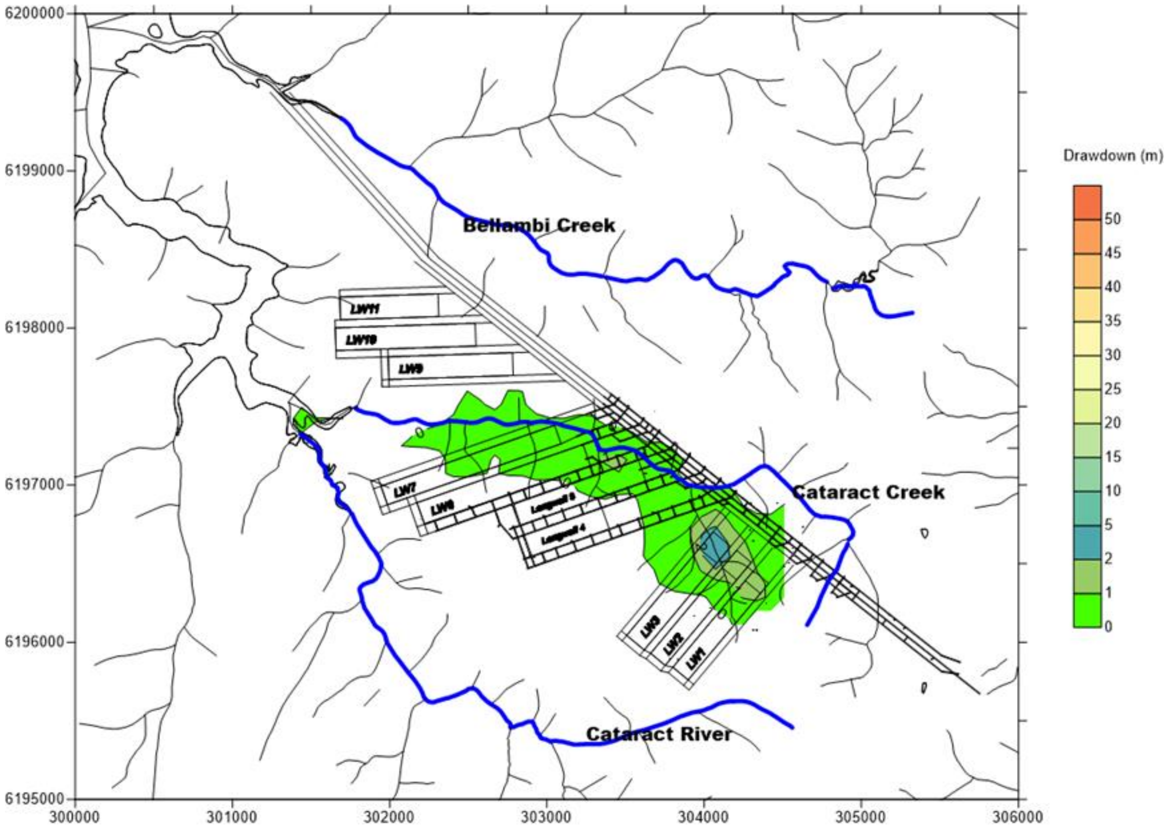


Figure 46 Layer 1 Recovery 100 Years After Mining at Wonga East

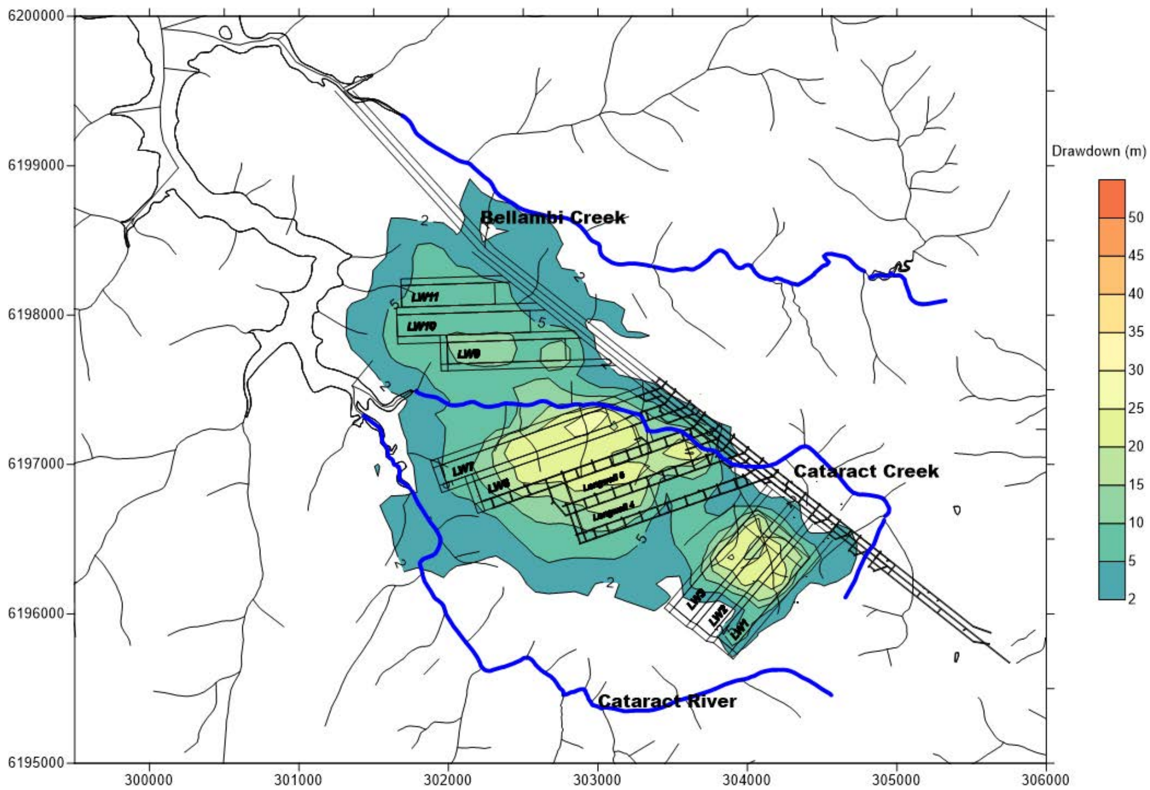


Figure 47 Layer 3 Drawdown After Mining at Wonga East in Comparison to Pre Wongawilli Seam Development

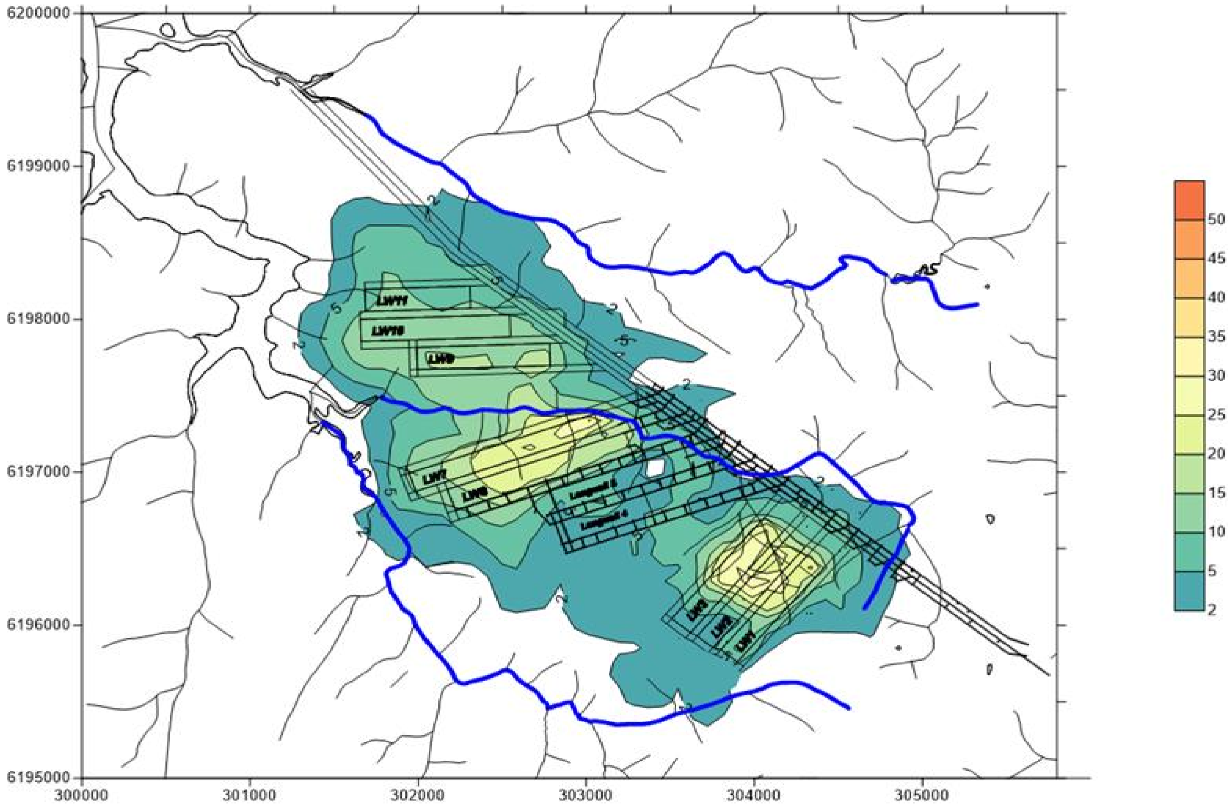


Figure 48 Layer 3 Drawdown After Mining at Wonga East in Comparison to Post LW5 Development

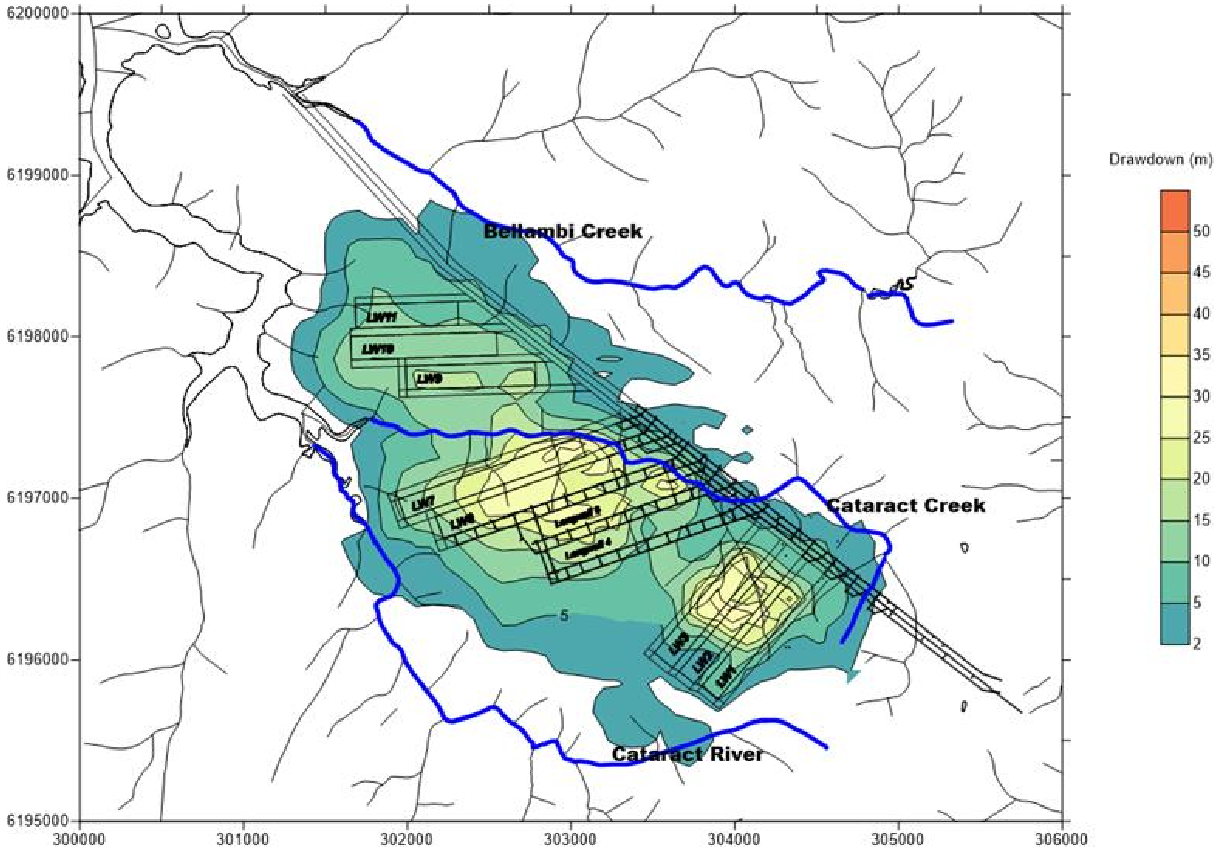


Figure 49 Layer 3 Recovery 50 Years After Mining at Wonga East

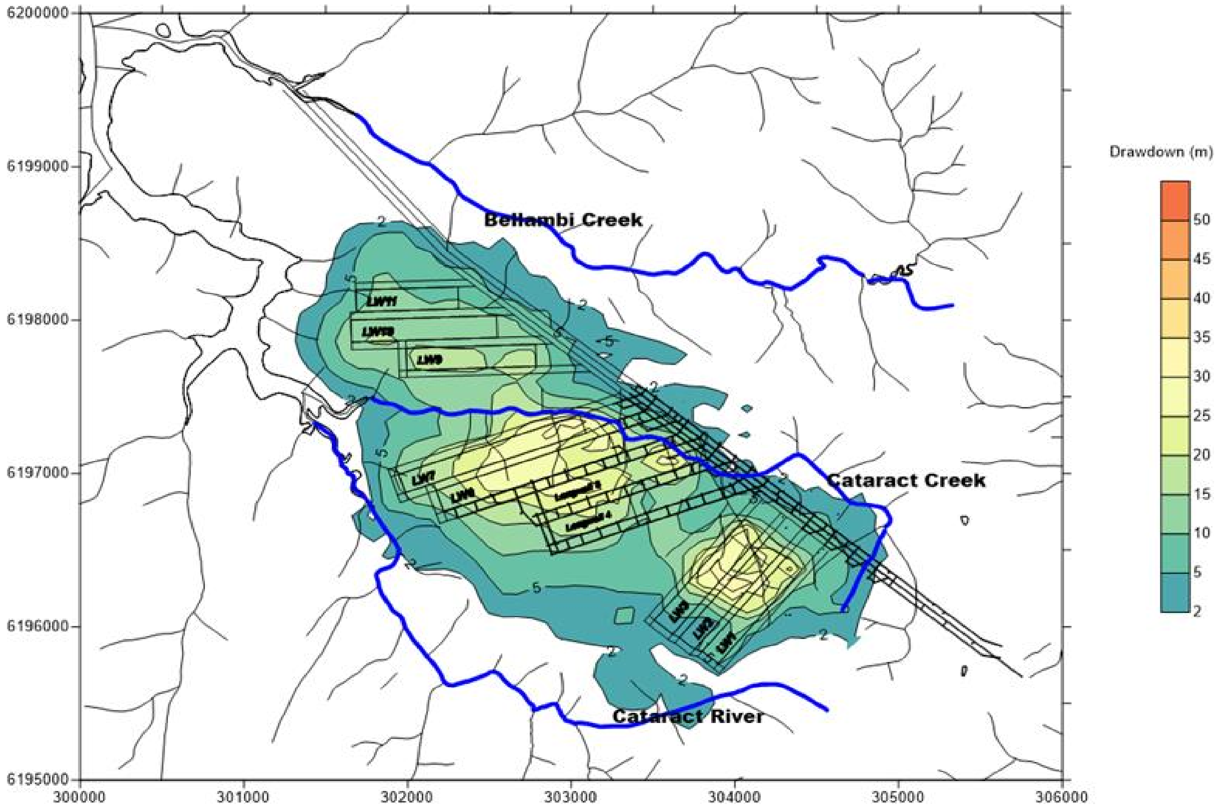


Figure 50 Layer 3 Recovery 100 Years After Mining at Wonga East

10.3.4 Upper Bulgo Sandstone

Modelling of Layer 5 (Bulgo Sandstone) after the end of mining, indicates up to 45m of drawdown over Wonga East, which occurs within the footprint of LW6, LW7 and part of LW9 in comparison to pre Wongawilli Seam development. **Figure 51** shows drawdown after mining is completed in comparison to post LW5 groundwater levels. As in overlying layers, the main difference between these two drawdown periods is the drawdown over LW4 and LW5. No significant increase in the areal extent of the drawdown cone is observed between the two scenarios.

Elsewhere over LW1 to LW3, drawdown of up to 25m occurs after the completion of mining as shown in **Figure 52.**

Modelling indicates that drawdown of up to 2m extends a maximum of 1km to the west of LW7 following completion of mining.

Figures 53 and **54** indicate that 50 and 100 years respectively after mining has been completed, the drawdown footprint in comparison to initial conditions remains relatively static to that predicted at the end of mining in Wonga East. Within the 50 years following mining, an additional 5m drawdown is predicted with signs of recovery in the following 50 year period.

The degree of drawdown increases with increasing depth towards the workings in the upper, mid to lower Bulgo Sandstone in association with an upward migration of zero pore pressures over subsided Wongawilli longwalls.

10.3.5 Scarborough Sandstone

Modelling of Scarborough Sandstone (Layer 10) after the end of mining Wonga East indicates drawdown below the base of the layer as shown in **Figure 55**, with the depressurisation after extraction of Longwall 5 shown in **Figure 56.** The predicted areal extent of drawdown at the end of mining shows 2m extending a maximum of 2km to the west of LW10

Figure 57 indicates that 50 years after mining has been completed, water levels over the longwall footprint are still depressed in comparison to pre-mining levels.

However, the drawdown cone has recovered significantly with the 2m drawdown contour extending a maximum of 1km to the northwest of the mains. After 100 years, drawdown continues to contract such that the 2m contour is less than 500m from the longwall and mains headings as shown in **Figure 58**.

10.3.6 Bulli Seam

No Bulli Seam drawdown figures are presented in this section as the seam is generally dry in the vicinity of the Wonga East workings.

10.3.7 Wongawilli Seam

Drawdown in the Wongawilli Seam at the end of mining in comparison to pre Wongawilli Seam development in Wonga East is modelled to reach up to 46m over LW10. Less drawdown occurs up dip with up to 30m overlying LW4 – LW7 and up to 12m overlying LW1 – LW3. The areal extent of the 2m drawdown contour at the end of mining at Wonga East extends a maximum of 1100m to the north of Longwall 11 as shown in **Figure 59**.

Figure 60 shows drawdown after mining is completed in comparison to post LW5 (currently approved) groundwater levels. As in overlying layers, the main difference between these two drawdown periods is the drawdown over LW4 and LW5. There is a significant difference in the areal extent of the drawdown cones observed between the two scenarios due to the drawdown associated with the currently approved mining of LW5 and development headings for LW6.

Fifty years after mining is completed, the Wongawilli Seam is modelled to recover by up to 90m in comparison to initial conditions over Wonga East as shown in **Figure 61**.

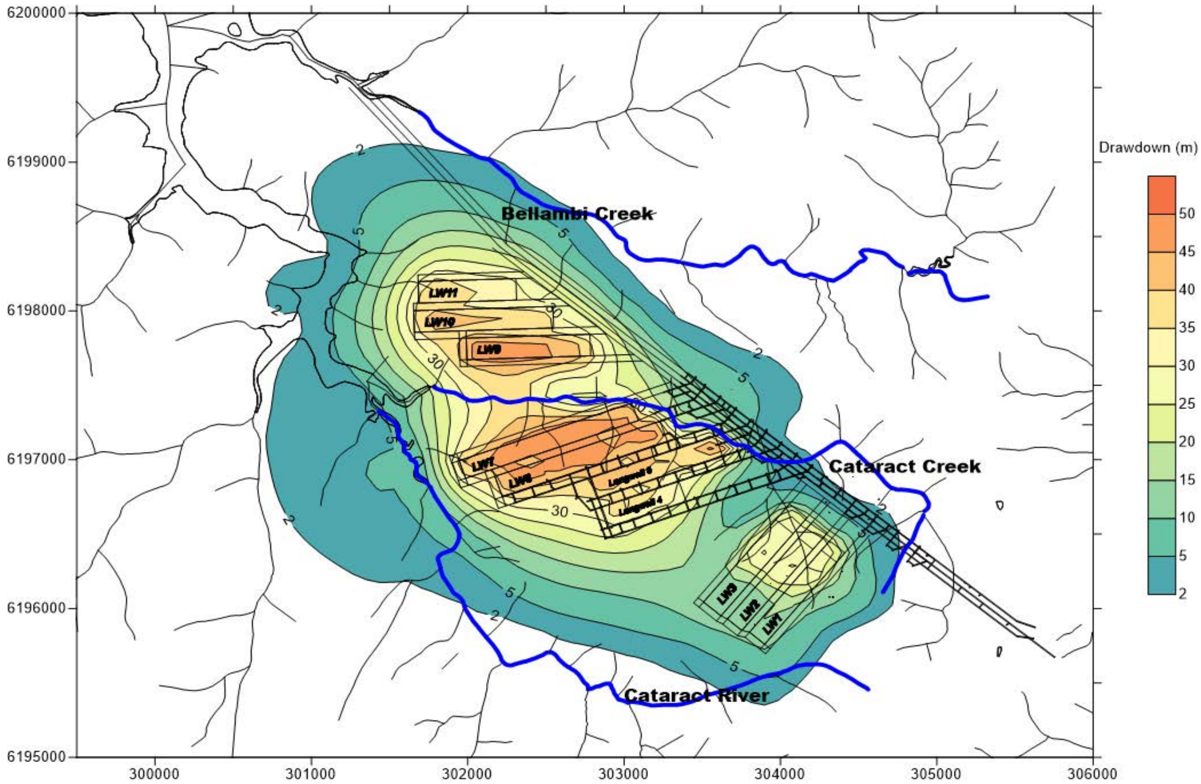


Figure 51 Upper Bulgo Sandstone Drawdown After Mining Wonga East in Comparison to Pre Wongawilli Seam Development

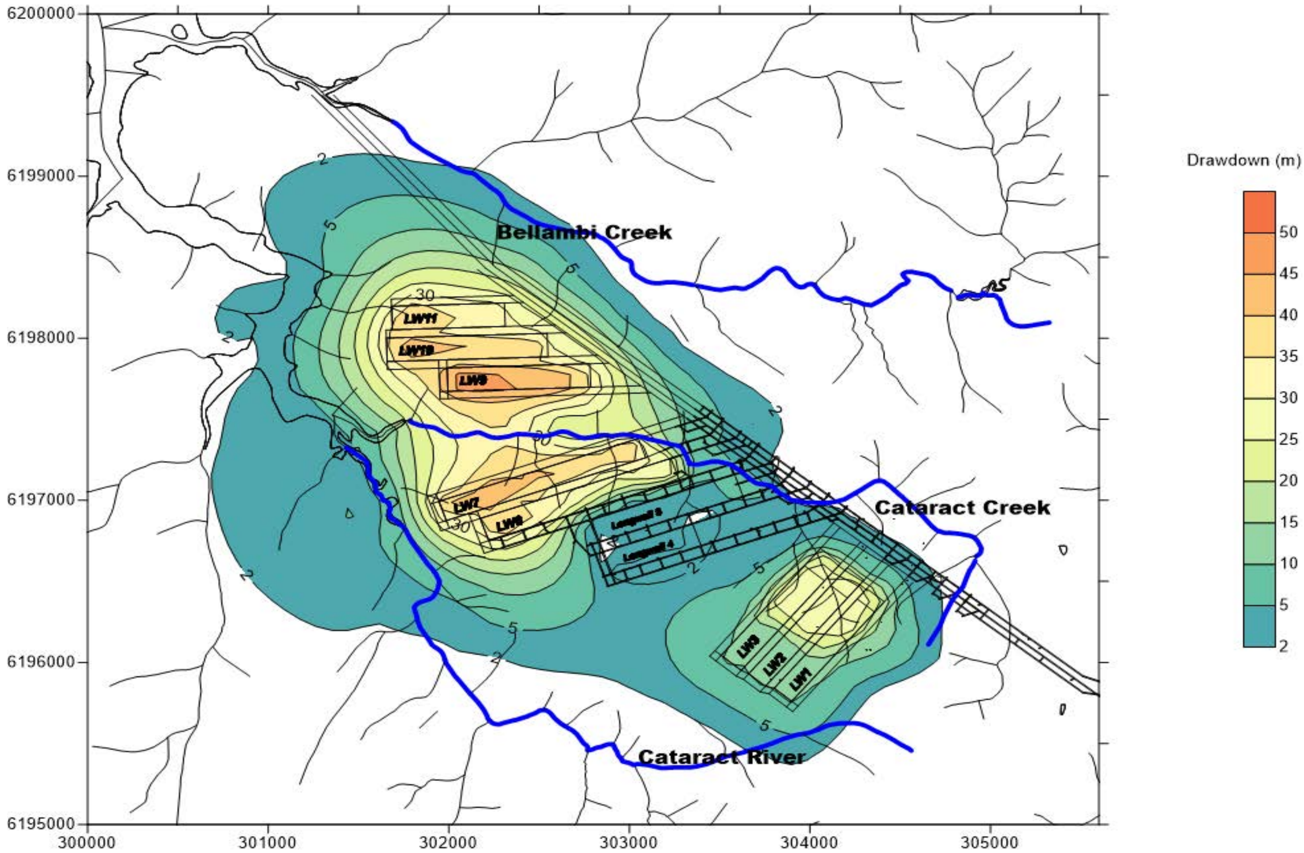


Figure 52 Upper Bulgo Sandstone Drawdown After Mining at Wonga East in Comparison to Post LW5 Development

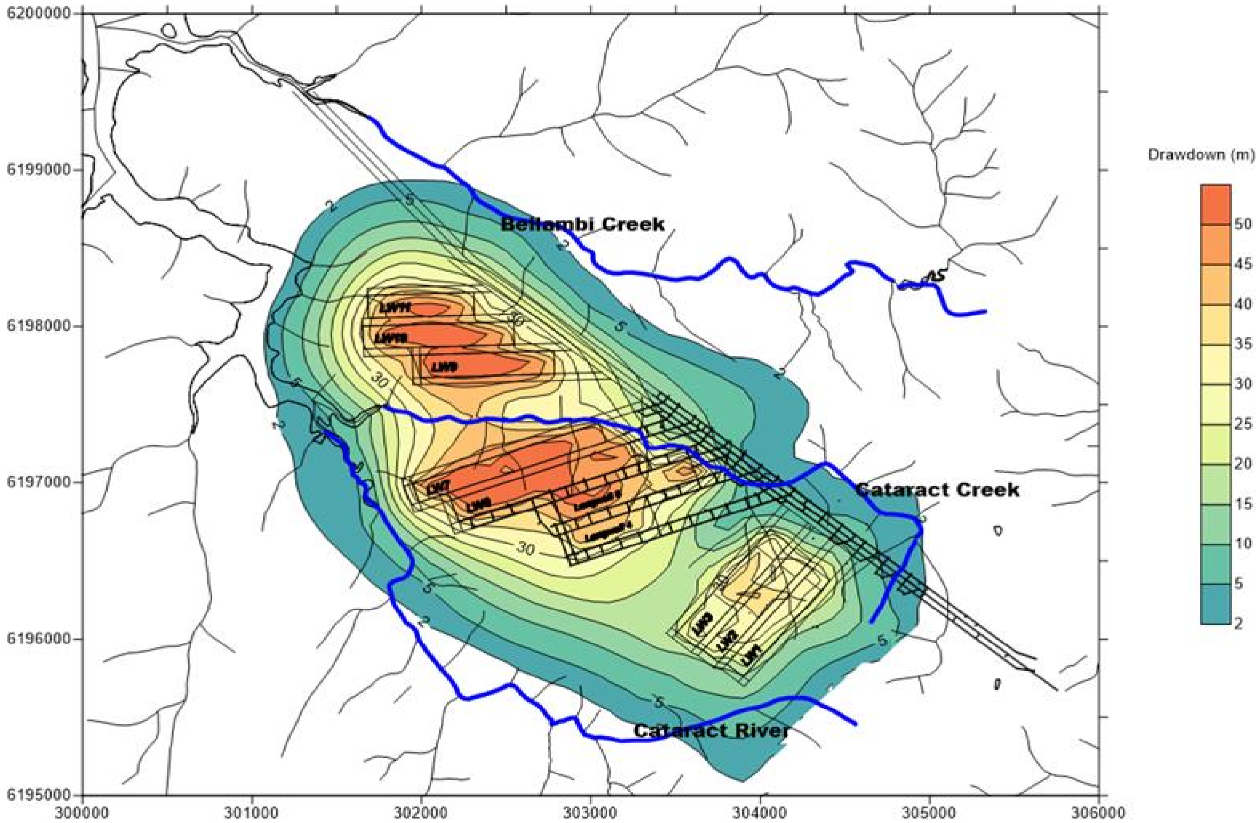


Figure 53 Upper Bulgo Sandstone Recovery 50 Years After Mining at Wonga East

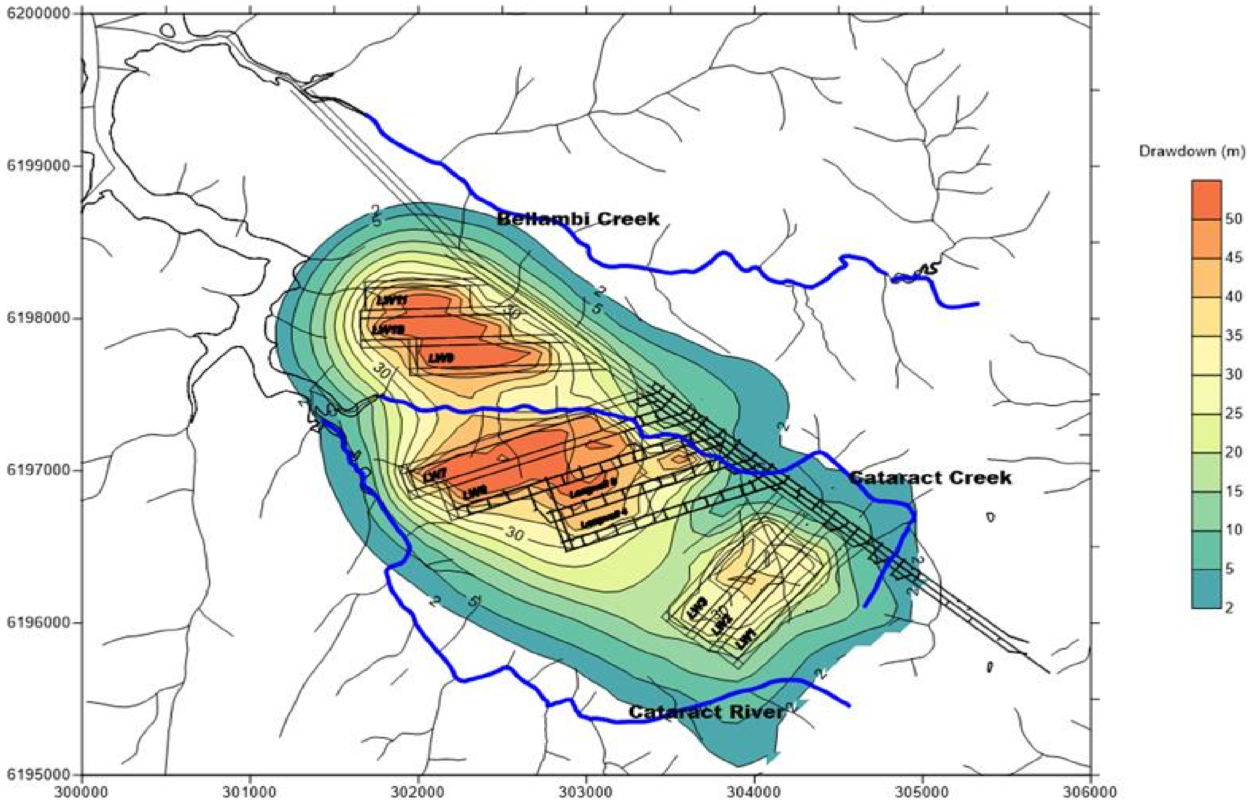


Figure 54 Upper Bulgo Sandstone Recovery 100 Years After Mining at Wonga East

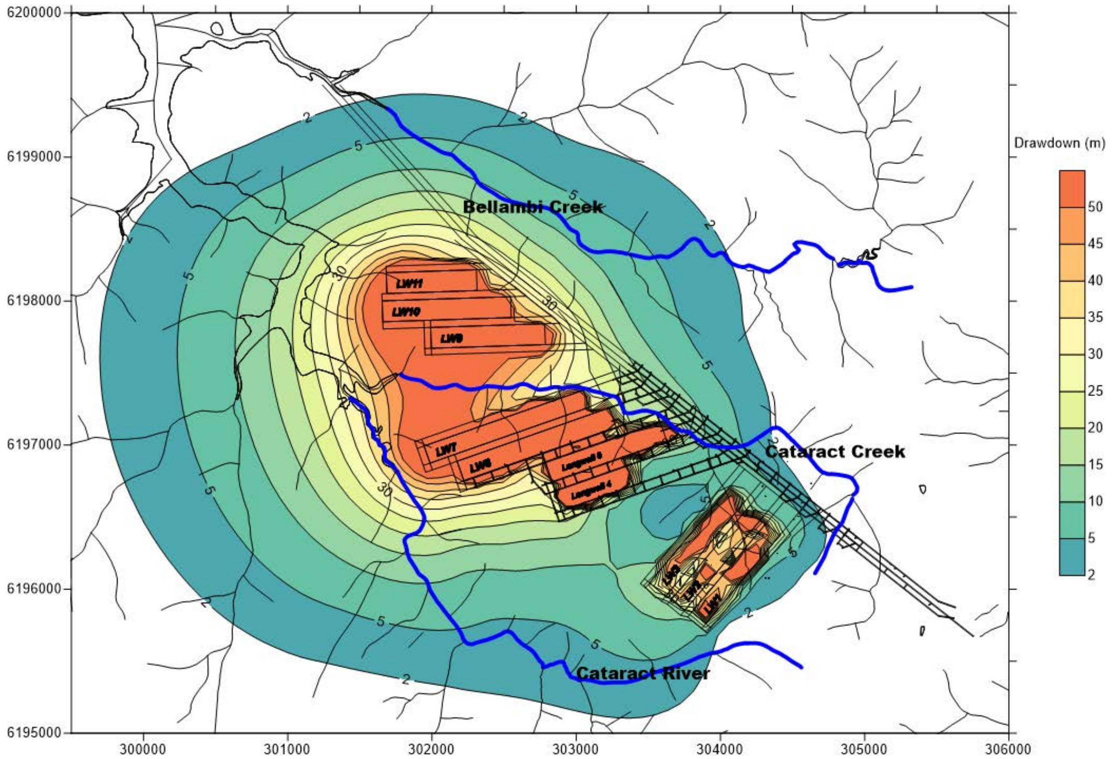


Figure 55 Scarborough Sandstone Drawdown After Mining Wonga East in Comparison to Pre Wongawilli Seam Development

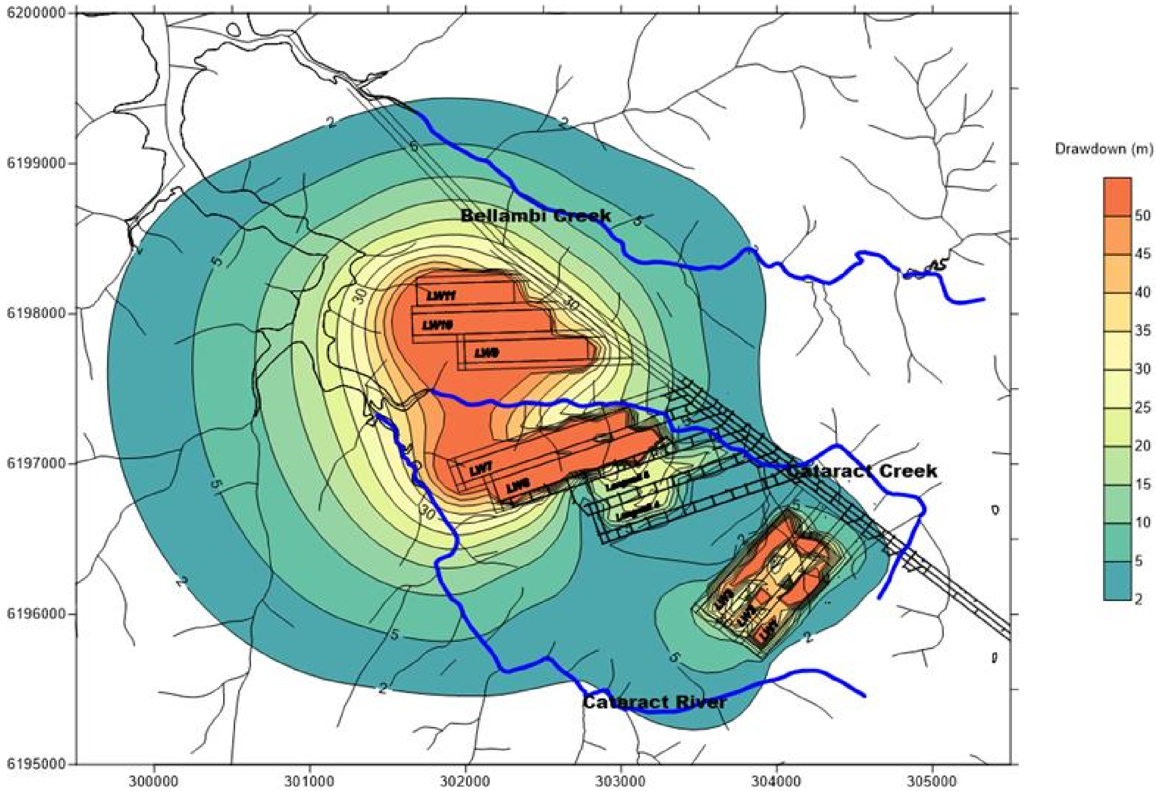


Figure 56 Scarborough Sandstone Drawdown After Mining at Wonga East in Comparison to Post LW5 Development

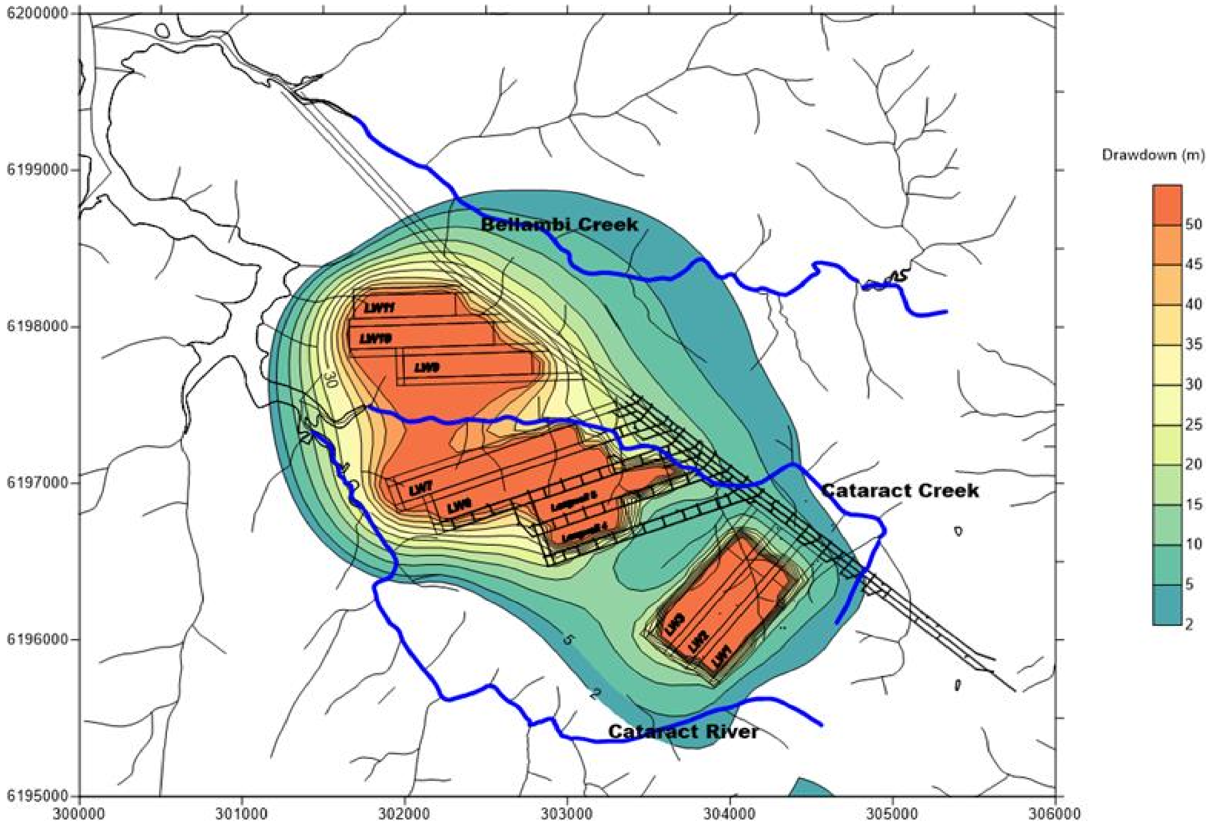


Figure 57 **Scarborough Sandstone Recovery 50 Years After Mining**

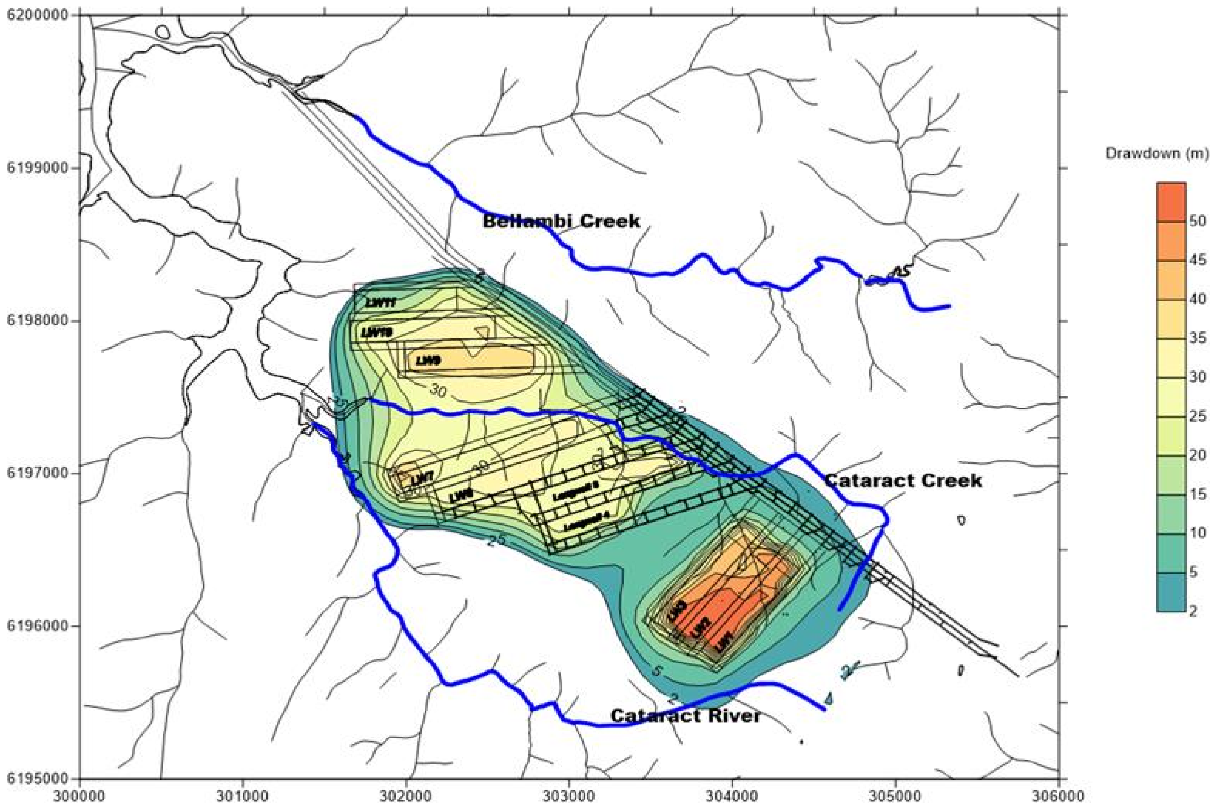


Figure 58 **Scarborough Sandstone Recovery 100 Years After Mining**

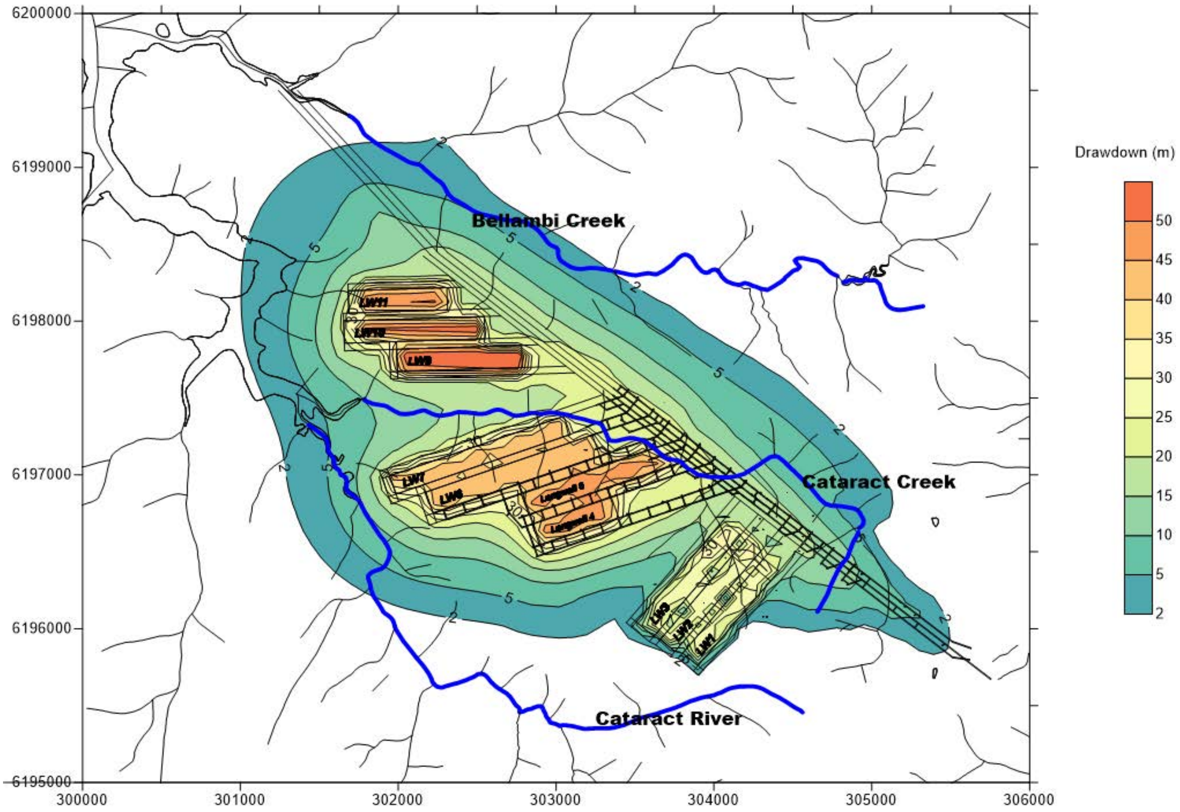


Figure 59 Wongawilli Seam Drawdown After Mining Wonga East in Comparison to Pre Wongawilli Seam Development

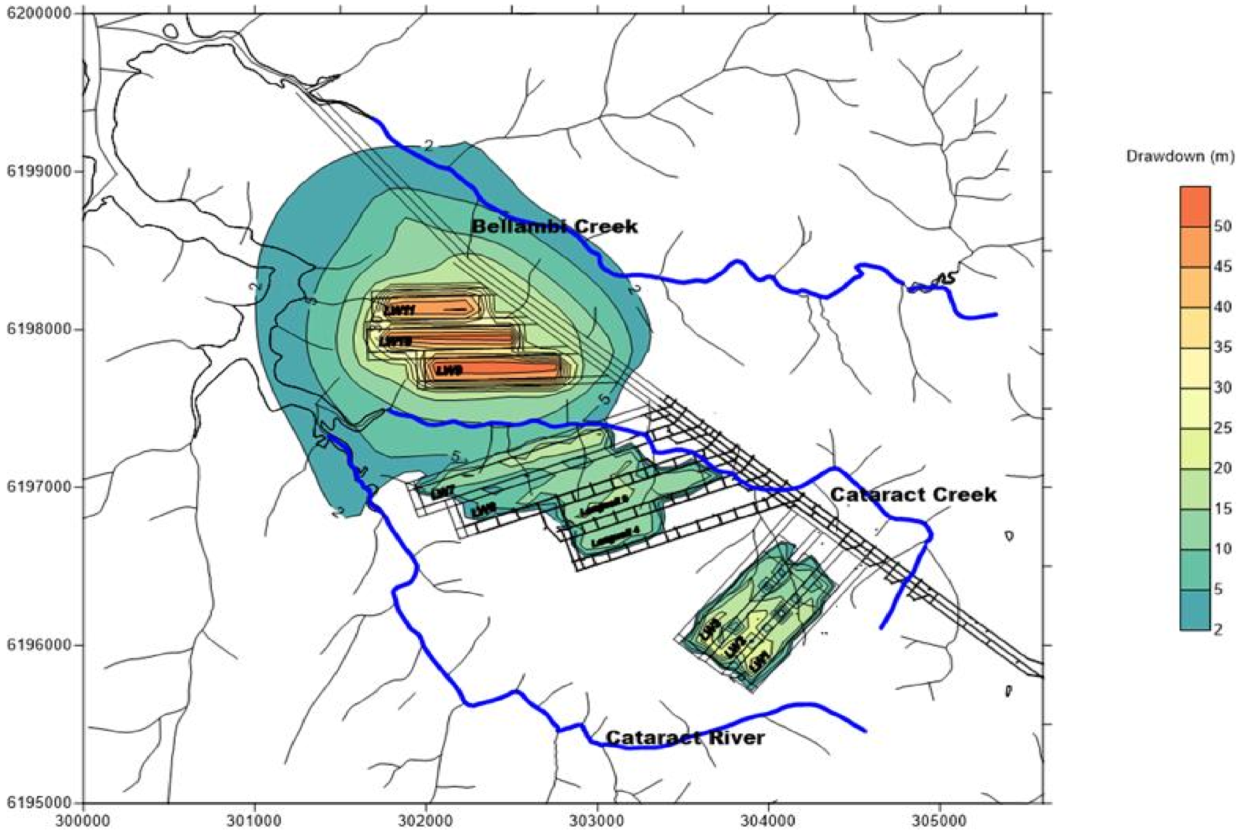


Figure 60 Wongawilli Seam Drawdown After Mining at Wonga East in Comparison to Post LW5 Development

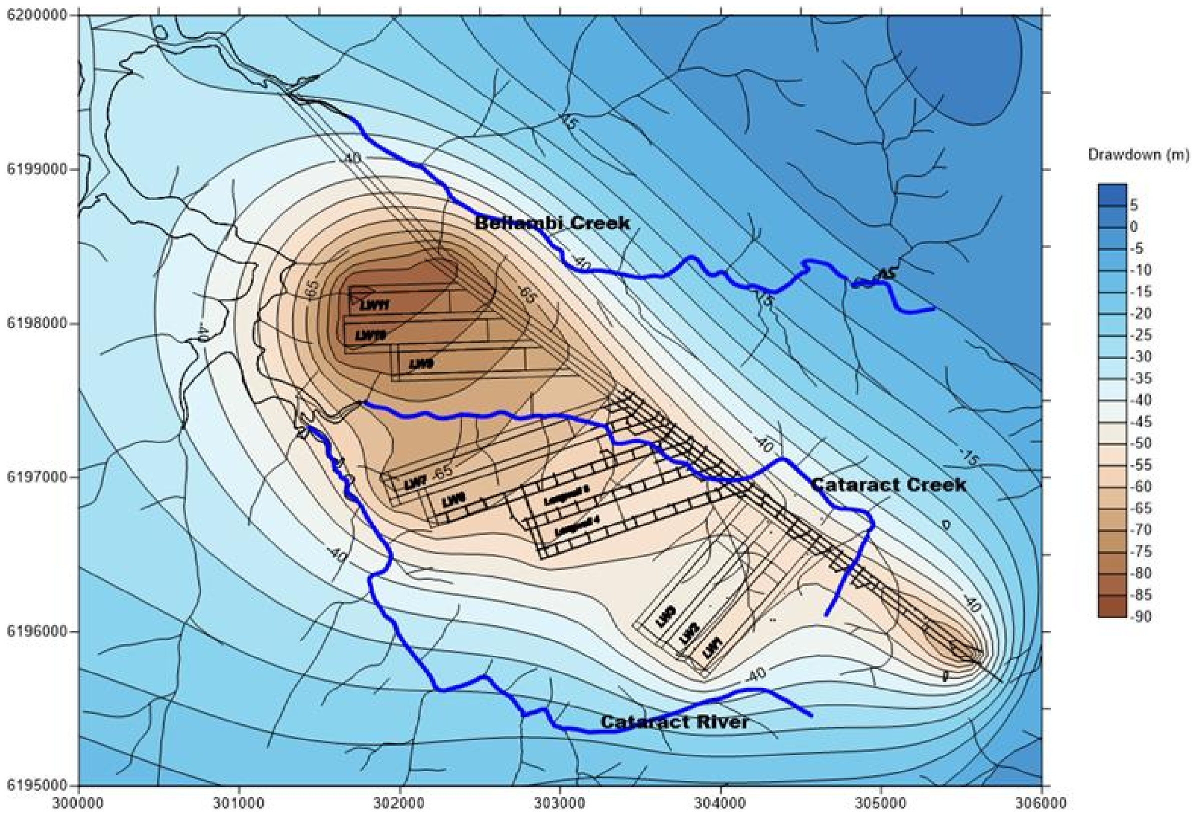


Figure 61 Wongawilli Seam Recovery 50 Years After Mining

10.4 Stream and Groundwater System Connectivity

A number of mechanisms can potentially occur within shallow groundwater systems associated with streams:

- direct flow of surface water into mining induced fracture systems with vertical drainage into the shallow basement groundwater system;
- inter-connection of the depressurised strata and horizontal to sub-horizontal or "stepped" shear plane/s located beneath a stream bed and associated subsided hill slopes;
- flow of surface water from "gaining" streams into the shallow groundwater system which then migrates along the local hydraulic gradient and re-emerges further down stream, with no hydraulic connection to the workings if there is no continuous, vertically connected fracturing;
- reversal of water transfer from the shallow groundwater system to the "losing" streams during periods of high recharge; or
- flow of stream water into the shallow groundwater system migrating along the hydraulic gradient to emerge further downstream within other groundwater catchment regimes.

10.4.1 Cataract Creek

The geotechnical subsidence assessment (SCT Operations 2013) concluded the multi-seam mined Bulli and Balgownie Seam workings at Wonga East diminished the spanning capacity remaining in the Bulgo Sandstone directly above the proposed Wongawilli Seam longwalls.

Observations over Longwall 4 in the Wongawilli Seam indicate that due to the previously fractured nature of the overburden above the Bulli and Balgownie Seam workings the subsidence “bowl” did not effectively extend outside of the longwall footprint (SCT Operations, 2013);and Seedsman Geotechnics, 2012A).

In the multi-seam mined area, even though horizontal bedding displacement may have extended up into the upper Bulgo Sandstone, this does not mean a direct, free vertical drainage hydraulic connection is present from the surface to the workings.

Monitoring of mine water balance (SCT Operations 2014) has not detected any associated short term increase in mine water make from the current Wonga East workings following significant rain in the catchments over the Wonga East workings.

Monitoring of water level trends in piezometer NRE-A over the multi-seam mined area indicates the upper Hawkesbury Sandstone down to the Upper Bulgo Sandstone lithologies have an enhanced response to rainfall recharge. However, no adverse effect on stream flow has been observed as the headwater tributaries and main channel of Cataract Creek have had continuous flow throughout the monitoring period.

The bord and pillar mined areas represented by the open standpipe and vibrating wire piezometers at NRE-B, C and D have a limited to minor response to rainfall recharge.

Where only Bulli seam first workings have been extracted, the proposed workings are not predicted to destabilise the Bulli seam pillars sufficiently to cause fracturing or displacement that will extend into the upper Bulgo Sandstone (Seedsman Geotechnics, 2012). This means there will be no predicted free drainage connection from surface to seam in these areas.

Beneath the plateau over the Bulli and Balgownie workings in the vicinity of Cataract Creek, extraction of the proposed longwalls is modelled to generate up to 3m of depressurisation in Layer 1 at the end of mining Wonga East.

The modelled, localised reduction is anticipated to reduce the regional phreatic surface gradient from the plateau to Cataract Creek, as well as toward Cataract reservoir, thereby potentially reducing baseline seepage flow volumes to the creek and dam.

It is also possible that, where they exist, or have been generated as a result of dilational movement of the hillslope after subsidence, perched and / or phreatic hillslope seepage outflow points may be relocated to lower elevations in the catchment due to the dilational fracturing of the hillslopes and associated hillslope basal shear zone movement as a result of valley closure.

Although the effect could not be addressed in the groundwater model due to the very thin zones of up to 10cm thickness (Mills, K.W, pers comm), the potential generation of a horizontal to sub - horizontal shear plane (or planes) in accordance with the theory of Mills (2007) in the perched hillslope aquifers and between 6 – 10m below the valley floor may lower the hillslope seepage outflow elevations. This could mean that the post Wongawilli Seam extraction baseflow seepage to the valley could occur lower down in the catchment, and could generate a re-location in the transition point in the creek from ephemeral to intermittent / perennial flow.

It is also likely that three stages of dilational, horizontal to sub-horizontal hillslope shear zones have previously been generated following extraction of the secondary workings in the Bulli Seam, the longwalls in the Balgownie Seam, and Longwalls 4 and 5 in the Wongawilli Seam, and that the incremental effect due to extraction of the proposed Longwalls 6 to 11 (and Longwalls 1 to 3) will not cause an observable change in overall stream discharge into Cataract Reservoir.

Mapping of the stream bed and tributaries indicates that baseflow seepage changes have probably already occurred in Cataract Creek, prior to extraction of Longwalls 4 and 5 in the Wongawilli Seam, based on the high degree of iron hydroxide seepage and precipitation present in the upper reaches all the way down to the Cataract Reservoir.

Due to the lack of stream bed, flow and chemistry monitoring prior to July 2008, quantification of the changes in water flow and chemistry in Cataract Creek due to mining the Bulli Seam and Balgownie Seam is not possible.

However, no observable change has been noted in the flow and chemistry of Cataract Creek due to extraction of Longwalls 4 and 5 in the Wongawilli Seam (Geoterra, 2014A).

Stream flow modelling indicates the average daily stream flow from Cataract Creek to Cataract Reservoir is 11.2ML/d of which 3.5ML/d is baseflow, with a median baseflow of 2.2ML/d (WRM Water & Environment, 2014).

The groundwater modelling predicts a 0.013ML/day (4.74ML/year) loss of stream baseflow in the Cataract Creek catchment at the end of the proposed mining as shown in **Table 12** and **Figure 62**.

The modelled (0.12%) annual change in the Cataract Creek catchment flows are therefore relatively minor compared to the average annual stream flow into Cataract Reservoir.

10.4.2 Cataract River (Upstream of Cataract Reservoir) and Bellambi Creek

Although groundwater level reductions are predicted over the Wonga East workings, the majority of the changes are contained within the Cataract Creek catchment.

As such, there is anticipated to be no observable change in stream flow or groundwater seepage in the Cataract River (upstream of Cataract Reservoir) and Bellambi Creek catchments due to the very low proportion of the two catchments that may be partially depressurised as shown in **Table 12** and **Figure 62**.

The modelling predicts a reduction in baseflow of 1.20ML/yr in the Cataract River (upstream of Cataract Reservoir) and a reduction of 0.88ML/yr in Bellambi Creek. The modelled annual changes for the Cataract River (0.03%) and Bellambi Creek (0.02%) flows are therefore relatively minor compared to the average annual stream flow into Cataract Reservoir.

Table 12 Modelled Cataract Creek, Cataract River and Bellambi Creek Stream Flow Changes

	Baseflow Loss (ML/day) / (ML/year)	Change Due to Proposed Mining Compared to Current Flows (ML/day) / (ML/year)
Cataract Creek (Upstream of Cataract Reservoir)		
Current	0.005 / 1.83	-
End of Mining	0.018 / 6.57	0.013 / 4.74
Cataract River (Upstream of Cataract Reservoir)		
Current	0.0007 / 0.26	-
End of Mining	0.004 / 1.46	0.0033 / 1.20
Bellambi Creek		
Current	0.0006 / 0.22	-
End of Mining	0.003 / 1.10	0.0024 / 0.88
TOTAL		**0.0187 / 6.83**

10.5 Cataract Reservoir

Cataract Reservoir has a full operating storage of 97,190ML. The lowest level of the storage as advised by the SCA is 27,620ML or 29.3% capacity on 20 July 2006.

10.5.1 Stream Inflow

Due to the setback of the proposed workings from the Cataract reservoir, no adverse impacts on stored water quantity or quality are predicted to occur on, or in, Cataract Reservoir, based on the factors discussed in previous sections.

It is anticipated, however, that the water will flow via subsurface fractures and discharge down gradient into the lower section of the streams, and / or into Cataract Reservoir. As such, the change is anticipated to be a sub-surface diversion, not an overall loss, to the surface water balance.

The modelled sub-surface total transfer of 6.83 ML/year from the Cataract Creek, Cataract River and Bellambi Creek catchments at the end of the proposed mining at Wonga East is less than 0.03% of the low level storage, or 0.007% of its full storage capacity.

10.5.2 Strata Depressurisation

The modelled transfer of stored water within Cataract Reservoir to the underlying groundwater system due to depressurisation of the regional groundwater system in the vicinity of the lake is 0.005ML/day (1.83ML/year) at the end of mining.

The modelled sub-surface transfer of 1.83ML /year from the stored waters at the end of the proposed mining is less than 0.007% of the low level, or 0.002% of its full storage capacity.

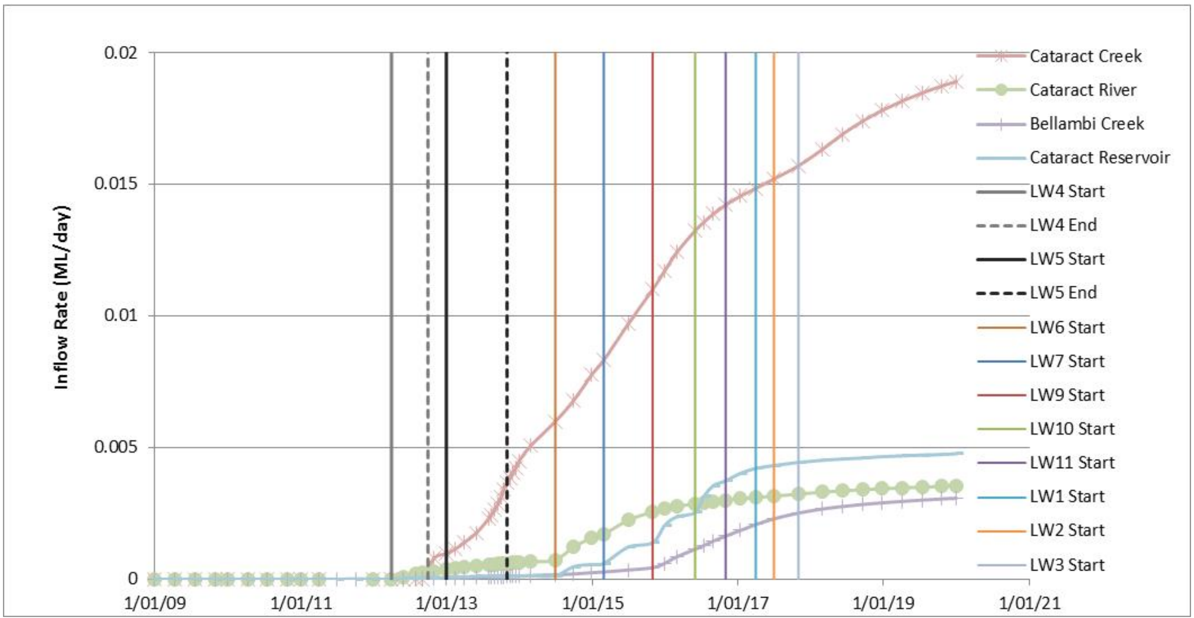


Figure 62 Wonga East Stream and Cataract Reservoir Related Depressurisation Losses

10.6 Subsidence Interaction with Faults and Dykes

The Corrimal Fault is mapped as crossing over the proposed Wonga East workings in Longwalls 6 to 9, however it is not anticipated to generate a hydraulic connection to the surface water system or Cataract Reservoir through extraction of LW6. The fault has been identified as a "hinge fault" with a varying throw of approximately 25m in the east, reducing to 1.8m at Maingate 5, and predicted to reduce to no displacement around Longwalls 7 and 8.

Recent intersection of the Corrimal Fault during development of the Longwall 6 gate-road indicates the fault zones contains three "normal" faults with up to 0.93m displacement, and associated smaller faults, with no associated groundwater inflow (Wollongong Coal, 2014). This indicates that the Corrimal Fault "zone" is diminishing to the north and is anticipated to fade out before it intersects with the reservoir. This observation indicates the potential re-activation or displacement of the Corrimal Fault due to subsidence and, therefore, its potential to cause a significant hydraulic connection between the workings and the mine, and to cause a significant drainage potential from the reservoir to the mine is not considered likely.

A thin (<1m wide) highly weathered dyke is located over the Wonga East workings, however, due to its highly weathered clay state and associated low intrinsic permeability, undermining this structure is not anticipated to enhance its permeability or potential hydraulic connection to the surface water systems (including Cataract Reservoir).

If inflow monitoring in the mine and observation of the piezometers installed over the Wonga East mining domain indicate there may be a potential for increased permeability along the Corrimal Fault due to mining induced changes, then the mining of subsequent panels can be adjusted through adaptive management of the mine workings.

To date, mining in the Bulli seam on both sides of the Corrimal Fault (both first and second workings), has not resulted in observable increased flows to the mine workings (Gujarat

NRE Coking Coal, 2013).

Based on past mining experience and interpretation of the mine water balance monitoring (SCT Operations, 2014), the faults in the Bulli / Balgownie workings are essentially dry and are not anticipated to provide enhanced permeability fluid pathways in the proposed mining area.

No water inrush has been observed with mining through faults or dykes in the Bulli, Balgownie or Wongawilli Seam workings (S Wilson, pers comm).

10.7 Groundwater Inflow to the Workings

The predicted modelled inflow to the proposed workings for each stage is shown in **Table 13** and **Figure 63**.

It should be noted that the proposed extraction will start with Longwall 6, progress to Longwall 11 and then re-locate and extract Longwalls 1 to 3, which are higher up in the catchment.

Table 13 Predicted Groundwater Mine Inflows

Stage	Measured Inflow (ML/day)	Predicted Inflow (ML/day)	Predicted Inflow (ML/year)
Pre Longwall 4	n/a	0.63	230
Post Longwall 5	1.05	1.06	370
Post Longwalls 6 and 7	-	1.27	464
Post Longwalls 8 to 11	-	1.7	620
Post Longwalls 1 to 3	-	1.2	438

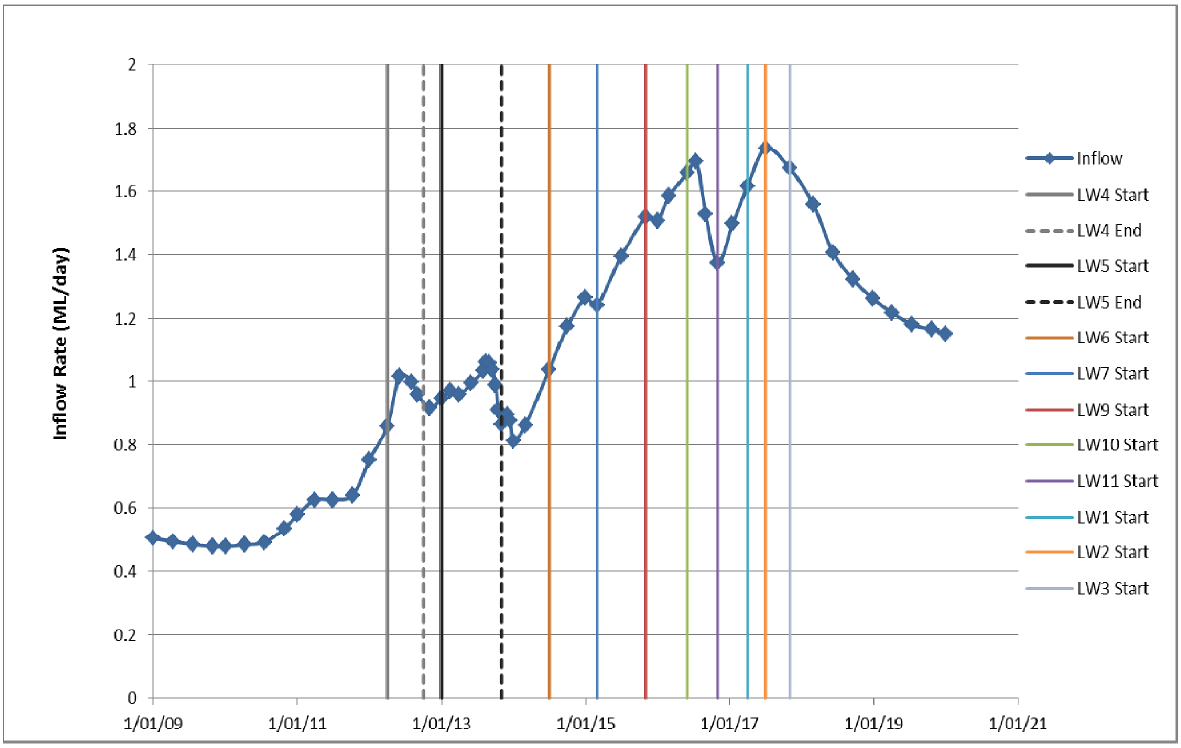


Figure 63 Predicted Groundwater Inflows

The modelled seepage rates into the workings may be enhanced if unidentified fracture related storages are intercepted, which may lead to short term increases of potentially up to 0.1 - 0.5ML/day which should dissipate over a period of weeks to months.

10.8 Groundwater Quality

Previous observations at Russell Vale indicate that groundwater quality within the regional groundwater system has not been adversely affected, however there may be some localised increased iron hydroxide precipitation and limited lowering of pH if the groundwater is exposed to “fresh” surfaces in the strata through dissolution of unweathered iron sulfide or carbonate minerals.

The degree of iron hydroxide and pH change is difficult to predict, and can range from no observable effect to a distinct discolouration of the formation water. The discolouration does not pose a health hazard, however it can cause iron hydroxide precipitation at seepage points in local streams which can also be associated with algal matting and / or lowering of dissolved oxygen levels in the creek at the seepage point.

It should be noted that many Hawkesbury Sandstone aquifers in the Southern Coalfield already have significant iron hydroxide levels, and that ferruginous seeps can also be observed in previously un-subsided catchment areas.

As a result of the proposed workings, pH acidification of up to 1 unit may occur, however the change may be reduced if the aquifer has sufficient bicarbonate levels.

Outside of isolated iron hydroxide seepages, no adverse groundwater quality is anticipated to discharge from the proposed Wongawilli Seam workings subsidence areas.

10.9 Loss of Bore Yield

There will be no loss of bore yield as there are no registered private bores or wells located within the Study Area.

11. CUMULATIVE GROUNDWATER RELATED IMPACTS

11.1 Upland Swamps

As outlined in Biosis (2014), no other adjoining mining operations provide a cumulative impact on swamps in the Study Area.

No swamps are present downstream of the Wollongong Coal lease area.

11.2 Basement Groundwater

The cumulative impact of the existing and proposed Russell Vale workings along with the surrounding mines has been assessed in the model runs by including the effects of:

- hydraulic permeability distribution over non-mining areas;
- subsidence, fracture propagation and associated hydraulic permeability distribution over bord and pillar, pillar extraction or longwalls on the regional groundwater pressure distribution;
- known or estimated degree of flooding in the adjoining workings, and;
- the separation distance from adjoining workings, where Appin / Westcliff / Northcliff / Metropolitan / Tahmoor mining areas were interpreted to be sufficiently distant from the existing and proposed Russell Vale Colliery workings to be discounted.

Groundwater modelling indicates that the influence of the Project within the Wongawilli Seam can be broken down into the depressurisation of two separate regimes:

- saturated coal measures above the Wongawilli Seam; and the
- shallower stratigraphy.

Deeper coal measure strata of the Wongawilli Seam and overburden immediately overhead would be depressurised to mining levels in the immediate footprint of the mine plan with up to 2m of drawdown in the Wongawilli Seam out to 1km beyond the mine plan at the end of the mining period.

The overlying Balgownie and Bulli seams have previously been mined and therefore significant depressurisation has occurred historically.

The shallower strata have the potential to be depressurised, most notably in the Bulgo Sandstone and the Hawkesbury Sandstone (where it is present) from Wongawilli subsidence related fracturing, as well as reworking the existing overburden fracture systems due to historical mining in the Bulli, Balgownie and Wongawilli Seams.

Modelling indicates significant depressurisation within these sandstone units overlying the proposed Russell Vale Wongawilli workings with the 2m depressurisation cone in the Upper Bulgo Sandstone extending to a distance or 1km beyond the proposed workings.

Regionally, the closest mining operations include those utilised for the model boundaries. The Appin Mine is located 13 km to the north-west operates within the Bulli Seam. Twelve kilometres to the south-west, Dendrobium Colliery is mining the Wongawilli Seam.

A review of the groundwater related studies undertaken for these projects indicates that regional drawdown at Appin extends approximately 2-3 km from the southern margins of the current operation (Heritage Computing 2009) and similarly at Dendrobium (Coffey

Geotechnics, 2012).

Modelling conducted for this study and previous studies in the Southern Coalfield indicates there will not be any superposition of drawdown cones between the Russell Vale and Appin / Dendrobium mining areas. Therefore, there is no cumulative depressurisation resulting from the Project and other mines.

Cumulative losses are therefore as shown in the model, which includes all of the adjoining historical, decommissioned mining areas and depressurisation due to the proposed Wongawilli Seam extraction does not expand into, or interact with, the current or proposed mining operations at Appin Mine and Dendrobium Colliery.

12. MODELLING UNCERTAINTY

The Australian groundwater modelling guidelines provide a guiding principle in relation to model uncertainty as shown below:

"Models should be constructed to address specific objectives, often well-defined predictions of interest. Uncertainty associated with a model is directly related to these objectives" (SKM 2012).

All models contain uncertainty and a groundwater model's predictive capacity is limited by the ability to simulate the study area at a sufficiently detailed scale.

The model predicts a negligible reduction in baseflow derived from the regional water table. Due to the observed isolation between perched and regional water tables, there is an expectation that there would be little effect on baseflow derived from aquifer sources due to regional depressurisation.

As the discrete features are too thin, not regionally pervasive, whilst their distribution in the strata and their associated hydraulic parameters are not known, the model can not predict the effect of water flow through horizontal to sub-horizontal shear zones associated with hillslope strata fracturing and valley closure.

The groundwater regime is heavily impacted within the overburden and regional stratigraphy due to past mining which has been ongoing since the end of the 19th century. However, no historical groundwater calibration data in terms of mine inflows and / or water levels is available prior to the installation of P501, P502 and P514 in 1992 within the Russell vale lease area.

The current proposal would mine beneath previously mined strata and has the potential to reactivate earlier subsidence impacted zones. It has been the intent of the model setup to adopt a conservative approach whereby fracturing is extended into the lower sections of the Hawkesbury Sandstone, with the modelling indicating there is a potential for depressurisation to shallow levels in the Hawkesbury Sandstone (or Bulgo Sandstone where it is exposed in the bed of Cataract Creek).

Setup of the fracturing and associated depressurisation distribution in the overburden utilised an adapted version of a theoretical depressurisation model, which is based on single seam longwall extraction (Tammetta, 2012). The applicability of the empirical model, and its adaptation to multiple seam extraction has not yet been sufficiently tested in the Russell Vale lease area as there is only one multiple intake vibrating wire piezometer within the Wonga East area (GW1) and it is not ideally located over the centre of the triple seam mined area near Longwalls 4 and 5. Further drilling and VWP / open standpipe piezometer installation is planned, and will commence after approval from the

SCA is attained.

In addition, other theoretical fracturing and strata depressurisation models are available that may be equally applicable to set up the fracturing and associated depressurisation distribution, such as the model developed by Ditton Geotechnical Services Pty Ltd (DGS).

The DGS based approach has been used and accepted by the Department of Planning and Environment for the modelling of the following mining proposals:

- Chain Valley - Mining Extension 1
- Whitehaven Coal - Narrabri North
- Donaldson Coal - Abel Underground Mine
- Donaldson Coal – Tasman Extension Underground Mine
- West Wallsend Underground Mine
- Wambo Underground Mine
- Angus Place
- Springvale

The possible connection of surface water features to a potential subsidence generated depressurisation field and subsequent depletion of stream flow in overlying drainage pathways is a significant potential environmental impact that may result from subsidence within a multi seam mining environment. To address this issue, a probabilistic or stochastic approach has been undertaken where hydraulic conductivity has been randomly generated using “fieldgen”, which is part of the PEST (Watermark Numerical Computing, 2014) suite of programs. The stochastic approach has been used to explore the uncertainty in the model predictions arising from hydraulic property heterogeneity and in this case specifically lateral or horizontal hydraulic conductivity.

The stochastic field arrays are generated using a statistical function for a chosen property. In this case, only horizontal hydraulic conductivity is varied. This includes the calibrated value within the model and using the standard deviation to vary the field array based on the observed population of measured conductivities. Standard deviation defines an acceptable range in Kx values.

Variation of the conductivity field was limited to the horizontal plane only because the base case predictions indicated that depressurisation to surface is likely. Therefore any interaction with surface water entities, (i.e. Cataract Creek) are likely to be more sensitive to lateral variability. Host vertical hydraulic conductivity was maintained from the base case predictive model.

The realisations have been used to generate 30 models with the randomised arrays from layers 1 to 10 (Hawkesbury Sandstone to Scarborough Sandstone), with each conductivity array in the upper 12 layers being different from corresponding arrays in the other models, whilst having the random values centred around the calibrated value for each model layer.

Each model is then run two times (complete model run from 1993) for the case with and without mining of the proposal. In this way, the changes to base flows from the drainage pathways which potentially interact with the mining proposal were compared and the potential variability of responses was assessed.

Statistics were derived from the packer database as shown in **Table 14**, which provides a summary of the stratigraphic test interval and sample number as well as the standard deviation for each interval.

Table 14 Stratigraphic Test Interval, sample Number and Standard Deviation

Stratigraphic Unit	Sample Number	SD of Log Kh
Hawkesbury Sandstone	52	1.04
Bald Hill Claystone	9	1.36
Bulgo Sandstone	55	1.15
Stanwell Park Claystone	15	1.28
Scarborough Sandstone	14	1.13
Wombarra Claystone	13	1.01
Coal Cliff Sandstone	21	0.77

Losses from Cataract Creek, Cataract River upstream of the reservoir, Bellambi Creek and Cataract Reservoir were extracted from each model along with predicted mine inflow rates for the Wonga East Workings.

Figure 64 shows mine inflow rates (ML/d) for the 30 stochastic model runs as well as the predicted base case predictive inflow for the calibrated model. It shows a peak inflow (R20) of 2.0ML/d which is a 10% increase on the base case predicted inflow peak. Early model time inflows which represent predominantly Bulli Seam inflows show that the Base Case model is in the higher end of the inflow estimates. **Figures 65** and **66** show losses from Cataract Creek and the combined loss curve for Cataract Creek, Cataract River, Bellambi Creek and Cataract Reservoir combined for the 30 model runs and the base case model results.

Figure 67 shows a probability distribution for mine inflow rates. Mean values (based on the period from start of mining in the Wongawilli Seam to End of Mining) are influenced by the long period of model time where inflows are predominantly from the unmined areas of the Bulli Seam. Average inflow for the Base Case model of 0.75 ML/d is in the upper quartile of the 30 model runs, whilst peak inflow rates show that the Base Case model peak inflows are approximately in the 50 to 60 percentile range.

The probability distribution for base flow losses from Cataract Creek is shown in **Figure 68** where the Base Case model results are within the upper quartile of the mean and maximum rates found from the multiple stochastic model runs. Similarly, base flow losses from the combined surface water features including Cataract Creek, Cataract River upstream of the reservoir, Bellambi Creek and Cataract Reservoir for the base case model are in the higher range of results which were found in the multiple model runs.

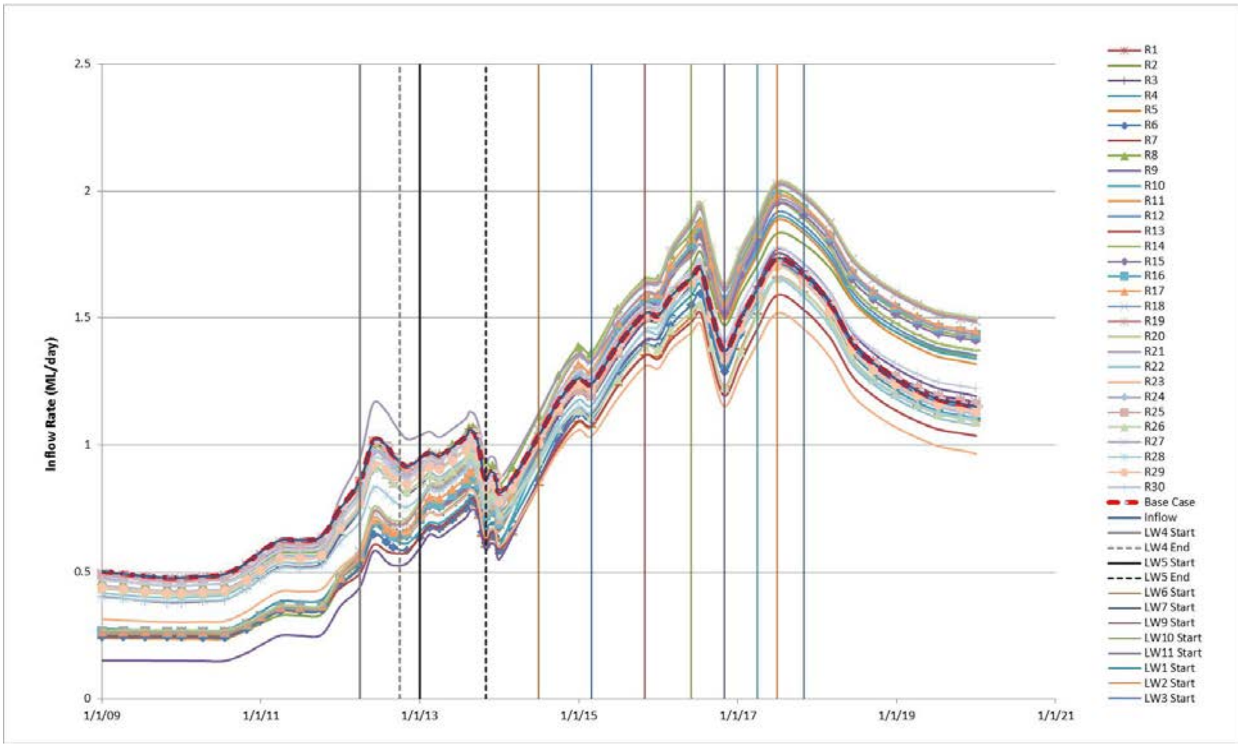


Figure 64 Mine Inflow

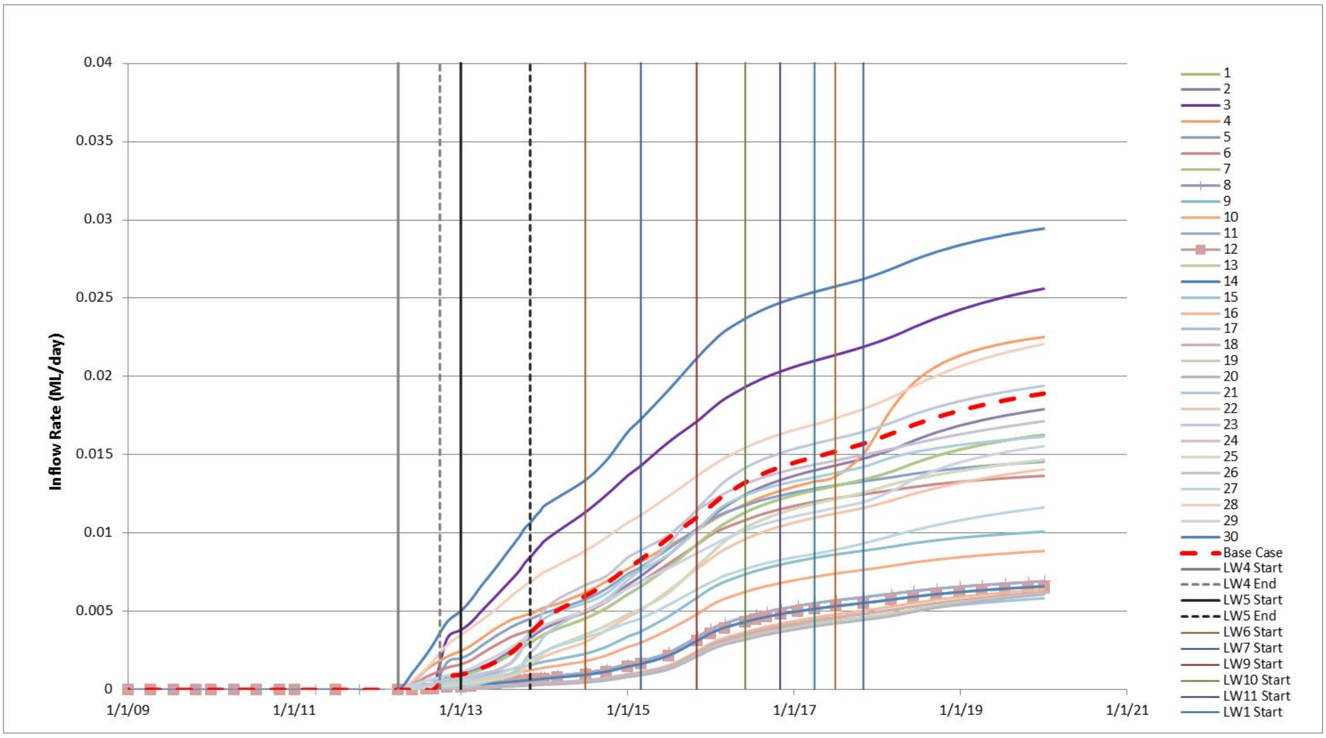


Figure 65 Base Flow Loss From Cataract Creek

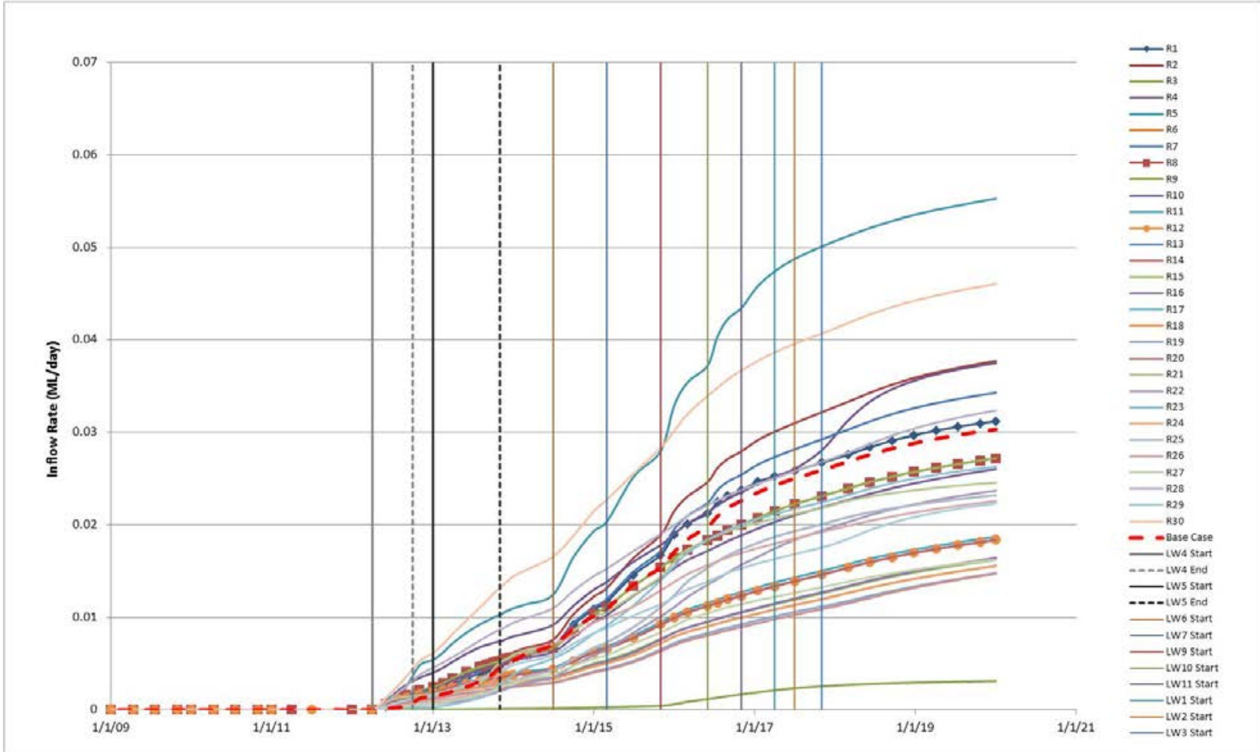


Figure 66 Combined Base Flow Losses from Cataract Creek, Cataract River, Bellambi Creek and Cataract Reservoir

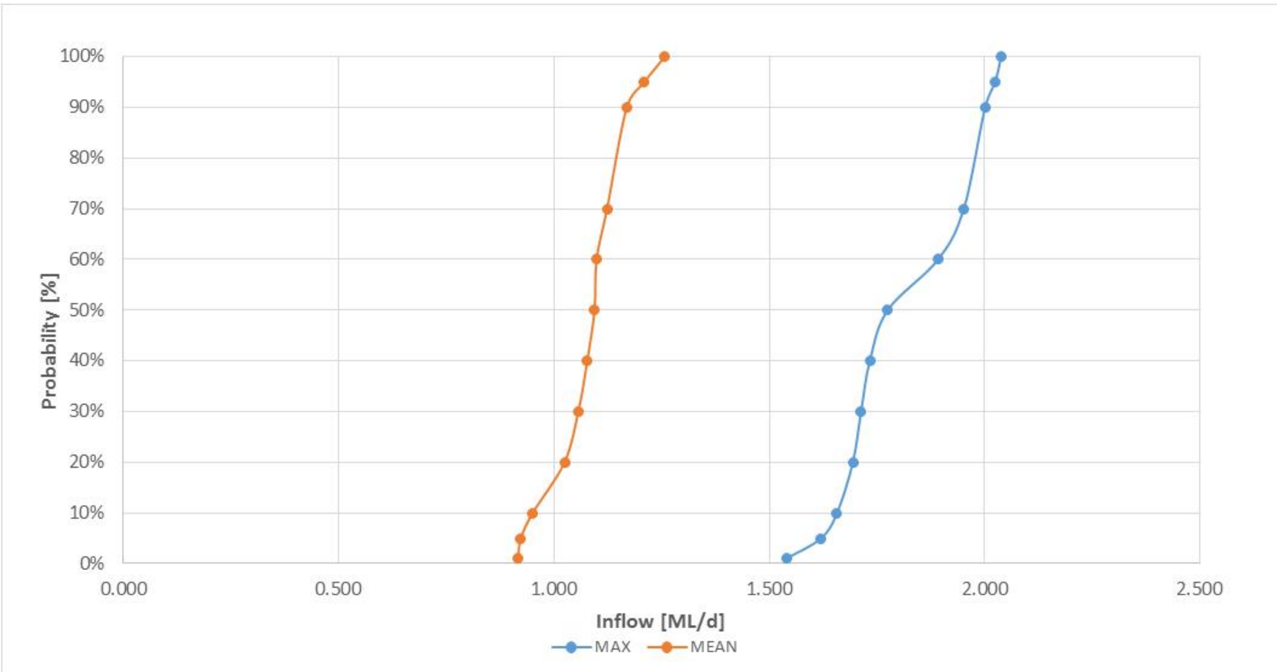


Figure 67 Mine Inflow Probability Frequency Distribution

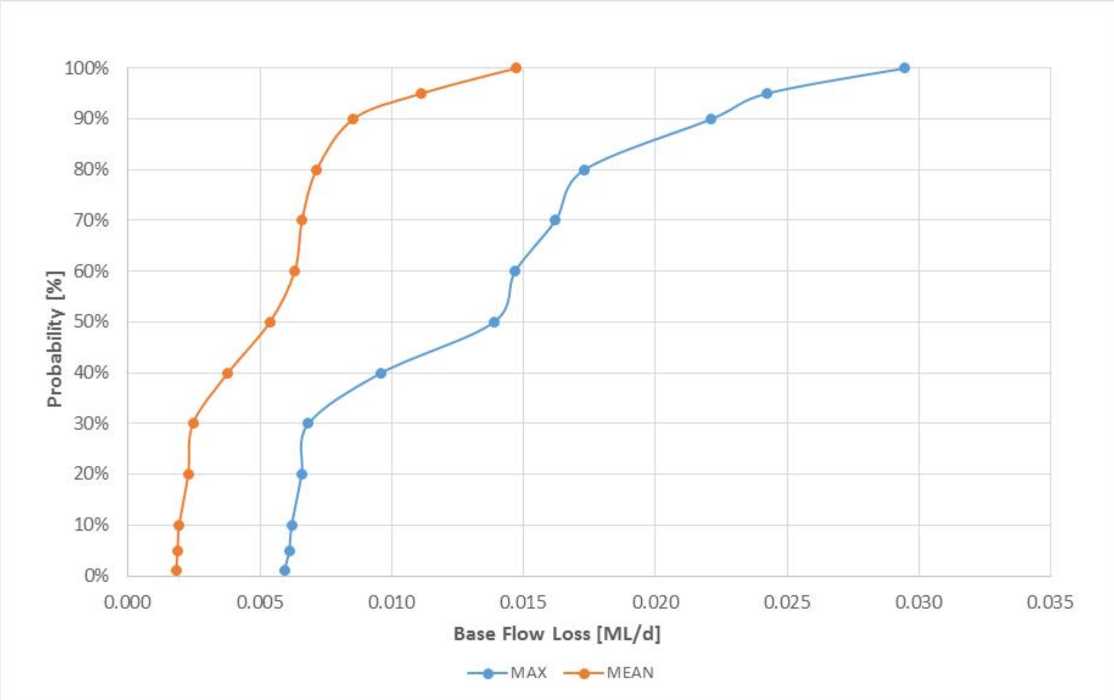


Figure 68 Cataract Creek Base Flow Loss Probability Frequency Distribution

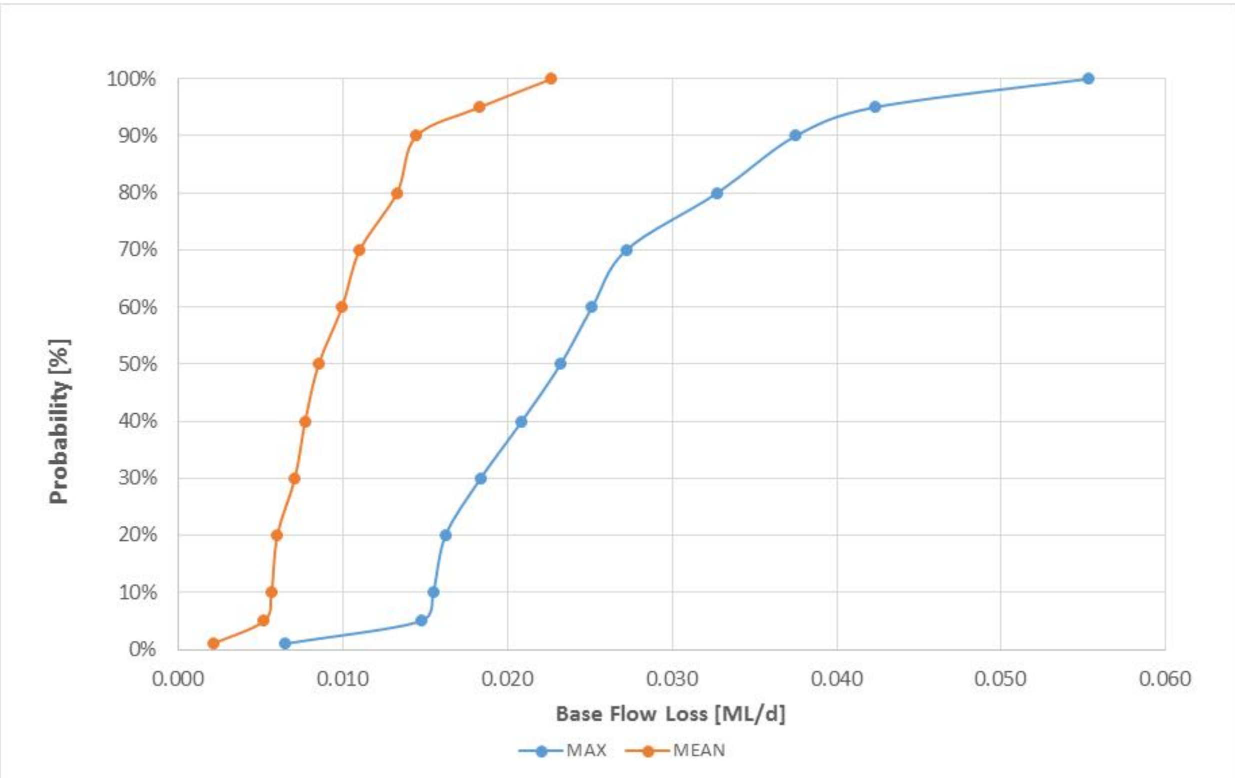


Figure 69 Combined Base Flow Loss Probability Frequency Distribution

12.1 Recharge Sensitivity

An analysis has also been carried out to assess the sensitivity of the model calibration to the assumed input parameters for recharge. The sensitivity analysis was carried out by first decreasing and then increasing recharge and evaluating the impacts of the changes on the calibration statistics. A range of multipliers was used with an upper and lower bound of 10 and 0.1 respectively. That is the range being an order of magnitude above and below the assumed calibrated value for recharge.

Figure 70 shows the results of the sensitivity analysis whereby calibration performance is measured in terms of the sum of residuals of calibration targets. It shows that increasing and decreasing recharge over the model domain does not improve calibration performance.

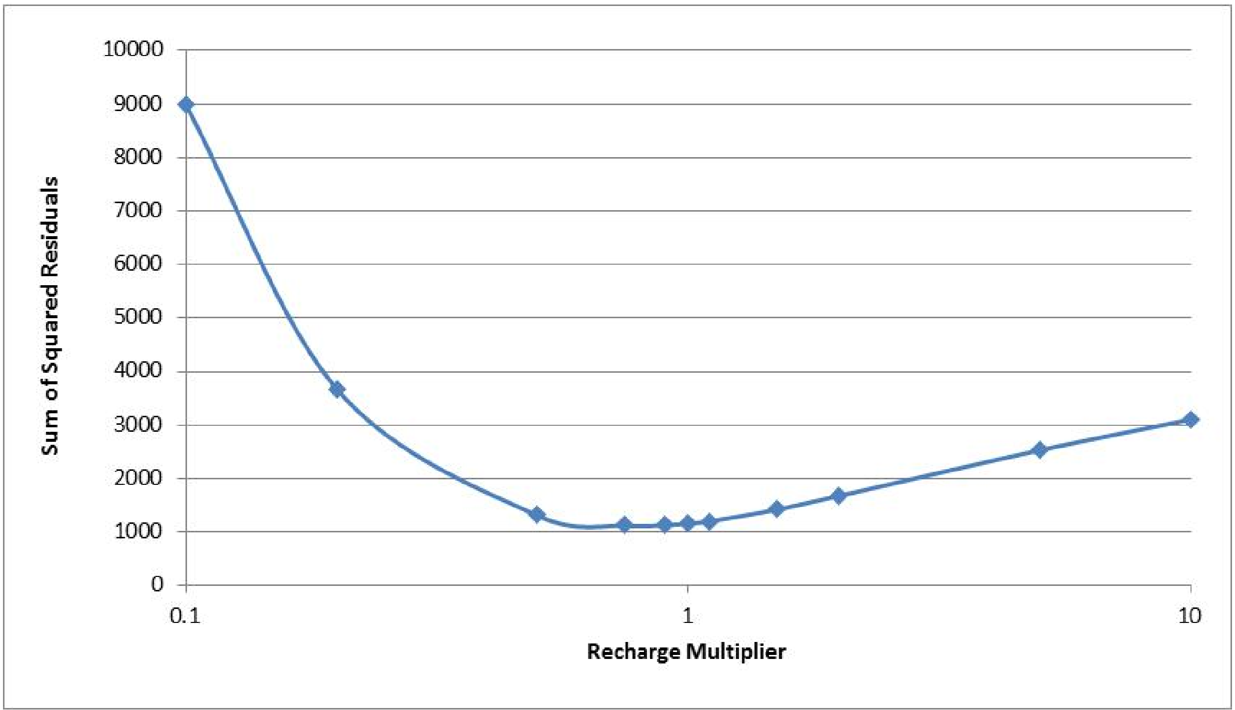


Figure 70 Recharge Sensitivity Analysis Results

13. MODEL LIMITATIONS

The adopted model has been designed to simulate the propagation of both near-field and far-field depressurisation effects throughout the regional aquifer system.

The model has not been designed to simulate the effects of near-surface tensile cracking or discrete structural features, such as the presence of faults or dykes or their displacement due to subsidence resulting from underground extractive mining.

The model does not include structural features such as faults and dykes which have the potential to compartmentalise or connect facets of sub-regional aquifers and also potentially surface water features to sub-surface strata. The current model has not assessed geological faults and structures due to the uncertainty in their location, vertical persistence, and their resultant attributes as barriers or transmissive conduits.

14. WATER LICENSING

14.1 Groundwater

The Project is covered by the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011* (Groundwater WSP), which applies to 13 groundwater sources.

The current groundwater licence under Part 5 of the *Water Act 1912* that is held by Russell Vale Colliery for 365ML/year (Licence No. 10BL602992) is located within Management Zone 2 of the Sydney Basin Nepean Groundwater Source. This includes all aquifers below the surface of the ground (clause 4), and covers alluvium, weathered and basement rocks.

As the current licence is held under part 5 of the *Water Act 1912*, Wollongong Coal will need to convert its existing licence to a WAL.

For the purposes of the WM Act, an ‘aquifer’ is defined as *“a geological structure or formation, or an artificial landfill that is permeated with water or is capable of being permeated with water”*. Abandoned workings are not geological structures or formations and as such, do not constitute aquifers. Therefore, water make sourced from abandoned workings does not constitute the taking of water from the water source, whereas the Wongawilli coal seam and overburden satisfy the definition of ‘aquifer” and the mining effects on them are deemed to be a water “take”.

Since the Groundwater WSP applies to all aquifers, Wollongong Coal will require WALs for all groundwater taken in the course of mining. The total licensing entitlement required will be the maximum mine water make, which will include the water taken from each formation.

Based on the predicted maximum inflow of 620ML/year, which includes approximately 0.2ML/day (73ML/year) of seepage inflow from adjoining, upgradient decommissioned workings which is not required to be licensed, Wollongong Coalwill require a WAL for at least 182 ML/year in addition to their current licence. This is the maximum predicted inflow (620ML/year) minus the existing licensing entitlement (365ML/yr) and the water taken from former mine workings (73 ML/year).

The Sydney Basin Nepean Groundwater Source WSP limits the total share component for aquifer licences in this water source to 16,283 unit shares.

14.2 Surface Water

The Project is located within the area covered by the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011* (Unregulated River WSP). The Unregulated River WSP includes six water sources, with the Project situated entirely within the ‘Upper Nepean and Upstream Warragamba Water Source”.

Clause 4 of the Unregulated River WSP states that these water sources include all water:

- *Occurring naturally on the surface of the ground shown on the Registered Map; and*
- *In rivers, lakes, estuaries and wetlands in these water sources.*

Wollongong Coal currently does not hold any licences for surface water use for the region covering the proposed mining area and will need to obtain WALs for the total volume of surface water taken from the Upper Nepean and Upstream Warragamba Water Source.

The WSP limits the total share component for unregulated river licences in this water source to 15,540.2 unit shares.

Impacts that would give rise to licensing requirements include:

- Reduction in base flows to streams due to drawdown;
- Additional runoff that infiltrates into the groundwater system via subsidence induced shallow cracking;
- Leakage from swamps; and
- Loss of water from Cataract Reservoir due to depressurisation.

Cracking of streams may result in a reduction of stream flow through re-directing water into the bedrock. Although this water may re-emerge downstream, the water is deemed to have been “taken” as it is diverted from above to below the ground surface. Section 60I of the WM Act indicates that the water is deemed to be taken even if it is returned to the water source. Section 60I states:

“a person takes water in the course of carrying out a mining activity if, as a result of or in connection with, the activity or a past mining activity carried out by the person, water is removed or diverted from a water source (whether or not water is returned to that water source) or water is re-located from one part of an aquifer to another part of an aquifer”.

The maximum predicted loss of stream baseflow due to basement depressurisation under the Cataract Creek, Cataract River and Bellambi Creek catchments within Management Zone 2 of the Sydney Basin Nepean Groundwater Source, as a result of the proposed mining, is 6.83 ML/yr at the end of mining as shown in **Table 15**.

Table 15 Surface Water Licensing Requirements

Surface Water Source	Predicted Surface Water “Take” (ML/year)
Wonga East Stream Baseflow	6.83
Cataract Reservoir Leakage	1.83
(TOTAL)	**8.66**

Volumetric assessment of potential annual stream flow changes due to valley closure related cracking and transfer to sub-surface flow can not be assessed by the groundwater model, nor can it be predicted by any other method as the response of a stream bed to valley closure and compressional / tensional cracking is highly site specific and highly variable within a stream bed due to up to 36 factors (Kay, D.R, Waddington, A.A, 2014) and (Barbato, J et al, 2014).

Under the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources, which encompasses the Study Area and is contained within the Sydney Basin Nepean Groundwater Source Area, Wollongong Coal will require a WAL for the annual take of up to 8.66 ML/yr of stream baseflow resulting from depressurisation of deeper aquifers.

15. NSW AQUIFER INTERFERENCE POLICY MINIMAL IMPACT CONSIDERATIONS

The Aquifer Interference policy (AIP) prescribes minimal impact considerations which must be satisfied.

The minimal impact considerations for a water source vary depending on the nature of the water source (i.e. alluvial, coastal, fractured rock etc) and whether it is "highly productive groundwater" or "less productive groundwater".

The minimal impact considerations for less productive porous rock water sources are presented in **Table 16** and for the perched, ephemeral aquifers in **Table 17**.

The aquifers are not considered to be "highly" productive as although they contain total dissolved solids of less than 1500mg/L in the Hawkesbury Sandstone, there are no water supply works that yield water at a rate greater than 5L/sec in the Wonga East area.

Table 16 NSW Minimal Impact Considerations for Less Productive Porous Rock Water Sources

Minimal Impact Consideration	Proponent Response
<u>Water Table – Level 1</u> Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan variations, 40m from any: a) high priority groundwater dependent ecosystem, or b) high priority culturally significant site listed in the schedule of the relevant water sharing plan, or A maximum of a 2 m decline cumulatively at any water supply work unless make good provisions should apply.	There are no: • high priority groundwater dependent ecosystems, or; • high priority culturally significant sites listed under Schedule 4 of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011. The swamps above the mine plan are not classified as Temperate Highland Peat Swamps on Sandstone (which is high priority GDE). There are no water supply works (i.e. groundwater bores) in the Wonga East proposal area that will undergo more than a 2m decline.
<u>Water Table – Level 2</u> If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than 2m decline cumulatively at any water supply work then make good provisions should apply.	Level 2 does not apply as Level 1 criteria is not exceeded
<u>Water Pressure – Level 1</u> A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head	There are no water supply works (i.e. groundwater bores) in the Wonga East proposal area that will undergo a greater than 40% post water sharing plan pressure head decline

above the base of the water source to a maximum of a 2m decline, at any water supply work.	above the base of the water source, and no water supply work will undergo greater than 2m decline
<u>Water Pressure – Level 2</u> If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	Level 2 does not apply as Level 1 criteria is not exceeded
<u>Water Quality – Level 1</u> a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity, and b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a "reliable water supply" is not an appropriate mitigation measure to meet considerations 1(a) and 1(b) above. c) No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply".	The beneficial use category of the groundwater source will not be changed beyond 40m from the Wonga East proposal area. There are no highly connected surface water sources (alluvial aquifers) in the Wonga East proposal area There are no highly connected alluvial surface water sources defined as a reliable water supply within the Wonga East proposal area
<u>Water Quality – Level 2</u> If condition 1(a) is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works. If condition 1(b) is not met then appropriate studies are required to demonstrate to the Minister's satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity. Condition 1(c) does not apply as there are no river bank or high wall instability risks and no need for low permeability barriers between the site and highly connected surface waters	Level 2 does not apply as Level 1 is not exceeded

Table 17 NSW Minimal Impact Considerations for Perched Ephemeral Aquifer Water Sources

Minimal Impact Consideration	Proponent Response
Water Table – Level 1 Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan variations, 40m from any: c) high priority groundwater dependent ecosystem, or d) high priority culturally significant site listed in the schedule of the relevant water sharing plan, or A maximum of a 2 m decline cumulatively at any water supply work unless make good provisions should apply.	There are no: • high priority groundwater dependent ecosystems, or; • high priority culturally significant sites listed under Schedule 4 of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011. The swamps above the mine plan are not classified as Temperate Highland Peat Swamps on Sandstone (which is high priority GDE). There are no water supply works (i.e. groundwater bores) in the Wonga East proposal area that will undergo more than a 2m decline.
Water Table – Level 2 If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: c) high priority groundwater dependent ecosystem, or d) high priority culturally significant site listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than 2m decline cumulatively at any water supply work then make good provisions should apply.	Level 2 does not apply as Level 1 criteria is not exceeded
Water Pressure – Level 1 A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work.	There are no water supply works (i.e. groundwater bores) in the Wonga East proposal area that will undergo a greater than 40% post water sharing plan pressure head decline above the base of the water source, and no water supply work will undergo greater than 2m decline
Water Pressure – Level 2 If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	Level 2 does not apply as Level 1 criteria is not exceeded
Water Quality – Level 1 d) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity;	The beneficial use category of the groundwater source will not be changed beyond 40m from the Wonga East proposal

and e) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a "reliable water supply" is not an appropriate mitigation measure to meet considerations 1(a) and 1(b) above. f) No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply".	area. There are no highly connected surface water sources (alluvial aquifers) in the Wonga East proposal area There are no highly connected alluvial surface water sources defined as a reliable water supply within the Wonga East proposal area
Water Quality – Level 2 If condition 1(a) is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works. If condition 1(b) is not met then appropriate studies are required to demonstrate to the Minister's satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity. Condition 1(c) does not apply as there are no river bank or high wall instability risks and no need for low permeability barriers between the site and highly connected surface waters	Level 2 does not apply as Level 1 is not exceeded

16. MONITORING, CONTINGENCY MEASURES & REPORTING

Wollongong Coal will prepare a Water Management Plan in accordance with conditions of Project Approval.

The Water Management Plan will include a groundwater monitoring program, which will include monitoring of groundwater levels, water quality, pumping volumes and stream flows.

The ongoing collection and interpretation of the data will be used to update the TARP trigger levels and the groundwater model, as required.

16.1 Groundwater Levels

Piezometers to be included in the monitoring suite are shown in **Table 18**.

The suite is divided into standpipe and vibrating wire piezometers, with water level transducers and vibrating wire piezometers used to monitor standing water levels or pressure heads twice daily to assess variations in the colluvial and basement formations.

Table 18 Groundwater Level Monitoring Suite

	Piezometer Type
Basement	
NREA, C, D, E, G, NRE3, GW1A	Open Standpipe
NREA, B, D, NRE3, GW1	VWP

NOTE: VWP = vibrating wire piezometer

Inclusion of additional groundwater monitoring locations and depths will be incorporated, if required, following discussions with the SCA and NOW.

Monitoring will also involve bi-monthly manual standing water level measurement in all open standpipe piezometers, at which time the loggers will be downloaded and re-initiated as shown in **Table 19**.

Table 19 Standing Water Level Monitoring Method and Frequency

Monitoring Site	Sampling Method	Frequency / Download	Units
NREA, C, D, E, G, NRE3, GW1A	Water level logger / dip meter	twice daily / bi-monthly	mbgl
NREA, B, D, NRE3, GW1A	Vibrating wire piezometer	twice daily / quarterly	m head pressure
SP1, SP2	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PL1A, B PL18, PL25A, B, C, D	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PW1, 4, 11	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PCc2, 3, 4, 5A, 5B, 6	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PCr1	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PB4	Water level logger / dip meter	twice daily / bi-monthly	mbgl

NOTE: mbgl = meters below ground level

16.2 Groundwater Quality

Tables 20 and **21** present the parameters to be measured, frequency of monitoring and sampling method for groundwater quality monitoring, with monitoring to continue for 12 months after mining has ceased.

Table 20 Groundwater Quality Monitoring Parameters

ANALYTES	Units	FREQUENCY
EC, pH	µS/cm, pH units	Bi - monthly
(EC, pH) + TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P, hardness, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd (metals filtered)	mg/L	Start / finish of panel for piezometers adjacent to a panel, or in an active mining area, otherwise 1 sample per year

The frequency of monitoring will be reassessed after mining is complete as it may be possible, depending on results, to lengthen the intervals. The frequency of monitoring and the parameters to be monitored may be varied by NOW once the variability of the groundwater quality is established.

Groundwater samples should be collected at the start and finish of each panel from piezometers either adjacent to an active panel, or within an active mining area and analysed at a NATA registered laboratory for major ions and selected metals. Piezometers not within an active mining area should be sampled and analysed once per year.

It is anticipated that the groundwater monitoring program will be maintained in its current status, with possible modification of the program at the end of each panel after a review of all monitoring data has been conducted.

Additional piezometers may be added to the existing suite if required.

The groundwater monitoring program is anticipated to be extended beyond the active mining period in order to assess the potential long term change in groundwater level recovery and quality changes for 12 months after completion of mining.

Table 21 Groundwater Quality Monitoring Method and Frequency

Monitoring Site	Sampling Method	Frequency
Open Standpipe Piezometers	Pumped field meter readings	Bi-monthly
Open Standpipe Piezometers	Pumped sample for laboratory analysis	Start / finish of each panel for piezometers adjacent to a panel or in an active mining area, otherwise 1 sample per year

16.3 Surface Water and Groundwater Connectivity

The potential for surface water and groundwater system hydraulic connectivity will be assessed through monitoring of stream flows in and near actively mined areas, as outlined in Geoterra (2012) as well as through monitoring and interpretation of the basement groundwater open standpipe and vibrating wire piezometers water levels / pressures and mine inflow changes.

16.4 Mine Water Pumping

The volume of water pumped into and out of the Russell Vale Colliery workings will be monitored daily to enable the differential groundwater seepage into the workings to be assessed.

In addition, completion of the pump calibration tests, ongoing QA / QC and regular assessment of the pumping data will be required to enable reliable assessment of mine groundwater make due to extraction of the proposed workings.

16.5 Ground Survey

The ground surface over the proposed underground workings will be surveyed in accordance with the Extraction Plan (to be prepared in accordance with the conditions of Project Approval).

16.6 Rainfall

Daily rainfall data will be obtained from a local weather station for the duration of mining in the proposal catchment area.

16.7 Ongoing Monitoring

All results will be reviewed after each panel is completed and an updated monitoring and remediation program will be developed, if required, in consultation with NOW and DRE.

16.8 Quality Assurance and Control

QA/QC should be attained by calibrating all measuring equipment, ensuring that sampling equipment is suitable for the intended purpose, using NATA registered laboratories for chemical analyses and ensuring that site inspections and reporting follow procedures outlined in the ANZECC 2000 Guidelines for Water Quality Monitoring and Reporting.

16.9 Impact Assessment Criteria

16.9.1 Groundwater Levels

Impact assessment criteria investigation trigger levels should be initially set where a groundwater level reduction exceeds more than 10% of the saturated aquifer thickness over a 12 month period, compared to the minimum height within the last 12 months of data, excluding any short term recharge peaks. Should the trigger be exceeded, the actual rate of change of water levels should be investigated to determine whether the change is solely subsidence induced or due to a range of other potential factors.

If a significant increase in the rate of water level decline is noted, based on interpretation by a qualified hydrogeologist, then an assessment should be conducted to determine the cause of the change (such as variation in climate or effects from adjacent mining operations) and to consider potential contingency measures that may be adopted.

16.9.2 Groundwater Quality

Groundwater quality impact assessment criteria are sourced from the Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC, 2000) for Aquatic Ecosystems as shown in **Table 22.**

Table 22 Groundwater Quality Impact Assessment Criteria

Indicator	Irrigation Criteria
pH	<6.5 or >7.5 or >10% variation over 4 months compared to previous 12 months data
Conductivity	>10% variation over 4 months compared to previous 12 months data
TDS	>350mg/L or >10% variation compared to previous 12 months data
Total Nitrogen	>250µg/L or >10% variation compared to previous 12 months data
Total Phosphorus	>20µg/L or >10% variation compared to previous 12 months data

A trigger to assess the cause and effects of adverse groundwater quality changes should be implemented when there is a prolonged and extended non-conformance of the outlined criteria at a particular piezometer. If a field parameter (pH, conductivity) is outside the designated criteria for at least six months in a sequence, or alternatively, exceeds its previous range of results by greater than a 10% variation for at least 4 months, then the cause should be investigated, and a remediation strategy should be proposed, if warranted.

The criteria and triggers should be reviewed after each 12 month block of data is interpreted and may be modified as appropriate, depending on the results.

If the impacts on the groundwater system resulting from future underground operations are demonstrated to be greater than anticipated, the proponent should:

- assess the significance of these impacts;
- investigate measures to minimise these impacts; and
- describe what measures would be implemented to reduce, minimise, mitigate or remediate these impacts in the future to the satisfaction of the Director-General, NOW and the Sydney Catchment Authority.

16.10 Contingency Procedures

Contingency procedures should be developed as required, with the measures to be developed being dependent on the issue that requires addressing.

The procedures should be used to manage any impacts identified by monitoring that demonstrate the groundwater management strategies may not have adequately predicted or managed the groundwater system's anticipated response to mining.

Activation of contingency procedures should be linked to the assessment of monitoring results, including water quality, aquifer hydrostatic pressure levels and the rate of water level changes.

Performance indicators should be identified prior to extraction of the proposed underground workings and a statistical assessment should be undertaken to detect when, or if, a significant change has occurred in the groundwater system which should benchmark the natural variation in groundwater quality and standing water levels.

A monitoring and management strategy along with an outline of a Trigger Action Response Plan (TARP) should be prepared to provide guidance on the procedures and actions required in regard to the surface water and groundwater systems in the proposed mining area.

16.11 Piezometer Maintenance and Installation

The current network should be maintained by protecting the wellhead from damage by animals and scrub fires by maintaining their steel sealed wellheads.

If required, the piezometers may be cleaned out by air sparging if they become clogged.

In the event that any new piezometers are required, they should be installed by suitably licensed drillers after obtaining the approvals from the SCA and NOW.

16.12 Reporting

Following completion of extraction of each panel, a report should be prepared for all prior panels that summarises all relevant monitoring to date. The report should outline any changes in the groundwater system over the relevant mining area.

The report should contain an interpretation of the data along with:

- a basic statistical analysis (mean, range, variance, standard deviation) of the results for the parameters measured;
- an interpretation of water quality and standing water level changes supported with graphs or contour plots; and

- an interpretation and review of the results in relation to the impact assessment criteria.

Relevant monitoring and management activities for each year should also be reported in the AEMR.

16.13 Adaptive Management

The proponent has committed to developing a valley closure based trigger system for managing impacts on the creek with the exact values to be determined based on the best available predictive models and assessment of existing closure data from LW 4 & 5. This will be undertaken in liaison with regulators as part of the development of management plans for Cataract Creek.

An adaptive management plan should be developed to use the monitoring program to detect the need for adjustment to the mining operation so that the subsidence predictions are not exceeded and so that subsidence impacts creating a risk of negative environmental consequences do not occur.

The adaptive management procedures should be implemented to provide a systematic process for continually detecting impacts, validating predictions and improving mining operations to prevent further adverse impacts on the swamp and basement groundwater systems overlying the proposed mining domains.

Monitoring, evaluation, and reporting on management performance and ecological impact should be integrated into the site's core management systems to progress the technical understanding and predictive capability of subsidence effects, impacts and consequences on surface water systems.

An evidence-based approach should be used to validate the extent to which outcomes are being achieved, with the monitoring results being related to, and demonstrating how management strategies have been achieved or where improvements can be made.

As Longwalls 6 to 11 are planned to be mined first, and as they do not overlie the main channel or significant tributaries of Cataract Creek, they would provide a "baseline" monitoring opportunity to assess the effect of subsidence on fracture propogation and development through the overburden, height of fracturing, development of cracking at surface, changes to an upland swamp perched water system (Crus1) as well as flow and water quality in Cataract Creek and any changes in mine inflows.

Data gained from monitoring a suite of extensometers, vibrating wire piezometer arrays and open standpipe piezometers as well as geochemical monitoring of groundwater and surface water and stream flow regimes over the panels would then be able to be used to update the current geotechnical, hydrogeological and hydrological assessments for the proposed mining and to incorporate, if required, adaptive management measures for future panels.

Additional groundwater related monitoring that could be used to enhance the adaptive management process may include:

- continuation of the existing mine water pump monitoring and updating the mine water balance;
- additional drilling, with a range of vibrating wire piezometers and core testing to establish the mechanical and hydraulic properties of the overburden in proximity to

water dependent systems in the catchments (including swamps);
- installation of additional deep vibrating wire piezometers and extensiometers to assess/quantify the impacts of fracturing within the subsidence zone;
- installation of paired shallow piezometers (where appropriate) targeting swamps and the underlying shallow Hawkesbury Sandstone aquifer to assess their hydraulic connection and climatic implications;
- sediment profiling in swamps to characterise type, thickness and sensitivity to differential subsidence; and
- updating of the numerical modelling when sufficient additional data becomes available to enhance the prediction of subsidence zone fracture distributions, connectivity and groundwater transmissivity capacities.

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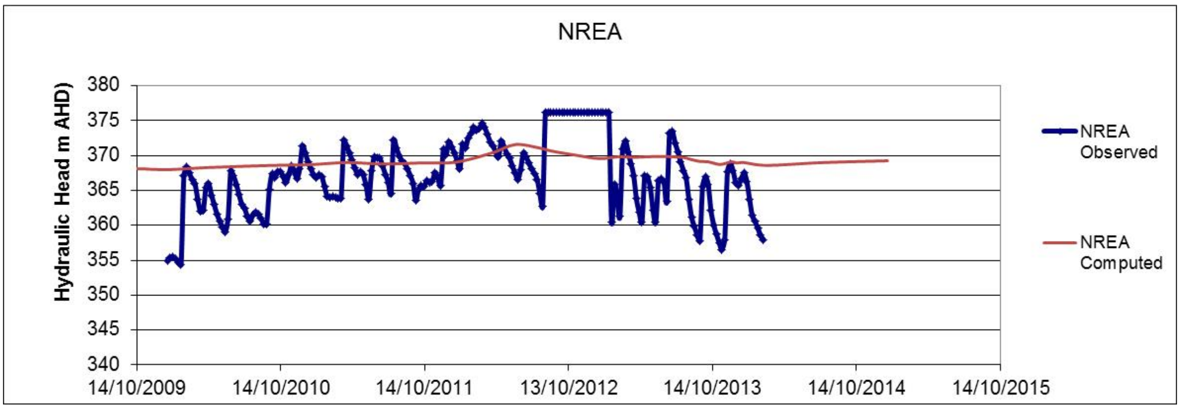
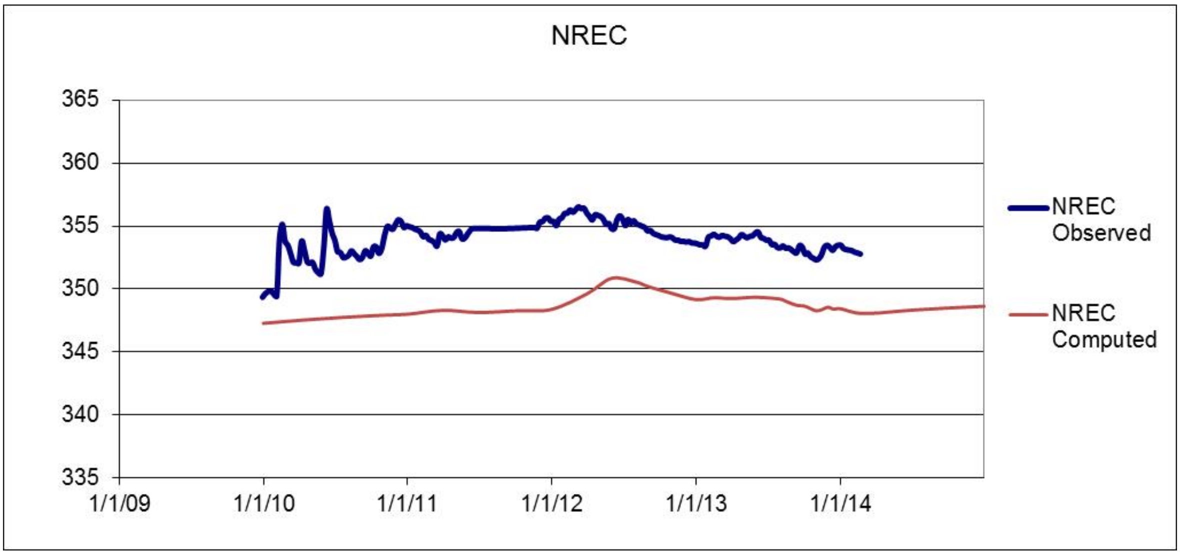
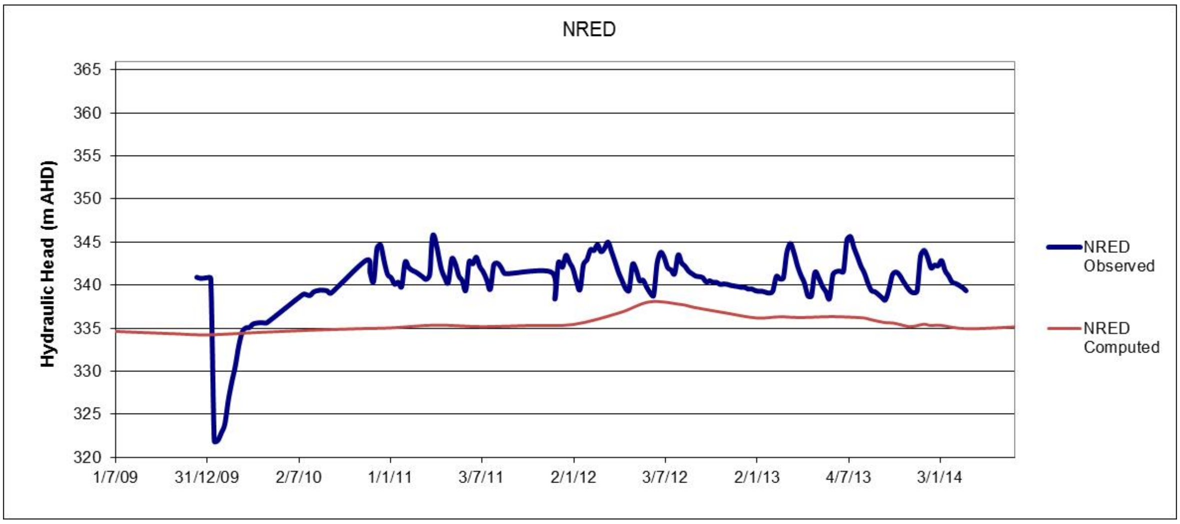
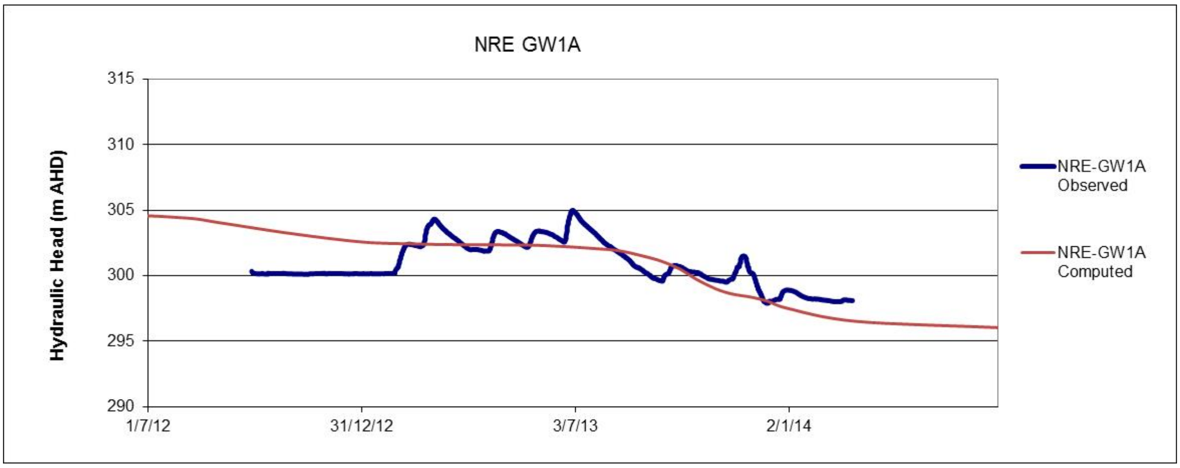
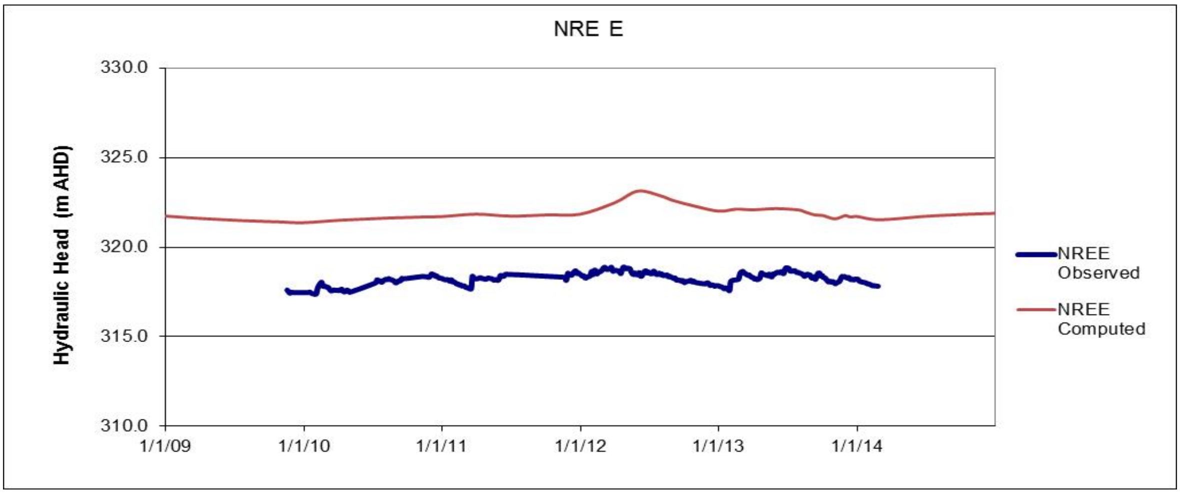
Appendix A
Piezometer Water Level Calibration Graphs

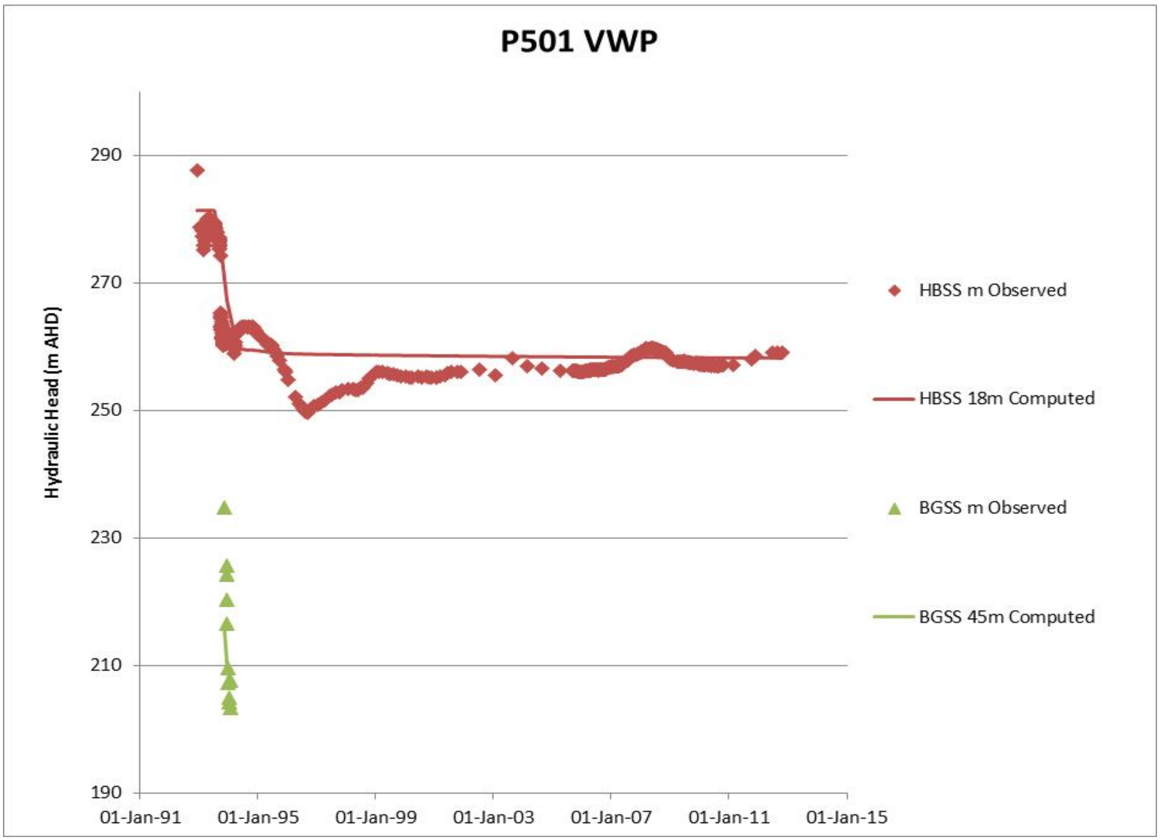

NREA
Hydraulic Head m AHD)
380
375
370
365
360
355
350
345
340
14/10/2009
14/10/2010
14/10/2011
13/10/2012
14/10/2013
14/10/2014
14/10/2015
NREA Observed
NREA Computed


NREC
365
360
355
350
345
340
335
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14
NREC Observed
NREC Computed


NRED
Hydraulic Head (m AHD)
365
360
355
350
345
340
335
330
325
320
1/7/09
31/12/09
2/7/10
1/1/11
3/7/11
2/1/12
3/7/12
2/1/13
4/7/13
3/1/14
NRED Observed
NRED Computed


NRE GW1A
Hydraulic Head (m AHD)
315
310
305
300
295
290
1/7/12
31/12/12
3/7/13
2/1/14
NRE-GW1A Observed
NRE-GW1A Computed


NRE E
Hydraulic Head (m AHD)
330.0
325.0
320.0
315.0
310.0
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14
NREE Observed
NREE Computed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Hydraulic Head (m AHD)
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210
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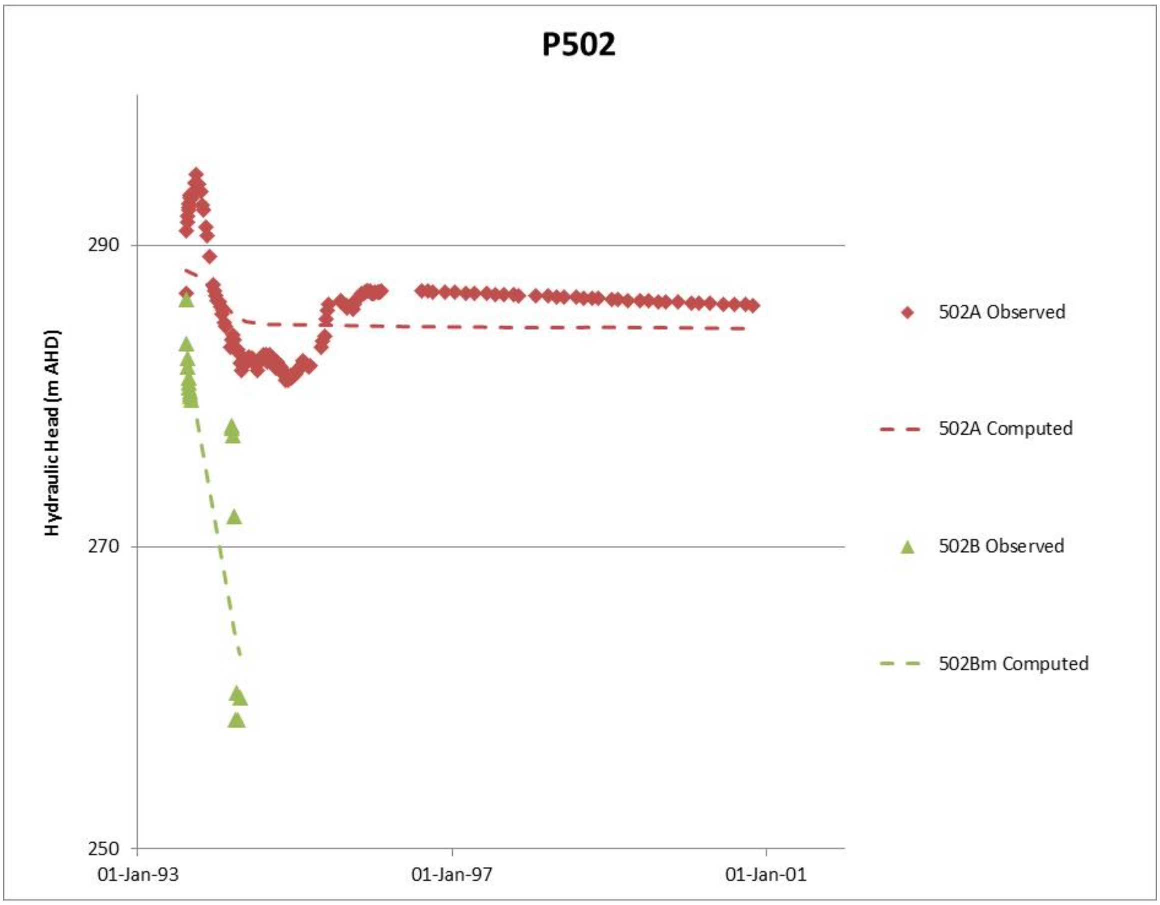
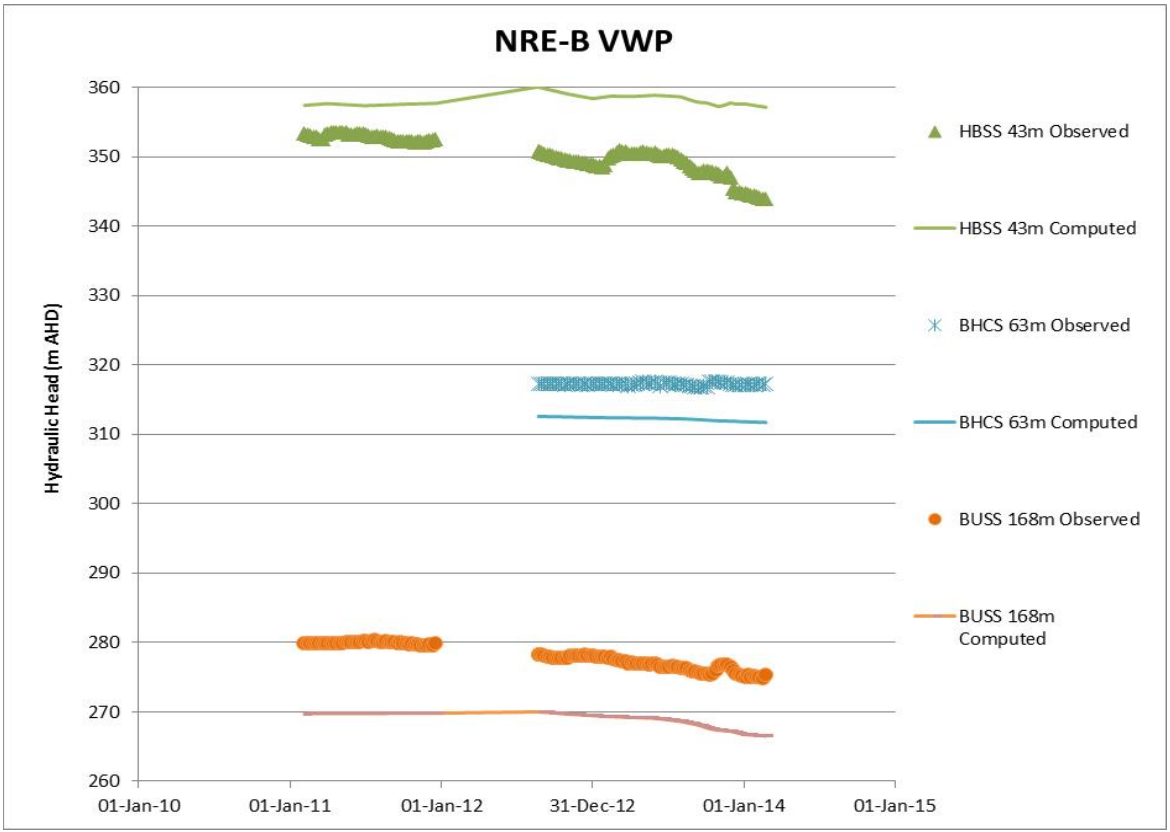
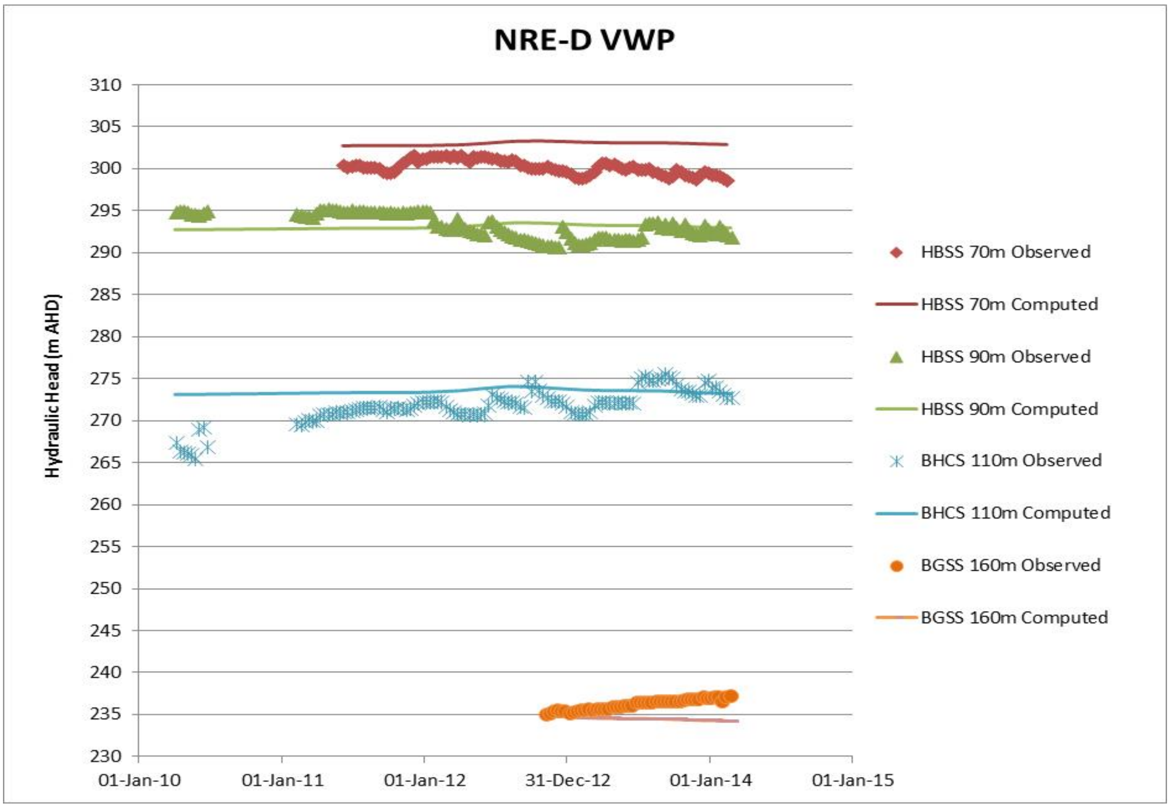
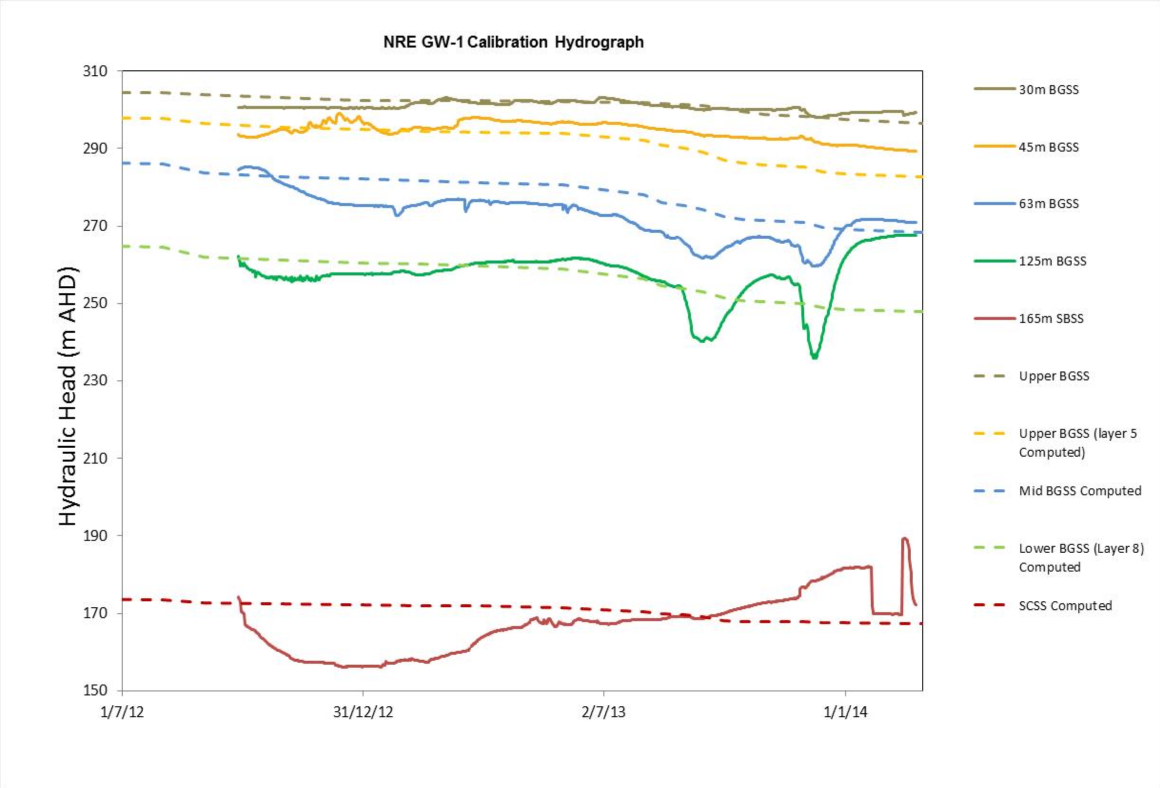
01-Jan-91
01-Jan-95
01-Jan-99
01-Jan-03
01-Jan-07
01-Jan-11
01-Jan-15
HBSS m Observed
HBSS 18m Computed
BGSS m Observed
BGSS 45m Computed


P502
Hydraulic Head (m AHD)
290
270
250
01-Jan-93
01-Jan-97
01-Jan-01
502A Observed
502A Computed
502B Observed
502Bm Computed


NRE-B VWP
Hydraulic Head (m AHD)
360
350
340
330
320
310
300
290
280
270
260
01-Jan-10
01-Jan-11
01-Jan-12
31-Dec-12
01-Jan-14
01-Jan-15
HBSS 43m Observed
HBSS 43m Computed
BHCS 63m Observed
BHCS 63m Computed
BUSS 168m Observed
BUSS 168m Computed


NRE-D VWP
Hydraulic Head (m AHD)
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
235
230
01-Jan-10
01-Jan-11
01-Jan-12
31-Dec-12
01-Jan-14
01-Jan-15
HBSS 70m Observed
HBSS 70m Computed
HBSS 90m Observed
HBSS 90m Computed
BHCS 110m Observed
BHCS 110m Computed
BGSS 160m Observed
BGSS 160m Computed


NRE GW-1 Calibration Hydrograph
Hydraulic Head (m AHD)
310
290
270
250
230
210
190
170
150
1/7/12
31/12/12
2/7/13
1/1/14
30m BGSS
45m BGSS
63m BGSS
125m BGSS
165m SBSS
Upper BGSS
Upper BGSS (layer 5 Computed)
Mid BGSS Computed
Lower BGSS (Layer 8) Computed
SCSS Computed

Appendix B
IESC Significance Guidelines Response

EPBC Significant Impact Criteria Response

Criteria	Proponent's Response
Hydrological Characteristics	
Will the proposal change the water quantity, including the timing of variations in water quantity	A maximum "take" of 620 ML/year is predicted from the combined surface water system associated with the proposed Wonga East extraction
Will the proposal change the integrity of hydrological or hydrogeological connections, including substantial structural damage (e.g. large scale subsidence)	Yes
Will the proposal change the area or extent of a water resource	No
Water Quality	
Is there a risk that the ability to achieve relevant local or regional water quality objectives will be materially compromised	No
Will the proposal create risks to human or animal health or to the condition of the natural environment as a result of the change in water quality	No risks to human or animal health, or adverse effects on upland swamps due to change in water quality
Will the proposal substantially reduce the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality	No observable reduction in water quality available for human consumption, other uses, or environmental use is predicted
Will the proposal cause persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment	No
Will the proposal seriously affect the habitat or lifecycle of a native species dependent on a water resource	No serious effect on the habitat or lifecycle of a native species dependent on a water resource is predicted in the streams. Vegetation in upland swamp CCUS4 may be affected directly overlying the subsided workings
Is there predicted significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives	No
Will high quality water be released into an ecosystem which is adapted to a lower quality of water	No

GeoTerra

Groundwater Exploration Services

WOLLONGONG COAL LTD

RUSSELL VALE COLLIERY UNDERGROUND EXPANSION PROJECT LONGWALL 6 (400m Extraction) WONGA EAST GROUNDWATER ASSESSMENT ADDENDUM

Bellambi, NSW

NRE8 – R1A GW_LW6

Addendum

19 JUNE, 2014

NRE8-R1A GW_ LW6 (19 JUNE, 2014)

GeoTerra / GES

Wollongong Coal Ltd
PO Box 281
Fairy Meadow NSW 2519

Attention: Dave Clarkson

Dave,

RE: Russell Vale Colliery – Underground Expansion Project, Longwall 6 (400m Extraction), Wonga East Groundwater Assessment Addendum

Please find enclosed a copy of the above mentioned report.

Yours Faithfully

GeoTerra Pty Ltd	**GES Pty Ltd**
Andrew Dawkins	**Andy Fulton**
Principal Hydrogeologist (MAusIMM CP-Env)	Principal Hydrogeologist

Distribution:	Original	Geoterra Pty Ltd / GES Pty Ltd
	1 electronic PDF copy	Wollongong Coal Ltd
	1 electronic copy	Hansen Bailey / HydroSimulations

Authorised on behalf of Geoterra Pty Ltd / GES Pty Ltd:	
Name:	Andrew Dawkins / Andy Fulton
Signature:	
Position:	Principal Hydrogeologist / Principal Hydrogeologist

Date	Rev	Comments
2/06/2014		Draft
19/6/2014	A	Incorporate Review Comments

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FIGURES

TABLES

1. INTRODUCTION

Wollongong Coal Limited (WCL) has made a modification application under section 75W of the *Environmental Planning and Assessment Act 1979*. WCL has sought a modification of Project Approval 10_0046 to facilitate extraction of a 400 m length of Longwall 6 (LW6).

This modification application was supported by *Environment Assessment: Russell Vale Colliery Commencement of Long Wall 6* (AECOM, 2014). The purpose of this addendum is to support the modification application by assessing the potential impacts on groundwater systems and connected surface water systems.

This addendum has been prepared as an extract of the findings of a larger assessment (Geoterra / GES, 2014) of the potential effects on the local groundwater and surface water systems resulting from the Underground Expansion Project (UEP). The UEP involves the proposed extraction of Longwalls 1 to 3, 6, 7 and 9 to 11 in the Wongawilli Seam at Wonga East.

The findings summarised in the following sections are based on groundwater modelling conducted for the revised groundwater assessment associated with the Preferred Project Report (PPR) for the Russell Vale Colliery Underground Expansion Project (UEP).

This addendum assesses the potential changes to the groundwater and connected surface water systems associated with the proposed longwall extraction of the first 400m of Longwall 6 from the Wongawilli Seam in the Wonga East mining domain as shown in **Figure 1**.

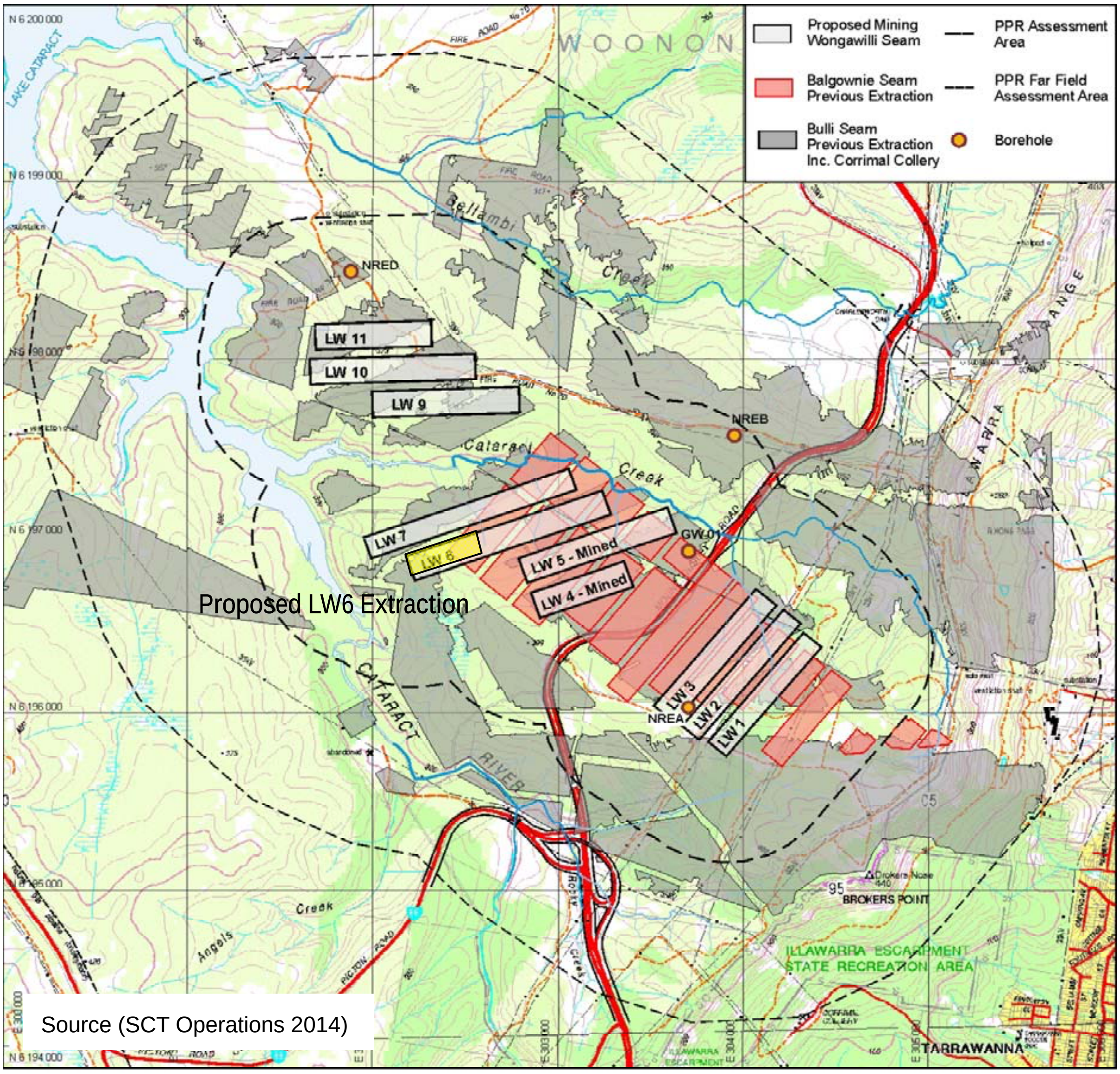

Figure 1 Wonga East Historic and Proposed Mining of LW6 (400m)

This addendum should be read in association with the full groundwater assessment conducted for the PPR (Geoterra / GES, 2014).

The following predictions have been extracted from transient modelling of the entire PPR assessment groundwater model, at a stage where 450m of Longwall 6 is planned to be mined.

Although the 450m "extract" from the model does not exactly correlate to 400m of mining proposed in the Longwall 6 application to the Department of Planning and Environment (DPE), this assessment therefore represents a conservative estimation of the potential effects due to the proposed 400m of mining.

This approach was used as it was expedient to utilise the existing transient stages in the overall PPR model, rather than setting up and running the model again as a separate exercise for exactly 400m of mining in Longwall 6.

2. MODEL OUTPUTS

2.1 Strata Depressurisation

The depressurisation of Layer 1 associated with the extraction of 400m of Longwall 6 is shown in **Figure 2**.

Layer 1 represents the Hawkesbury Sandstone on the hillslopes as well as the underlying Newport / Garie formation, the Bald Hill Claystone and Upper Bulgo Sandstone where they are exposed in the bed of Cataract Creek.

The maximum depressurisation is predicted to occur in 2020. The maximum depressurisation of Layer 1 is predicted to be 1m.

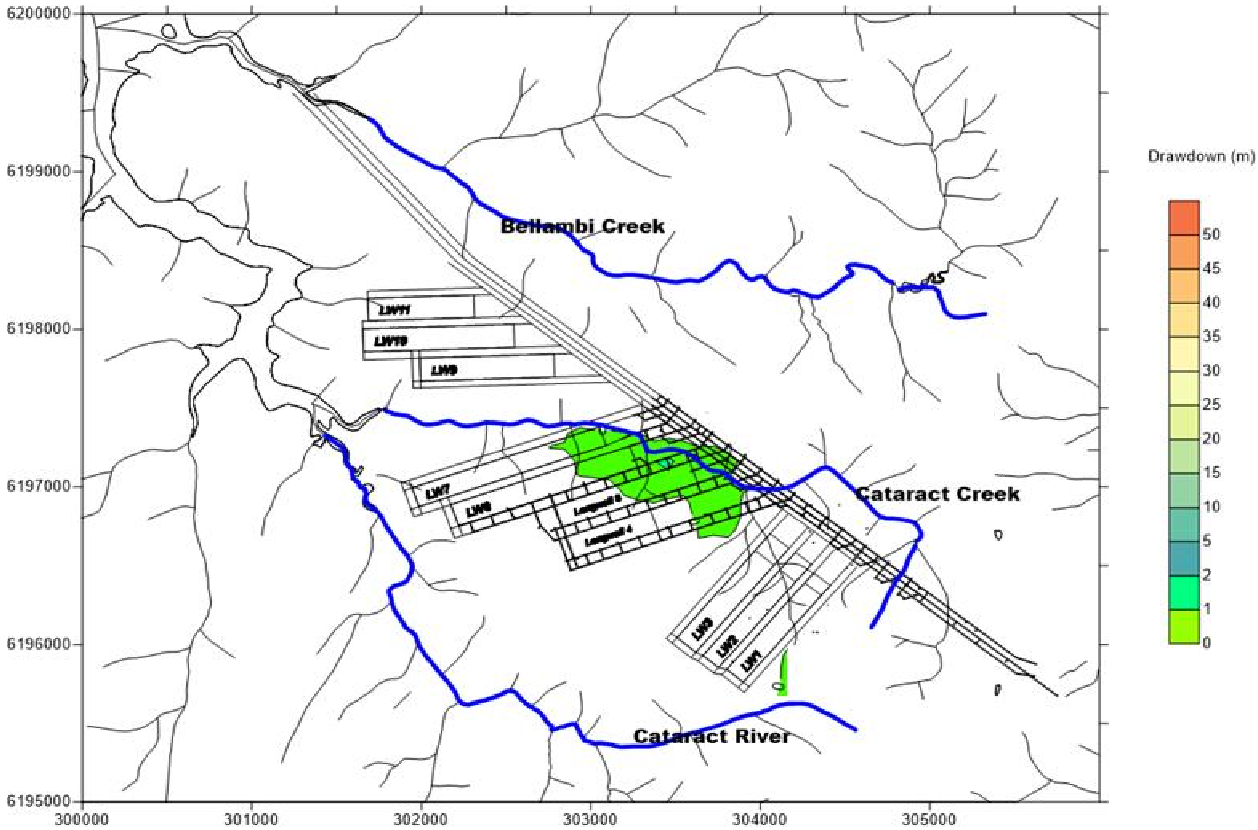

Figure 2 Layer 1 Depressurisation Associated with the Proposed Mining of LW6 (400m)

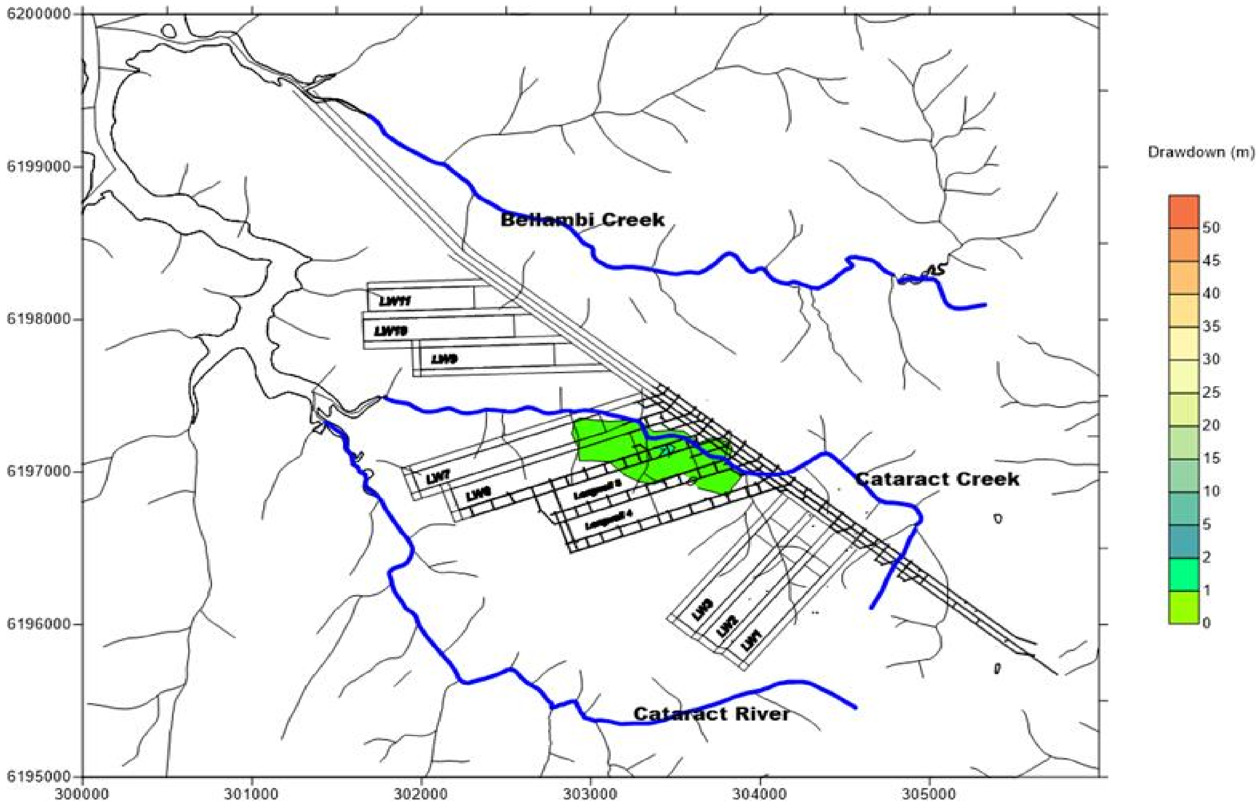

Figure 3 Layer 1 Depressurisation Associated with the Proposed Mining of LW6 (400m) at 2020

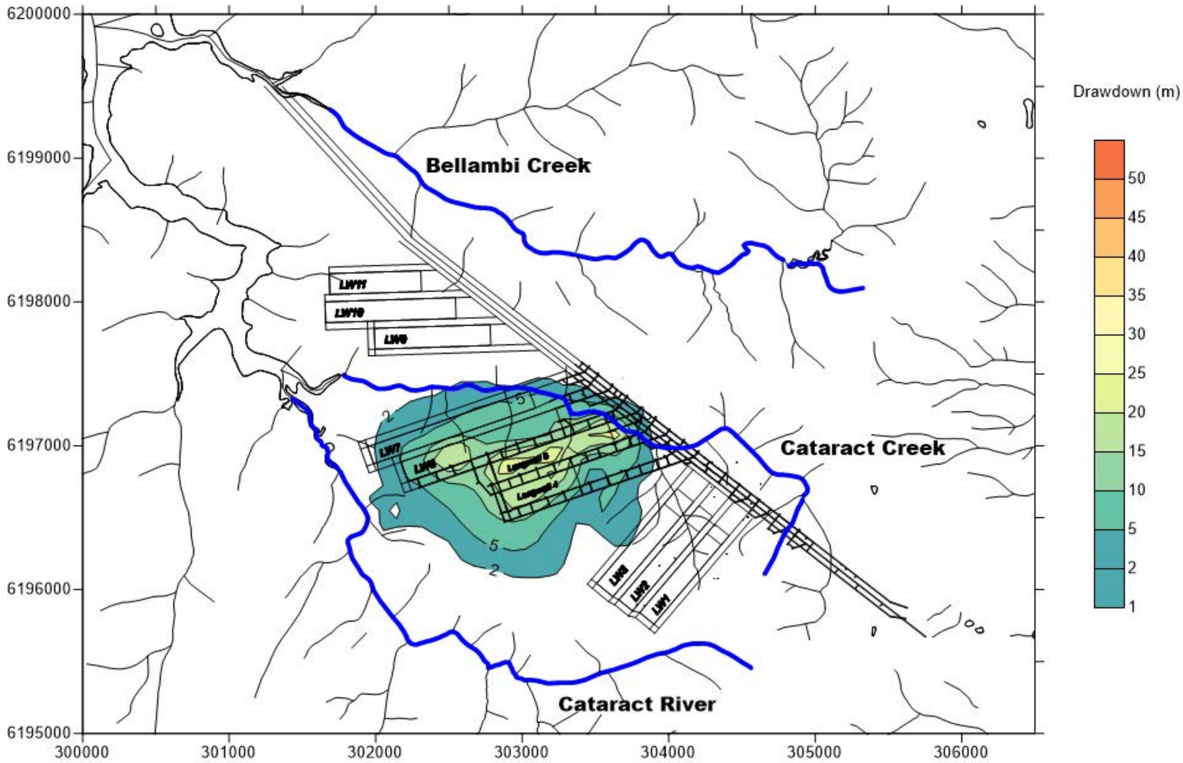

Figure 4 **Layer 3 Depressurisation Associated with the Proposed Mining of LW6 (400m)**

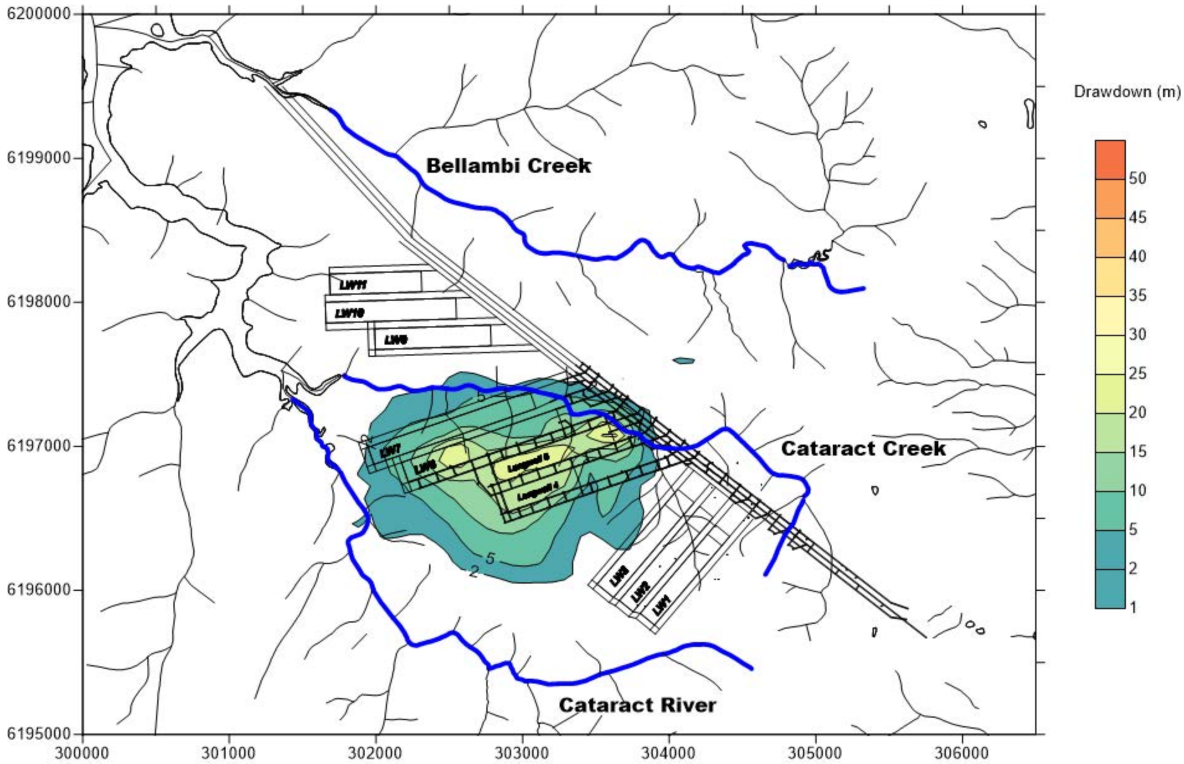

Figure 5 **Layer 3 Depressurisation Associated with the Proposed Mining of LW6 (400m) at 2020**

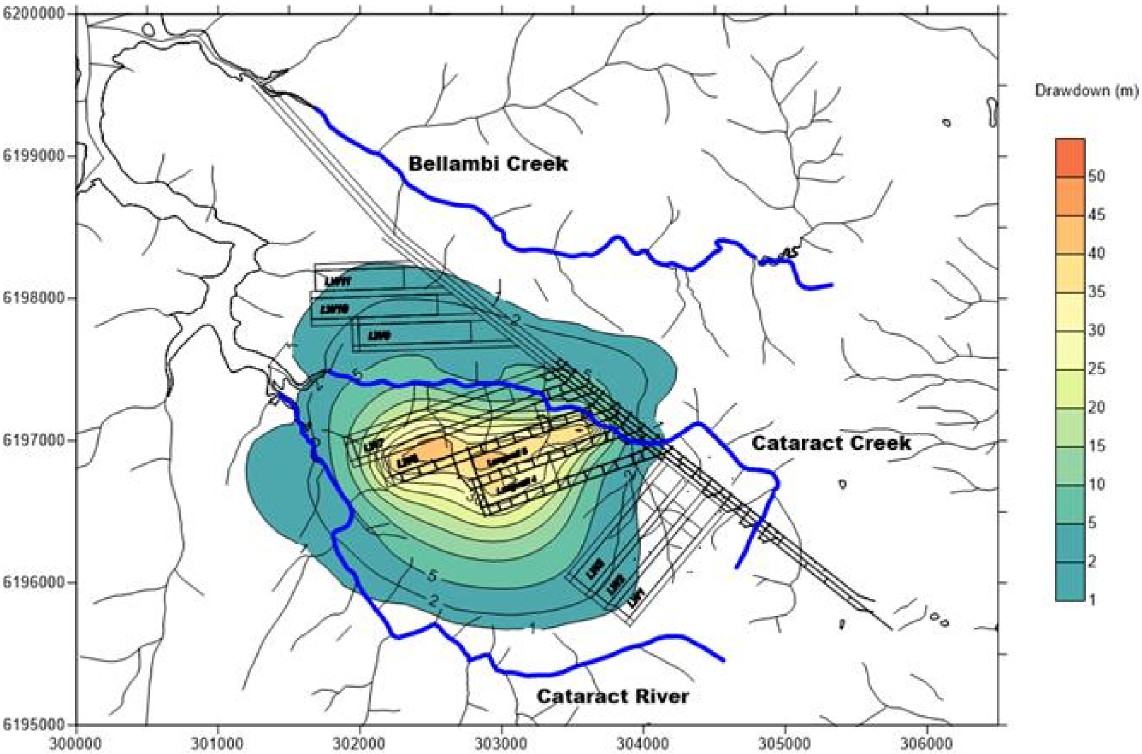

Figure 6 Upper Bulgo Sandstone Depressurisation Associated with the Proposed Mining of LW6 (400m)

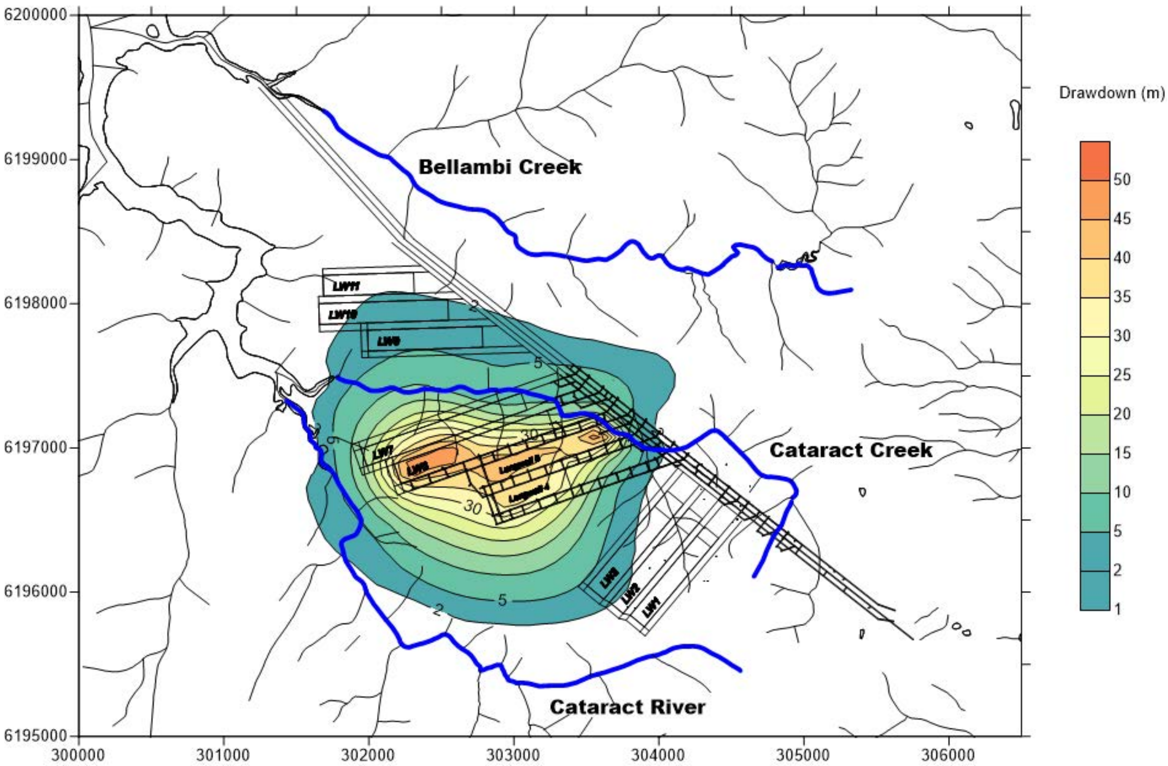

Figure 7 Upper Bulgo Sandstone Depressurisation Associated with the Proposed Mining of LW6 (400m) at 2020

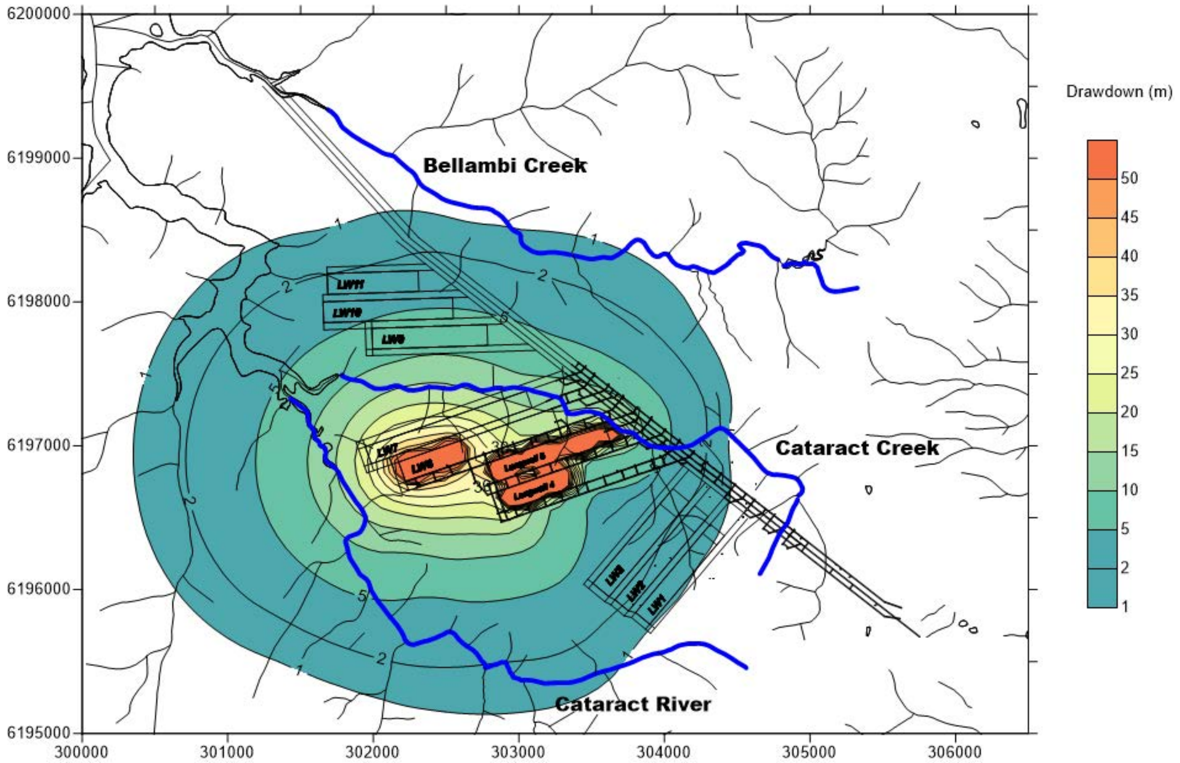

Figure 8 **Scarborough Sandstone Depressurisation Associated with the Proposed Mining of LW6 (400m)**

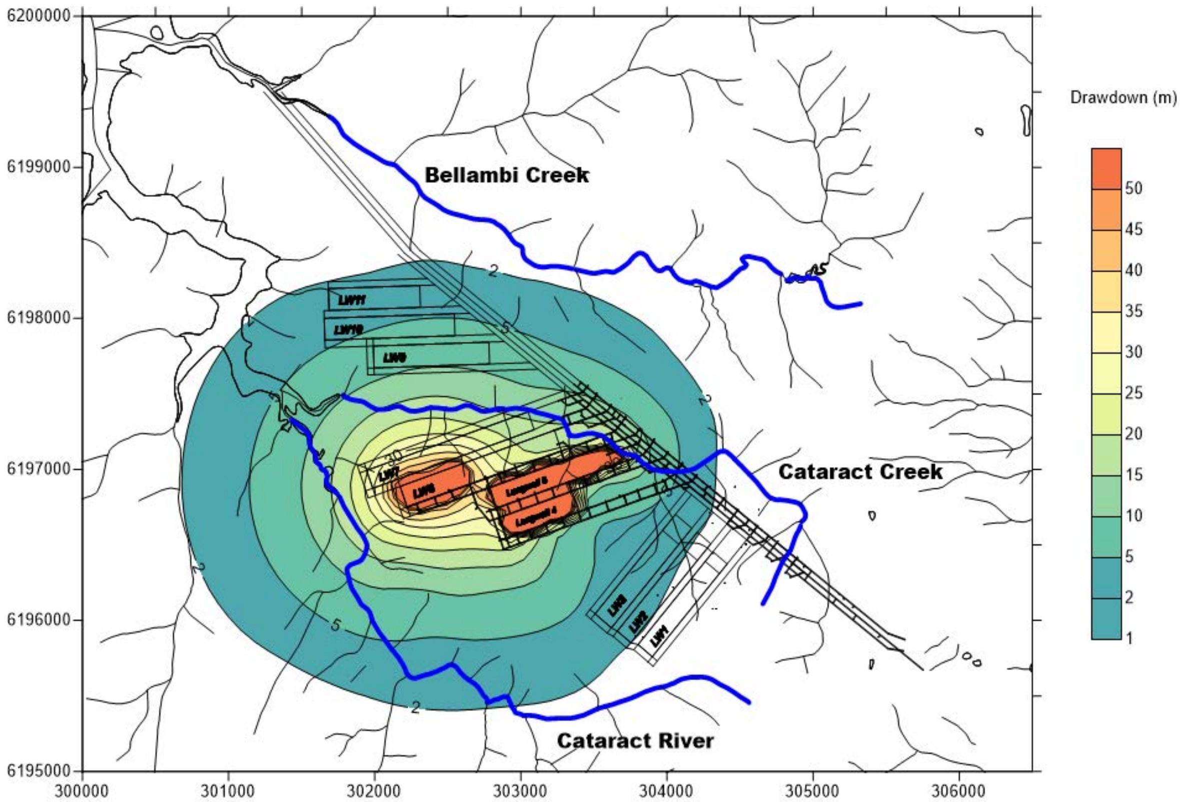

Figure 9 **Scarborough Sandstone Depressurisation Associated with the Proposed Mining of LW6 (400m) at 2020**

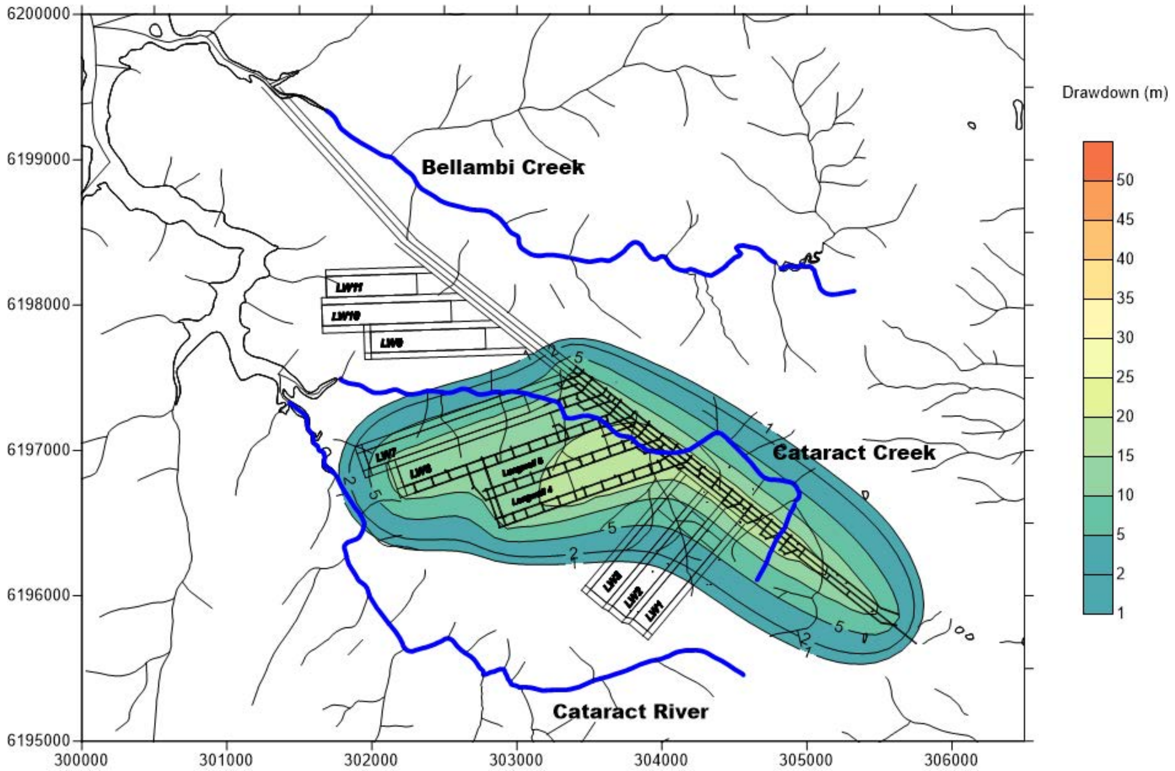

Figure 10 **Wongawilli Seam Depressurisation Associated with the Proposed Mining of LW6 (400m)**

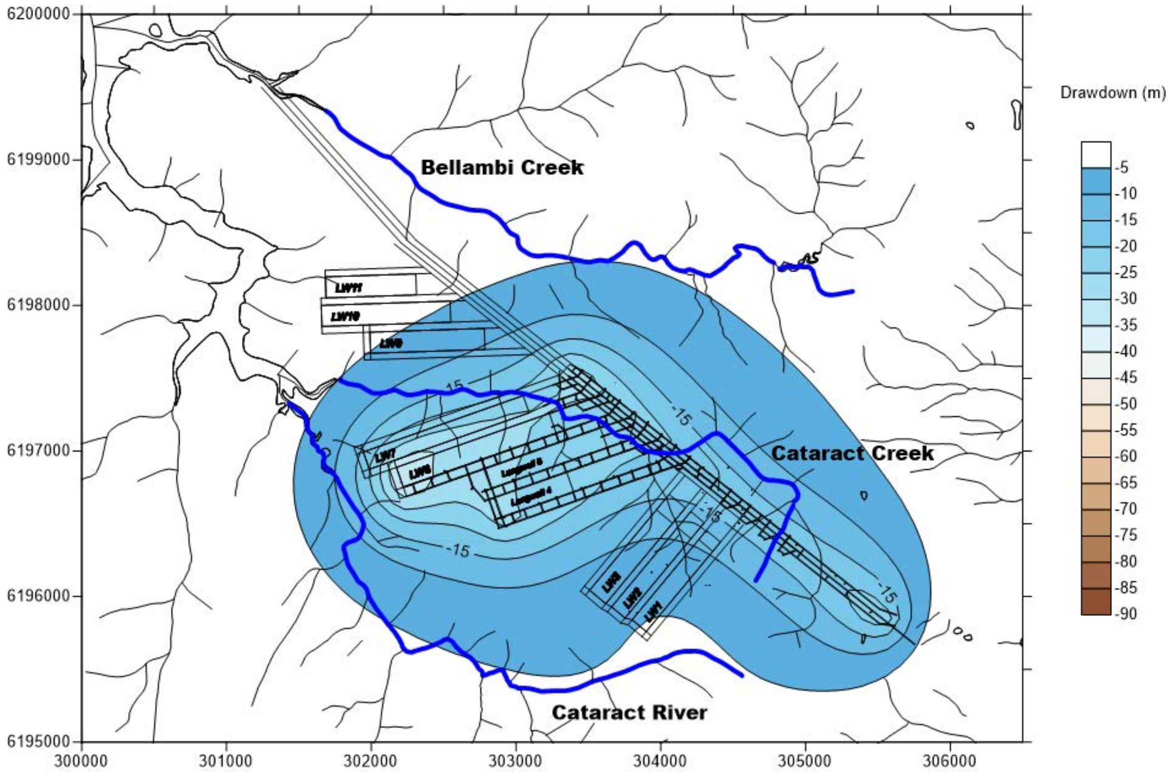

Figure 11 **Wongawilli Seam Depressurisation Associated with the Proposed Mining of LW6 (400m) at 2020**

2.2 Mine Groundwater Inflow

The predicted modelled inflow to the proposed workings for each stage is shown in **Table 1** and **Figure 12**.

Table 1 Predicted Groundwater Mine Inflow Associated with Longwall 6 (400m)

Stage	Measured Inflow (ML/day)	Predicted Inflow (ML/day)	Predicted Inflow (ML/year)
Pre Longwall 4	n/a	0.63	230
Post Longwall 5	1.05	1.10	402
Post Longwall 6 (400m)	-	0.80	292

The rate of inflow to the workings due to the proposed 400m of extraction of Longwall 6 in the Wongawilli Seam is predicted to reduce from the current 1.05ML/day (383.3 ML/year) to 0.8 ML/day (292 ML/year). It should be noted, however, that 72ML/year of this inflow is sourced from upgradient seepage out of adjoining decommissioned workngs.

Pre-drainage of the LW6 footprint occurs during develoment of LW6 development headings which occurred in parallel with LW5.

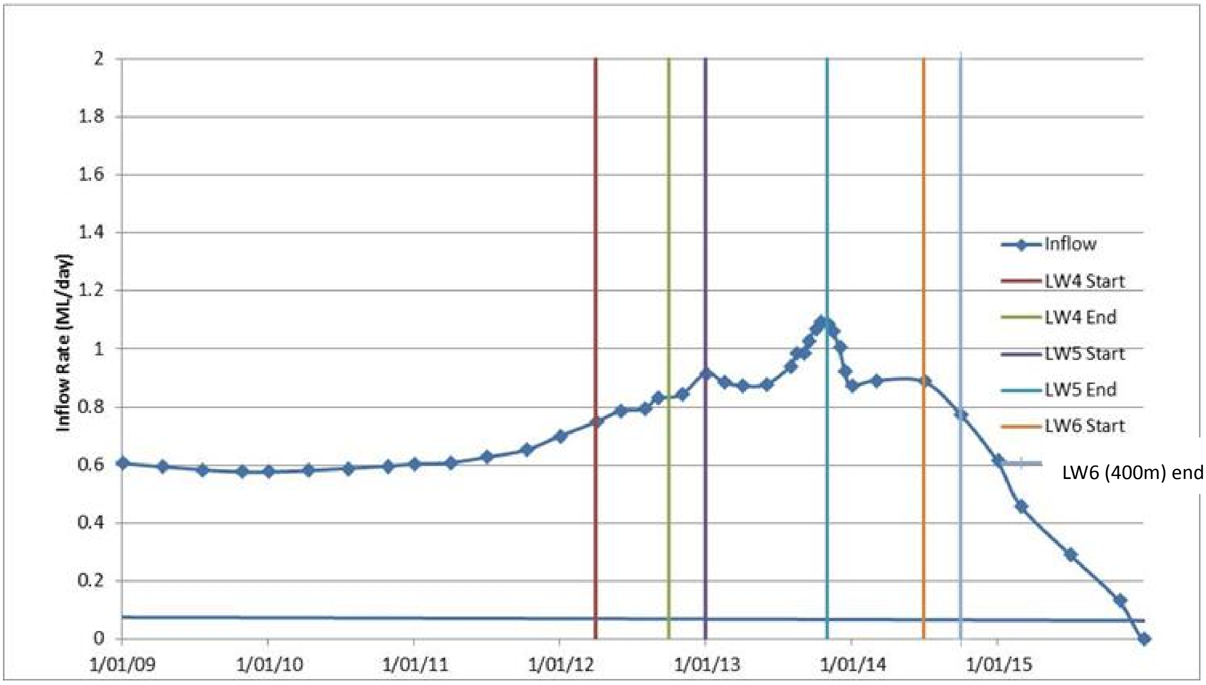

Figure 12 Longwall 6 (400m) Modelled Mine Groundwater Inflows

The modelled seepage rates into the workings may be enhanced if unidentified fracture related storages are intercepted, which may lead to short term increases of potentially up to 0.1 - 0.5ML/day which should dissipate over a period of weeks to months.

2.3 Upland Swamps

The first 400m of extraction in Longwall 6 is proposed to undermine the northern periphery of swamp CRUS1 and the western edge of CCUS4 as shown in **Figure 13**.

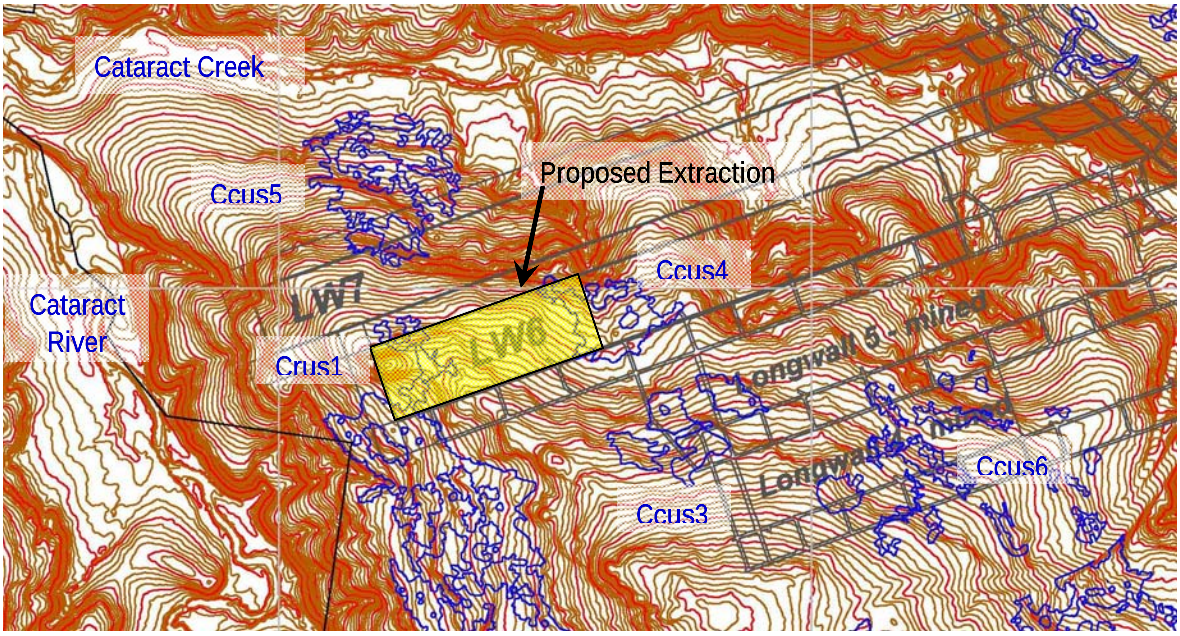

Figure 13 Longwall 6 (400m) Streams and Swamps

For a description of the field and office investigations, swamp assessment, classification and potential subsidence impacts on these two swamps, refer to (Biosis, 2014).

2.4 Effects on Local Stream Base Flows

The first 400m of proposed extraction of Longwall 6 is contained within land managed by the Sydney Catchment Authority, and is within the Cataract Creek and Cataract River catchments as shown in **Figure 13**.

No extraction is proposed under the main channel of Cataract Creek, Cataract River or Cataract Reservoir, with the mining layout designed to avoid valley closure related stream flow and pool water level impacts on the bed of the respective creeks and the reservoir.

The proposed workings do not underlie the stored waters (up to the high water mark) of Cataract Reservoir.

The proposed 400m of extraction also does not underlie any 1st order or higher stream beds.

The predicted depressurisation associated with the extraction of 400m of Longwall 6 is predicted to reduce baseflows to the connected surface water system by a maximum of 2.57ML/year, as shown in **Table 2** and **Figure 14**.

The maximum reduction in baseflow is predicted to occur in the year 2020.

Table 2 Modelled Cataract Creek, Cataract River and Bellambi Creek Stream Flow Changes Due to Extraction of Longwall 6 (400m)

	Baseflow Loss (ML/day) / (ML/year)	Change Due to Proposed Mining Compared to Current Flows (ML/day) / (ML/year)
Cataract Creek (Upstream of Cataract Reservoir)		
Current	0.005 / 1.83	-
End of Mining	0.007 / 2.55	0.002 / 0.73
1/1/2020	0.01 / 3.65	0.005 / 1.83
Cataract River (Upstream of Cataract Reservoir)		
Current	0.0007 / 0.26	-
End of Mining	0.001 / 0.365	0.0003 / 0.11
1/1/2020	0.0025 / 0.91	0.0018 / 0.657
Bellambi Creek		
Current	0.00015 / 0.055	-
End of Mining	0.0002 / 0.073	0.00005 / 0.018
1/1/2020	0.0004 / 0.146	0.00025 / 0.091
TOTAL (1/1/2020)		**0.0071 /2.57**

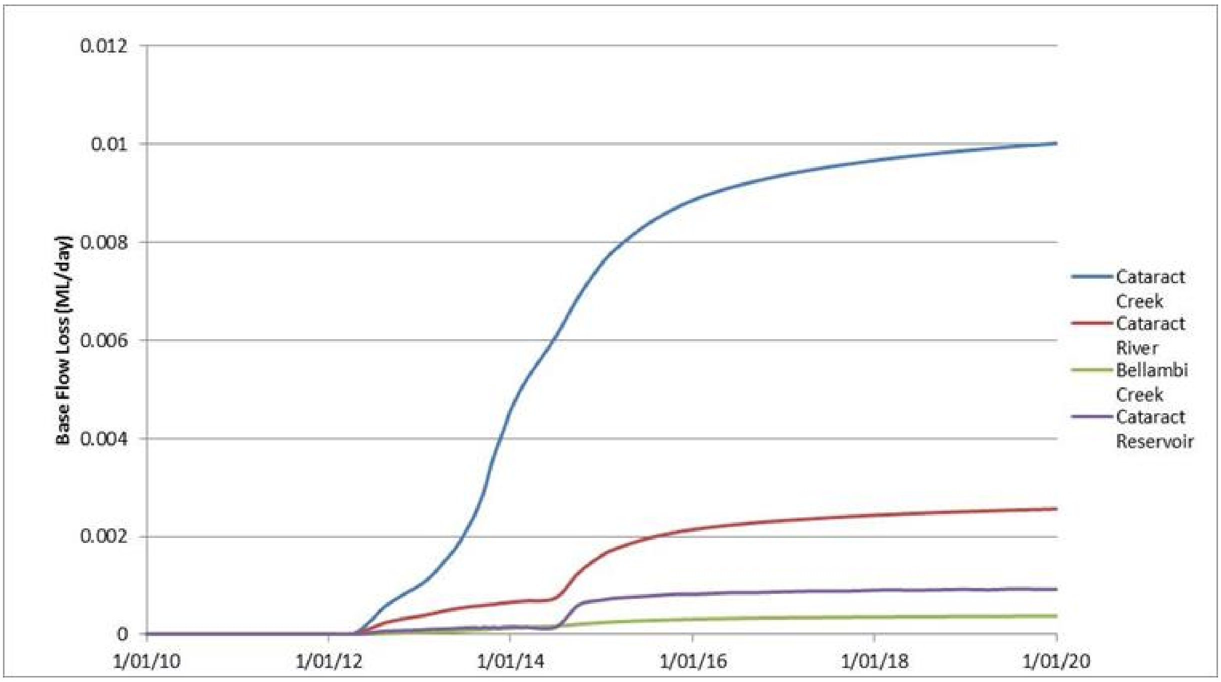

Figure 14 Longwall 6 (400m) Streams Baseflow Changes Due to LW6 (400m)

For further detailed discussion regarding streams, refer to (WRM Water and Environment, 2014A).

2.5 Effect on Inflows and Storage Within Cataract Reservoir

Cataract Reservoir has a full operating storage of 97,190ML. The lowest level of the storage as advised by the SCA is 27,620ML (29.3% capacity), as recorded on 20 July 2006.

2.5.1 Stream Inflow

Due to the setback of the proposed workings from the Cataract Reservoir, no adverse stored water quantity or quality impacts are predicted to occur on, or in, Cataract Reservoir, based on the factors discussed in the main report (Geoterra / GES, 2014).

It is anticipated, however, that the water will flow via subsurface fractures and discharge down gradient into the lower section of the streams, and / or into Cataract Reservoir. As such, the change is anticipated to be a sub-surface diversion, not an overall loss, to the surface water balance.

The modelled sub-surface total transfer of 2.57 ML/year from the Cataract Creek, Cataract River and Bellambi Creek catchments (maximum impact occurring in 2020) represents less than 0.01% of the low level, or 0.003% of its full storage capacity of Cataract Reservoir.

2.5.2 Strata Depressurisation

The modelled transfer of stored water within Cataract Reservoir to the underlying groundwater system due to depressurisation of the regional groundwater system in the vicinity of the reservoir due to extraction of Longwall 6 (400m) is predicted to be 0.0009ML/day (0.33ML/year).

The modelled sub-surface transfer of 0.33ML /year from the stored waters at the end of the proposed mining is less than 0.001% of the low level, or 0.0003% of its full storage capacity.

2.6 Groundwater Quality

Previous observations at Russell Vale indicates that groundwater quality within the regional groundwater system has not been adversely affected, however there may be some localised increased iron hydroxide precipitation and limited lowering of pH if the groundwater is exposed to “fresh” surfaces in the strata through dissolution of unweathered iron sulfide or carbonate minerals.

The degree of iron hydroxide and pH change is difficult to predict, and can range from no observable effect to a distinct discolouration of the formation water. The discolouration does not pose a health hazard, however it can cause iron hydroxide precipitation at seepage points in local streams which can also be associated with algal matting and / or lowering of dissolved oxygen levels in the creek at the seepage point.

It should be noted that many Hawkesbury Sandstone aquifers in the Southern Coalfield already have significant iron hydroxide levels, and that ferruginous seeps can also be observed in previously un-subsided catchment areas.

As a result of the proposed workings, pH acidification of up to 1 order of magnitude may occur, however the change may be reduced if the aquifer has sufficient bicarbonate levels.

Outside of isolated iron hydroxide seepages, no adverse groundwater quality is anticipated to discharge from the proposed Wongawilli Seam workings subsidence areas.

2.7 Loss of Bore Yield

There will be no loss of bore yield as there are no private bores or wells registered by the NSW Office of Water (NOW) in the Study Area.

3. WATER ACCESS LICENCING

3.1 Groundwater

The Project is covered by the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011* (Groundwater WSP), which applies to 13 groundwater sources.

Under the Groundwater WSP, the proposed mining is located within Management Zone 2 of the Sydney Basin Nepean Groundwater Source. This includes all aquifers below the surface of the ground (clause 4), and covers alluvium, weathered and basement rocks.

WCL currently holds a groundwater licence under Part 5 of the *Water Act 1912* for 365ML/year (Licence No. 10BL602992). As the current licence is held under part 5 of the *Water Act 1912*, Wollongong Coal will need to convert its existing licence to a WAL.

For the purposes of the WM Act, an 'aquifer' is defined as *"a geological structure or formation, or an artificial landfill that is permeated with water or is capable of being permeated with water"*. Abandoned workings are not geological structures or formations and as such, do not constitute aquifers. Therefore, water make sourced from abandoned workings does not constitute the taking of water from the water source, whereas the Wongawilli coal seam and overburden satisfy the definition of 'aquifer" and the mining effects on them are deemed to be a water "take".

Since the Groundwater WSP applies to all aquifers, Wollongong Coal will require WALs for all groundwater taken in the course of mining. The impacts that would give rise to licensing requirements include:

- Inflows into mine workings (mine water make); and
- Leakage from shallow aquifers.

Although downward leakage from shallow aquifers is not physically taken from the aquifer, the water is deemed to have been 'taken' (pursuant to section 60I of WM Act) as it has been re-located from one part of an aquifer to another.

The predicted maximum inflow of 292ML/year includes approximately 0.2ML/day (73ML/year) of seepage inflow from adjoining, upgradient decommissioned workings. This volume is not required to be licenced by the proponent, and the groundwater licence currently held by WCL will be sufficient, once it is converted to a WAL.

The Sydney Basin Nepean Groundwater Source WSP limits the total share component for aquifer licences in this water source to 16,283 unit shares.

3.2 Surface Water

The Project is located within the area covered by the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011* (Unregulated River WSP). The Unregulated River WSP includes six water sources, with the Project situated entirely within the 'Upper Nepean and Upstream Warragamba Water Source".

Clause 4 of the Unregulated River WSP states that these water sources include all water:

- *Occurring naturally on the surface of the ground shown on the Registered Map; and*
- *In rivers, lakes, estuaries and wetlands in these water sources.*

Wollongong Coal currently does not hold any licences for surface water use for the region covering the proposed mining area and will need to obtain WALs for the total volume of surface water taken from the Upper Nepean and Upstream Warragamba Water Source.

The WSP limits the total share component for unregulated river licences in this water source to 15,540.2 unit shares.

Impacts that would give rise to licensing requirements include:

- Reduction in base flows to streams due to drawdown of the regional aquifer;
- Additional runoff that infiltrates into the groundwater system via subsidence induced shallow cracking;
- Leakage from swamps; and
- Leakage of water directly from the Cataract Reservoir.

Cracking of streams may result in a reduction of stream flow through re-directing water into the bedrock. Although this water may re-emerge downstream, the water is deemed to have been "taken" as it is diverted from above to below the ground surface. Section 60I of the WM Act indicates that the water is deemed to be taken even if it is returned to the water source. Section 60I states:

"a person takes water in the course of carrying out a mining activity if, as a result of or in connection with, the activity or a past mining activity carried out by the person, water is removed or diverted from a water source (whether or not water is returned to that water source) or water is re-located from one part of an aquifer to another part of an aquifer".

The maximum predicted loss of stream baseflow due to basement depressurisation under the Cataract Creek, Cataract River and Bellambi Creek catchments within Management Zone 2 of the Sydney Basin Nepean Groundwater Source, as a result of the proposed mining of LW6, is 2.90 ML/year (in the year 2020), as shown in **Table 3**.

Table 3 Surface Water Licensing Requirements

Surface Water Source	Predicted Surface Water "Take" (ML/year)
Wonga East Stream Baseflow	2.57
Cataract Reservoir Leakage	0.33
(TOTAL)	**2.90**

Volumetric assessment of potential annual stream flow changes due to valley closure related cracking and transfer to sub-surface flow can not be assessed by the groundwater model, nor can it be predicted by any other method as the response of a stream bed to valley closure and compressional / tensional cracking is highly site specific and highly variable within a stream bed due to up to 36 factors (Kay, D.R, Waddington, A.A, 2014) and (Barbato, J et al, 2014).

Under the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources, which encompasses the Study Area and is contained within the Sydney Basin Nepean Groundwater Source Area, the annual take of up to 2.90ML/yr of stream baseflow resulting from depressurisation of deeper aquifers will require an unregulated river WAL

4. NSW AQUIFER INTERFERENCE POLICY MINIMAL IMPACT CONSIDERATIONS

The Aquifer Interference policy (AIP) prescribes minimal impact considerations which must be satisfied.

The minimal impact considerations for a water source vary depending on the nature of the water source (i.e. alluvial, coastal, fractured rock etc) and whether it is “highly productive groundwater” or “less productive groundwater”.

The minimal impact considerations for highly productive porous rock water sources are presented in **Table 4** and for the shallow perched aquifers in **Table 5**.

Table 4 NSW Minimal Impact Considerations for Less Productive Porous Rock Water Sources

Minimal Impact Consideration	Proponent Response
Water Table – Level 1 Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan variations, 40m from any: a) high priority groundwater dependent ecosystem, or b) high priority culturally significant site listed in the schedule of the relevant water sharing plan, or A maximum of a 2 m decline cumulatively at any water supply work unless make good provisions should apply.	There are no: • high priority groundwater dependent ecosystems, or; • high priority culturally significant sites listed under Schedule 4 of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011. The swamps above the mine plan are not classified as Temperate Highland Peat Swamps on Sandstone (which is high priority GDE). There are no water supply works (i.e. groundwater bores) in the Wonga East proposal area that will undergo more than a 2m decline.
Water Table – Level 2 If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: a) high priority groundwater dependent ecosystem; or b) high priority culturally significant site listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than 2m decline cumulatively at any water supply work then make good provisions should apply.	Level 2 does not apply as Level 1 criteria is not exceeded
Water Pressure – Level 1 A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work.	There are no water supply works (i.e. groundwater bores) in the Wonga East proposal area that will undergo a greater than 40% post water sharing plan pressure head decline above the base of the water source, and no water supply work will undergo greater than 2m decline
Water Pressure – Level 2 If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	Level 2 does not apply as Level 1 criteria is not exceeded
Water Quality – Level 1 a) Any change in the groundwater quality should not	The beneficial use category of the groundwater source will

lower the beneficial use category of the groundwater source beyond 40m from the activity, and b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a "reliable water supply" is not an appropriate mitigation measure to meet considerations 1(a) and 1(b) above. c) No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply".	not be changed beyond 40m from the Wonga East proposal area. There are no highly connected surface water sources (alluvial aquifers) in the Wonga East proposal area There are no highly connected alluvial surface water sources defined as a reliable water supply within the Wonga East proposal area
<u>Water Quality – Level 2</u> If condition 1(a) is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works. If condition 1(b) is not met then appropriate studies are required to demonstrate to the Minister's satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity. Condition 1(c) does not apply as there are no river bank or high wall instability risks and no need for low permeability barriers between the site and highly connected surface waters	Level 2 does not apply as Level 1 is not exceeded

Table 5 NSW Minimal Impact Considerations for Perched Ephemeral Aquifer Water Sources

Minimal Impact Consideration	Proponent Response
<u>Water Table – Level 1</u> Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan variations, 40m from any: c) high priority groundwater dependent ecosystem, or d) high priority culturally significant site listed in the schedule of the relevant water sharing plan, or A maximum of a 2 m decline cumulatively at any water supply work unless make good provisions should apply.	There are no: • high priority groundwater dependent ecosystems, or; • high priority culturally significant sites listed under Schedule 4 of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011. The swamps above the mine plan are not classified as Temperate Highland Peat Swamps on Sandstone (which is high priority GDE). There are no water supply works (i.e. groundwater bores) in the Wonga East proposal area that will undergo more than a 2m decline.
<u>Water Table – Level 2</u> If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: c) high priority groundwater dependent ecosystem, or d) high priority culturally significant site listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than 2m decline cumulatively at any water supply work then make good provisions should apply.	Level 2 does not apply as Level 1 criteria is not exceeded
<u>Water Pressure – Level 1</u> A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work.	There are no water supply works (i.e. groundwater bores) in the Wonga East proposal area that will undergo a greater than 40% post water sharing plan pressure head decline above the base of the water source, and no water supply work will undergo greater than 2m decline
<u>Water Pressure – Level 2</u> If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	Level 2 does not apply as Level 1 criteria is not exceeded
<u>Water Quality – Level 1</u> d) Any change in the groundwater quality should not	The beneficial use category of the groundwater source will

lower the beneficial use category of the groundwater source beyond 40m from the activity; and e) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a "reliable water supply" is not an appropriate mitigation measure to meet considerations 1(a) and 1(b) above. f) No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply".	not be changed beyond 40m from the Wonga East proposal area. There are no highly connected surface water sources (alluvial aquifers) in the Wonga East proposal area There are no highly connected alluvial surface water sources defined as a reliable water supply within the Wonga East proposal area
Water Quality – Level 2 If condition 1(a) is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works. If condition 1(b) is not met then appropriate studies are required to demonstrate to the Minister's satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity. Condition 1(c) does not apply as there are no river bank or high wall instability risks and no need for low permeability barriers between the site and highly connected surface waters	Level 2 does not apply as Level 1 is not exceeded

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The findings contained in this report are the result of discrete / specific methodologies used in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site / sites in question. Under no circumstances, however, can it be considered that these findings represent the actual state of the site / sites at all points. Should information become available regarding conditions at the site, Geoterra reserve the right to review the report in the context of the additional information.

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WOLLONGONG COAL LTD

RUSSELL VALE COLLIERY UNDERGROUND EXPANSION PROJECT PREFERRED PROJECT REPORT GROUNDWATER & SURFACE WATER RESPONSE TO SUBMISSIONS RESIDUAL MATTERS ADDENDUM

Bellambi, NSW

NRE8 - RTS - A
19 JUNE, 2014

GeoTerra PTY LTD **ABN 82 117 674 941**

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GeoTerra

NRE8 – RTS - A (19 June, 2014)

Wollongong Coal Ltd
PO Box 281
Fairy Meadow NSW 2519

Attention: D Clarkson

Dave,

RE: Wonga East Surface Water Residual Matters Addendum

Please find enclosed a copy of the above mentioned report.

Yours faithfully

GeoTerra Pty Ltd

Andrew Dawkins (AuSIMM CP-Env)
Principal Hydrogeologist

Distribution: Original		GeoTerra Pty Ltd
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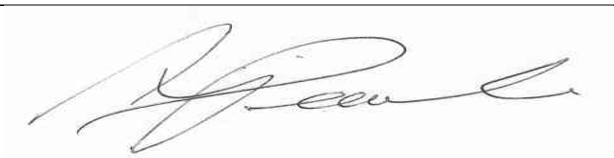
Signature:	
Position:	Principal Hydrogeologist

Date	Rev	Comments
05.06.2014		Draft
19.06.2014	A	Incorporate review comments

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FIGURES

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APPENDICES

1. INTRODUCTION

This addendum covers outstanding matters that have not been addressed in the Response to Submissions for the Wollongong Coal Ltd (WCL), Russell Vale Colliery, Underground Expansion Project – Preferred Project Report and prior assessments.

The accompanying reports are outlined in the references section.

The remaining issues are addressed in the following sections, based on a summarised compilation of all government agency responses to the Preferred Project Report.

2. STREAM WATER QUALITY MONITORING

2.1 Stream Monitoring Sites

The location of the Wonga East stream monitoring sites and the respective Bulli, Balgownie and Wongawilli (proposed and extracted) workings are shown in **Figures 1** to **3.**

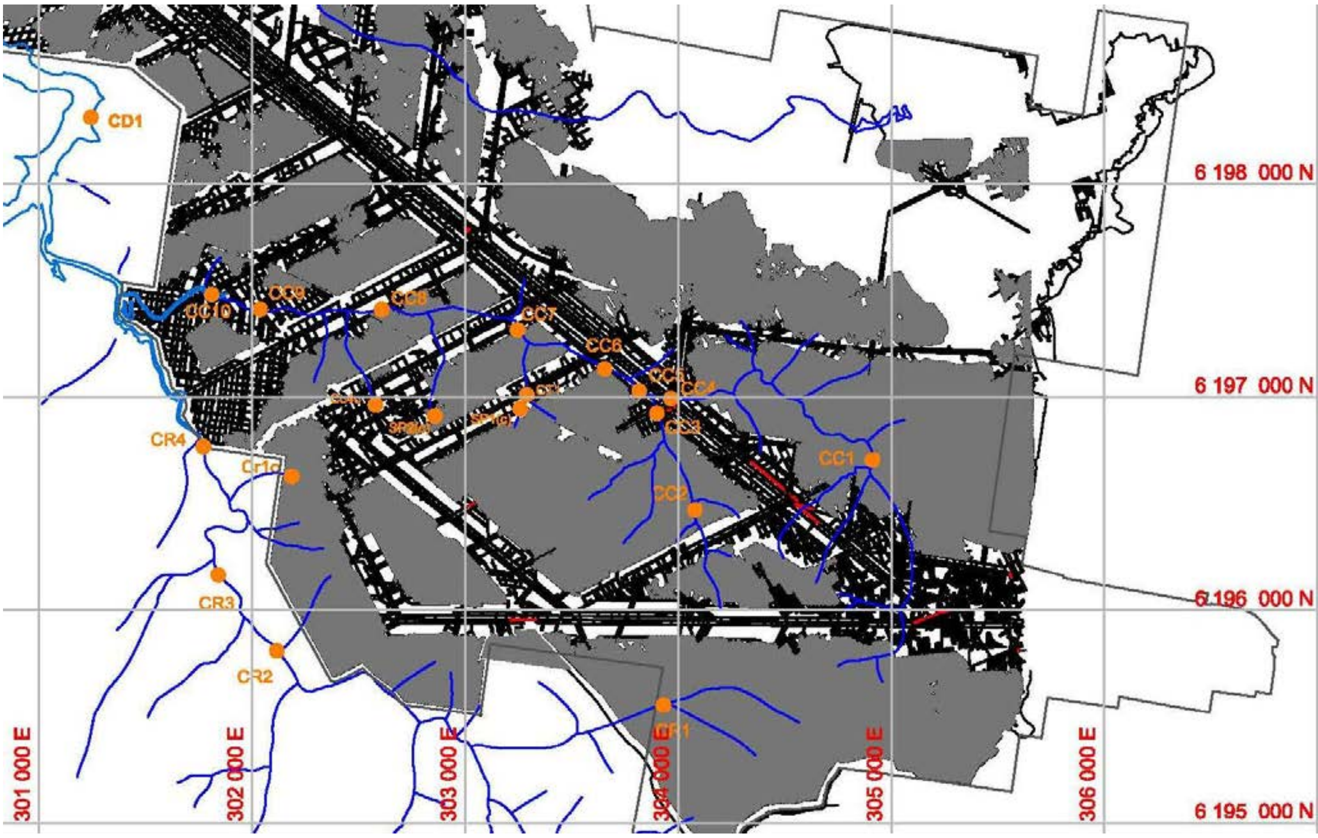


Figure 1 Stream Monitoring Sites and Bulli Workings

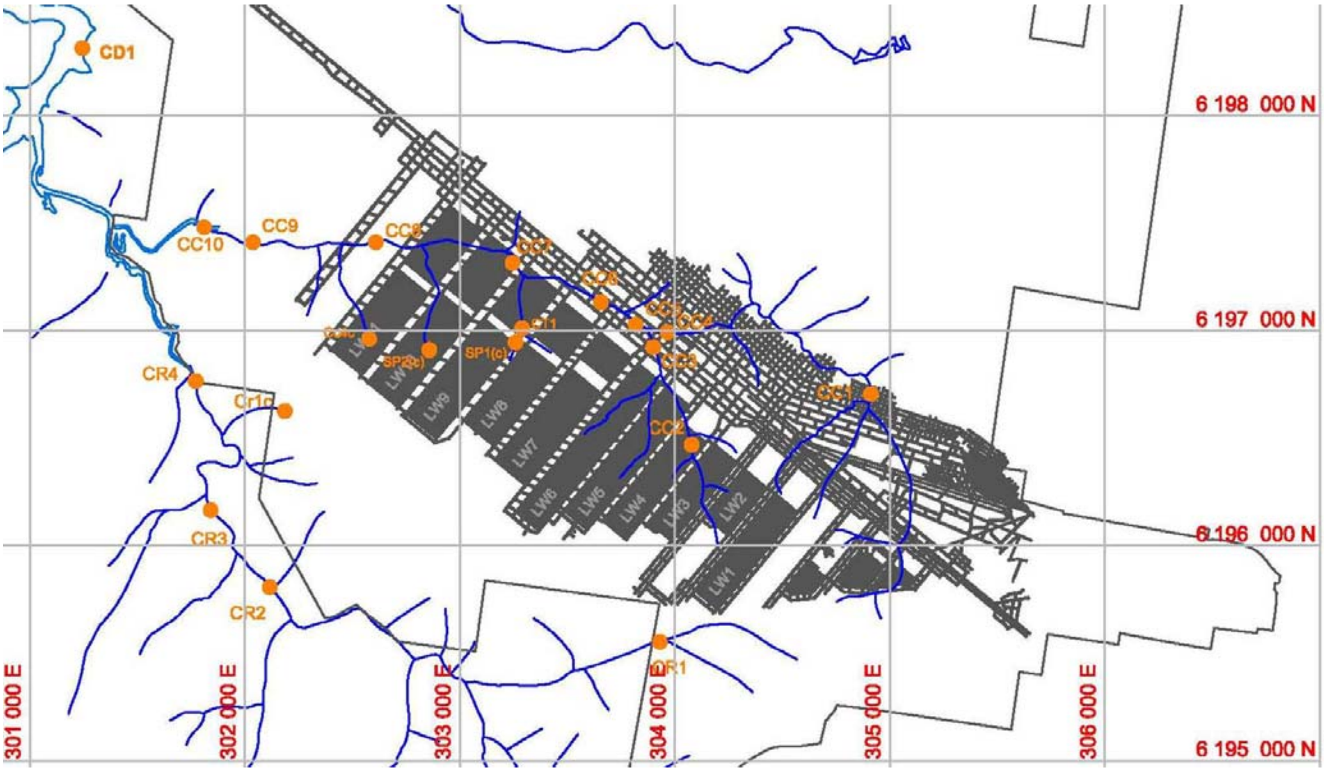


Figure 2 Stream Monitoring Sites and Balgownie Workings

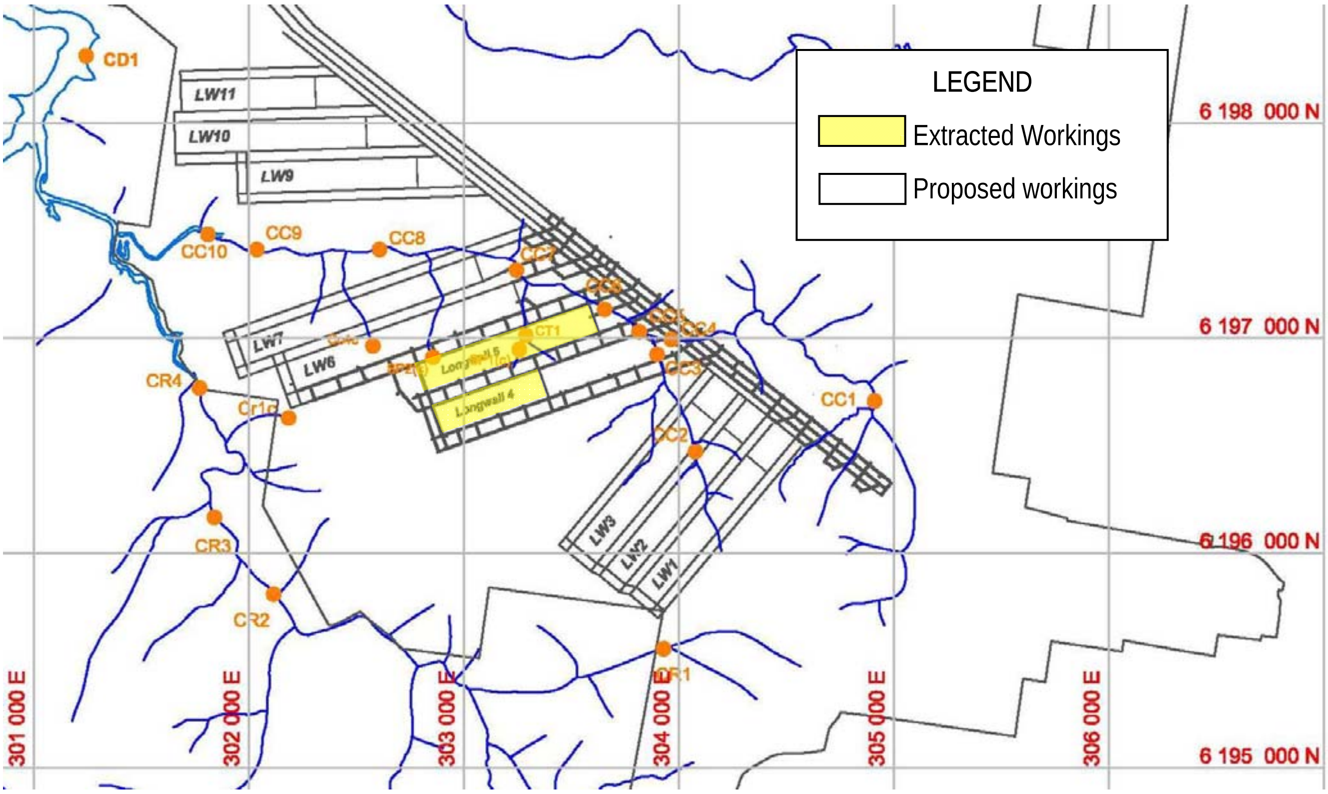


Figure 3 Stream Monitoring Sites and Wongawilli Workings

2.1.1 Cataract Creek

Cataract Creek field pH, electrical conductivity, temperature, dissolved oxygen and oxidation / reduction potential has been monitored using calibrated, hand held meters since August 2008 at the locations shown in **Table 1** and **Figures 1 to 3**.

The CC1 to CC4 tributary only overlies secondary extraction workings in the Bulli Seam, whilst it also overlies bord and pillar first workings in the Balgownie Seam and (in the lower reach), first workings in the Wongawilli Seam.

The CC2 to CC3 tributary overlies secondary extraction workings in the Bulli and Balgownie Seam, as well as proposed secondary extraction in the Wongawilli Seam.

Stream monitoring sites CC5 and CC6 overlie first workings in the Bulli, Balgownie and Wongawilli Seams, upstream of Longwalls 4 and 5.

Sites CC7 to CC8 overlie secondary pillar extraction workings in the Bulli and Balgownie Seams, and proposed first workings of the Wongawilli Seam, as well as being downstream of Longwalls 4 and 5 in the Wongawilli Seam.

Sites CC9 and CC10 overlie first workings in the Bulli Seams and do not overlie any proposed workings in the Balgownie or Wongawilli Seams.

Site CT1 is located in a tributary which overlies the Wongawilli Seam Longwall 5, with its headwaters located over Longwall 4.

Table 1 Cataract Creek Monitoring Sites

SITE	E (MGA)	N (MGA)	DESCRIPTION
CC1	304893	6196615	Tributary draining east of the escarpment to the east of proposed Panel A1 LW2
CC2	304107	6196418	Tributary draining east of the escarpment over proposed Panel A1 LW3
CC3	303937	6196961	Nthn tributary junction east of freeway, between proposed Panels A1 LW3 and A2 LW4
CC4	303964	6196992	Sthn tributary junction east of freeway, between proposed Panels A1 LW3 and A2 LW4
CC5	303852	6197005	Start of main Cataract Ck channel west of freeway upstream of proposed panel A2 LW5
CC6	303645	6197145	Adjacent to proposed Longwall 5
CT1	303300	6197020	2nd order tributary draining into Cataract Creek downstream of CC6 / upstream of CC7
CC7	303299	6196994	Adjacent to proposed Longwall 6, downstream of tributary CT1
CC8	302595	6197425	Over Longwall 8
CC9	302175	6197415	Upstream of dam high water level over proposed panel A2 LW9
CC10	301740	6197495	Creek site within creek high water level on western edge of proposed panel A2 LW9

NOTE: Co-ordinates supplied from GPS

2.1.2 Cataract River

Stream flow, height and water quality monitoring installations were installed by Gujarat (now WCL) on 12 April 2012 at locations shown in **Figures 1 to 3**, and as summarised in **Table 2**.

Table 2 Cataract River Stream Monitoring Sites

SITE	E (MGA)	N (MGA)	DESCRIPTION
CR1	303905	6195540	Upstream of Freeway
CR2	302175	6195745	At SCA weir flow monitoring site, downstream of Freeway
CR3	301915	6196130	Upstream of Swamp Crus1
CR4**	301780	6196770	Within high water section of Cataract Reservoir

NOTE: Co-ordinates supplied from GPS

**CR4 is currently not monitored as it lies within the FSL of Cataract Reservoir

2.1.3 Bellambi Creek

Apart from some short term, once off monitoring in mid 2008, no ongoing monitoring of Bellambi Creek has been conducted as there are no predicted subsidence effects on the main channel of the creek.

2.2 Stream Flow and Ponding Observations

2.2.1 Cataract Creek

The tributary containing monitoring site CC1 has only been observed to be dry on 22/1/2013, however it was flowing at CC4 at the same time. The stream reach contains significant iron hydroxide precipitation, indicating that groundwater baseflow from the Hawkesbury Sandstone is prevalent.

The CC2 to CC3 tributary has not dried out since monitoring began in mid 2008, and has been observed to generate significant iron precipitate from a seepage point in the stream headwaters over the proposed Wongawilli Seam Longwall 1 location. Subsequent iron hydroxide seepage points are evident along the tributary reach, particularly from 1st order side creeks, as either groundwater seepage or as creek “flow”. These iron hydroxide seeps are indicative of baseflow seepage out of the Hawkesbury Sandstone.

Both tributaries are typically steep in their headwaters, with the stream flowing over colluvial soil, then exposed Hawkesbury Sandstone / colluvial soil near the watershed, trending to exposed sandstone and boulder accumulations in the steeper sections, which migrate into sand / clay / colluvial stream beds in the flatter reaches.

No rock bar constrained pools are located in the upper headwaters, due to the steepness of the catchment, whilst the lower reaches are dominated by extended lengths of stream bed incised into sandy / clay colluvial soil, with occasional boulder / cobble constrained pools. No significant rock bar constrained pools are evident in either tributary, upstream of the freeway.

The fourth order stream channel at CC5, which has a sandy substrate, with no rock bar constrained pools has also been continuously flowing, however no flow (with ponding in the rock bar constrained pool) was observed at CC6 between late August and late

October, 2012.

Between CC7 and CC9, the creek is composed of interspersed incised channels in sandy clay colluvium, cobble / boulder constrained pools and rock bar constrained pools in exposed Bulgo Sandstone. No reduction in stream flow or drying out of pools has been observed in this reach since mid 2008.

Details of the pool types between CC5 and CC9 are outlined in Geoterra (2012) and are not reproduced here.

Downstream of CC5 the creek water becomes sequentially clearer, although ferruginous precipitation is observed along the entire reach down to the headwaters of the dam, particularly where first and second order tributaries enter the main channel.

Tributary CT1 has a notable development of ferruginous sandy sediment and discoloured runoff, and has often been observed to raise the ferruginous discolouration downstream of its confluence with Cataract Creek, upstream of site CC7.

No adverse effects on stream flow continuity or stream ponding have been observed in Cataract Creek due to previous mining in the Bulli, Balgownie or Wongawilli workings.

No mining induced cracking or compressional buckling of rock bars, or loss of pool holding capacity has been observed in the creek at any sites.

Pool height water level monitoring commenced in November 2010 under the management of Gujarat (now WCL) at sites CC3, CC4, CC7 and CC9. Site CT1 pool level monitoring was initiated in April 2012, whilst CC6, CC7 and CC8 commenced in January 2013 as shown in **Figure 4**.

The CT1 tributary, which drains off the Longwall 4 and 5 catchment area has dried up after extended lack of runoff.

During high rain periods, CC9 is inundated by Cataract Reservoir. The full supply level (FSL) of Cataract Reservoir extends approximately 100m upstream of CC9. As a result, volumetric flow monitoring at CC9 temporarily ceases during these periods.

Site CC10 is often inundated by Cataract Reservoir and is no longer regularly monitored.

Volumetric stream flow monitoring using either the cross sectional / flow velocity or temporary box notch weirs was initiated at CC3 and CC4 by Gujarat during April 2012 and subsequently at CC6, CC7 and CC8 in January 2013.

Conversion of the pool depths and weir / transect measured flows in a continuous volumetric flow record along with flow duration curves has been conducted by WRM Water and Environment (2014) and the reader is referred to this reference for further detail.

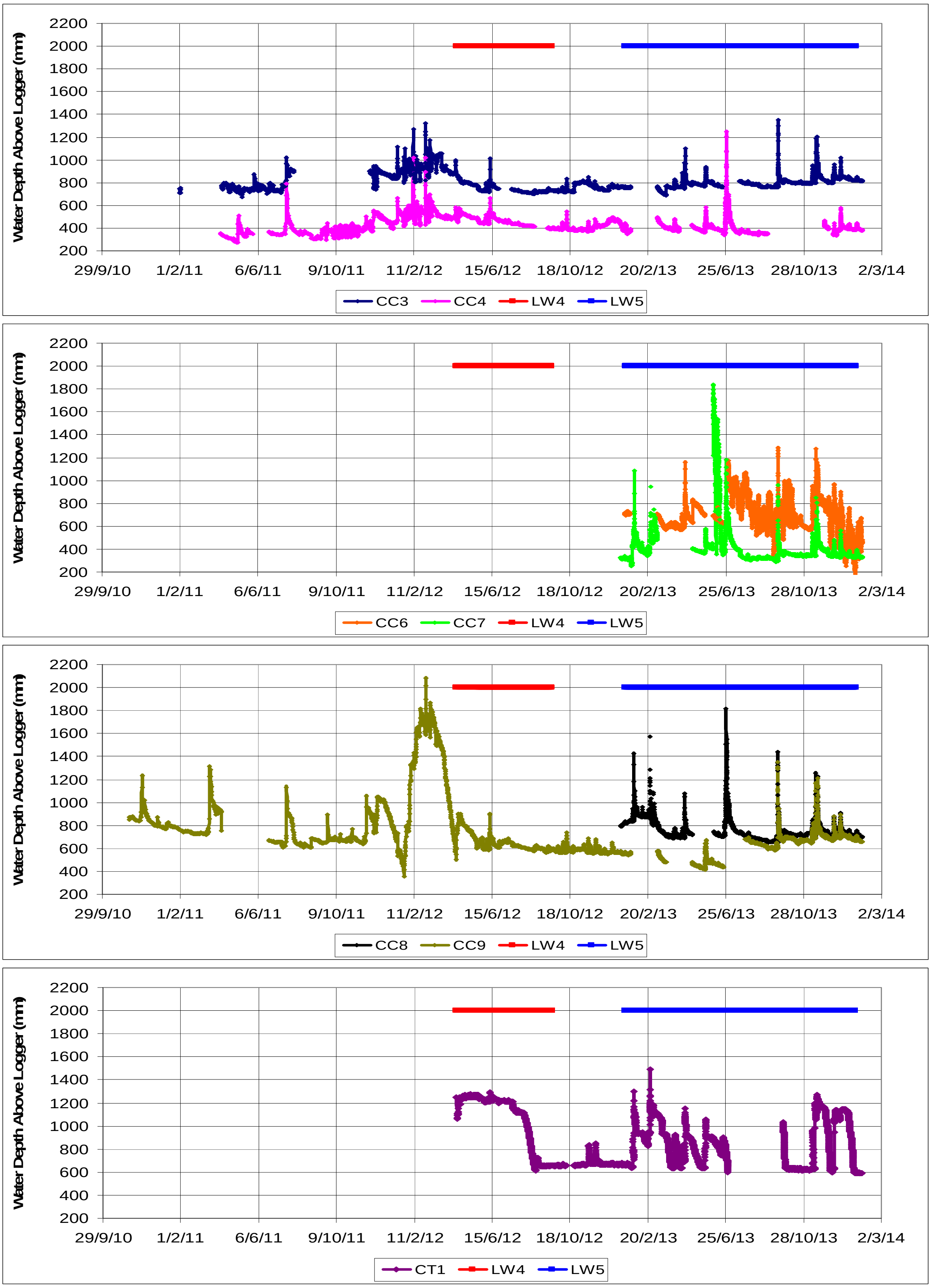


Figure 4 Cataract Creek Stream Pool Depths

2.2.2 Cataract River

The Cataract River between sites CR1 and CR4 has been continuously flowing during the monitoring period, and usually contains ferruginous precipitates.

No adverse effects on stream flow continuity or stream ponding have been observed in Cataract Creek.

No obvious mining induced cracking of rock bars and loss of pool holding capacity has been observed in the river.

Pool height water level monitoring, which commenced in April 2012 under the management of Gujarat, and is currently conducted at sites CR1, CR2 and CR3 as shown in **Figure 5**.

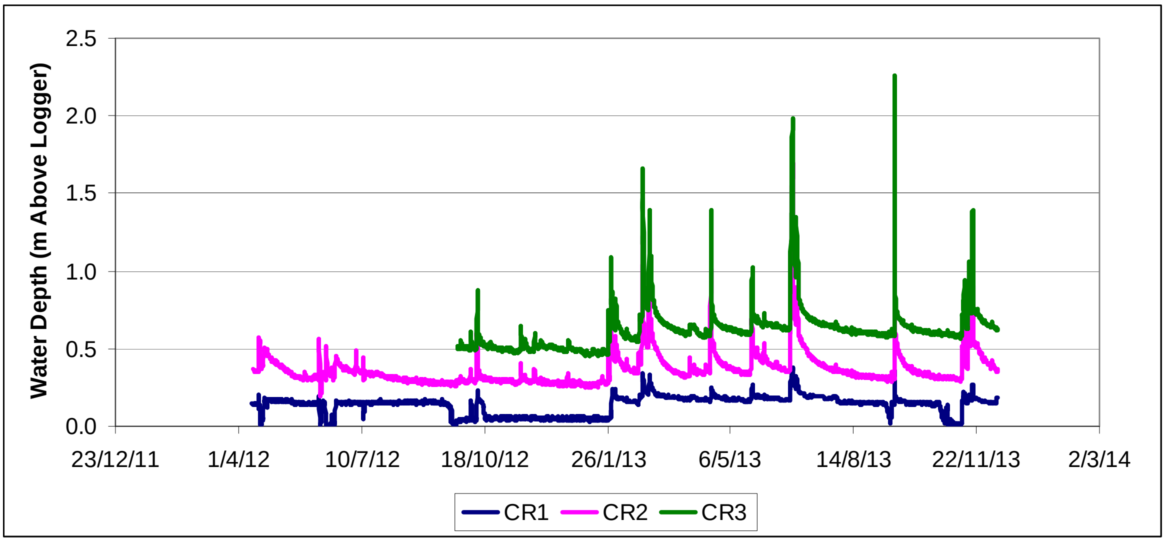


Figure 5 Cataract Creek Stream Pool Depths

Volumetric stream flow monitoring using the cross sectional / flow velocity method at sites CR1 and CR3 as well as an SCA weir at CR2 was initiated by Gujarat during April 2012.

Site CR4 was installed, but has not yet been used as it is under the high water of Cataract Reservoir after extended rain periods.

Site CR1 lies within the Russell Vale Colliery lease area and does not overlie any previous mining. Sites CR2, CR3 and CR4 overlie the old BHP Cordeaux Colliery Bulli seam bord and pillar workings.

All pools between Sites CR1 and CR3 do not show an enhanced pool drainage rate, and have not dried up during the monitoring period.

Volumetric stream flow monitoring using the cross sectional / flow velocity or the SCA weir at CC2 was initiated by Gujarat (now Wollongong Coal) in January 2013.

Conversion of the pool depths and weir / transect measured flows in a continuous volumetric flow record along with flow duration curves has been conducted by WRM Water and Environment (2014) and the reader is referred to this reference for further detail.

2.2.3 Bellambi Creek

No stream pool type, water depth or stream flow monitoring has been conducted in Bellambi Creek as it is not within the predicted 20mm subsidence zone.

2.3 Stream Water Quality Observations

2.3.1 Cataract Creek

The CC1 – CC5 and CD1 monitoring sites were installed by GeoTerra in August 2008, and were regularly monitored on a bi-monthly basis up until Gujarat (now Wollongong Coal) took over ongoing management and implementation of the field work, monitoring and laboratory analyses in July 2010. Since Gujarat took over the field monitoring, additional sites have been sequentially added, with the suite now containing Sites CC1 to CC10 and CT1.

Monitoring of field and laboratory water quality and general observation of the stream flow commenced in March 2012 and is conducted by WCL in the first order gully drainage sites Crus1c, Ccus3c and Ccus4c, which are downstream of upland swamps Crus1, Ccus3 and Ccus4, as well as in the SP1c swamp outflow.

Monitoring at these sites is conducted when there is flowing or ponded water in the ephemeral drainage gullies.

In addition to the current bi-monthly stream water depth, stream flow and stream water quality monitoring, photographic records of each monitoring site are taken during each field visit.

In general, enhanced rainfall in the catchment has the effect of reducing salinity, marginally raising pH, increasing dissolved oxygen, diluting ferruginous precipitates, 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.

Cataract Creek's overall pH ranges from 4.39 to 6.91, with a median of 5.56 upstream at CC1, along with a relatively "flat" trend at all other sites from 6.1 to 6.3 as shown in **Figure 6**.

The stream pH is more acidic where it discharges out of the humic / fulvic acid dominated swamp areas, or Hawkesbury Sandstone seepage locations, then becomes more alkaline as it flows down the main stream, with no significant acidification downstream of upwelling seepage locations.

The stream's pH is outside the ANZECC 2000 South Eastern Australia Upland Stream criteria, which is not uncommon in natural catchments draining off Hawkesbury Sandstone in the Southern Coalfields.

The median creek salinity ranges from 130 - 145µS/cm, with a minor decrease with distance downstream as shown in **Figure 6**.

The locations which drain out of Hawkesbury Sandstone dominated catchment over previously subsided areas show the lowest median pH (highest acidity) as observed at Sites CC1 and CT1.

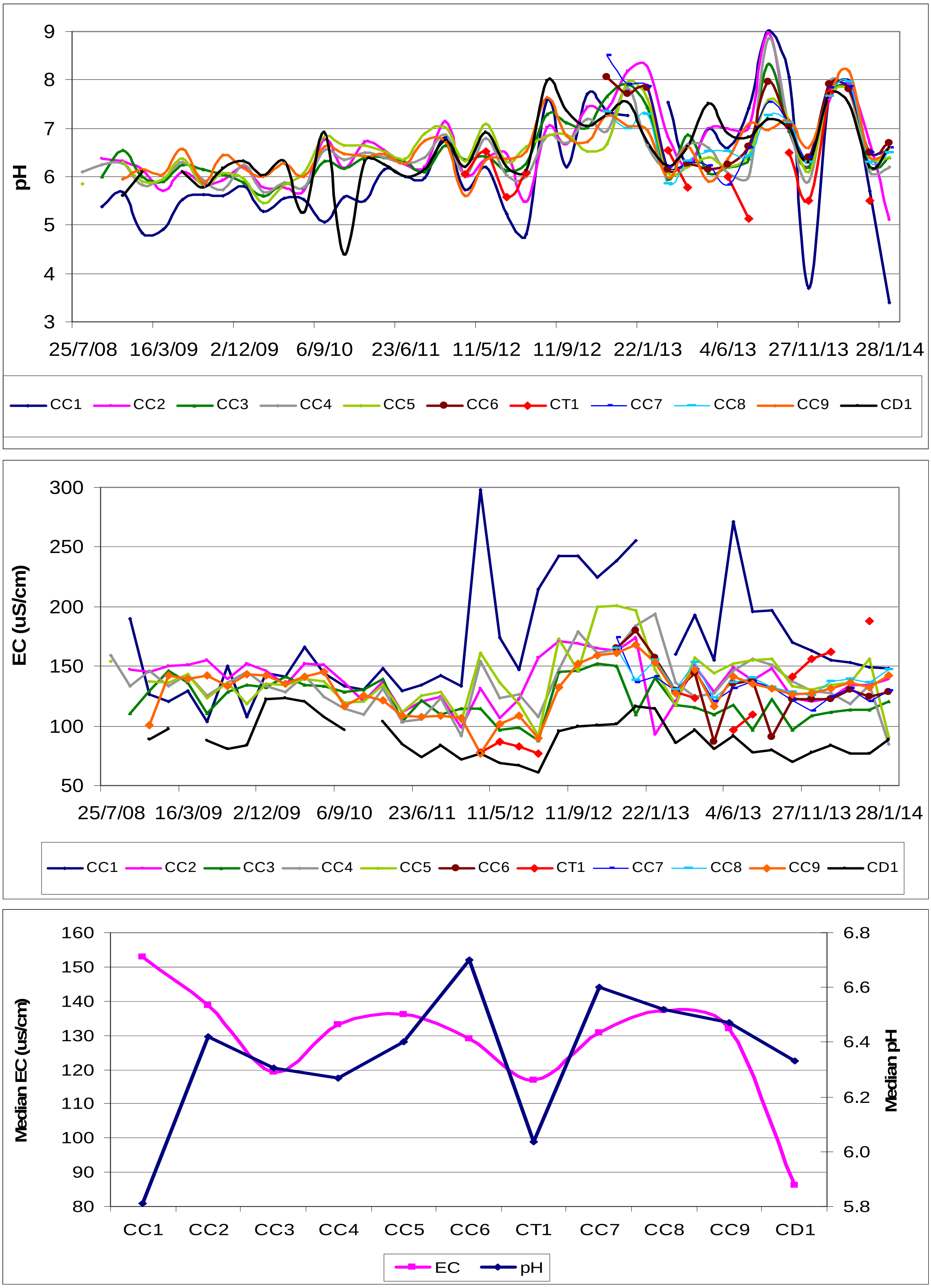


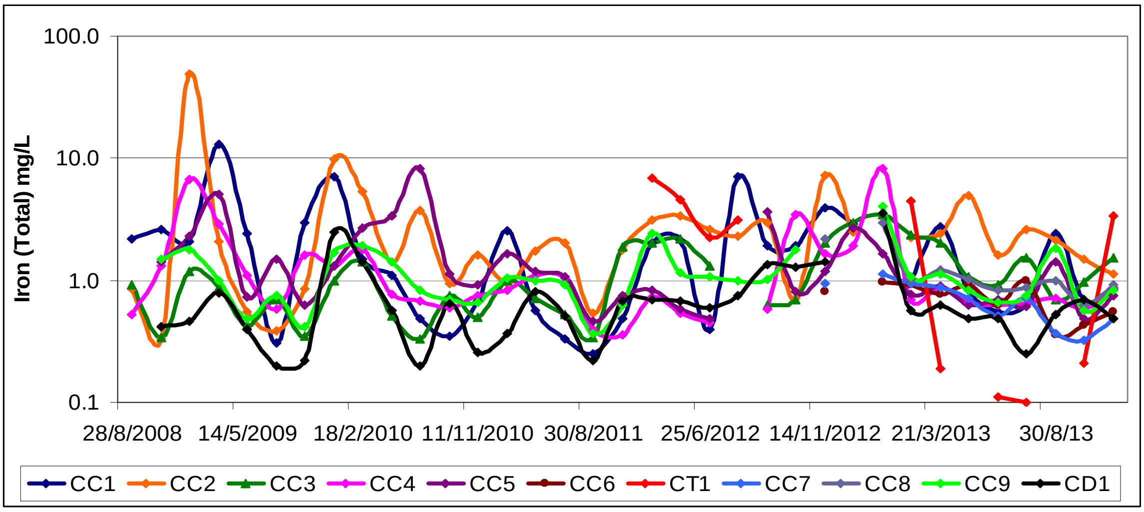
Figure 6 Cataract Creek Field Water Chemistry

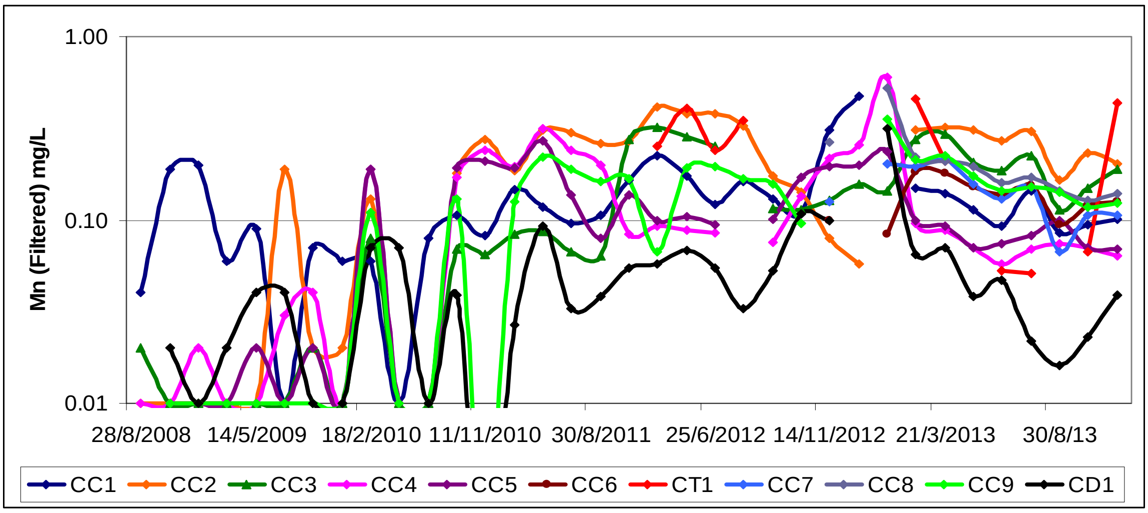
As shown in **Figure 7**, filtered iron levels are variable with flow downstream, with higher levels associated with hydrous ferruginous groundwater baseflow seeps at locations such as CC2 and CT1. Numerous other, smaller seeps are relatively common in Cataract Creek, usually in association with first and second order tributary seeps into the main channel, however iron hydroxide 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.

Figure 7 also illustrates that median total manganese peaks at CC2 and CT1, with a general reduction with flow downstream of these sites.

The total and filtered median iron discharges into Cataract Reservoir at CC9 is 0.96mg/L and 0.26mg/L, whilst manganese is 0.08g/L and 0.01mg/L respectively, which is below the ANZECC 2000 criteria of 1.9mg/L.





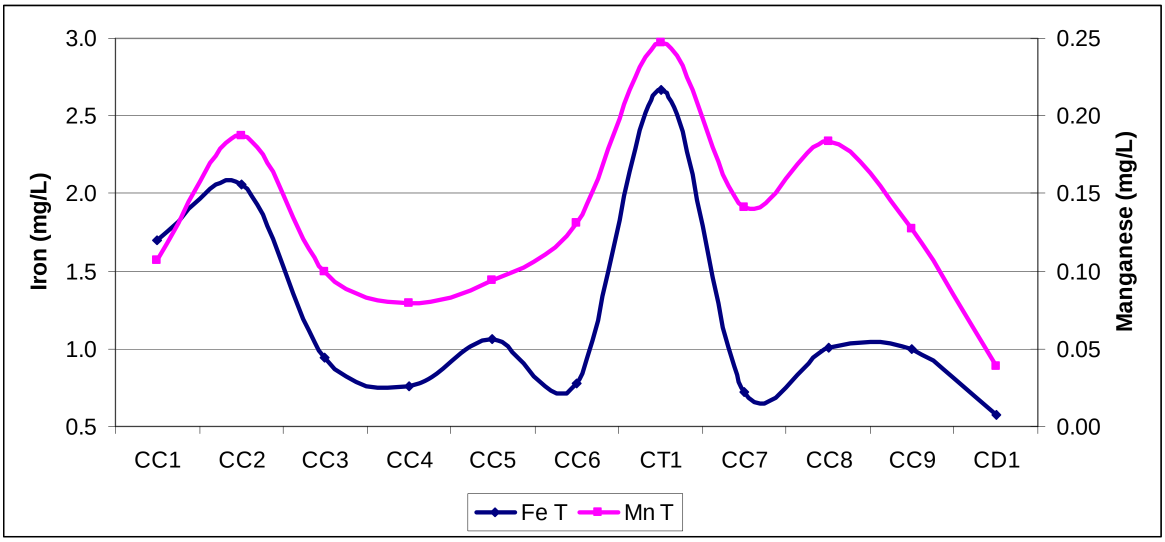


Figure 7 Cataract Creek Iron and Manganese

A peak in sulfate is present at CC2 and CT1 as shown in **Figure 8**, which corresponds with the lower pH and higher iron / manganese and represents the relatively enhanced dissolution of sulfuric acid following iron sulfide weathering as a result of shallow subsurface flow through cracks in the subsided Hawkesbury Sandstone.

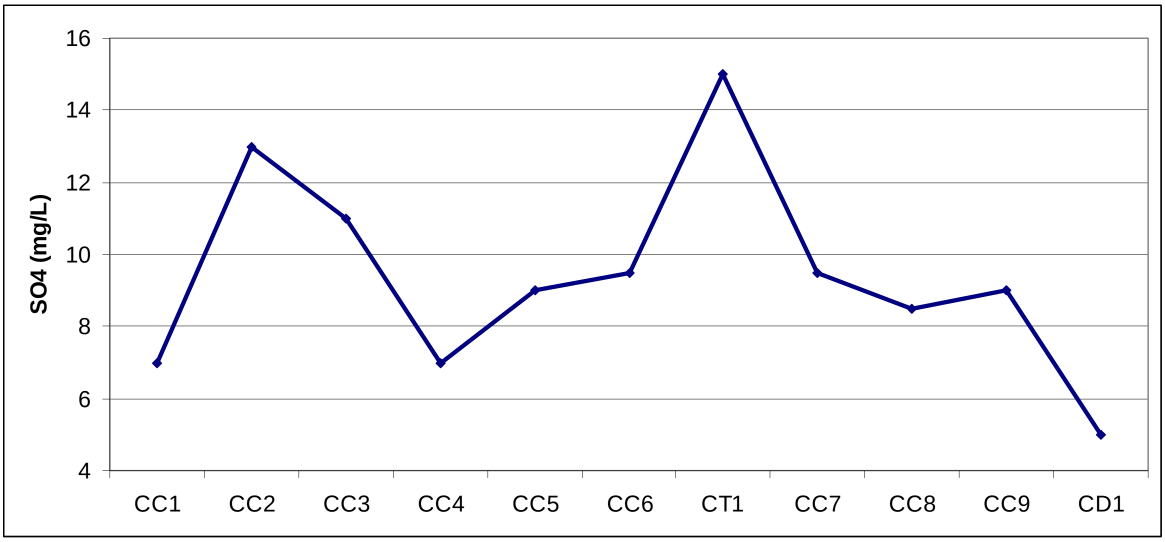


Figure 8 Cataract Creek Median Sulfate Levels

Monitoring to date, as shown in **Appendix A**, indicates the water quality of the creek is within the acceptable range for potable water, except for pH which is generally outside the ANZECC 2000 South Eastern Australia Upland Stream Criteria.

The creek can also be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines depending on the flow conditions at the time of sampling for:

- filtered zinc at CC1, CC4 and CD1, with a high variability;
- total phosphorous at all sites, generally;
- total nitrogen, at all sites, infrequently;
- occasionally filtered copper, and;
- aluminium on only one occasion (CC1 on 2/12/11), as although some values exceed 55µg/L, they do not exceed the ANZECC 2000 criteria as they are below pH 6.5.

Where the ferruginous deposits occur, the stream water quality can exceed ANZECC 2000 criteria between CC1 and CC5 for;

- filtered copper up to 0.004mg/L, very infrequently
- filtered zinc up to 0.12mg/L, infrequently
- filtered aluminium up to 0.1mg/L, very infrequently
- total nitrogen up to 1.9mg/L, very occasionally, and

- total phosphorous up to 0.27 mg/L, occasionally
- with a gradually rising pH with distance downstream from 5.54 – 6.1 and a relatively static salinity of 141µS/cm

Where Cataract Creek discharges into Cataract Reservoir at CC9, the above criteria parameters can be;

- pH, which is generally below pH 6.5;
- filtered copper (<0.004mg/L) and filtered lead (<0.0014mg/L), very rarely;
- filtered zinc (<0.029mg/L), occasionally, and;
- total nitrogen (<1.2mg/L) and total phosphorous (<0.11mg/L) occasionally.

During and after extraction of Longwalls 4 and 5, field water pH or electrical conductivity (EC) in Cataract Creek did not observably change, although minor variations in response to the quantum and duration of rainfall recharge in the catchment were observed.

No observable change in iron and manganese concentrations in Cataract Creek has occurred due to extraction of LW4 and LW5.

2.3.2 Cataract River

The CR1 – CR4 monitoring sites were installed by Gujarat (now Wollongong Coal) in May 2012, when bi-monthly monitoring of field and laboratory water quality and general observation of the stream flow commenced.

In addition to the current bi-monthly stream water depth, stream flow and stream water quality monitoring, photographic records of each monitoring site are taken during each field visit.

In general, enhanced rainfall in the catchment has the effect of reducing salinity, marginally raising pH, increasing dissolved oxygen, diluting ferruginous hydroxide discolouration, 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.

Cataract River's pH ranges from 5.1 – 6.4, whilst salinity ranges from 52 - 117µS/cm as shown in **Figure 9**.

The stream's pH is outside the ANZECC 2000 South Eastern Australia Upland Stream criteria, which is not uncommon in natural catchments draining off Hawkesbury Sandstone in the Southern Coalfields.

All sites have been observed to have perennial flow.

Ongoing data collection will be used to assess longer term trends for iron, manganese and sulfate.

Monitoring to date as shown in **Appendix B** indicates the water quality for Cataract River is within the acceptable range for potable water, however is generally outside the ANZECC 2000 South Eastern Australia Upland Stream Criteria for pH. Depending on the flow conditions at the time of sampling, water quality can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for filtered zinc, total phosphorous and total nitrogen.

Where Cataract River discharges out of the Study Area, and into Cataract Reservoir at CR3, the above criteria parameters can be;

- pH, which is below 6.5;
- filtered copper (<0.002mg/L), very rarely;
- filtered zinc (<0.388mg/L), generally, and;
- total nitrogen (<1.2mg/L) and total phosphorous (<1.32mg/L) generally.

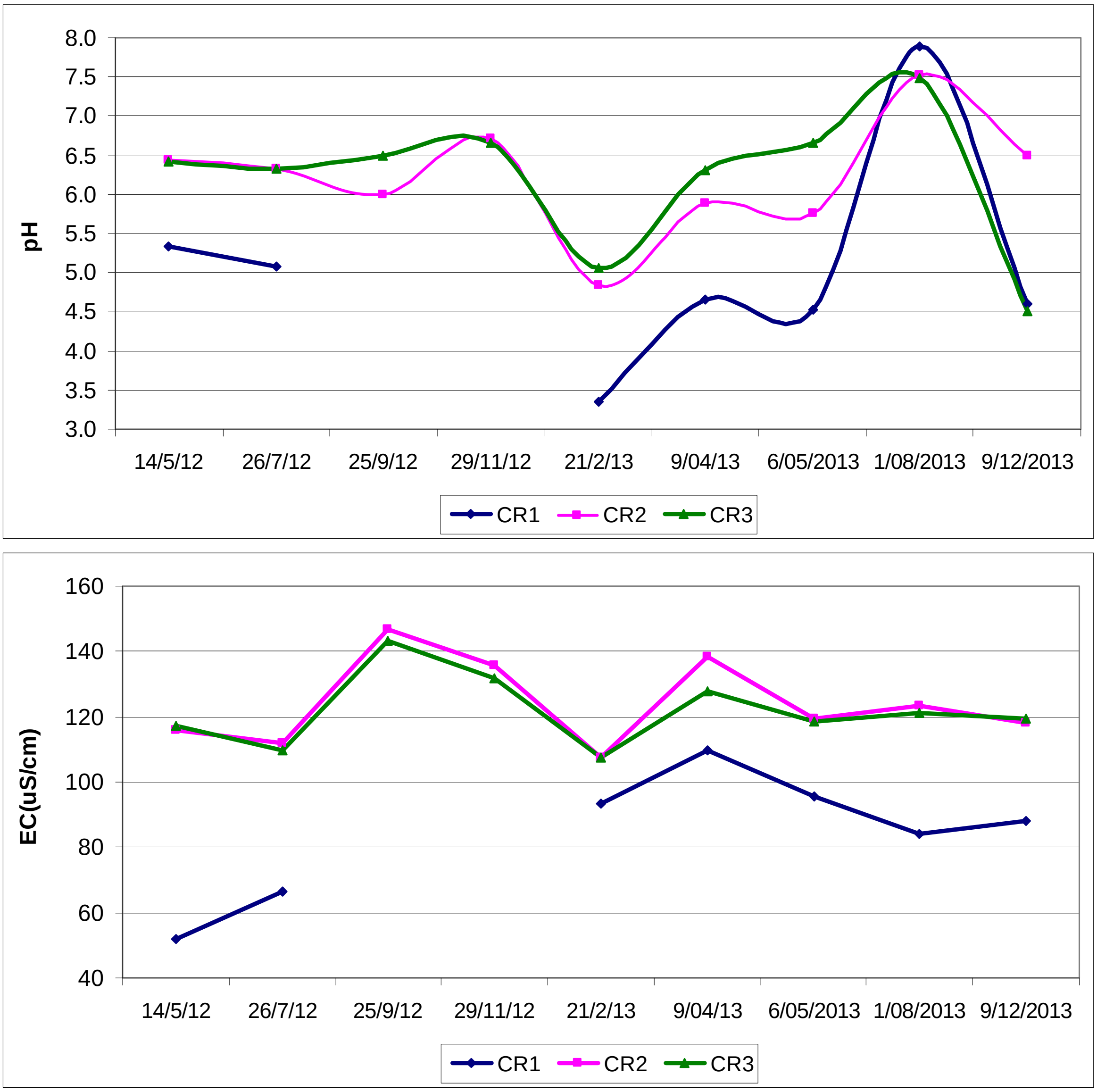


Figure 9 Cataract River Field Water Chemistry

2.3.3 Bellambi Creek

As the main channel of Bellambi Creek is outside the predicted 20mm subsidence zone, no ongoing water chemistry monitoring has been conducted.

3. LOSS AND RE-APPERANCE OF STREAM FLOW

3.1 Cataract Creek

No evidence of stream bed cracking, bedding delamination, flow loss or adverse effects on pool levels has been observed in Cataract Creek in the areas within, or adjacent to, where the main channel of the stream has been undermined by the Bulli, Balgownie or Wongawilli workings.

As a result, it is not possible to definitively establish the volumes and locations of water flow loss and stream flow re-entry in the creek, however it is obvious that groundwater seeps are present along the majority of the creek, downstream of the mid section of the proposed Longwall 1 in the Wongawilli Seam, based on the location of persistent iron hydroxide development at various locations along the creek.

As shown in **Figures 1** to **3**, Cataract Creek overlies the north west / south east and south west / north east oriented Bulli Seam bord and pillar workings as well as the south west / north east oriented longwalls in the underlying Balgownie Seam and is adjacent to Longwalls 4 and 5 in the Wongawilli Seam.

The tributaries between Sites CC1 - CC4 and CC2 – CC3 have been continuously flowing during all site visits and have not been observed to dry out, except for a short period in late January 2013 at CC1.

The fourth order stream channel between CC5 and CC9 has also been continuously flowing, although ferruginous precipitation is generally observed at site CC5 and downstream of tributary CT1.

Previous extraction in the overlying Bulli and Balgownie Seams occurred above Longwalls 4 and 5 as shown in **Figures 1** to **3**.

Up to 1.9m of subsidence was observed over Longwall 4 and 0.9m over Longwall 5 due to the previous extraction.

Wongawilli Seam Longwall 4 extraction caused up to 1.6m of subsidence, with a tilt of up to 30mm/m and tensile / compressive strain of up to +7.5 and -14 mm/m as shown in **Table 6**.

Subsequent extraction of Longwall 5 caused up to 1.8m of total maximum subsidence, with tilt up to 30mm/m and tensile / compressive strain up to +8.1 and –11.4mm/m over Longwalls 4 and 5 as shown in **Table 3**.

Valley Closure in Cataract Creek was not accurately measured for LW4, and reached up to 49mm after extraction of LW5 at creek closure survey location CC4 (as opposed to stream flow / chemistry monitoring site CC4), which is perpendicular to and downstream of Longwall 5, as well as 42mm at creek closure survey location CC1, which is in the creek as an extension of the LW4 centreline.

Note that the creek closure locations CC1 to CC4 do not equate to the creek geochemistry / pool level / flow monitoring locations of the same name.

Table 3 Wongawilli LW4 and LW5 Subsidence Summary

Longwall	Historical Subsidence (m)	Maximum Subsidence (mm)	Maximum Tilt (mm/m)	Maximum Tensile Strain (mm/m)	Maximum Compressive Strain (mm/m)	Maximum Cataract Creek Closure (mm)
Longwall 4	1.9	1.6	30	+7.5	-14.0	n/a
Longwall 5 (and 4)	0.9	1.8	30	+8.1	-11.4	49

4. POTENTIAL STREAM EFFECTS, IMPACTS AND CONSEQUENCES

4.1 Cataract Creek

4.1.1 Main Stream Flow and Ponding

As a worst case scenario, a potential risk to the integrity of stream flow and connectivity in Cataract Creek could be present in:

- the area of Longwalls 6 and 7, that may potentially undergo valley closure of up to 400mm, and;
- over Longwalls 1 to 3, that may potentially undergo valley closure of up to 650mm.

Based on current observations on the lack of observable stream bed cracking or delamination, it is not anticipated that the stream reaches containing exposed Newport and Garie Formations, Bald Hill Claystone or the upper Bulgo Sandstone will experience the same degree of surface cracking observed over Hawkesbury Sandstone reaches in other streams in the Southern Coalfields, due to the enhanced ductility of the exposed lithologies.

However, minor fracturing in the bed of Cataract Creek may occur, which may lead to minor diversion of stream flow or minor reduction in pool holding capacity.

The proponent has committed to developing a closure based trigger system for managing impacts on the creek with the exact values to be determined based on the best available predictive models and assessment of existing closure data from Longwalls 4 & 5. This will be undertaken in consultation with the appropriate regulatory authorities as part of the development of management plans for Cataract Creek.

It is not anticipated, however, that the total volume of water entering Cataract Creek will be observably affected due to stream bed or rock bar subsidence related fracturing.

Discussion of stream flow losses due to regional groundwater depressurisation and strata depressurisation directly over the proposed longwalls is covered in Geoterra, GES (2014).

4.1.2 Main Stream Rock Bars

A low potential risk to the integrity of rock bar constrained pools is predicted to be present in Cataract Creek in the area adjacent to Longwalls 5 and 6.

However, minor fracturing of rock bars in Cataract Creek may occur, which may lead to minor diversion of stream flow or minor reduction in pool holding capacity.

Although valley closure is likely to cause stream bed compression, fracturing or bedding delamination in the vicinity of Longwalls 1 to 3, there are no rock bar constrained pools in this reach over the proposed longwalls.

4.1.3 Tributaries

The tributaries which overlie the proposed workings may be at risk of subsidence related stream bed cracking, bedding delamination or enhancement of stream bed underflow.

4.1.4 Upland Swamp Outflow

A detailed significance and impact assessment of the Wonga East swamps is contained in (Biosis, 2014).

4.1.5 Main Stream Water Quality

Elevated iron and manganese as well as higher dissolved ions are currently prevalent where Hawkesbury Sandstone based groundwater seeps, or tributaries, enter the main channel of Cataract Creek.

Minor impacts on water quality due to the proposed longwall mining may occur due to reduced flow and / or increased interaction of groundwater and surface water such as reduced dissolved oxygen, higher dissolved ions and precipitates, as well as possibly lower pH and lower temperature variation due to more prevalent groundwater inflows.

Cataract Creek currently contains above (or outside) ANZECC criteria pH and zinc, and occasionally copper, as well nitrogen and phosphorous at its discharge point into Cataract Reservoir at Site CC9.

Based on the currently elevated levels of iron, manganese and associated zinc and copper, as well as nitrogen and phosphorous, and the lack of change in water quality due to extraction of Longwalls 4 and 5, no observable adverse change in stream water chemistry discharging into Cataract Reservoir is anticipated due to the proposed extraction of Longwalls 1 to 3, 6, 7 and 9 to 11.

4.1.6 Tributary Stream Water Quality

Elevated iron and manganese as well as higher dissolved ions are currently prevalent where Hawkesbury Sandstone based groundwater seeps discharge into the Cataract Creek tributaries.

Impacts on water quality due to the proposed longwall mining may occur due to reduced flow and / or increased interaction of groundwater and surface water such as reduced dissolved oxygen, higher dissolved ions and precipitates, as well as possibly lower pH and lower temperature variation due to more prevalent groundwater inflows.

4.2 Cataract River and Bellambi Creek

4.2.1 Main Stream Flow and Ponding

Negligible stream flow or ponding effects, impacts or consequences are anticipated to be generated in Cataract River or Bellambi Creek due to the low to absent levels of predicted valley closure associated with the proposed workings.

4.2.2 Main Stream Rock Bars

No potential risk to the integrity of rock bar constrained pools in Cataract River and Bellambi Creek is present.

4.2.3 Tributaries

The first order tributaries which overly the proposed 20mm subsidence zone are at low risk of subsidence related stream bed cracking, enhancement of stream bed underflow, discharge of ferruginous springs and reduced stream water quality at their confluence with Cataract River or Bellambi Creek.

However, it is anticipated that the total volume of water entering Cataract River or Bellambi Creek will not be observably affected.

4.2.4 Upland Swamp Outflow

A detailed significance and impact assessment of the Wonga East swamps is contained in (Biosis, 2014).

4.2.5 Main Stream and Tributary Water Quality

The headwaters of the first and second order streams draining off the predicted Wonga East subsidence area have the potential to undergo subsidence related bedrock cracking.

However, it is considered that the risk of adverse steam water quality changes are low, and that the quality of water entering Cataract River or Bellambi Creek from the headwater streams will not be observably affected.

4.3 Cataract Reservoir Water Quality

No observable change in Cataract Reservoir water quality is anticipated due to the proposed mining at Wonga East.

5. SURFACE WATER IMPACT PERFORMANCE MEASURES

The SCA's submission on the PPR included suggested subsidence impact performance measures. The proponent agrees with these peformance measures, except for special significance swamps. The proponent has also proposed performance measures for Bellambi Creek, which was not addressed in the SCA's submission.

The proponent will adhere to the following performance measures for surface water resources:

Cataract Reservoir

Negligible impacts including:

- negligible reduction in the quantity or quality of surface water inflows to the reservoir;
- negligible reduction in the quantity or quality of groundwater inflows to the reservoir;
- negligible increase in the quantity of water entering the groundwater system from the reservoir;
- negligible leakage from the reservoir to underground mine workings, and;
- no connective cracking between the reservoir surface and the mine.

Cataract Creek

Negligible impacts including:

- negligible diversion of flows or changes in the natural drainage behaviour of pools;
- negligible gas releases and iron staining;
- negligible increase in water cloudiness;
- negligible increase in bank erosion, and;
- negligible increase in sediment load.

Cataract River and Bellambi Creek

Negligible impacts including:

- negligible diversion of flows or changes in the natural drainage behaviour of pools;
- negligible gas releases and iron staining;
- negligible increase in water cloudiness;
- negligible increase in bank erosion, and;
- negligible increase in sediment load.

Special Significance Swamps

Minor impacts including:

- negligible erosion of the swamp surface;
- minor changes in the size of swamps;
- minor change in ecosystem functionality of the swamp;
- no significant change to the composition or distribution of species within the swamps; and
- maintenance (or restoration) of the structural integrity of controlling rockbars.

  These performance measures are consistent with the performance measures prescribed by the Subsidence Management Plan Approval for the nearby Dendrobium Colliery.

All other swamps

- no significant environmental consequences beyond predictions in the EA.

negligible impacts for a watercourse means no diversion of flow, no change in the natural drainage behaviour of pools and minimal iron staining, in accordance with the NSW Planning Assessment Commission (2009).

minor impacts include minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality, in accordance with Schedule 3, Specific Environmental Conditions – Mining Area for the Dendrobium Underground Coal Mine development consent conditions (NSW Department of Planning, 2008).

6. REFERENCES

Biosis, 2014 Russell Vale Colliery – Underground Expansion Project, Preferred Project Report – Biodiversity

Geoterra, 2012 Gujarat NRE Coking Coal Ltd Russell Vale Colliery Stream Assessment

Geoterra, GES 2014 Russell Vale Colliery Underground Expansion Project Preferred Project Report Wonga East Groundwater Assessment

Gujarat NRE Coking Coal, 2014 Gujarat NRE No.1 Colliery Geological Report on the Wonga East Area

NSW Department of Planning, 2008 Development Consent Conditions – Dendrobium Underground Coal Mine

NSW Planning Assessment Commission, 2009 The Metropolitan Coal Project Review Report

SCT Operations, 2013 Subsidence Assessment for Gujarat NRE Preferred Project Russell Vale No 1 Colliery

SCT Operations, 2014 Assessment of Groundwater Data for Russell Vale Colliery and Implications for Further Mining in the Wonga East Area

WRM Water & Environment, 2014 Russell Vale Colliery Wonga East Underground Expansion Project Surface Water Modelling

enquiries in regard to conclusions and recommendations made in this document. GeoTerra accept no responsibility for any consequences arising from any information or condition that was concealed, withheld, misrepresented, or otherwise not fully disclosed or available to GeoTerra.

The findings contained in this report are the result of discrete / specific methodologies used in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site in question. Under no circumstances, however, can it be considered that these findings represent the actual state of the site at all points.

Interpretations and recommendations provided in this report are opinions provided for our Client's sole use in accordance with the specified brief. As such they do not necessarily address all aspects of water, soil or rock conditions on the subject site. The responsibility of GeoTerra is solely to its client and it is not intended that this report be relied upon by any third party. This report shall not be reproduced either wholly or in part without the prior written consent of GeoTerra.

APPENDIX A

CATARACT CREEK LABORATORY ANALYSES

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
28/8/2008	CC1	86	5	8	44	3	5	23	1.0	0.1			0.1	0.01		0.11	2.20	0.04	0.04	0.03	0.001		0.001		0.007		0.010		0.001		0.010		0.030		0.010		1			
5/11/2008	CC1	82	4	6	38	2	4	21	1.0	0.1			0.7	0.11		0.82	2.60	0.19	0.19	0.10	0.001		0.001		0.006		0.010		0.003		0.010		0.020		0.010		3			
9/1/2009	CC1	62	3	4	32	3	4	14	0.1	0.1			0.1	0.04		0.02	2.10	0.20	0.20	0.03	0.004		0.001		0.120		0.010		0.001		0.040		0.070		0.010		2			
17/3/2009	CC1	68	11	5	32	2	3	17	0.6	0.2			0.2	0.01		0.02	13.00	0.06	0.07	0.04	0.001		0.001		0.006		0.010		0.001		0.010		0.020		0.010		1			
14/5/2009	CC1	68	10	6	30	2	4	17	1.9	0.1			0.8	0.06		0.04	2.40	0.09	0.10	0.04	0.001		0.001		0.008		0.010		0.002		0.020		0.020		0.010		2			
23/7/2009	CC1	110	38	8	40	13	6	19	0.9	0.1			0.1	0.01		0.10	0.31	0.01	0.01	0.04	0.001		0.001		0.010		0.010		0.006		0.030		0.060		0.010		2			
2/10/2010	CC1	58	3	5	28	2	3	13	0.5	0.1			0.3	0.03		0.07	3.00	0.07	0.09	0.03	0.001		0.001		0.005		0.010		0.010		0.008		0.023		0.010		3			
2/12/2009	CC1	65	6	5	32	3	3	16	0.6	0.1			0.1	0.04		0.53	7.10	0.06	0.10	0.04	0.001		0.001		0.010		0.010		0.010		0.016		0.016		0.010		2			
18/2/2010	CC1	76	6	6	37	2	3	20	0.8	0.1			0.1	0.01		0.17	1.50	0.06	0.10	0.03	0.001		0.001		0.007		0.010		0.003		0.019		0.015		0.010		4			
5/5/2010	CC1	73	5	6	40	2	3	22	0.9	0.1			0.3	0.01		0.02	1.10	0.01	0.08	0.04	0.001		0.001		0.010		0.010		0.010		0.012		0.017		0.010		1			
8/7/2010	CC1	78	5	6	39	2	4	21	0.6	0.1			0.1	0.01		0.02	0.48	0.08	0.08	0.04	0.003		0.001		0.021		0.010		0.002		0.015		0.023		0.010		1			
6/9/2010	CC1	118	1	12	21	2	3	15	1.0	0.1			0.1	0.01		0.14	0.35	0.11	0.11	0.18	0.002		0.001		0.006		0.002		0.001		0.010		0.015		0.001		1			
11/11/2010	CC1	72	7	7	32	2	3	19	1.0	0.1			0.5	0.05	5.69	0.21	0.67	0.082	0.08	0.09	0.001		0.001		0.005		0.002		0.001		0.011		0.022		0.001		2			
31/1/2011	CC1	74	5	5	41	2	3	20	1.0	0.1			0.4	0.1	4.17	0.59	2.56	0.146	0.148	0.1	0.001		0.001		0.008		0.002		0.001		0.01		0.021		0.001		2			
8/4/2011	CC1	79	2	6	38	2	3	17	1.0	0.1			0.1	0.1	5.58	0.38	0.56	0.117	0.119	0.08	0.001		0.001		0.009		0.002		0.001		0.012		0.026		0.001		2			
23/6/2011	CC1	159	2	6	38	2	3	22	1.0	0.1			0.1	0.1	4.69	0.24	0.33	0.096	0.1	0.11	0.001		0.001		0.009		0.002		0.001		0.014		0.02		0.001		1			
30/8/2011	CC1	72	5	5	40	2	3	20	1.0	0.1			0.1	0.01	5.28	0.22	0.25	0.106	0.1	0.11	0.001		0.001		0.008		0.002		0.001		0.012		0.019		0.001		1			
2/12/2011	CC1	135	3	9	38	2	3	21	2.0	0.1			0.1	0.01	5.55	0.25	0.49	0.164	0.166	0.13	0.003		0.001		0.049		0.004		0.002		0.013		0.022		0.001		4			
5/4/2012	CC1	139	1	8	57	3	4	25	1.0	0.1			2	0.04	5.96	1.32	2.03	0.226	0.235	0.09	0.002		0.001		0.021		0.003		0.001		0.018		0.031		0.001		1			
11/5/2012	CC1	98	2	9	55	3	5	32	1.0	0.1			0.6	0.5	5.55	0.65	2.14	0.174	0.188	0.08	0.001		0.001		0.024		0.003		0.001		0.018		0.031		0.001		1			
25/6/2012	CC1	83	1	6	36	2	3	18	1.0	0.1	0.08	0.1	0.1	0.01	4.29	0.21	0.4	0.121	0.123	0.12	0.001		0.001		0.01		0.002		0.001		0.015		0.018		0.001		1		1.14	1.13
17/7/2012	CC1	94	5	7	47	2	4	22	1.0	0.1	0.02	0.2	0.2	0.05	5.24	0.41	6.97	0.161	0.137	0.06	0.001		0.001		0.008		0.002		0.001		0.015		0.028		0.001		11		1.57	1.39
22/8/2012	CC1	108	8	8	47	3	5	24	1.0	0.1	0.04	0.3	0.3	0.01	5.19	0.94	1.9	0.13	0.134	0.07	0.001		0.001		0.01		0.001		0.001		0.016		0.03		0.001		2		1.65	1.63
24/10/2012	CC1	115	4	7	54	3	4	25	3.0	0.1	0.02	0.7	0.7	0.06	4.94	0.46	1.9	0.108	0.229	0.07	0.002		0.001		0.163		0.002		0.001		0.012		0.025		0.001		4		1.75	1.64
14/11/2012	CC1	128	7	5	49	3	4	25	2.0	0.1	0.02	0.4	0.4	0.07		1.85	3.9	0.308	0.33	0.16	0.001		0.002		0.014		0.003		0.001		0.012		0.029		0.001		7		1.63	1.62
20/12/2012	CC1	152	8	3	49	4	5	24	5.0	0.1	0.02	1	1	0.07	5.08	1.27	2.92	0.474	0.53	0.12	0.002		0.001		0.013		0.003		0.001		0.02		0.032		0.001		4		1.6	1.78
7/3/2013	CC1	127	1	15	38	2	3	22	3.0	0.1	1.56	2.3	3.9	0.04	5.17	0.59	1.02	0.15	0.167	0.18	0.002	0.004	0.001	0.001	0.049	0.083	0.003	0.004	0.001	0.001	0.011	0.012	0.022		0.001	0.001	5		1.38	1.38
21/3/2013	CC1	168	-	9	43	2	3	22	4.0	0.2	0.02	0.4	0.4	0.01	5.4	0.55	2.76	0.14	0.194	0.1	0.002	0.003	0.001	0.001	0.026	0.017	0.003	0.003	0.001	0.001	0.011	0.013	0.022	0.025	0.001	0.001	4			
1/05/2013	CC1	86	4	8	45	2	3	20	2.0	0.1	0.01	0.2	0.2	0.05	6.1	0.46	0.84	0.114	0.103	0.1	0.001	0.001	0.001	0.001	0.011	0.01	0.002	0.002	0.001	0.001	0.011	0.011	0.023	0.021	0.001	0.001	3		1.52	1.27
4/06/2013	CC1	109	4	8	38	2	3	24	2.0	0.1	0.04	0.4	0.4	0.02	5.74	0.37	0.55	0.093	0.091	0.09	0.002	0.003	0.001	0.001	0.017	0.017	0.002	0.002	0.001	0.001	0.012	0.012	0.021	0.022	0.001	0.001	3		1.32	1.44
16/7/13	CC1	110	3	7	40	2	4	25	1.0	0.1	0.03	0.2	0.2	0.01	5.62	0.26	0.64	0.145	0.16	0.1	0.006	0.008	0.001	0.001	0.031	0.036	0.004	0.004	0.001	0.001	0.016	0.016	0.024	0.025	0.001	0.001	3	5	1.33	1.52
30/8/13	CC1	91	3	8	46	2	4	26	1.0	0.1	0.02	0.4	0.4	0.02	7.35	0.16	2.43	0.085	0.139	0.03	0.001	0.006	0.001	0.001	0.014	0.021	0.001	0.004	0.001	0.001	0.013	0.017	0.021	0.026	0.001	0.001	6	5	1.52	1.59
24/9/13	CC1	93	3	7	44	2	3	25	2.0	0.1	0.03	2.3	2.3	0.01	5.34	0.26	0.69	0.094	0.105	0.07	0.002	0.003	0.001	0.001	0.025	0.019	0.002	0.002	0.001	0.001	0.01	0.012	0.01	0.022	0.001	0.001	4	5	1.45	1.49
27/11/13	CC1	91	2	7	43	2	3	24	2.0	0.1	2.6	0.3	2.9	0.01	5.32	0.43	0.86	0.101	0.101	0.11	0.001	0.002	0.001	0.001	0.008	0.013	0.002	0.001	0.001	0.001	0.009	0.01	0.02	0.02	0.001	0.001	3	5	1.4	1.44
	ST Dev	29	6	2	8	2	1	4	1.0	0.0	0.77	0.7	0.9	0.09	0.66	0.42	2.53	0.086	0.092	0.04	0.001	0.002	0.000	0.000	0.033	0.024	0.004	0.001	0.003	0.000	0.006	0.002	0.011	0.002	0.004	0.000	2	0	0.17	0.17
	Max	168	38	15	57	13	6	32	5.0	0.2	2.60	2.3	3.9	0.50	7.35	1.85	13.00	0.474	0.530	0.18	0.006	0.008	0.002	0.001	0.163	0.083	0.010	0.004	0.010	0.001	0.040	0.017	0.070	0.026	0.010	0.001	11	5	1.75	1.78
	Min	58	1	3	21	2	3	13	0.1	0.1	0.01	0.1	0.1	0.01	4.17	0.02	0.25	0.010	0.010	0.03	0.001	0.001	0.001	0.001	0.005	0.010	0.001	0.001	0.001	0.001	0.008	0.010	0.010	0.020	0.001	0.001	1	5	1.14	1.13
	Median	91	4	7	40	2	3	22	1.0	0.1	0.03	0.4	0.3	0.03	5.34	0.26	1.70	0.107	0.113	0.09	0.001	0.003	0.001	0.001	0.010	0.018	0.003	0.003	0.001	0.001	0.012	0.012	0.022	0.022	0.001	0.001	2	5	1.52	1.49

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													**0.3**	**0.02**				**1.90**	**1.90**	**0.055**	**0.001**	**0.001**	**0.003**	**0.003**	**0.008**	**0.008**	**0.011**	**0.011**							**0.024 (III) / 0.013(V)**	**0.024 (III) / 0.013(V)**				
28/8/2008	**CC2**	80	25	16	22	7	5	14	1.2	0.1			0.1	0.01		0.05	0.85	0.01	0.01	0.01	0.001		0.001		0.004		0.010		0.001		0.010		0.060		0.010		2			
5/11/2008	**CC2**	77	23	14	21	6	5	14	1.1	0.1			0.3	0.04		0.07	0.33	0.01	0.01	0.02	0.001		0.001		0.002		0.010		0.011		0.070		0.050		0.010		2			
9/1/2009	**CC2**	72	25	13	20	6	5	13	0.4	0.1			1.9	0.27		0.02	49.00	0.01	0.51	0.01	0.001		0.001		0.008		0.010		0.013		0.070		0.080		0.010		3			
17/3/2009	**CC2**	80	34	14	23	6	5	17	1.0	0.2			0.2	0.01		0.02	2.10	0.01	0.03	0.01	0.001		0.001		0.001		0.010		0.012		0.050		0.050		0.010		2			
14/5/2009	**CC2**	94	32	19	23	7	6	19	1.0	0.1			0.2	0.01		0.04	0.55	0.01	0.05	0.01	0.001		0.001		0.001		0.010		0.015		0.040		0.040		0.010		2			
23/7/2009	**CC2**	89	21	18	28	8	6	15	1.2	0.1			0.1	0.01		0.11	0.39	0.19	0.20	0.01	0.001		0.001		0.005		0.010		0.015		0.070		0.030		0.010		1			
2/10/2010	**CC2**	75	27	14	22	6	5	16	0.9	0.1			0.1	0.01		0.04	0.86	0.02	0.04	0.02	0.001		0.001		0.001		0.010		0.013		0.055		0.047		0.010		1			
2/12/2009	**CC2**	75	27	14	22	6	5	15	0.9	0.1			0.1	0.07		0.20	9.80	0.02	0.53	0.01	0.001		0.001		0.003		0.010		0.010		0.060		0.046		0.010		2			
18/2/2010	**CC2**	69	12	10	26	3	4	15	0.7	0.1			0.2	0.01		0.08	5.30	0.13	0.21	0.01	0.001		0.001		0.010		0.010		0.002		0.040		0.031		0.010		6			
5/5/2010	**CC2**	79	25	15	26	5	4	19	1.0	0.1			0.4	0.02		0.05	1.40	0.01	0.04	0.01	0.001		0.001		0.003		0.010		0.007		0.051		0.041		0.010		1			
8/7/2010	**CC2**	77	28	14	24	5	5	15	0.9	0.1			0.1	0.02		0.18	3.70	0.01	0.04	0.01	0.001		0.001		0.002		0.010		0.010		0.049		0.037		0.010		1			
6/9/2010	**CC2**	117	24	12	21	6	4	14	1.0	0.1			0.1	0.01		0.15	0.95	0.18	0.19	0.02	0.001		0.001		0.010		0.002		0.010		0.102		0.051		0.001		1			
10/11/2010	**CC2**	65	16	13	25	4	4	12	1.0	0.1			0.1	0.11	7.27	0.43	1.62	0.274	0.27	0.01	0.001		0.001		0.015		0.004		0.008		0.092		0.041		0.001		1			
31/1/2011	**CC2**	79	21	14	27	6	4	14	1.0	0.1			0.2	0.05	7.36	0.23	0.94	0.185	0.187	0.01	0.004		0.001		0.033		0.004		0.012		0.102		0.049		0.001		4			
8/4/2011	**CC2**	72	12	12	23	5	4	12	1.0	0.1			0.1	0.16	7.44	0.6	1.73	0.308	0.318	0.01	0.001		0.001		0.01		0.004		0.009		0.096		0.039		0.001		1			
23/6/2011	**CC2**	153	11	12	36	6	4	16	1.0	0.1			0.2	0.01	6.87	0.75	2.02	0.298	0.324	0.01	0.001		0.001		0.011		0.005		0.009		0.102		0.04		0.001		1			
30/8/2011	**CC2**	81	11	13	23	6	4	14	1.0	0.1			0.1	0.01	8.33	0.52	0.54	0.262	0.265	0.01	0.001		0.001		0.006		0.004		0.01		0.099		0.042		0.001		1			
2/12/2011	**CC2**	107	8	13	22	3	3	13	1.0	0.1			0.1	0.01	6.57	0.73	1.77	0.269	0.274	0.05	0.001		0.001		0.028		0.006		0.008		0.07		0.028		0.001		2			
5/4/2012	**CC2**	98	4	16	21	4	4	12	1.0	0.1			0.8	0.05	7.81	1	3.14	0.411	0.437	0.01	0.001		0.001		0.012		0.005		0.009		0.102		0.038		0.001		1			
11/5/2012	**CC2**	60	15	13	19	5	4	14	1.0	0.1			2.4	2.65	7.02	0.8	3.36	0.382	0.396	0.01	0.001		0.001		0.008		0.004		0.011		0.104		0.04		0.001		1			
25/6/2012	**CC2**	74	5	20	17	5	4	12	1.0	0.1	0.69	0.3	1	0.02	6.22	0.96	2.6	0.382	0.396	0.01	0.001		0.001		0.011		0.004		0.01		0.099		0.037		0.001		1		1	1.1
17/7/2012	**CC2**	64	19	12	19	5	3	12	1.0	0.1	0.03	0.1	0.1	0.01	7.09	0.58	2.29	0.328	0.323	0.01	0.001		0.001		0.005		0.003		0.011		0.103		0.042		0.001		2		1.17	1.02
22/8/2012	**CC2**	95	10	18	23	6	4	13	1.0	0.1	0.91	1	1.9	0.03	7.34	0.27	2.97	0.175	0.262	0.01	0.002		0.001		0.015		0.002		0.01		0.085		0.039		0.001		1		1.22	1.22
24/10/2012	**CC2**	85	18	14	22	5	4	16	2.0	0.1	0.02	0.2	0.2	0.02	6.95	0.16	0.72	0.142	0.13	0.01	0.001		0.001		0.016		0.001		0.009		0.076		0.04		0.001		2		1.27	1.33
14/11/2012	**CC2**	77	17	14	27	5	4	14	1.0	0.1	3.31	0.8	4.1	0.05		0.22	7.27	0.079	0.277	0.01	0.001		0.001		0.007		0.001		0.01		0.082		0.042		0.001		1		1.39	1.21
20/12/2012	**CC2**	98	20	12	22	6	4	14	1.0	0.1	0.02	0.1	0.1	0.02	7.22	0.16	2.49	0.058	0.184	0.01	0.001		0.001		0.005		0.001		0.01		0.075		0.043		0.001		1		1.27	1.26
7/3/2013	**CC2**	109	1	13	26	3	3	14	1.0	0.1	2.82	1.9	4.7	0.06	5.79	0.71	2.22	0.312	0.31	0.04	0.001	0.003	0.001	0.001	0.03	0.081	0.005	0.007	0.007	0.006	0.07	0.068	0.030		0.001	0.001	2		1	1.03
21/3/2013	**CC2**	69	16	11	21	4	3	13	1.0	0.1	0.02	0.3	0.3	0.01	6.91	0.59	2.42	0.322	0.352	0.01	0.001	0.001	0.001	0.001	0.024	0.018	0.004	0.005	0.009	0.01	0.091	0.102	0.038	0.041	0.001	0.001	2		1.14	1.04
1/05/2013	**CC2**	55	16	13	27	5	4	12	1.0	0.1	0.02	0.3	0.3	0.02	7.45	0.47	4.96	0.31	0.342	0.01	0.001	0.001	0.001	0.002	0.011	0.016	0.004	0.004	0.009	0.008	0.084	0.102	0.041	0.040	0.001	0.001	2		1.35	1.13
4/06/2013	**CC2**	87	14	11	21	4	4	14	1.0	0.1	0.07	0.5	0.6	0.02	7.36	0.6	1.61	0.269	0.285	0.01	0.001	0.004	0.001	0.003	0.012	0.024	0.004	0.004	0.008	0.009	0.102	0.102	0.036	0.042	0.001	0.001	1		1.1	1.14
16/7/13	**CC2**	74	12	10	18	4	3	13	1.0	0.1	0.01	0.1	0.1	0.01	6.94	0.82	2.64	0.306	0.322	0.01	0.002	0.001	0.001	0.001	0.014	0.015	0.004	0.004	0.009	0.008	0.086	0.096	0.033	0.037	0.001	0.001	2	5	0.96	1.01
30/8/13	**CC2**	66	23	12	22	5	4	15	1.0	0.1	0.04	0.1	0.1	0.02	9.72	0.2	2.11	0.164	0.192	0.01	0.001	0.001	0.001	0.001	0.005	0.005	0.002	0.002	0.01	0.011	0.089	0.118	0.038	0.041	0.001	0.001	2	5	1.33	1.26
24/9/13	**CC2**	65	13	10	22	4	3	13	1.0	0.1	0.02	0.3	0.3	0.01	6.89	0.46	1.49	0.231	0.243	0.02	0.005	0.001	0.001	0.001	0.036	0.044	0.005	0.005	0.007	0.008	0.074	0.076	0.074	0.033	0.001	0.001	2	5	1.09	1.01
27/11/13	**CC2**	76	10	11	27	3	3	13	1.0	0.1	0.05	0.1	0.2	0.02	6.6	0.42	1.14	0.202	0.251	0.02	0.001	0.001	0.001	0.001	0.012	0.017	0.004	0.004	0.007	0.008	0.071	0.084	0.03	0.037	0.001	0.001	2	5	1.19	0.98
	ST Dev	19	8	2	4	1	1	2	0.2	0.0	1.10	0.5	1.1	0.45	0.79	0.30	8.24	0.132	0.139	0.01	0.001	0.001	0.000	0.001	0.009	0.024	0.003	0.001	0.003	0.002	0.023	0.016	0.01	0.003	0.004	0.000	1	0	0.14	0.11
	Max	153	34	20	36	8	6	19	2.0	0.2	3.31	1.9	4.7	2.65	9.72	1.00	49.00	0.411	0.530	0.05	0.005	0.004	0.001	0.003	0.036	0.081	0.010	0.007	0.015	0.011	0.104	0.118	0.08	0.042	0.010	0.001	6	5	1.39	1.33
	Min	55	1	10	17	3	3	12	0.4	0.1	0.01	0.1	0.1	0.01	5.79	0.02	0.33	0.010	0.010	0.01	0.001	0.001	0.001	0.001	0.001	0.005	0.001	0.002	0.001	0.006	0.010	0.068	0.03	0.033	0.001	0.001	1	5	0.96	0.98
	Median	77	17	13	22	5	4	14	1.0	0.1	0.04	0.3	0.2	0.02	7.09	0.25	2.06	0.188	0.264	0.01	0.001	0.001	0.001	0.001	0.010	0.018	0.004	0.004	0.010	0.008	0.079	0.099	0.04	0.040	0.001	0.001	2	5	1.18	1.12

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
28/8/2008	CC3	69	12	16	21	5	4	12	1.0	0.1			0.1	0.01		0.17	0.92	0.02	0.03	0.01	0.001		0.001		0.004		0.010		0.010		0.080		0.030		0.010		1			
5/11/2008	CC3	70	13	14	21	5	4	12	0.9	0.1			0.2	0.12		0.20	0.34	0.01	0.03	0.04	0.001		0.001		0.002		0.010		0.007		0.060		0.040		0.010		2			
9/1/2009	CC3	66	14	12	22	5	5	12	0.1	0.1			0.1	0.04		0.06	1.20	0.01	0.05	0.01	0.001		0.001		0.005		0.010		0.008		0.060		0.060		0.010		2			
17/3/2009	CC3	73	18	14	24	5	4	14	0.8	0.1			0.1	0.01		0.11	0.87	0.01	0.02	0.02	0.001		0.001		0.001		0.010		0.008		0.040		0.040		0.010		2			
14/5/2009	CC3	85	24	15	27	5	5	17	0.6	0.1			0.1	0.01		0.04	0.43	0.01	0.04	0.01	0.001		0.001		0.005		0.010		0.008		0.090		0.050		0.010		2			
23/7/2009	CC3	78	14	14	27	5	5	15	1.0	0.1			0.1	0.01		0.09	0.69	0.01	0.02	0.01	0.001		0.001		0.006		0.010		0.011		0.060		0.060		0.010		1			
2/10/2010	CC3	69	16	15	23	5	4	15	0.9	0.1			0.1	0.01		0.16	0.35	0.02	0.02	0.01	0.001		0.001		0.004		0.010		0.004		0.050		0.037		0.010		2			
2/12/2009	CC3	66	17	13	22	5	4	14	0.9	0.1			0.1	0.01		0.36	0.98	0.01	0.14	0.02	0.001		0.001		0.004		0.010		0.002		0.051		0.037		0.010		2			
18/2/2010	CC3	73	9	6	34	3	3	18	0.6	0.1			0.2	0.01		0.08	1.40	0.08	0.10	0.01	0.001		0.001		0.011		0.010		0.003		0.025		0.024		0.010		3			
5/5/2010	CC3	72	15	14	27	4	4	16	0.8	0.1			0.1	0.01		0.07	0.51	0.01	0.01	0.01	0.001		0.001		0.004		0.010		0.004		0.040		0.032		0.010		1			
8/7/2010	CC3	72	16	14	24	5	4	14	0.7	0.1			0.1	0.01		0.04	0.33	0.01	0.01	0.01	0.001		0.001		0.005		0.010		0.009		0.045		0.034		0.010		1			
6/9/2010	CC3	107	11	5	26	3	3	15	1.0	0.1			0.2	0.01		0.42	0.75	0.07	0.07	0.19	0.001		0.001		0.005		0.001		0.001		0.023		0.027		0.001		1			
10/11/2010	CC3	77	5	7	26	3	3	16	1.0	0.1			0.3	0.03	6.02	0.29	0.5	0.065	0.066	0.05	0.002		0.001		0.03		0.002		0.001		0.02		0.024		0.001		1			
31/1/2011	CC3	80	21	5	39	3	3	17	1.0	0.1			0.1	0.01	5.18	0.51	1	0.084	0.083	0.04	0.001		0.001		0.005		0.001		0.001		0.023		0.027		0.001		1			
8/4/2011	CC3	80	5	6	33	3	3	15	1.0	0.1			0.3	0.2	6.32	0.44	0.71	0.086	0.089	0.05	0.001		0.001		0.006		0.001		0.001		0.019		0.024		0.001		1			
23/6/2011	CC3	132	6	6	31	3	3	20	1.0	0.1			0.1	0.01	4.93	0.33	0.52	0.067	0.07	0.04	0.001		0.001		0.005		0.001		0.001		0.019		0.023		0.001		1			
30/8/2011	CC3	78	5	6	35	3	3	19	2.0	0.1			0.1	0.02	5.76	0.32	0.34	0.064	0.063	0.03	0.001		0.001		0.014		0.002		0.001		0.02		0.023		0.001		1			
2/12/2011	CC3	87	5	11	21	3	3	13	1.0	0.1			0.4	0.01	5.79	0.62	1.88	0.274	0.283	0.04	0.003		0.001		0.023		0.004		0.004		0.048		0.022		0.001		1			
5/4/2012	CC3	83	8	9	21	3	3	11	1.0	0.1			0.4	0.04	6.58	0.73	2.04	0.322	0.354	0.03	0.001		0.001		0.015		0.003		0.005		0.052		0.025		0.001		1			
11/5/2012	CC3	99	9	12	19	3	3	13	1.0	0.1			3.7	3.93	5.86	0.67	2.21	0.283	0.305	0.03	0.001		0.001		0.016		0.003		0.006		0.054		0.025		0.001		1			
25/6/2012	CC3	69	8	10	18	3	3	11	1.0	0.1	2.56	1.1	3.7	0.01	5.25	0.62	1.32	0.251	0.258	0.03	0.001		0.001		0.014		0.003		0.05		0.05		0.023		0.001		1		0.88	0.88
22/8/2012	CC3	75	9	9	19	4	3	11	1.0	0.1	0.02	0.1	0.1	0.01	6.35	0.28	0.62	0.116	0.123	0.01	0.001		0.001		0.014		0.002		0.005		0.05		0.027		0.001		1		0.9	0.92
24/10/2012	CC3	79	10	13	21	3	3	14	1.0	0.1	0.01	0.1	0.1	0.01	6.25	0.45	0.7	0.114	0.143	0.02	0.001		0.001		0.009		0.001		0.004		0.051		0.035		0.001		1		1.06	1.03
14/11/2012	CC3	86	10	13	27	4	3	13	1.0	0.1	0.01	0.2	0.2	0.01		1.41	2.04	0.127	0.148	0.03	0.001		0.001		0.426		0.001		0.004		0.049		0.028		0.001		2		1.23	1.04
20/12/2012	CC3	84	10	11	23	4	3	13	1.0	0.1	0.12	0.1	0.1	0.01	6.41	0.75	2.93	0.157	0.225	0.02	0.001		0.001		0.007		0.001		0.005		0.046		0.028		0.001		1		1.08	1.01
23/1/2013	CC3	79	10	12	4	4	3	16	1.0	0.1	0.22	0.5	0.7	0.01	6.06	0.49	3.48	0.144	0.293	0.02	0.001		0.001		0.006		0.001		0.004		0.04		0.029		0.001		2		1.44	1.17
7/3/2013	CC3	71	4	8	23	3	3	13	1.0	0.1	0.09	0.2	0.3	0.01	5.31	0.66	2.36	0.276	0.298	0.05	0.001	0.001	0.001	0.001	0.016	0.023	0.004	0.003	0.004	0.004	0.04	0.044	0.023		0.001	0.001	2		0.9	0.96
21/3/2013	CC3	95	8	11	18	3	3	12	1.0	0.1	0.04	0.1	0.1	0.01	5.96	0.64	2	0.295	0.32	0.03	0.001	0.001	0.001	0.001	0.022	0.016	0.003	0.004	0.005	0.006	0.054	0.06	0.026	0.028	0.001	0.001	2		0.9	0.92
1/05/2013	CC3	115	7	10	21	3	3	12	1.0	0.1	0.03	0.1	0.1	0.01	6.26	0.54	1.08	0.207	0.226	0.07	0.001	0.001	0.001	0.001	0.025	0.012	0.003	0.003	0.005	0.005	0.051	0.055	0.026	0.025	0.001	0.001	1		0.94	0.92
4/06/2013	CC3	77	7	10	21	3	3	13	1.0	0.1	0.16	0.4	0.6	0.02	6.28	0.56	0.92	0.185	0.186	0.02	0.001	0.002	0.001	0.001	0.024	0.028	0.003	0.003	0.005	0.005	0.050	0.054	0.023	0.026	0.001	0.001	2		0.94	0.96
16/7/13	CC3	72	8	10	16	3	3	12	1.0	0.1	0.03	0.1	0.1	0.01	5.99	0.6	1.52	0.223	0.238	0.03	0.001	0.001	0.001	0.001	0.016	0.016	0.003	0.003	0.005	0.005	0.051	0.053	0.026	0.027	0.001	0.001	2	5	0.82	0.92
30/8/13	CC3	55	10	12	21	3	3	13	1.0	0.1	0.01	0.1	0.1	0.01	9.02	0.37	0.7	0.114	0.113	0.01	0.001	0.001	0.001	0.001	0.012	0.012	0.002	0.002	0.005	0.006	0.056	0.055	0.026	0.027	0.001	0.001	2	5	1.04	0.96
25/9/13	CC3	58	7	10	21	3	3	12	1.0	0.1	0.05	0.1	0.2	0.01	6.03	0.34	0.96	0.15	0.163	0.03	0.001	0.001	0.001	0.001	0.014	0.015	0.003	0.003	0.005	0.005	0.044	0.047	0.044	0.023	0.001	0.001	1	5	0.94	0.92
29/11/13	CC3	66	7	11	22	3	3	13	1.0	0.1	0.05	0.1	0.2	0.01	5.75	0.52	1.54	0.189	0.22	0.04	0.001	0.002	0.001	0.001	0.014	0.017	0.003	0.003	0.005	0.005	0.044	0.048	0.022	0.025	0.001	0.001	2	5	0.99	0.96
	ST Dev	16	5	3	6	1	1	2	0.3	0.0	0.67	0.3	0.9	0.67	0.81	0.28	0.78	0.099	0.11	0.03	0.000	0.000	0.000	0.000	0.072	0.006	0.004	0.001	0.008	0.001	0.016	0.005	0.010	0.002	0.004	0.000	1	0	0.16	0.07
	Max	132	24	16	39	5	5	20	2.0	0.1	2.56	1.1	3.7	3.93	9.02	1.41	3.48	0.322	0.35	0.19	0.003	0.002	0.001	0.001	0.426	0.028	0.010	0.004	0.050	0.006	0.090	0.060	0.060	0.028	0.010	0.001	3	5	1.44	1.17
	Min	55	4	5	4	3	3	11	0.1	0.1	0.01	0.1	0.1	0.01	4.93	0.04	0.33	0.010	0.01	0.01	0.001	0.001	0.001	0.001	0.001	0.012	0.001	0.002	0.001	0.004	0.019	0.044	0.022	0.023	0.001	0.001	1	5	0.82	0.88
	Median	77	10	11	22	3	3	13	1.0	0.1	0.05	0.1	0.1	0.01	6.02	0.40	0.94	0.100	0.12	0.03	0.001	0.001	0.001	0.001	0.010	0.016	0.003	0.003	0.005	0.005	0.050	0.054	0.027	0.026	0.001	0.001	1	5	0.94	0.96

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													**0.3**	**0.02**				**1.90**	**1.90**	**0.055**	**0.001**	**0.001**	**0.003**	**0.003**	**0.008**	**0.008**	**0.011**	**0.011**							**0.024 (III) / 0.013(V)**	**0.024 (III) / 0.013(V)**				
28/8/2008	**CC4**	75	9	8	32	4	4	17	1.0	0.1			0.1	0.01		0.12	0.52	0.01	0.01	0.03	0.001		0.001		0.001		0.010		0.006		0.060		0.030		0.010		1			
5/11/2008	**CC4**	71	10	6	30	4	4	15	1.0	0.1			0.3	0.06		0.42	1.30	0.01	0.02	0.08	0.001		0.001		0.002		0.010		0.002		0.030		0.030		0.010		3			
9/1/2009	**CC4**	66	14	4	30	4	4	15	0.2	0.1			0.1	0.06		0.39	6.70	0.02	0.17	0.01	0.002		0.001		0.011		0.010		0.001		0.040		0.050		0.010		3			
17/3/2009	**CC4**	74	19	5	31	4	4	17	0.9	0.1			0.1	0.01		0.67	2.90	0.01	0.02	0.03	0.001		0.001		0.001		0.010		0.002		0.030		0.030		0.010		3			
14/5/2009	**CC4**	72	15	7	29	4	4	16	0.7	0.1			0.2	0.01		0.11	1.10	0.01	0.03	0.02	0.001		0.001		0.001		0.010		0.002		0.020		0.020		0.010		3			
23/7/2009	**CC4**	81	14	8	34	4	4	20	0.9	0.1			0.1	0.01		0.11	0.58	0.03	0.03	0.02	0.001		0.001		0.004		0.010		0.003		0.030		0.030		0.010		1			
2/10/2010	**CC4**	72	19	5	31	4	4	18	1.0	0.1			0.2	0.01		0.19	1.60	0.04	0.06	0.03	0.001		0.001		0.002		0.010		0.002		0.034		0.033		0.010		3			
2/12/2009	**CC4**	63	17	6	27	4	4	16	1.0	0.1			0.1	0.01		0.77	1.30	0.01	0.05	0.02	0.001		0.001		0.003		0.010		0.003		0.032		0.029		0.010		3			
18/2/2010	**CC4**	70	12	9	28	3	4	15	0.5	0.1			0.1	0.01		0.12	1.80	0.19	0.20	0.02	0.001		0.001		0.012		0.010		0.002		0.036		0.026		0.010		3			
5/5/2010	**CC4**	75	11	10	35	4	4	19	0.8	0.1			0.1	0.01		0.11	0.77	0.01	0.01	0.01	0.001		0.001		0.002		0.010		0.001		0.024		0.025		0.010		1			
8/7/2010	**CC4**	70	14	7	33	4	4	18	0.7	0.1			0.1	0.01		0.14	0.67	0.01	0.01	0.02	0.001		0.001		0.014		0.010		0.005		0.042		0.034		0.010		1			
6/9/2010	**CC4**	101	13	12	24	4	4	12	1.0	0.1			0.1	0.01		0.32	0.60	0.17	0.18	0.01	0.001		0.001		0.021		0.001		0.005		0.059		0.032		0.001		1			
10/11/2010	**CC4**	70	11	11	25	4	3	12	1.0	0.1			0.1	0.04	5.38	0.38	0.75	0.238	0.23	0.02	0.001		0.001		0.022		0.004		0.005		0.054		0.029		0.001		1			
31/1/2011	**CC4**	67	9	13	30	4	3	13	1.0	0.1			0.6	0.01	6.21	0.26	0.83	0.195	0.201	0.01	0.001		0.001		0.017		0.003		0.006		0.057		0.031		0.001		1			
8/4/2011	**CC4**	41	8	10	24	4	3	12	1.0	0.1			0.2	0.05	7.79	0.58	1.11	0.315	0.328	0.03	0.001		0.001		0.016		0.004		0.004		0.053		0.026		0.001		2			
23/6/2011	**CC4**	130	7	10	22	4	3	15	1.0	0.1			0.1	0.02	5.79	0.53	1.05	0.241	0.268	0.02	0.001		0.001		0.017		0.004		0.005		0.057		0.027		0.001		1			
30/8/2011	**CC4**	65	7	11	24	4	3	14	1.0	0.1			0.1	0.01	6.9	0.38	0.4	0.199	0.205	0.02	0.001		0.001		0.017		0.003		0.006		0.055		0.027		0.001		1			
2/12/2011	**CC4**	111	4	8	29	3	3	18	1.0	<0.1			0.1	0.01	5.16	0.18	0.36	0.084	0.087	0.06	0.001		0.001		0.015		0.002		0.002		0.018		0.022		0.001		2			
5/4/2012	**CC4**	98	5	6	37	3	3	16	1.0	0.1			0.1	0.03	5.69	0.42	0.73	0.093	0.096	0.04	0.001		0.001		0.009		0.002		0.001		0.021		0.026		0.001		1			
11/5/2012	**CC4**	109	5	7	33	3	3	19	1.0	0.1			0.7	0.7	5	0.38	0.54	0.088	0.088	0.03	0.001		0.001		0.006		0.002		0.001		0.022		0.025		0.001		1			
25/6/2012	**CC4**	78	5	6	29	3	3	16	1.0	0.1	0.06	0.1	0.1	0.01	4.53	0.33	0.45	0.085	0.056	0.04	0.001		0.001		0.005		0.002		0.001		0.021		0.023		0.001		<1		1.04	1.09
22/8/2012	**CC4**	89	7	7	31	4	4	16	1.0	0.1	0.04	0.1	0.4	0.01	5.15	0.43	0.58	0.075	0.082	0.02	0.001		0.001		0.007		0.002		0.001		0.022		0.024		0.001		<1		1.16	1.22
24/10/2012	**CC4**	97	11	8	33	4	3	18	1.0	0.1	0.15	0.5	0.6	0.05	5.28	0.47	3.44	0.135	0.162	0.01	0.001		0.001		0.005		0.001		0.001		0.024		0.033		0.001		2		1.32	1.26
14/11/2012	**CC4**	84	90	5	29	4	3	17	1.0	0.1	0.03	0.1	0.1	0.01		0.87	1.64	0.216	0.227	0.04	0.008		0.001		0.018		0.002		0.001		0.024		0.026		0.001		2		1.1	1.21
20/12/2012	**CC4**	99	12	3	26	4	3	16	1.0	0.1	0.52	0.2	0.7	0.05	5.65	0.86	1.92	0.255	0.252	0.03	0.001		0.001		0.012		0.002		0.001		0.024		0.027		0.001		<1		1.04	1.17
23/1/2013	**CC4**	90	23	2	8	8	4	18	1.0	0.1	0.02	0.6	0.6	0.01	6.56	0.38	8.16	0.597	0.605	0.01	0.001		0.001		0.005		0.001		0.001		0.028		0.036		0.001		3		1.49	1.54
7/3/2013	**CC4**	92	4	6	31	3	3	18	1.0	0.1	0.08	0.2	0.3	0.01	4.73	0.34	0.7	0.096	0.097	0.07	0.001	0.001	0.001	0.001	0.005	0.006	0.001	0.001	0.001	0.001	0.016	0.016	0.023		0.001	0.001	2		1.08	1.18
21/3/2013	**CC4**	136	7	6	29	3	3	16	1.0	0.1	0.05	0.2	0.2	0.01	4.96	0.56	0.89	0.088	0.098	0.04	0.001	0.001	0.001	0.001	0.008	0.005	0.001	0.001	0.001	0.001	0.020	0.023	0.024	0.028	0.001	0.001	2		1.08	1.09
1/05/2013	**CC4**	66	5	6	29	3	3	16	1.0	0.1	0.08	0.1	0.1	0.01	5.46	0.41	0.66	0.07	0.074	0.03	0.001	0.001	0.001	0.001	0.007	0.005	0.001	0.001	0.001	0.001	0.019	0.023	0.022	0.025	0.001	0.001	2		1.04	1.09
4/06/2013	**CC4**	94	7	7	31	3	3	18	1.0	0.1	0.14	0.3	0.4	0.01	5.44	0.42	0.62	0.058	0.077	0.05	0.001	0.002	0.001	0.001	0.005	0.025	0.001	0.002	0.001	0.001	0.019	0.021	0.019	0.022	0.001	0.001	2		1.16	1.18
16/7/13	**CC4**	93	5	6	29	3	3	18	1.0	0.1	0.07	0.1	0.2	0.03	5.15	0.3	0.65	0.069	0.072	0.04	0.001	0.001	0.001	0.001	0.005	0.008	0.001	0.002	0.001	0.001	0.020	0.02	0.024	0.025	0.001	0.001	2	5	1.04	1.18
30/8/13	**CC4**	68	7	6	30	3	3	18	1.0	0.1	0.03	0.1	0.1	0.01	7.27	0.36	0.72	0.074	0.077	0.02	0.001	0.001	0.001	0.001	0.005	0.006	0.001	0.002	0.001	0.001	0.025	0.024	0.025	0.024	0.001	0.001	2	7	1.11	1.18
25/9/13	**CC4**	71	6	7	31	3	3	17	1.0	0.1	0.06	0.1	0.1	0.01	5.27	0.3	0.58	0.07	0.074	0.06	0.001	0.001	0.001	0.001	0.006	0.005	0.001	0.001	0.001	0.001	0.019	0.018	0.019	0.022	0.001	0.001	1	5	1.14	1.14
29/11/13	**CC4**	70	5	8	24	2	3	17	1.0	0.1	0.16	0.1	0.3	0.01	5.08	0.33	0.88	0.064	0.07	0.06	0.001	0.003	0.001	0.001	0.005	0.008	0.001	0.002	0.001	0.001	0.017	0.018	0.021	0.021	0.001	0.001	2	8	0.94	1.09

	ST Dev	20	15	2	5	1	0	2	0.2	0.0	0.13	0.2	0.2	0.12	0.85	0.20	1.68	0.120	0.12	0.02	0.001	0.001	0.000	0.000	0.006	0.007	0.004	0.001	0.002	0.000	0.014	0.003	0.006	0.002	0.004	0.000	1	2	0.14	0.11
	Max	136	90	13	37	8	4	20	1.0	0.1	0.52	0.6	0.7	0.70	7.79	0.87	8.16	0.597	0.61	0.08	0.008	0.003	0.001	0.001	0.022	0.025	0.010	0.002	0.006	0.001	0.060	0.024	0.050	0.028	0.010	0.001	3	8	1.49	1.54
	Min	41	4	2	8	2	3	12	0.2	0.1	0.02	0.1	0.1	0.01	4.53	0.11	0.36	0.010	0.01	0.01	0.001	0.001	0.001	0.001	0.001	0.005	0.001	0.001	0.001	0.001	0.016	0.016	0.019	0.021	0.001	0.001	1	5	0.94	1.09
	Median	75	9	7	30	4	3	17	1.0	0.1	0.07	0.1	0.1	0.01	5.38	0.38	0.76	0.080	0.08	0.03	0.001	0.001	0.001	0.001	0.006	0.006	0.002	0.002	0.001	0.001	0.025	0.021	0.026	0.024	0.001	0.001	2	6	1.09	1.18

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
5/11/2008	CC5	75	15	11	26	5	4	14	0.9	0.1			0.1	0.07		0.50	1.40	0.01	0.03	0.06	0.001		0.001		0.003		0.010		0.001		0.040		0.040		0.010		3			
9/1/2009	CC5	70	19	11	23	6	4	13	0.1	0.1			0.1	0.04		0.05	2.30	0.01	0.12	0.02	0.002		0.001		0.004		0.010		0.006		0.050		0.060		0.010		2			
17/3/2009	CC5	75	20	12	26	5	4	14	0.9	0.1			0.1	0.01		0.18	5.10	0.01	0.03	0.02	0.001		0.001		0.001		0.010		0.004		0.030		0.040		0.010		2			
14/5/2009	CC5	74	21	11	26	5	5	16	0.6	0.1			0.2	0.01		0.11	0.73	0.02	0.03	0.01	0.001		0.001		0.004		0.010		0.009		0.040		0.040		0.010		2			
23/7/2009	CC5	80	16	12	29	5	5	16	1.0	0.1			0.1	0.02		0.09	1.50	0.01	0.02	0.01	0.001		0.001		0.003		0.010		0.010		0.040		0.030		0.010		1			
2/10/2010	CC5	82	19	14	29	5	4	16	0.8	0.1			0.1	0.01		0.17	0.62	0.02	0.03	0.01	0.001		0.001		0.003		0.010		0.006		0.042		0.034		0.010		2			
2/12/2009	CC5	67	19	11	24	5	4	15	0.9	0.1			0.1	0.01		0.47	1.30	0.01	0.15	0.02	0.001		0.001		0.003		0.010		0.005		0.040		0.034		0.010		2			
18/2/2010	CC5	70	13	9	28	4	4	15	0.5	0.1			0.4	0.01		0.09	2.70	0.19	0.84	0.02	0.001		0.001		0.010		0.010		0.001		0.035		0.025		0.010		2			
5/5/2010	CC5	75	14	11	30	4	4	17	0.8	0.1			0.1	0.01		0.10	3.40	0.01	0.08	0.04	0.001		0.001		0.012		0.010		0.003		0.089		0.047		0.010		2			
8/7/2010	CC5	75	17	13	27	4	4	16	0.7	0.1			0.1	0.04		0.06	8.30	0.01	0.10	0.02	0.001		0.001		0.002		0.010		0.009		0.032		0.027		0.010		1			
6/9/2010	CC5	101	6	12	20	4	4	12	1.0	0.1			0.1	0.01		0.29	1.14	0.19	0.20	0.02	0.001		0.001		0.033		0.003		0.005		0.050		0.033		0.001		1			
10/11/2010	CC5	89	1	13	22	4	3	14	1.0	0.1			0.1	0.13	7.24	0.51	0.92	0.209	0.202	0.02	0.001		0.001		0.033		0.003		0.004		0.044		0.03		0.001		2			
31/1/2011	CC5	66	24	9	34	4	3	15	1.0	0.1			0.3	0.08	6.18	0.53	1.65	0.194	0.212	0.02	0.001		0.001		0.014		0.002		0.004		0.044		0.031		0.001		1			
8/4/2011	CC5	43	8	9	25	4	3	13	1.0	0.1			0.2	0.01	7.59	0.57	1.19	0.272	0.274	0.03	0.001		0.001		0.024		0.003		0.003		0.044		0.024		0.001		2			
23/6/2011	CC5	148	7	8	27	4	3	19	1.0	0.1			0.2	0.02	5.51	0.48	1.06	0.137	0.169	0.03	0.001		0.001		0.009		0.002		0.002		0.031		0.027		0.001		1			
30/8/2011	CC5	80	6	6	35	4	3	18	1.0	0.1			0.1	0.01	5.79	0.44	0.46	0.08	0.081	0.02	0.001		0.001		0.008		0.002		0.001		0.022		0.025		0.001		1			
2/12/2011	CC5	111	5	10	25	4	3	17	1.0	0.1			0.1	0.03	5.17	0.4	0.75	0.137	0.146	0.06	0.002		0.001		0.039		0.003		0.002		0.025		0.022		0.001		3			
5/4/2012	CC5	88	3	5	37	3	3	16	1.0	0.1			0.4	0.05	5.74	0.4	0.82	0.1	0.107	0.03	0.001		0.001		0.006		0.002		0.001		0.021		0.029		0.001		1			
11/5/2012	CC5	99	8	8	32	4	3	19	2.0	0.1			0.3	0.13	5.12	0.39	0.58	0.104	0.107	0.03	0.001		0.001		0.006		0.002		0.002		0.023		0.026		0.001		1			
25/6/2012	CC5	79	5	8	29	3	3	17	1.0	0.1	0.2	0.2	0.4	0.01	4.56	0.36	0.49	0.094	0.097	0.04	0.001		0.001		0.006		0.002		0.001		0.021		0.023		0.001		1		1.08	1.14
22/8/2012	CC5	91	11	8	29	5	4	16	2.0	0.1	0.18	0.2	0.1	0.4	5.34	0.35	3.68	0.101	0.112	0.02	0.001		0.001		0.007		0.001		0.001		0.03		0.027		0.001		1		1.2	1.33
24/10/2012	CC5	97	15	9	30	5	3	17	1.0	0.1	0.07	0.5	0.6	0.03	5.6	0.46	0.8	0.171	0.15	0.01	0.001		0.001		0.005		0.001		0.001		0.025		0.032		0.001		3		1.33	1.26
14/11/2012	CC5	89	15	7	26	6	3	16	1.0	0.1	1.22	0.7	1.9	0.02		0.42	1.18	0.197	0.189	0.02	0.001		0.001		0.005		0.001		0.002		0.028		0.029		0.001		2		1.18	1.27
20/12/2012	CC5	85	20	9	28	7	4	15	1.0	0.1	0.03	0.1	0.1	0.01	6.26	0.49	2.7	0.2	0.284	0.02	0.001		0.001		0.008		0.001		0.002		0.031		0.033		0.001		1		1.38	1.36
23/1/2013	CC5	78	22	10	7	7	4	15	2.0	0.1	0.58	0.5	1.1	0.01	6.32	0.58	1.66	0.236	0.241	0.02	0.001		0.001		0.009		0.002		0.004		0.039		0.036		0.001		3		1.44	1.378
7/3/2013	CC5	135	8	5	32	4	3	18	1.0	0.1	0.25	0.2	0.4	0.01	4.89	0.49	0.77	0.099	0.103	0.07	0.001	0.001	0.001	0.001	0.07	0.006	0.001	0.001	0.001	0.001	0.016	0.016	0.026		0.001	0.001	2		1.17	1.26
21/3/2013	CC5	67	8	6	29	3	3	16	1.0	0.1	0.05	0.2	0.2	0.01	4.92	0.53	0.89	0.093	0.101	0.04	0.001	0.001	0.001	0.001	0.005	0.009	0.001	0.002	0.001	0.001	0.019	0.023	0.024	0.027	0.001	0.001	2		1.1	1.09
1/05/2013	CC5	80	6	6	30	3	3	16	1.0	0.1	0.42	0.4	0.8	0.02	5.3	0.38	0.62	0.071	0.076	0.02	0.001	0.001	0.001	0.001	0.007	0.032	0.001	0.001	0.001	0.001	0.020	0.02	0.023	0.024	0.001	0.001	2		1.09	1.09
4/06/2013	CC5	95	12	7	30	5	3	17	1.0	0.1	0.22	0.3	0.5	0.01	5.56	0.37	0.69	0.074	0.078	0.05	0.001	0.001	0.001	0.001	0.009	0.01	0.001	0.002	0.001	0.001	0.020	0.02	0.024	0.028	0.001	0.001	2		1.23	1.24
16/7/13	CC5	89	5	6	29	3	3	18	1.0	0.1	0.04	0.2	0.2	0.03	5.18	0.34	0.61	0.082	0.0.72	0.04	0.001	0.001	0.001	0.001	0.005	0.009	0.001	0.002	0.001	0.001	0.022	0.021	0.025	0.027	0.001	0.001	2	5	1.04	1.18
30/8/13	CC5	69	10	7	31	4	3	18	1.0	0.1	0.18	0.3	0.5	0.01	7.68	0.32	1.42	0.099	0.109	0.02	0.001	0.001	0.001	0.001	0.006	0.012	0.001	0.001	0.001	0.001	0.024	0.025	0.028	0.03	0.001	0.001	2	5	1.22	1.23
25/9/13	CC5	72	7	7	30	3	3	17	1.0	0.1	0.06	0.2	0.3	0.03	5.18	0.28	0.48	0.071	0.067	0.05	0.001	0.001	0.001	0.001	0.005	0.008	0.001	0.001	0.001	0.001	0.017	0.02	0.017	0.023	0.001	0.001	1	5	1.13	1.14
29/11/13	CC5	69	7	8	25	3	3	17	1.0	0.1	0.06	0.1	0.2	0.01	5.09	0.33	0.74	0.069	0.077	0.05	0.001	0.002	0.001	0.001	0.006	0.014	0.001	0.002	0.001	0.001	0.018	0.019	0.021	0.023	0.001	0.001	2	5	1.01	1.14

ST Dev	20	6	2	5	1	1	2	0.4	0.0	0.32	0.2	0.4	0.07	0.87	0.16	1.60	0.076	0.145	0.016	0.000	0.000	0.000	0.000	0.014	0.008	0.004	0.001	0.003	0.000	0.014	0.003	0.008	0.003	0.004	0.000	1	0	0.13	0.10
Max	148	24	14	37	7	5	19	2.0	0.1	1.22	0.7	1.9	0.40	7.68	0.58	8.30	0.272	0.840	0.070	0.002	0.002	0.001	0.001	0.070	0.032	0.010	0.002	0.010	0.001	0.089	0.025	0.060	0.030	0.010	0.001	3	5	1.44	1.38
Min	43	1	5	7	3	3	12	0.1	0.1	0.03	0.1	0.1	0.01	4.56	0.05	0.46	0.010	0.020	0.010	0.001	0.001	0.001	0.001	0.001	0.006	0.001	0.001	0.001	0.001	0.016	0.016	0.017	0.023	0.001	0.001	1	5	1.01	1.09
Median	80	11	9	29	4	3	16	1.0	0.1	0.18	0.2	0.2	0.01	5.51	0.38	1.06	0.094	0.107	0.020	0.001	0.001	0.001	0.001	0.006	0.010	0.002	0.002	0.002	0.001	0.030	0.020	0.028	0.027	0.001	0.001	2	5	1.18	1.24

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
14/11/2012	CC6	95	16	11	28	6	3	15	1.0	0.1					0.34	0.26	0.8	0.099	0.11	0.03	0.001	0.006	0.001	0.01	0.001	0.02	0.038	0.004		0.14					0.005	0.002				
23/1/2013	CC6	71	17	10	6	6	3	15	1.0	0.1					0.13	0.47	0.97	0.084	0.105	0.032	0.001	0.001	0.001	0.005	0.001	0.02	0.032	0.003	6.52	0.08					0.005	0.003				
7/3/2013	CC6	110	7	7	29	3	3	16	1.0	0.1	0.06	0.2	0.3	0.01	5.22	0.42	0.93	0.182	0.185	0.07	0.001	0.001	0.001	0.001	0.01	0.012	0.002	0.002	0.002	0.003	0.028	0.029	0.024		0.001	0.001	2		1.1	1.09
21/3/2013	CC6	78		9	24	3	3	14	1.0	0.2	0.07	0.1	0.2	1.46	5.63	0.39	0.76	0.181	0.183	0.03	0.001	0.001	0.001	0.001	0.016	0.006	0.002	0.002	0.003	0.004	0.038	0.039	0.026	0.027	0.001	0.001	2			
1/05/2013	CC6	51	9	10	31	4	3	13	1.0	0.1	0.03	0.3	0.3	0.01	6.12	0.3	0.92	0.152	0.142	0.02	0.001	0.005	0.001	0.001	0.009	0.016	0.002	0.003	0.003	0.002	0.031	0.033	0.025	0.023	0.001	0.001	2		1.26	1.01
4/06/2013	CC6	88	8	8	27	4	3	15	1.0	0.1	0.05	0.2	0.2	0.01	5.95	0.34	0.63	0.137	0.135	0.05	0.001	0.001	0.001	0.001	0.012	0.015	0.002	0.002	0.003	0.003	0.033	0.038	0.023	0.027	0.001	0.001	1		1.09	1.1
16/7/13	CC6	76	6	8	22	3	3	15	1.0	0.1	0.09	0.1	0.2	0.05	5.64	0.3	0.99	0.154	0.149	0.03	0.001	0.001	0.001	0.001	0.01	0.012	0.002	0.002	0.003	0.003	0.037	0.039	0.026	0.026	0.001	0.001	2	5	0.91	1.05
30/8/13	CC6	59	10	10	23	4	3	15	1.0	0.1	0.01	0.1	0.1	0.01	8.11	0.11	0.36	0.095	0.1	0.02	0.001	0.001	0.001	0.001	0.008	0.006	0.002	0.002	0.004	0.004	0.043	0.048	0.028	0.028	0.001	0.001	2	5	1.06	1.1
25/9/13	CC6	61	8	9	25	3	3	14	1.0	0.1	0.07	0.2	0.3	0.02	5.78	0.19	0.43	0.119	0.122	0.03	0.001	0.001	0.001	0.001	0.01	0.012	0.001	0.002	0.003	0.003	0.032	0.033	0.032	0.023	0.001	0.001	1	5	1.05	1.01
29/11/13	CC6	66	7	10	21	3	3	15	1.0	0.1	0.05	0.1	0.2	0.01	5.78	0.24	0.55	0.125	0.129	0.03	0.001	0.002	0.001	0.001	0.009	0.011	0.002	0.002	0.003	0.003	0.031	0.034	0.022	0.024	0.001	0.001	2	5	0.94	1.05
	ST Dev	18	4	1	7	1	0	1	0.0	0.0	0.03	0.1	0.1	0.51	2.56	0.11	0.23	0.035	0.030	0.015	0.000	0.002	0.000	0.003	0.005	0.005	0.014	0.001	2.172	0.047	0.005	0.006	0.003	0.002	0.002	0.001	0	0	0.12	0.04
	Max	110	17	11	31	6	3	16	1.0	0.2	0.09	0.3	0.3	1.46	8.11	0.47	0.99	0.182	0.185	0.070	0.001	0.006	0.001	0.010	0.016	0.020	0.038	0.004	6.520	0.140	0.043	0.048	0.032	0.028	0.005	0.003	2	5	1.26	1.10
	Min	51	6	7	6	3	3	13	1.0	0.1	0.01	0.1	0.1	0.01	0.13	0.11	0.36	0.084	0.100	0.020	0.001	0.001	0.001	0.001	0.001	0.006	0.001	0.002	0.002	0.002	0.028	0.029	0.022	0.023	0.001	0.001	1	5	0.91	1.01
	Median	74	8	10	25	4	3	15	1.0	0.1	0.06	0.2	0.2	0.01	5.71	0.30	0.78	0.131	0.132	0.030	0.001	0.001	0.001	0.001	0.010	0.012	0.002	0.002	0.003	0.003	0.033	0.036	0.026	0.026	0.001	0.001	2	5	1.06	1.05

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001		0.003		0.008		0.011								0.024 (III) / 0.013(V)					
5/4/2012	CT1	42	2	9	13	1	2	8	1.0	0.1			0.3	0.01	4.98	2.87	6.88	0.254	0.343	0.17	0.001		0.001		0.033		0.004		0.002		0.038		0.019		0.001		4			
11/5/2012	CT1	73	3	15	16	2	3	11	1.0	0.1			0.3	0.24	5.77	3.38	4.6	0.406	0.427	0.03	0.001		0.001		0.023		0.004		0.003		0.077		0.026		0.001		1			
25/6/2012	CT1	53	3	9	14	1	2	9	1.0	0.1	0.07	0.1	0.1	0.01	4.65	1.86	2.24	0.24	0.254	0.04	0.001		0.001		0.02		0.003		0.003		0.05		0.017		0.001		1		0.64	0.61
17/7/2012	CT1	46	18	10	12	2	3	10	1.0	0.1	0.03	0.1	0.1	0.01	5.59	2.17	3.09	0.351	0.334	0.01	0.001		0.001		0.015		0.003		0.004		0.058		0.022		0.001		1		0.91	0.78
7/3/2013	CT1	100	4	17	22	3	3	13	1.0	0.1	0.01	0.1	0.1	0.01	5.71	4.1	4.43	0.454	0.449	0.04	0.001	0.001	0.001	0.001	0.092	0.092	0.019	0.019	0.006	0.006	0.078	0.082	0.034		0.001	0.001	2		1.05	0.96
21/3/2013	CT1	67	2	16	16	2	3	11	1.0	0.1	0.02	0.2	0.2	0.01	6.06	0.13	0.19	0.21	0.183	0.05	0.001	0.001	0.001	0.001	0.076	0.077	0.009	0.01	0.006	0.006	0.078	0.079	0.025	0.026	0.001	0.001	1		0.82	0.85
4/06/2013	CT1	64	<1	10	14	1	2	11	1.0	0.1	3.76	1.5	5.3	0.02	5.72	0.05	0.11	0.053	0.06	0.03	0.001	0.004	0.001	0.001	0.044	0.049	0.005	0.005	0.005	0.005	0.048	0.047	0.017	0.018	0.001	0.001	2		0.6	0.69
16/7/13	CT1	67	2	15	11	2	3	11	1.0	0.1	0.01	0.2	0.2	0.01	6.33	0.06	0.1	0.051	0.096	0.04	0.001	0.001	0.001	0.001	0.04	0.043	0.005	0.006	0.007	0.006	0.060	0.061	0.022	0.020	0.001	0.001	2	5	0.66	0.85
25/9/13	CT1	78	8	28	13	4	5	13	1.0	0.1	0.02	0.1	0.1	0.05	8.15	0.11	0.21	0.067	0.067	0.03	0.001	0.001	0.001	0.001	0.047	0.048	0.006	0.006	0.010	0.011	0.1	0.105	0.100	0.044	0.001	0.001	1	5	1.11	1.2
29/11/13	CT1	96	9	32	22	5	5	15	1.0	0.1	0.02	0.1	0.1	0.01	8.01	2.94	3.4	0.436	0.419	0.02	0.001	0.001	0.001	0.001	0.079	0.066	0.012	0.011	0.011	0.011	0.153	0.155	0.053	0.054	0.001	0.001	1	5	1.47	1.34
	ST Dev	19	5	8	4	1	1	2	0.0	0.0	1.32	0.5	1.6	0.07	1.15	1.57	2.37	0.158	0.153	0.045	0.000	0.001	0.000	0.000	0.027	0.019	0.005	0.005	0.003	0.003	0.033	0.038	0.026	0.016	0.000	0.000	1	0	0.30	0.25
	Max	100	18	32	22	5	5	15	1.0	0.1	3.76	1.5	5.3	0.24	8.15	4.10	6.88	0.454	0.449	0.170	0.001	0.004	0.001	0.001	0.092	0.092	0.019	0.019	0.011	0.011	0.153	0.155	0.100	0.054	0.001	0.001	4	5	1.47	1.34
	Min	42	2	9	11	1	2	8	1.0	0.1	0.01	0.1	0.1	0.01	4.65	0.05	0.10	0.051	0.060	0.010	0.001	0.001	0.001	0.001	0.015	0.043	0.003	0.005	0.002	0.005	0.038	0.047	0.017	0.018	0.001	0.001	1	5	0.60	0.61
	Median	67	3	15	14	2	3	11	1.0	0.1	0.02	0.1	0.2	0.01	5.75	2.02	2.67	0.247	0.294	0.035	0.001	0.001	0.001	0.001	0.042	0.058	0.005	0.008	0.006	0.006	0.069	0.081	0.024	0.026	0.001	0.001	1	5	0.87	0.85

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													0.3	0.02				1.90	1.90	0.055	0.001	0.001	0.003	0.003	0.008	0.008	0.011	0.011							0.024 (III) / 0.013(V)	0.024 (III) / 0.013(V)				
14/11/2012	CC7	91	15	11	29	5	3	14	2.0	0.1	0.02	0.1	0.1	0.02		0.37	0.95	0.126	0.116	0.01	0.004		0.001		0.007		0.001		0.003		0.041		0.032		0.001		2		1.35	1.16
23/1/2013	CC7	77	22	8	7	7	4	15	2.0	0.1	0.06	0.3	0.4	0.01	6.42	0.48	1.12	0.203	0.202	0.01	0.001		0.001		0.008		0.001		0.003		0.039		0.036		0.001		3		1.37	1.38
7/3/2013	CC7	122	6	8	29	3	3	16	1.0	0.1	0.02	0.2	0.2	0.01	5.26	0.41	0.95	0.196	0.204	0.04	0.001	0.001	0.001	0.001	0.015	0.017	0.004	0.003	0.003	0.003	0.033	0.032	0.024		0.001	0.001	2		1.1	1.09
21/3/2013	CC7	54	9	11	24	4	3	13	1.0	0.1	0.04	0.2	0.2	0.01	5.7	0.31	0.88	0.213	0.203	0.03	0.001	0.001	0.001	0.001	0.011	0.015	0.002	0.003	0.003	0.003	0.041	0.042	0.027	0.028	0.001	0.001	1		1.09	1.01
1/05/2013	CC7	56	9	10	31	4	3	12	1.0	0.1	0.09	0.1	0.2	0.19	6.19	0.22	0.72	0.156	0.183	0.02	0.001	0.001	0.001	0.001	0.009	0.011	0.002	0.002	0.003	0.003	0.030	0.041	0.025	0.030	0.001	0.001	1		1.26	0.97
4/06/2013	CC7	82	8	9	25	4	3	16	1.0	0.1	1.19	0.5	1.7	0.01	5.95	0.28	0.51	0.13	0.144	0.04	0.001	0.001	0.001	0.001	0.012	0.017	0.002	0.002	0.003	0.003	0.033	0.036	0.022	0.024	0.001	0.001	2		1.05	1.14
16/7/13	CC7	79	7	8	22	3	3	15	1.0	0.1	0.06	0.1	0.1	0.04	5.66	0.3	0.72	0.152	0.159	0.04	0.001	0.001	0.001	0.001	0.009	0.01	0.003	0.003	0.003	0.003	0.035	0.038	0.026	0.027	0.001	0.001	2	5	0.93	1.05
30/8/13	CC7	65	10	10	23	4	3	15	1.0	0.1	0.04	0.2	0.2	0.02	8.18	0.09	0.37	0.067	0.065	<0.01	0.001	0.001	0.001	0.001	0.005	0.007	0.001	0.001	0.004	0.004	0.037	0.039	0.03	0.026	0.001	0.001	2	5	1.06	1.1
25/9/13	CC7	62	7	9	22	3	3	14	1.0	0.1	0.06	0.1	0.2	0.03	5.82	0.11	0.32	0.106	0.11	0.03	0.001	0.001	0.001	0.001	0.015	0.012	0.001	0.002	0.003	0.003	0.034	0.035	0.034	0.024	0.001	0.001	2	5	0.95	1.01
29/11/13	CC7	69	7	10	21	3	3	14	1.0	0.1	0.06	0.1	0.2	0.01	5.86	0.13	0.48	0.106	0.11	0.03	0.001	0.002	0.001	0.001	0.015	0.018	0.002	0.002	0.003	0.003	0.033	0.034	0.023	0.023	0.001	0.001	2	5	0.94	1.01
	ST Dev	20	5	1	7	1	0	1	0.4	0.0	0.36	0.1	0.5	0.06	0.84	0.13	0.27	0.048	0.049	0.012	0.001	0.000	0.000	0.000	0.004	0.004	0.001	0.001	0.000	0.000	0.004	0.003	0.005	0.003	0.000	0.000	1	0	0.16	0.12
	Max	122	22	11	31	7	4	16	2.0	0.1	1.19	0.5	1.7	0.19	8.18	0.48	1.12	0.213	0.204	0.040	0.004	0.002	0.001	0.001	0.015	0.018	0.004	0.003	0.004	0.004	0.041	0.042	0.036	0.030	0.001	0.001	3	5	1.37	1.38
	Min	54	6	8	7	3	3	12	1.0	0.1	0.02	0.1	0.1	0.01	5.26	0.09	0.32	0.067	0.065	0.010	0.001	0.001	0.001	0.001	0.005	0.007	0.001	0.001	0.003	0.003	0.030	0.032	0.022	0.023	0.001	0.001	1	5	0.93	0.97
	Median	73	9	10	24	4	3	15	1.0	0.1	0.06	0.2	0.2	0.02	5.86	0.29	0.72	0.141	0.152	0.030	0.001	0.001	0.001	0.001	0.010	0.014	0.002	0.002	0.003	0.003	0.035	0.037	0.027	0.026	0.001	0.001	2	5	1.08	1.07

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													**0.3**	**0.02**				**1.90**	**1.90**	**0.055**	**0.001**		**0.003**		**0.008**		**0.011**								**0.024 (III) / 0.013(V)**					
14/11/2012	**CC8**	92	16	8	30	5	3	14	1.0	0.1	0.01	0.1	0.1	0.02		0.38	2.18	0.265	0.278	0.02	0.001		0.001		0.005		0.001		0.005		0.068		0.036		0.001		2		1.33	1.13
23/1/2013	**CC8**	71	25	3	6	6	4	16	1.0	0.1	0.06	0.3	0.4	0.01	6.54	0.44	2.94	0.528	0.576	0.02	0.001		0.001		0.005		0.002		0.005		0.067		0.039		0.001		3		1.35	1.35
7/3/2013	**CC8**	94	8	8	27	3	3	16	1.0	0.1	0.04	0.1	0.1	0.01	5.52	0.57	1.03	0.22	0.231	0.08	0.001	0.001	0.001	0.001	0.023	0.018	0.002	0.002	0.004	0.004	0.041	0.044	0.031		0.001	0.001	2		1.09	1.09
21/3/2013	**CC8**	58	15	9	21	4	3	14	1.0	0.1	0.03	0.1	0.1	0.01	6.08	0.61	1.21	0.21	0.216	0.02	0.001	0.001	0.001	0.001	0.014	0.012	0.003	0.003	0.004	0.004	0.052	0.056	0.030	0.032	0.001	0.001	2		1.08	1.06
1/05/2013	**CC8**	34	11	10	30	4	3	13	1.0	0.1	0.03	0.4	0.4	0.01	6.43	0.75	1.03	0.196	0.186	0.02	0.001	0.001	0.001	0.001	0.01	0.011	0.002	0.002	0.004	0.004	0.044	0.049	0.029	0.028	0.001	0.001	1		1.27	1.01
4/06/2013	**CC8**	76	10	8	24	4	3	15	1.0	0.1	2.84	0.6	3.4	0.04	6.14	0.57	0.83	0.16	0.157	0.02	0.001	0.001	0.001	0.001	0.014	0.017	0.002	0.002	0.004	0.004	0.044	0.047	0.027	0.028	0.001	0.001	2		1.04	1.1
16/7/13	**CC8**	79	10	8	20	3	3	15	1.0	0.1	0.04	0.2	0.2	0.01	6.11	0.48	0.88	0.171	0.164	0.03	0.001	0.001	0.001	0.001	0.011	0.015	0.002	0.003	0.004	0.004	0.049	0.052	0.030	0.030	0.001	0.001	2	5	0.93	1.05
30/8/13	**CC8**	63	12	10	23	4	3	14	1.0	0.1	0.02	0.2	0.2	0.01	8.37	0.32	0.99	0.145	0.153	0.01	0.001	0.001	0.001	0.001	0.005	0.007	0.001	0.001	0.004	0.004	0.055	0.059	0.03	0.032	0.001	0.001	2	5	1.1	1.06
25/9/13	**CC8**	68	12	10	22	4	3	15	1.0	0.1	0.13	0.1	0.2	0.02	6.63	0.35	0.62	0.128	0.133	0.02	0.001	0.001	0.001	0.001	0.011	0.011	0.001	0.002	0.004	0.004	0.049	0.051	0.049	0.03	0.001	0.001	1	5	1.07	1.1
29/11/13	**CC8**	70	14	11	19	4	3	16	1.0	0.1	0.04	0.1	0.1	0.01	6.57	0.37	0.91	0.14	0.139	0.02	0.001	0.002	0.001	0.001	0.014	0.015	0.002	0.003	0.004	0.004	0.052	0.05	0.03	0.03	0.001	0.001	2	5	1.04	1.14
	ST Dev	17	5	2	7	1	0	1	0.0	0.0	0.88	0.2	1.0	0.01	0.79	0.14	0.72	0.12	0.132	0.020	0.000	0.000	0.000	0.000	0.006	0.004	0.001	0.001	0.000	0.000	0.009	0.005	0.007	0.002	0.000	0.000	1	0	0.14	0.09
	Max	94	25	11	30	6	4	16	1.0	0.1	2.84	0.6	3.4	0.04	8.37	0.75	2.94	0.53	0.576	0.080	0.001	0.002	0.001	0.001	0.023	0.018	0.003	0.003	0.005	0.004	0.068	0.059	0.049	0.032	0.001	0.001	3	5	1.35	1.35
	Min	34	8	3	6	3	3	13	1.0	0.1	0.01	0.1	0.1	0.01	5.52	0.32	0.62	0.13	0.133	0.010	0.001	0.001	0.001	0.001	0.005	0.007	0.001	0.001	0.004	0.004	0.041	0.044	0.027	0.028	0.001	0.001	1	5	0.93	1.01
	Median	71	12	9	23	4	3	15	1.0	0.1	0.04	0.2	0.2	0.01	6.43	0.46	1.01	0.18	0.175	0.020	0.001	0.001	0.001	0.001	0.011	0.014	0.002	0.002	0.004	0.004	0.051	0.051	0.030	0.030	0.001	0.001	2	5	1.09	1.10

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													**0.3**	**0.02**				**1.90**	**1.90**	**0.055**	**0.001**	**0.001**	**0.003**	**0.003**	**0.008**	**0.008**	**0.011**	**0.011**							**0.024 (III) / 0.013(V)**	**0.024 (III) / 0.013(V)**				
5/11/2008	**CC9**	52	14	5	20	2	3	13	0.8	0.1			0.6	0.08		0.82	1.50	0.01	0.04	0.08	0.001		0.001		0.001		0.010		0.003		0.020		0.020		0.010		6			
9/1/2009	**CC9**	68	25	9	22	7	4	12	0.1	0.1			0.1	0.06		0.28	1.80	0.01	0.02	0.01	0.001		0.001		0.003		0.010		0.005		0.060		0.110		0.010		2			
17/3/2009	**CC9**	80	28	11	25	6	4	16	1.0	0.1			0.1	0.01		0.21	1.00	0.01	0.02	0.03	0.001		0.001		0.001		0.010		0.003		0.050		0.040		0.010		2			
14/5/2009	**CC9**	81	21	12	27	6	5	17	0.7	0.1			0.1	0.01		0.03	0.49	0.01	0.02	0.01	0.001		0.001		0.001		0.010		0.009		0.030		0.030		0.010		2			
23/7/2009	**CC9**	78	18	11	29	5	5	17	0.9	0.1			0.1	0.04		0.09	0.74	0.01	0.01	0.02	0.001		0.001		0.003		0.010		0.007		0.050		0.030		0.010		1			
2/10/2010	**CC9**	69	22	13	23	5	4	15	0.9	0.1			0.1	0.01		0.12	0.42	0.01	0.01	0.01	0.001		0.001		0.001		0.010		0.008		0.056		0.040		0.010		2			
2/12/2009	**CC9**	71	20	11	23	6	4	14	1.0	0.1			0.1	0.01		0.34	1.70	0.01	0.11	0.02	0.001		0.001		0.003		0.010		0.002		0.051		0.039		0.010		2			
18/2/2010	**CC9**	72	15	8	29	4	3	16	0.6	0.1			0.4	0.01		0.24	1.90	0.11	0.30	0.03	0.001		0.001		0.009		0.010		0.001		0.043		0.028		0.010		3			
5/5/2010	**CC9**	64	17	7	26	3	3	17	0.7	0.1			0.1	0.01		0.03	1.40	0.01	0.03	0.02	0.001		0.001		0.003		0.010		0.002		0.042		0.033		0.010		1			
8/7/2010	**CC9**	70	19	11	25	5	4	15	0.7	0.1			0.1	0.01		0.05	0.83	0.01	0.02	0.01	0.001		0.001		0.001		0.001		0.007		0.041		0.033		0.010		1			
7/9/2010	**CC9**	90	8	11	25	4	4	13	1.0	0.1			0.1	0.02		0.34	0.70	0.13	0.14	0.02	0.001		0.001		0.008		0.001		0.004		0.062		0.036		0.001		1			
11/11/2010	**CC9**	62	1	13	23	4	3	14	1.0	0.1			1.2	0.11	4.81	0.23	0.66	0.002	0.148	0.03	0.004		0.014		0.029		0.001		0.144		0.001		0.051		0.001		1			
31/1/2011	**CC9**	96	26	8	32	4	3	14	1.0	0.1			0.4	0.11	6.02	0.3	1.04	0.125	0.133	0.01	0.001		0.001		0.005		0.001		0.005		0.056		0.035		0.001		2			
8/4/2011	**CC9**	53	8	8	24	4	3	13	1.0	0.1			0.3	0.02	8.04	0.4	1	0.222	0.239	0.03	0.001		0.001		0.009		0.002		0.003		0.048		0.025		0.001		2			
23/6/2011	**CC9**	100	9	8	25	4	3	18	1.0	0.1			0.1	0.02	5.52	0.83	0.92	0.19	0.208	0.07	0.002		0.001		0.01		0.002		0.003		0.052		0.028		0.001		1			
30/8/2011	**CC9**	66	14	9	26	4	3	15	1.0	0.1			0.1	0.01	6.49	0.36	0.37	0.163	0.158	0.02	0.001		0.001		0.008		0.002		0.003		0.053		0.029		0.001		1			
2/12/2011	**CC9**	91	8	10	20	4	3	15	1.0	0.1			0.1	0.01	5.75	0.29	0.62	0.167	0.171	0.04	0.001		0.001		0.018		0.002		0.004		0.041		0.025		0.001		2			
5/4/2012	**CC9**	51	2	3	16	1	1	10	1.0	0.1			1.2	0.07	2.13	0.69	2.45	0.067	0.417	0.11	0.001		0.001		0.008		0.001		0.001		0.009		0.01		0.001		5			
11/5/2012	**CC9**	96	9	10	20	4	3	15	1.0	0.1			0.1	0.01	5.64	0.29	1.16	0.192	0.212	0.02	0.001		0.001		0.012		0.002		0.004		0.051		0.028		0.001		1			
26/6/2012	**CC9**	68	12	8	22	3	3	13	1.0	0.1	0.04	0.2	0.2	0.02	4.8	0.52	1.08	0.196	0.214	0.04	0.001		0.001		0.024		0.002		0.004		0.051		0.028		0.001		1		1.03	0.96
17/7/2012	**CC9**	55	7	8	24	3	2	12	1.0	0.1	0.03	0.1	0.1	0.01	5.45	0.54	0.98	0.169	0.158	0.03	0.001		0.001		0.006		0.001		0.004		0.047		0.027		0.001		1		0.98	0.84
22/8/2012	**CC9**	87	13	10	23	4	3	13	1.0	0.1	0.02	0.1	0.1	0.1	5.88	0.47	1.02	0.157	0.157	0.02	0.001		0.001		0.008		0.001		0.004		0.054		0.031		0.001		1		1.12	1.01
24/10/2012	**CC9**	80	14	9	23	4	3	15	2.0	0.1	0.02	0.3	0.3	0.02	6	0.59	1.8	0.096	0.191	0.01	0.001		0.001		0.005		0.001		0.003		0.055		0.034		0.001		3		1.12	1.15
23/1/2013	**CC9**	70	24	4	5	5	4	16	2.0	0.1	0.13	0.4	0.5	0.01	5.68	0.69	4.06	0.356	0.356	0.01	0.001		0.001		0.006		0.001		0.004		0.059		0.035		0.001		4		1.32	1.33
7/3/2013	**CC9**	95	7	8	27	3	3	16	1.0	0.1	3.75	0.9	4.6	0.02	5.41	0.47	1.08	0.212	0.213	0.04	0.001	0.001	0.001	0.001	0.017	0.023	0.002	0.002	0.003	0.003	0.042	0.043	0.029		0.001	0.001	2		1.07	1.09
21/3/2013	**CC9**	64	12	9	21	4	3	14	1.0	0.1	0.08	0.2	0.3	0.01	5.94	0.4	1.13	0.225	0.22	0.02	0.001	0.001	0.001	0.001	0.01	0.012	0.002	0.003	0.005	0.004	0.058	0.058	0.032	0.033	0.001	0.001	2		1.02	1.06
1/05/2013	**CC9**	28	11	9	30	4	3	13	1.0	0.1	0.01	0.2	0.2	0.01	6.33	0.37	0.84	0.174	0.174	0.02	0.001	0.001	0.001	0.001	0.009	0.011	0.002	0.002	0.004	0.003	0.045	0.053	0.030	0.030	0.001	0.001	2		1.25	1.01
4/06/2013	**CC9**	80	9	8	24	3	3	15	1.0	0.1	0.18	0.2	0.4	0.01	5.88	0.39	0.66	0.144	0.14	0.04	0.001	0.001	0.001	0.001	0.01	0.013	0.002	0.001	0.004	0.004	0.045	0.049	0.025	0.028	0.001	0.001	2		1.02	1.05
16/7/13	**CC9**	77	10	8	20	3	3	13	1.0	0.1	0.03	0.1	0.1	0.01	5.86	0.36	0.74	0.151	0.166	0.03	0.001	0.001	0.001	0.001	0.009	0.011	0.002	0.002	0.004	0.004	0.050	0.053	0.028	0.031	0.001	0.001	2	5	0.93	1.96
30/8/13	**CC9**	62	12	9	22	4	3	15	1.0	0.1	0.04	0.3	0.3	0.02	7.98	0.24	1.81	0.141	0.149	0.04	0.001	0.001	0.001	0.001	0.005	0.012	0.001	0.002	0.004	0.004	0.058	0.06	0.031	0.032	0.001	0.001	2	9	1.05	1.1
25/9/13	**CC9**	67	12	10	25	4	3	15	1.0	0.1	0.04	0.1	0.1	0.02	6.37	0.13	0.56	0.117	0.122	0.02	0.001	0.001	0.001	0.001	0.016	0.014	0.001	0.002	0.004	0.004	0.041	0.043	0.041	0.029	0.001	0.001	2	5	1.15	1.1
29/11/13	**CC9**	61	14	10	16	4	3	16	1.0	0.1	0.29	0.1	0.4	0.01	6.18	0.23	0.83	0.123	0.142	0.04	0.002	0.001	0.001	0.001	0.016	0.014	0.002	0.002	0.004	0.004	0.052	0.053	0.029	0.03	0.001	0.001	2	12	0.94	1.14
	ST Dev	16	7	2	5	1	1	2	0.3	0.0	1.02	0.2	0.8	0.03	1.16	0.21	0.72	0.088	0.099	0.022	0.001	0.000	0.002	0.000	0.007	0.004	0.004	0.001	0.025	0.000	0.014	0.006	0.016	0.002	0.004	0.000	1	3	0.11	0.27
	Max	100	28	13	32	7	5	18	2.0	0.1	3.75	0.9	4.6	0.11	8.04	0.83	4.06	0.356	0.417	0.110	0.004	0.001	0.014	0.001	0.029	0.023	0.010	0.003	0.144	0.004	0.062	0.060	0.110	0.033	0.010	0.001	6	12	1.32	1.96
	Min	28	1	3	5	1	1	10	0.1	0.1	0.01	0.1	0.1	0.01	2.13	0.03	0.37	0.002	0.010	0.010	0.001	0.001	0.001	0.001	0.001	0.011	0.001	0.001	0.001	0.003	0.001	0.043	0.010	0.028	0.001	0.001	1	5	0.93	0.84
	Median	70	13	9	24	4	3	15	1.0	0.1	0.04	0.2	0.1	0.01	5.88	0.34	1.00	0.128	0.153	0.020	0.001	0.001	0.001	0.001	0.008	0.013	0.002	0.002	0.004	0.004	0.050	0.053	0.030	0.030	0.001	0.001	2	7	1.05	1.09

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe Filt	Fe T	Mn Filt	Mn T	Al Filt	Cu Filt	Cu T	Pb Filt	Pb T	Zn Filt	Zn T	Ni Filt	Ni T	Li Filt	Li T	Ba Filt	Ba T	Sr Filt	Sr T	As Filt	As T	DOC	SS	TA	TC
ANZECC													**0.3**	**0.02**				**1.90**	**1.90**	**0.055**	**0.001**	**0.001**	**0.003**	**0.003**	**0.008**	**0.008**	**0.011**	**0.011**							**0.024 (III) / 0.013(V)**	**0.024 (III) / 0.013(V)**				
28/8/2008	**CD1**	52	7	6	21	2	2	12	0.8	0.1			0.3	0.01		0.31	0.42	0.02	0.02	0.05	0.004		0.001		0.009		0.010		0.001		0.010		0.030		0.010		5			
5/11/2008	**CD1**	46	7	6	19	1	2	12	0.8	0.1			1.1	0.10		0.28	0.46	0.01	0.02	0.03	0.001		0.001		0.001		0.010		0.001		0.010		0.020		0.010		7			
9/1/2009	**CD1**	44	5	3	20	2	2	11	0.4	0.1			0.8	0.04		0.07	0.79	0.02	0.03	0.03	0.001		0.001		0.007		0.010		0.001		0.090		0.070		0.010		5			
14/5/2009	**CD1**	60	17	6	21	2	2	17	1.1	0.1			0.4	0.01		0.03	0.40	0.04	0.07	0.01	0.001		0.001		0.009		0.010		0.007		0.020		0.030		0.010		5			
23/7/2009	**CD1**	78	30	7	25	3	3	21	0.9	0.1			0.1	0.01		0.07	0.20	0.04	0.06	0.03	0.001		0.001		0.020		0.010		0.001		0.020		0.050		0.010		3			
2/10/2010	**CD1**	55	7	6	23	2	3	14	0.7	0.1			0.3	0.01		0.12	0.22	0.01	0.02	0.01	0.001		0.001		0.002		0.010		0.002		0.005		0.025		0.010		3			
2/12/2009	**CD1**	63	17	6	24	4	3	14	1.2	0.1			0.3	0.01		0.92	2.50	0.01	0.17	0.01	0.001		0.001		0.002		0.010		0.001		0.041		0.029		0.010		4			
18/2/2010	**CD1**	61	10	6	26	3	3	14	0.5	0.1			0.1	0.01		0.20	1.40	0.07	0.17	0.02	0.001		0.001		0.007		0.010		0.002		0.026		0.019		0.010		4			
5/5/2010	**CD1**	65	12	6	27	3	3	15	0.6	0.1			0.2	0.01		0.03	0.57	0.07	0.02	0.02	0.001		0.001		0.004		0.010		0.001		0.020		0.020		0.010		2			
8/7/2010	**CD1**	54	9	6	22	2	2	14	0.7	0.1			0.1	0.01		0.06	0.20	0.01	0.01	0.02	0.001		0.001		0.015		0.010		0.001		0.040		0.027		0.010		4			
6/9/2010	**CD1**	86	4	5	21	2	2	13	1.0	0.1			0.4	0.01		0.22	0.64	0.04	0.05	0.03	0.001		0.001		0.005		0.001		0.001		0.020		0.019		0.001		4			
11/11/2010	**CD1**	70	4	7	24	2	2	12	1.0	0.1			0.8	0.05	0.94	0.18	0.26	0.001	0.055	0.06	0.001		0.079		0.014		0.001		0.057		0.005		0.014		0.001		7			
31/1/2011	**CD1**	44	12	5	26	1	2	13	1.0	0.1			0.3	0.02	1.08	0.13	0.37	0.027	0.039	0.02	0.001		0.001		0.007		0.002		0.001		0.009		0.014		0.001		5			
8/4/2011	**CD1**	58	1.0	10	21	2	2	11	1.0	0.1			3.7	0.21	1.97	0.29	0.8	0.092	0.105	0.04	0.001		0.001		0.007		0.001		0.001		0.01		0.012		0.001		6			
23/6/2011	**CD1**	99	3	4	22	2	2	15	1.0	0.1			0.3	0.06	2.6	0.17	0.51	0.033	0.05	0.08	0.001		0.001		0.005		0.001		0.001		0.013		0.012		0.001		4			
30/8/2011	**CD1**	35	2	4	16	1	2	12	1.0	0.1			0.1	0.01	1.54	0.21	0.22	0.038	0.039	0.08	0.001		0.001		0.005		0.001		0.001		0.01		0.011		0.001		4			
2/12/2011	**CD1**	66	2	5	20	1	2	12	1.0	0.1			1.2	0.05	1.37	0.3	0.67	0.055	0.066	0.07	0.002		0.001		0.022		0.001		0.001		0.009		0.011		0.001		5			
5/4/2012	**CD1**	42	2	3	16	1	1	9	1.0	0.1			3.2	0.04	1.98	0.33	0.7	0.058	0.074	0.12	0.002		0.001		0.023		0.001		0.001		0.008		0.01		0.001		5			
11/5/2012	**CD1**		8	4	17	1	2	11	1.0	0.1			0.9	0.54	1.98	0.36	0.67	0.068	0.077	0.14	0.001		0.001		0.006		0.001		0.001		0.008		0.01		0.001		5			
26/6/2012	**CD1**	36	6	4	16	1	1	9	1.0	0.1	0.02	0.2	0.2	0.02	1.86	0.42	0.6	0.055	0.057	0.1	0.001		0.001		0.006		0.001		0.001		0.009		0.009		0.001		5		0.65	0.52
17/7/2012	**CD1**	37	5	3	17	1	1	8	1.0	0.1	0.14	0.2	0.3	0.05	1.9	0.35	0.75	0.033	0.026	0.09	0.001		0.001		0.005		0.001		0.001		0.009		0.011		0.001		4		0.64	0.48
22/8/2012	**CD1**	62	3	4	18	1	2	9	1.0	0.1	0.01	0.6	0.6	0.6	1.62	0.39	1.34	0.053	0.074	0.07	0.001		0.001		0.005		0.001		0.001		0.01		0.011		0.001		3		0.65	0.61
24/10/2012	**CD1**	62	4	5	19	1	1	12	1.0	0.1	0.02	0.6	0.6	0.05	1.28	0.39	1.28	0.108	0.108	0.04	0.001		0.001		0.005		0.001		0.001		0.011		0.014		0.001		4		0.72	0.65
14/11/2012	**CD1**	64	3	4	19	1	2	10	1.0	0.1	0.29	0.4	0.7	0.01		0.6	1.4	0.1	0.105	0.06	0.001		0.001		0.005		0.001		0.001		0.008		0.013		0.001		4		0.68	0.65
23/1/2013	**CD1**	50	10	3	3	3	2	13	4.0	0.1	0.03	1	1	0.01	0.1	0.66	3.51	0.314	0.357	0.03	0.001		0.001		0.006		0.001		0.001		0.012		0.022		0.001		5		1	0.98
7/3/2013	**CD1**	105	2	3	22	1	2	12	1.0	0.1	0.01	0.5	0.5	0.01	1.76	0.25	0.56	0.065	0.069	0.12	0.002	0.002	0.001	0.001	0.01	0.012	0.001	0.001	0.001	0.001	0.01	0.010	0.011		0.001	0.001	6		0.72	0.76
21/3/2013	**CD1**	41	3	4	17	1	1	10	1.0	0.1	0.06	0.5	0.6	0.01	1.47	0.31	0.63	0.07	0.081	0.08	0.001	0.001	0.001	0.001	0.015	0.016	0.002	0.001	0.001	0.001	0.010	0.02	0.012	0.013	0.001	0.001	5		0.62	0.59
1/05/2013	**CD1**		3							0.1	0.01	0.4	0.4	0.01		0.26	0.48	0.038	0.042	0.04	0.001	0.001	0.001	0.001	0.006	0.006	0.001	0.001	0.001	0.001	0.007	0.008	0.012	0.011	0.001	0.001	5			
4/06/2013	**CD1**	59	2	5	17	2	2	12	1.0	0.1	0.42	0.5	0.9	0.01	1.99	0.19	0.49	0.047	0.051	0.04	0.001	0.004	0.001	0.001	0.011	0.028	0.001	0.001	0.001	0.001	0.012	0.014	0.014	0.014	0.001	0.001	4		0.62	0.79
16/7/13	**CD1**	40	2	4	13	1	1	9	1.0	0.1	0.02	0.4	0.4	0.08	1.07	0.3	0.25	0.022	0.022	0.2	0.001	0.001	0.001	0.001	0.006	0.005	0.001	0.001	0.001	0.001	0.008	0.008	0.010	0.010	0.001	0.001	7	5	0.49	0.47
30/8/13	**CD1**	44	2	4	15	1	1	11	1.0	0.1	0.17	0.6	0.8	0.01	1.95	0.22	0.52	0.016	0.019	0.1	0.001	0.001	0.001	0.002	0.008	0.014	0.001	0.001	0.001	0.001	0.011	0.012	0.011	0.011	0.001	0.001	6	5	0.55	0.64
25/9/13	**CD1**	43	2	4	20	1	1	9	1.0	0.1	0.03	0.3	0.3	0.01	1.4	0.22	0.7	0.023	0.032	0.12	0.001	0.002	0.001	0.001	0.005	0.01	0.001	0.001	0.001	0.001	0.009	0.01	0.009	0.01	0.001	0.001	6	5	0.69	0.52
29/11/13	**CD1**	41	2	5	15	1	1	10	1.0	0.1	0.03	0.2	0.2	0.01	1.52	0.23	0.49	0.039	0.048	0.07	0.002	0.003	0.001	0.001	0.008	0.008	0.001	0.002	0.001	0.001	0.009	0.01	0.01	0.011	0.001	0.001	2	5	0.57	0.57
	ST Dev	17	6	2	5	1	1	3	0.6	0.0	0.13	0.2	0.8	0.14	0.53	0.18	0.68	0.054	0.065	0.044	0.001	0.001	0.014	0.000	0.005	0.007	0.004	0.000	0.010	0.000	0.016	0.004	0.013	0.002	0.004	0.000	1	0	0.12	0.14
	Max	105	30	10	27	4	3	21	4.0	0.1	0.42	1.0	3.7	0.60	2.60	0.92	3.51	0.314	0.357	0.200	0.004	0.004	0.079	0.002	0.023	0.028	0.010	0.002	0.057	0.001	0.090	0.020	0.070	0.014	0.010	0.001	7	5	1.00	0.98
	Min	35	1	3	3	1	1	8	0.4	0.1	0.01	0.2	0.1	0.01	0.10	0.03	0.20	0.001	0.010	0.010	0.001	0.001	0.001	0.001	0.001	0.005	0.001	0.001	0.001	0.001	0.005	0.008	0.009	0.010	0.001	0.001	2	5	0.49	0.47
	Median	55	4	5	20	1	2	12	1.0	0.1	0.03	0.5	0.4	0.01	1.58	0.25	0.57	0.039	0.051	0.050	0.001	0.002	0.001	0.001	0.006	0.011	0.001	0.001	0.001	0.001	0.010	0.010	0.013	0.011	0.001	0.001	5	5	0.65	0.61

APPENDIX B

CATARACT RIVER LABORATORY ANALYSES

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe	Fe T	Mn	Mn T	Al	Cu	Pb	Zn	Ni	Li	Ba	Sr	As	DOC	TA	TC
ANZECC													0.25	0.02				1.9	1.9	0.055	0.001	0.003	0.008	0.011				0.024 (III) / 0.013(V)			
12/04/12	CR1	42	1	2	12	1	1	7	1	0.1	0.02	0.20	0.2	0.06	3.39	1.7	1.4	0.039	0.036	0.540	0.001	0.001	0.011	0.002	0.001	0.003	0.004	0.002	6	0.38	0.30
14/05/12	CR1	40	3	4	14	1	1	9	1	0.1	0.02	1.20	1.2	1.32	2.96	1.82	1.55	0.055	0.045	0.460	0.001	0.001	0.010	0.002	0.001	0.003	0.005	0.002	5	0.54	0.47
26/7/12	CR1	54	5	6	14	1	1	8	1	0.1	0.02	0.60	0.6	0.05	3.11	0.99	1.71	0.038	0.042	0.360	0.001	0.001	0.011	0.002	0.001	0.003	0.005	0.001	4	0.62	0.43
21/2/13	CR1	82	1	17	21	1	2	11	1	0.1	0.05	0.10	0.2	0.01	3.33	0.19	0.2	0.061	0.059	0.730	0.003	0.002	0.042	0.004	0.001	0.010	0.018	0.001	7	0.95	0.78
9/04/13	CR1	43	1	9	19	1	2	11	1	0.1	0.01	0.10	0.1	0.01	3.62	0.38	0.35	0.047	0.044	0.560	0.002	0.002	0.033	0.003	0.002	0.006	0.024	0.001	7	0.72	0.69
5/06/13	CR1	66	1	6	15	1	1	10	1	0.1	0.01	0.10	0.10	0.2	3.1	0.24	0.24	0.03	0.029	0.570	0.001	0.001	0.021	0.002	0.001	0.004	0.010	0.001	7	0.55	0.52
1/08/13	CR1	54	1	6	12	1	1	9	1	0.1			0.1	0.01		0.46	0.45	0.038	0.041	0.410	0.001	0.001	0.016	0.002	0.001	0.004	0.008	0.001	5	0.46	0.39
9/12/13	CR1	49	1	7	17	1	1	10	1	0.1	0.01	0.20	0.2	0.01	3.37	0.4	0.55	0.065	0.066	0.430	0.002	0.001	0.023	0.004	0.001	0.005	0.012	0.001	7	0.63	0.52
	ST Dev	14	1	4	3	0	0	1	0	0.0	0.01	0.41	0.39	0.45	0.22	0.66	0.63	0.013	0.012	0.118	0.001	0.000	0.012	0.001	0.000	0.002	0.007	0.000	1	0.17	0.16
	Max	82	5	17	21	1	2	11	1	0.1	0.05	1.20	1.20	1.32	3.62	1.82	1.71	0.065	0.066	0.730	0.003	0.002	0.042	0.004	0.002	0.010	0.024	0.002	7	0.95	0.78
	Min	40	1	2	12	1	1	7	1	0.1	0.01	0.10	0.10	0.01	2.96	0.19	0.20	0.030	0.029	0.360	0.001	0.001	0.010	0.002	0.001	0.003	0.004	0.001	4	0.38	0.30
	Median	52	1	6	15	1	1	10	1	0.1	0.02	0.20	0.20	0.03	3.33	0.43	0.50	0.043	0.043	0.500	0.001	0.001	0.019	0.002	0.001	0.004	0.009	0.001	7	0.59	0.50
13/04/12	CR2	85	10	6	23	4	3	15	1	0.1	0.03	0.70	0.7	0.04	5.77	1	0.51	0.116	0.115	0.070	0.001	0.001	0.008	0.001	0.002	0.042	0.028	0.001	2	0.97	1.10
14/05/12	CR2	74	8	6	21	3	2	14	1	0.1	0.08	0.60	0.7	0.52	4.86	1.1	0.47	0.133	0.114	0.070	0.001	0.001	0.009	0.001	0.002	0.046	0.030	0.001	2	0.88	0.92
26/7/12	CR2	56	9	6	20	4	2	12	1	0.1	0.03	0.10	0.1	0.01	4.88	0.78	0.8	0.094	0.089	0.050	0.001	0.001	0.005	0.001	0.002	0.047	0.026	0.001	2	0.87	0.89
25/9/12	CR2	72	13	6	25	4	3	13	1	0.1	0.06	0.20	0.3	0.02	5.04	0.28	1..07	0.082	0.098	0.020	0.001	0.001	0.005	0.001	0.003	0.056	0.037	0.001	<1	0.96	1.01
29/11/12	CR2	84	12	5	24	5	3	12	4	0.1	0.04	0.20	0.2	0.18	4.45	0.75	1.36	0.068	0.069	0.050	0.001	0.001	0.005	0.001	0.002	0.043	0.028	0.001	2	1.02	1.12
21/2/13	CR2	71	8	8	22	3	2	11	1	0.1	0.06	0.10	0.10	0.01	4.44	0.14	0.86	0.013	0.068	0.030	0.026	0.024	0.028	0.020	0.001	0.012	0.012	0.003	4	0.95	0.84
9/04/13	CR2	77	11	6	22	4	3	14	1	0.1	0.02	0.10	0.1	0.01	5.64	0.38	0.78	0.098	0.089	0.050	0.001	0.001	0.009	0.001	0.003	0.050	0.038	0.001	3	0.97	1.06
5/06/13	CR2	67	8	6	22	3	2	14	1	0.1	0.04	0.10	0.1	0.05	5.08	0.3	0.54	0.078	0.073	0.060	0.001	0.001	0.005	0.001	0.002	0.036	0.028	0.001	2	0.91	0.92
1/08/13	CR2	73	8	6	24	3	2	13	1	0.1			0.4	0.01		0.33	0.67	0.075	0.078	0.060	0.001	0.001	0.006	0.001	0.002	0.047	0.028	0.001	2	0.96	0.88
9/12/13	CR2	68	9	6	25	3	2	13	1	0.1	0.04	0.20	0.2	0.01	5.24	0.21	0.92	0.08	0.089	0.040	0.001	0.001	0.006	0.001	0.003	0.050	0.036	0.001	4	1.01	0.88
	ST Dev	8	2	1	2	1	1	1	1	0.0	0.02	0.23	0.24	0.16	0.46	0.35	0.27	0.032	0.017	0.016	0.008	0.007	0.007	0.006	0.001	0.012	0.007	0.001	1	0.05	0.10
	Max	85	13	8	25	5	3	15	4	0.1	0.08	0.70	0.70	0.52	5.77	1.10	1.36	0.133	0.115	0.070	0.026	0.024	0.028	0.020	0.003	0.056	0.038	0.003	4	1.02	1.12
	Min	56	8	5	20	3	2	11	1	0.1	0.02	0.10	0.10	0.01	4.44	0.14	0.47	0.013	0.068	0.020	0.001	0.001	0.005	0.001	0.001	0.012	0.012	0.001	2	0.87	0.84
	Median	73	9	6	23	4	2	13	1	0.1	0.04	0.20	0.20	0.02	5.04	0.36	0.78	0.081	0.089	0.050	0.001	0.001	0.006	0.001	0.002	0.047	0.028	0.001	2	0.96	0.92

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe	Fe T	Mn	Mn T	Al	Cu	Pb	Zn	Ni	Li	Ba	Sr	As	DOC	TA	TC
ANZECC													**0.25**	**0.02**				**1.9**	**1.9**	**0.055**	**0.001**	**0.003**	**0.008**	**0.011**				**0.024 (III) / 0.013(V)**			
13/04/12	CR3	79	9	5	20	3	2	13	1	0.1	0.04	0.60	0.6	0.02	5.61	1.11	0.36	0.151	0.143	0.060	0.001	0.001	0.008	0.002	0.002	0.046	0.032	0.001	1	0.85	0.88
8/05/12	CR3	99	8	6	22	4	3	14	1	0.1	0.04	0.20	0.2	0.03	4.95	0.93	0.26	0.115	0.096	0.060	0.001	0.001	0.128	0.001	0.002	0.036	0.026	0.001	1	0.91	1.06
26/7/12	CR3	53	9	6	20	3	2	12	1	0.1	0.04	0.20	0.2	0.02	4.85	0.34	0.78	0.077	0.083	0.050	0.001	0.001	0.009	0.001	0.002	0.040	0.023	0.001	2	0.95	0.84
25/9/12	CR3	97	3	16	23	4	3	12	1	0.1	1.64	1.10	2.7	0.1	5.05	0.31	1.09	0.083	0.101	0.020	0.001	0.001	0.022	0.001	0.002	0.050	0.033	0.001	1	1.04	0.97
29/11/12	CR3	77	14	5	22	4	2	11	1	0.1	0.06	0.30	0.4	0.03	4.37	0.52	1.51	0.051	0.058	0.040	0.001	0.001	0.011	0.001	0.002	0.040	0.028	0.001	2	1.00	0.87
21/2/13	CR3	75	10	8	23	3	2	12	1	0.1	0.07	0.10	0.10	0.01	4.5	0.28	0.97	0.06	0.075	0.100	0.002	0.001	0.013	0.001	0.002	0.032	0.027	0.001	4	1.02	0.86
9/04/13	CR3	95	10	9	21	4	3	14	1	0.1	0.33	0.20	0.5	0.01	5.44	0.36	0.79	0.094	0.086	0.040	0.003	0.001	0.013	0.001	0.002	0.044	0.035	0.001	3	0.92	1.06
5/06/13	CR3	70	1	11	22	3	3	15	1	0.1	0.7	0.40	1.1	0.63	5.06	0.32	0.54	0.08	0.076	0.070	0.001	0.001	0.011	0.001	0.002	0.036	0.026	0.001	2	0.85	1.05
1/08/13	CR3	72	8	6	24	3	2	13	1	0.1			9.7	0.1		0.3	0.69	0.074	0.083	0.050	0.001	0.001	0.008	0.001	0.002	0.040	0.026	0.001	3	0.96	0.88
9/12/13	CR3	66	1	14	25	3	2	14	1	0.1	1.23	0.30	1.5	0.01	5.22	0.26	0.98	0.102	0.089	0.060	0.001	0.001	0.010	0.001	0.003	0.048	0.010	0.001	4	1.00	0.95

ST Dev	15	4	4	2	1	1	1	0	0.0	0.60	0.31	2.92	0.19	0.40	0.30	0.37	0.029	0.022	0.021	0.001	0.000	0.037	0.000	0.000	0.006	0.007	0.000	1	0.07	0.09
Max	99	14	16	25	4	3	15	1	0.1	1.64	1.10	9.70	0.63	5.61	1.11	1.51	0.151	0.143	0.100	0.003	0.001	0.128	0.002	0.003	0.050	0.035	0.001	4	1.04	1.06
Min	53	1	5	20	3	2	11	1	0.1	0.04	0.10	0.10	0.01	4.37	0.26	0.26	0.051	0.058	0.020	0.001	0.001	0.008	0.001	0.002	0.032	0.010	0.001	1	0.85	0.84
Median	76	9	7	22	3	2	13	1	0.1	0.07	0.30	0.55	0.03	5.05	0.33	0.79	0.082	0.085	0.055	0.001	0.001	0.011	0.001	0.002	0.040	0.027	0.001	2	0.96	0.92

		TDS	HCO3	SO4	Cl	Ca	Mg	Na	K	F	NO2 NO3	TKN	TN	TP	Si	Fe	Fe T	Mn	Mn T	Al	Cu	Pb	Zn	Ni	Li	Ba	Sr	As	DOC	TA	TC
ANZECC													**0.25**	**0.02**				**1.9**	**1.9**	**0.055**	**0.001**	**0.003**	**0.008**	**0.011**				**0.024 (III) / 0.013(V)**			
17/04/12	CR4	49	8	4	17	1	1	10	1	0.1	0.02	0.40	0.4	0.07	2.04	1.78	0.72	0.107	0.086	0.100	0.002	0.001	0.388	0.001	0.001	0.010	0.012	0.001	6		