Appendix E

Surface Water Specialist Reports

GeoTerra

GUJARAT NRE COKING COAL LTD

NRE No.1 COLLIERY
MAJOR EXPANSION
STREAM ASSESSMENT

Bellambi, NSW

GUJ1-SWR1D

27 NOVEMBER, 2012

GeoTerra PTY LTD **ABN 82 117 674 941**

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GUJ1-SWR1D (27 NOVEMBER, 2012)

GeoTerra

Gujarat NRE Coking Coal Ltd
PO Box 281
Fairy Meadow NSW 2519

Attention: Dr C Harvey

Chris,

RE: Wonga East and Wonga West Stream Assessment

Please find enclosed a copy of the above mentioned report.

Yours faithfully

GeoTerra Pty Ltd

Andrew Dawkins (AuSIMM CP-Env)

Managing Geoscientist

Distribution:	Original	GeoTerra Pty Ltd
	1 electronic copy	Gujarat NRE Coking Coal Ltd
	1 electronic copy	ERM Australia Pty Ltd

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GeoTerra

Authorised on behalf of GeoTerra Pty Ltd:	
Name:	Andrew Dawkins
Signature:	
Position:	Managing Geoscientist

Date	Rev	Comments
11.08.2010		Draft
15.10.2010	A	Incorporate reviewer comments and add additional commentary
31.01.2011	B	Incorporate relevant Bulli PAC findings and review comments
05.11.2012	C	Incorporate adequacy review comments
27.11.2012	D	Incorporate review comments

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EXECUTIVE SUMMARY

Gujarat NRE Coking Coal (Gujarat) propose to extract the Wongawilli Seam via longwall mining in two areas at the NRE No.1 colliery. Wonga East is located to the east, whilst Wonga West is situated to the west of Cataract Reservoir.

The proposed workings are located approximately 13km north west of Wollongong in NSW.

The Study Area has previously been mined by bord and pillar workings to the east and west, as well as pillar extraction to the east of the reservoir in the Bulli Seam within the Gujarat lease since the turn of the century.

Bord and pillar mining in the Bulli Seam was also conducted in the same time period to the north and south by BHP Billiton Illawarra Coal (BHPBIC).

Longwall mining has been conducted in the Bulli Seam to the south in the BHPBIC Cordeaux mining area, in the Wonga West area by Gujarat, along with longwall mining in the Balgownie Seam and in longwall WE-A2-LW4 of the Wongawilli Seam at Wonga East in the Gujarat lease area.

The Study Area is defined as being within 600m of the edge of secondary longwall extraction.

The Bulli Seam overlies the Balgownie Seam by approximately 5 - 8m, and in turn, the Balgownie Seam overlies the Wongawilli Seam by approximately 22 - 26m.

The depth of cover ranges from 237 - 255m at Wonga East in Area 1 with three, 105m wide proposed longwall panels and from 267 - 320m in Area 2 with eight, 150m wide proposed panels which underlie the catchment and channel of Cataract Creek. The proposed mining, to a lesser degree, is also within the headwater catchments of Bellambi Creek and Cataract River (upstream of Cataract Reservoir).

The proposed Wonga West panels are subdivided into Area 3, to the west of Lizard Creek, and Area 4, to the north east of Lizard Creek. The proposed five Area 3 panels terminate to the north of Wallandoola Creek and do not undermine Lizard Creek.

The Area 3 longwalls are proposed to be 374 - 390m wide whilst longwalls 6 and 7 in Area 4 are proposed to be 155m wide, with a 457 – 512m depth of cover.

Maximum subsidence at Wonga East is predicted to range up to 1.2m, with up to 2.55m at Wonga West.

The main channels of Lizard Creek and Wallandoola Creek are predicted to undergo a maximum of 0.5m subsidence and 120mm uplift, whilst Cataract Creek is predicted to undergo 1.2m subsidence and 60mm uplift.

Surface water features within 600m of the proposed secondary workings consist of:

- 1st to 3rd order streams of Wallandoola Creek which drain into the Cataract River, downstream of the Cataract Dam wall at Wonga West;
- 1st to 4th order streams of Lizard Creek which drain into the Cataract River, downstream of the Cataract Dam wall at Wonga West;
- 1st to 4th order streams of Cataract Creek and Cataract River which flow into Cataract reservoir,

- 1st and 2nd order tributaries of Cataract River and Bellambi Creek (upstream of the reservoir) which will not be undermined by the Wonga East workings;
- Cataract Reservoir, which will not be undermined by the Wonga East workings, although the western end of longwall WE-A2-LW10 extends into the reservoir high water mark in Cataract Creek;
- thirty nine swamps at Wonga East within 600m of the proposed workings that meet the definition of the Coastal Upland Swamp Endangered Ecological Community, fourteen of which lie within the predicted 20mm subsidence zone. Of those fourteen, seven are assessed to be of “special significance” according to the NSW Office of Environment and Heritage criteria (OEH, 2012), and of those, five are predicted to be potentially subject to subsidence effects (Biosis, 2012), including
  - Crus1 as well as Ccus1, 4, 5 and Ccus10
- forty five swamps at Wonga West within 600m of the proposed workings that meet the definition of the Coastal Upland Swamp Endangered Ecological Community. Of these, thirty six lie within the predicted 20mm subsidence zone. Of those thirty six, eight are assessed to be of “special significance” according to the NSW Office of Environment and Heritage criteria (OEH, 2012), and of those, seven are predicted to be potentially subject to subsidence effects (Biosis, 2012), including;
  - Lcus1, 6, 8, 27 as well as Wcus4, 7 and Wcus 11

Note that a detailed discussion of upland swamps is contained in (Biosis, 2012).

Lizard, Wallandoola, Bellambi and Cataract creeks, as well as Cataract River and Cataract Reservoir are all contained within the Sydney Catchment Authority controlled Metropolitan Special Area.

The 3rd order or higher creek channels are interpreted to be “losing” streams in the upper catchments and “gaining” streams in the incised, sandstone based gorge reaches of Lizard Creek and Wallandoola Creek in Wonga West (Areas 3 and 4) as well as in the Cataract Creek, Cataract River and Bellambi Creek catchments at Wonga East (Areas 1 and 2).

No extraction is proposed under the 3rd order or higher channel of Lizard and Wallandoola Creeks, with the panel layout being designed to avoid subsidence impacts on the bed of the creeks and Cataract reservoir.

Extraction is proposed, however, under 3rd order tributaries of Lizard Creek at Wonga West in tributaries LCT1 and LCT2.

No extraction is proposed under the 3rd order or higher channels of Cataract River (upstream of the reservoir) or Bellambi Creek at Wonga East.

Cataract Creek is proposed to be undermined by longwalls in Wonga East (Area 2), with a predicted maximum subsidence of 0.8m, along with up to 10mm/m compressive and 5mm/m tensile strains over WE-A2-LW8 (Seedsman Geotechnics, 2012).

Within the overall catchment, Cataract Creek has the potential to subside by up to 1.2m (Seedsman Geotechnics, 2012) as a worst case scenario.

The proponent has provided an undertaking that it will terminate mining beneath Cataract Creek if subsidence and ground movements are predicted to exceed 250mm and the creek experiences greater than negligible impact.

The upper reaches of Lizard Creek and Wallandoola Creek are predominantly underlain by humic, clayey to sandy valley fill swamp sediments with interspersed shallow alluvium covered pools and shallow exposed Hawkesbury Sandstone substrate.

Downstream of the alluvium / shallow pool dominated reach, 20 - 25m high waterfalls are present in Wallandoola Creek (Waterfall W1) and Lizard Creek (Waterfall L1), with the creek bed containing increasingly exposed Hawkesbury Sandstone above and downstream of the waterfalls.

The lower reach of Cataract Creek at Wonga East contains the exposed Newport / Garie Formation shales and the Bald Hill Claystone, along with the Bulgo Sandstone with a thin alluvium, whilst the upper flanks of the valley and upper headwaters contains predominantly thin alluvium over Hawkesbury Sandstone.

The plateaus in both areas are covered in a thin or absent Hawkesbury Sandstone derived sandy colluvium, whilst up to 1.9m thick humic, clayey to sandy colluvial / alluvial sediments are located within the headwater swamps in the first order tributaries.

One regional scale SW / NE trending fault / dyke is located in the Bulli Seam workings, at seam level, over the proposed Wonga West workings, along with some thinner dykes, whilst a north / south trending fault is located to the west of the proposed Wonga West workings. .

The Rixons Pass Fault is interpreted to be sub-parallel to Cataract Creek, although it has not been mapped in the Bulli or Balgownie workings at Wonga East.

A SE / NW trending dyke has been identified in both the Bulli and Balgownie workings, whilst the Corrimal Fault has been mapped in the proposed Wonga East Area 2 workings footprint (GeoTerra, 2012).

Stream flow in Wallandoola Creek is permanent in the valley fill swamp and downstream reach to the upper section of Waterfall W1, where cracks in exposed sandstone enable overland flow to cease during extended dry periods. Permanent stream flow resumes downstream of Waterfall W1.

Flow in Lizard Creek is permanent in the valley fill swamps and downstream reach to Site LC3. Site LC3 can stop flowing, although remains ponded, during low flows. Between LC3 and LC4, where cracks are present in exposed sandstone, the creek bed can dry out during extended dry periods, with permanent flow or standing pools, resuming approximately 200m upstream of Waterfall L1, downstream to Site LC5.

Between LC5 and LC6, stream flow can cease after extended dry periods, with either standing pools or permanent flow resuming downstream of LC6 down to the confluence with Cataract River.

Flow in Cataract Creek has been observed to be perennial, with no evidence of stream bed cracking or adverse effects on pool water retention due to previous multi seam extraction in the Bulli bord and pillar, Bulli pillar extraction, Balgownie longwall and Wongawilli (longwall WE-A2-LW4) workings.

The high water mark of Cataract Reservoir depends on draw down from the dam and rainfall in the catchment, with a maximum high water extent in Cataract Creek near Site CC9 of 289.87mAHD.

Based on a comparison between rainfall and underground water management reports, no evidence of connective cracking from Cataract Creek to the multi-seam mined Wonga East workings is indicated.

No evidence of connective cracking is noted for the existing (deeper) western Bulli Seam workings (S Wilson, pers. Comm.).

As a result of logistical limitations due to unconstrained flow in valley fill swamp reaches, as well as both natural bedding plane / jointing and previous subsidence induced sub-surface diversions through cracks in the stream beds, limited volumetric flow monitoring locations have been installed. Measurement of pool depth is however measured at numerous locations in Lizard, Wallandoola and Cataract creeks as well as Cataract River.

Stream channel reaches have been defined as “significant” between CC5 and CC9 in Cataract Creek due to the presence of Macquarie Perch.

Lizard Creek is defined as “significant”, due to the unique nature and unaffected flow status at Waterfall L1.

Since regular water quality monitoring started in July 2007, Lizard Creek has had a pH range from 2.50 – 7.07 and electrical conductivity (EC) from 19 – 290µS/cm, whilst Wallandoola Creek ranges from pH 3.35 – 6.83 and EC from 56 – 199µS/cm.

Cataract Creek ranges from pH 4.39 – 6.91 and 101 - 190µS/cm EC, whilst Cataract River ranges from pH 5.1 – 6.5 and 52 - 147µS/cm EC.

All four streams and their tributaries exhibit ferruginous precipitation at seepage outflows along the valley, from upland swamps as well as above and below the waterfall reaches.

Swamp water levels and outflow seepage are highly variable, and have a direct relationship to rainfall recharge in the catchments. The headwater swamps have pH ranging from 3.64 – 7.48 and EC from 64 - 1121µS/cm, whilst the valley fill swamps range from 5.25 – 7.24 and EC from 83 - 358µS/cm.

No adverse effects have been observed in any of the swamps due to previous mining induced subsidence in the Gujarat lease area.

The potential effects, impacts and consequences of the proposed longwall mining in the Wongawilli Seam on the streams as well as Cataract Reservoir are summarised in the following tables.

Potential Lizard Creek Effect, Impact and Consequence Summary

REACH	EFFECT*	IMPACT	CONSEQUENCE
LC1 - 3	<0.02m S_{max}, <1mm/m strain, <1mm/m tilt <200mm valley closure <120mm uplift	No change to fabric or structure of the stream bed or water quality	Negligible potential impact on flow diversion, no connective cracking, pool drainage, iron staining, water quality or gas releases
LC3 - 4	0.02m S_{max} , <2mm/m strain, <1mm/m tilt <200mm valley closure <120mm uplift	No change to fabric or structure of the stream bed or water quality	Negligible potential impact on flow diversion, no connective cracking, pool drainage, iron staining, water quality or gas releases
LC4 - 5	<0.02m S_{max}, <1mm/m strain, <1mm/m tilt <200mm valley closure <120mm uplift	No change to fabric or structure of the stream bed or water quality	Negligible potential impact on flow diversion, no connective cracking, pool drainage, iron staining, water quality or gas releases
LC5 - 6	0.25m $S_{max,}$ <7mm/m (extension) strain <4mm/m tilt, <200mm valley closure, <120mm uplift	Potential cracking of creek bed due to the proximity of the northern end of Longwall A3 LW2 to creek bed	No connective cracking. Low potential impact on stream flow (with downstream flow re-emergence), as well as pool holding capacity, iron hydroxide seepage or gas release due to stream bed cracking. All of these aspects are currently adversely affected by existing Bulli workings subsidence
LC6 - 7	0.25m $S_{max,}$ <6mm/m (extension) strain <1mm/m tilt, <200mm valley closure <120mm uplift	Potential cracking of creek bed due to the proximity of the northern end of Longwall A4 LW7 to the creek bed	No connective cracking. Low potential impact on stream flow (with downstream flow re-emergence), as well as pool holding capacity, iron hydroxide seepage or gas release due to stream bed cracking. All of these aspects are currently adversely affected by existing Bulli workings subsidence
LCT1	2.25m $S_{max,}$ -7mm/m (compression) to <7mm/m (extension) strain <6mm/m tilt <200mm valley closure <120mm uplift	Potential cracking of 3rd order tributary bed due to undermining by Longwall A3 LW3	No potential for connective cracking. Potential impact on stream flow, pool holding capacity, iron hydroxide seepage or gas release. All of these aspects are currently adversely affected by existing Bulli workings subsidence.
LCT2	0.25m $S_{max,}$ <4mm/m (extension) strain <1mm/m tilt <200mm valley closure <120mm uplift	Limited potential for cracking of 3rd order tributary due to the proximity of the northern end of Longwall A3 LW5 to the creek bed	No connective cracking. Limited potential impact on the upper headwaters of the stream reach flow (with downstream flow re-emergence), as well as pool holding capacity, iron hydroxide seepage or gas release due to stream bed cracking
All reaches	Regional Groundwater Depressurisation	Up to 12m groundwater level reduction in upper Hawkesbury Sandstone	Negligible (0.02ML/day gain to 0.10ML/day reduction, or 0.012 gain to 0.0058ML/km^2/day reduction, or 0.2% gain to 0.8%reduction) of 17ML/day av. flow in Lizard Creek (GeoTerra, 2012)

NOTE: S_{max} = maximum subsidence (from Seedsman 2012)

Potential Wallandoola Creek Effect, Impact and Consequence Summary

REACH	EFFECT*	IMPACT	CONSEQUENCE
WC1 - 3	<0.02m S_{max}, <2mm/m strain, <1mm/m tilt <200mm valley closure <120mm uplift	No change to fabric or structure of the stream bed or water quality	No connective cracking. Minimal to no potential for flow diversion, change in pool drainage, iron staining, water quality or gas releases
WC3 - 4	<0.5m S_{max}, <6mm/m (extension) strain <4mm/m tilt <200mm valley closure <120mm uplift	Potential cracking of 3rd order stream bed due to the proximity of the southern end of Longwall WW-A3-LW3 and WW-A3LW4 to the stream. WW-A3-LW5 has limited potential to generate stream bed cracking	No connective cracking. Potential impact on stream flow (with down stream flow re-emergence), pool holding capacity, iron hydroxide seepage or gas release. Iron hydroxide seepage is currently present
WC4 - 5	<0.02m S_{max}, <2mm/m (extension) strain <1mm/m tilt <200mm valley closure <120mm uplift	No change to fabric or structure of the stream bed or water quality	No connective cracking. Minimal to no potential for flow diversion, change in pool drainage, iron staining, water quality or gas releases
All reaches	Regional Groundwater Depressurisation	Up to 12m reduction of groundwater level in upper Hawkesbury Sandstone	Negligible predicted 0.06 – 0.25ML/day, or 0.0018 – 0.0075ML/km^2/day, or 0.1 - 0.6% reduction in 33.0ML/day average flow in Wallandoola Creek

NOTE: S_{max} = maximum subsidence (from Seedsman 2012)

Potential Waterfall Effect, Impact and Consequence Summary

REACH	EFFECT*	IMPACT	CONSEQUENCE
Waterfall L1	<0.12m S_{max}, <3.5mm/m (extension) strain <2.9mm/m tilt <200mm valley closure <120mm uplift	Limited to no change to structural integrity of the waterfall	Limited to no potential for flow diversion through waterfall, iron staining or water quality
Waterfall W1	<0.02m S_{max}, <1mm/m strain <1mm/m tilt <200mm valley closure <120mm uplift	No change to structural integrity of the waterfall	Minimal to no potential for flow diversion through waterfall, iron staining or water quality

NOTE: S_{max} = maximum subsidence (from Seedsman 2012)

Potential Cataract Creek Effect, Impact and Consequence Summary

REACH	EFFECT*	IMPACT	CONSEQUENCE
CC1 – 4	<0.02m S_{max}, <-1 to 1mm/m strain <1mm/m tilt <200mm valley closure <120mm uplift	No change to fabric or structure of the stream bed or water quality	Negligible potential for connective cracking, flow diversion, negligible change in pool drainage, iron staining, water quality or gas releases
CC2 – 3	<0.16m S_{max} < -2 to 1 mm/m strain <3mm/m tilt <200mm valley closure <120mm uplift	Potential cracking of 1st and 2nd order tributary bed due to undermining by Longwalls A1 LW1, 2 and 3	Potential impact on 1st and 2nd order stream flow with downstream flow re-emergence. There are no 3rd order pools or stream reaches in this section. Potential effect on iron hydroxide seepage, although iron hydroxide seepage is currently present in the 1st and 2nd order stream reaches
CC5 - 9	<0.8m S_{max}, <-9.5 to 5 mm/m strain <4mm/m tilt <200mm valley closure <120mm uplift	Potential cracking of up to 4th order stream bed due to subsidence near / over WE-A2-LW7, LW8, LW9 and LW10	Potential impact on stream flow, with downstream flow re-emergence. Potential effect on pool holding capacity of rock bars CCRB10- 15. Potential iron hydroxide seepage, although iron hydroxide seepage is currently occurring.
All reaches	Regional Groundwater Depressurisation	Up to 4m groundwater level reduction in eroded Hawkesbury / upper Bulgo Sandstone	Predicted 0.06 – 0.07ML/day (0.0115 – 0.0135ML/km^2/day) or (0.5 – 0.6%) reduction of 11.73ML/day average flow in Cataract Creek. The proponent has provided an undertaking that it will terminate mining beneath Cataract Creek if subsidence and ground movements are predicted to exceed 250mm and the creek experiences greater than negligible impact

Potential Cataract Reservoir, Cataract River and Bellambi Creek Effect, Impact and Consequence Summary

STREAM	EFFECT	IMPACT	CONSEQUENCE
Cataract Reservoir	<0.02m S_{max}, <1mm/m strain <1mm/m tilt no valley closure or uplift	No change to the fabric or structure of the reservoir or dam wall	Negligible reduction in the quality and quantity of water resources reaching Cataract Reservoir. No connective cracking between the reservoir surface and the mine. Negligible leakage from Cataract Reservoir to the mine
Cataract River	<0.02m S_{max}, <1mm/m strain <1mm/m tilt no valley closure or uplift	No change to fabric or structure of the stream bed or water quality	Negligible potential for connective cracking, flow diversion, change in pool drainage, iron staining, water quality or gas releases
Bellambi Creek	<0.02m S_{max}, <1mm/m strain <1mm/m tilt no valley closure or uplift	No change to fabric or structure of the stream bed or water quality	Negligible potential for connective cracking, flow diversion, change in pool drainage, iron staining, water quality or gas releases

NOTE: S_{max} = maximum subsidence (from Seedsman 2012)

1. INTRODUCTION

This study assesses the potential mining impact on streams, as well as providing an indicative management and monitoring strategy to manage potential adverse effects on streams that may be caused by subsidence.

The Study Area is located approximately 13km northwest of Wollongong and is defined as being within a 600m distance from the edge of secondary extraction for the proposed workings (NSW Planning Assessment Commission, 2009).

Gujarat NRE Coking Coal Ltd (Gujarat) proposes to extract coal from the Wongawilli Seam by longwall extraction from eleven panels at Wonga East and seven panels in the Wonga West area. The proposed workings are contained within the NRE No. 1 Colliery in Consolidated Coal Lease 745 (CCL745) and Mining Lease 1575 (ML1575) as shown in **Drawing 1**.

The two main extractions areas are subdivided into Wonga East (Area 1) and Wonga East (Area 2) as shown in **Drawing 2** as well as Wonga West (Area 3) and Wonga West (Area 4) as shown in **Drawing 3**.

This study provides a baseline assessment of the current status of streams within the proposal area, and has been conducted to satisfy the Environmental Assessment approvals process as administered by the Department of Planning and Infrastructure.

Office studies, field monitoring, laboratory analysis and computer modelling studies have been used to prepare a baseline and potential post subsidence assessment of stream flow and standing pool water depths, as well as stream water quality and stream geomorphology.

The proposed workings are located within the Sydney Catchment Authority managed, restricted access, Metropolitan Special Area.

The mine plan has been designed so that the 3rd order or higher main channels of Wallandoola, Lizard and Bellambi creeks will not be directly undermined by the proposed workings.

The 3rd order tributary (LCT1) of Lizard Creek and a short section of the 3rd order reach of LCT2 are proposed to be undermined by Longwall 2 in Area 3 of the Wonga West workings, whilst Cataract Creek will be undermined by the Wonga East Area 2 workings.

Although Cataract Creek is proposed to be undermined, narrow longwalls with wide pillars have been planned to reduce the total subsidence to generally less than 250mm under the creek bed, except for WE-A2-LW8, which may subside by up to 0.8m.

The proponent has provided an undertaking that it will terminate mining beneath Cataract Creek if subsidence and ground movements are predicted to exceed 250 mm and the creek experiences greater than minimal impact

The channel of the Cataract River (upstream of the reservoir) will not be undermined, although one first order tributary is proposed to be undermined by the western edge of Wonga East Area 2.

Surface water related features within the Study Area include;

- 1st to 3rd order streams of Wallandoola Creek which drain into the Cataract River, downstream of the Cataract Dam wall at Wonga West;
- 1st to 4th order streams of Lizard Creek which drain into the Cataract River,

downstream of the Cataract Dam wall at Wonga West;

- 1st and 2nd order tributaries of Cataract River and Bellambi Creek (upstream of the reservoir) which will not be undermined by the Wonga East workings;
- Cataract Reservoir, which will not be undermined by the Wonga East workings, although the western end of longwall WE-A2-LW10 extends into the reservoir high water mark in Cataract Creek;
- thirty nine swamps at Wonga East within 600m of the proposed workings that meet the definition of the Coastal Upland Swamp Endangered Ecological Community, fourteen of which lie within the predicted 20mm subsidence zone. Of those fourteen, seven are assessed to be of “special significance” according to the NSW Office of Environment and Heritage criteria (OEH, 2012), and of those, five are predicted to be potentially subject to subsidence effects (Biosis, 2012), including;
    - o Crus1 as well as Ccus1, 4, 5 and Ccus10
- forty five swamps at Wonga West within 600m of the proposed workings that meet the definition of the Coastal Upland Swamp Endangered Ecological Community. Of these, thirty six lie within the predicted 20mm subsidence zone. Of those thirty six, eight are assessed to be of “special significance” according to the NSW Office of Environment and Heritage criteria (OEH, 2012), and of those, seven are predicted to be potentially subject to subsidence effects (Biosis, 2012), including;
    - o Lcus1, 6, 8, 27 as well as Wcus4, 7 and Wcus 11

Note that a detailed discussion of upland swamps is contained in (Biosis 2012).

The Study Area contains ephemeral 1st and intermittent 2nd order tributaries which drain into 3rd order Schedule 2 streams in the Wallandoola and Lizard Creek catchments over the proposed Wonga West workings.

Lizard Creek becomes 4th order where tributary LCT1 joins the main channel, and 5th order, downstream of the 4th order reach of the LCT2 confluence, whilst Wallandoola Creek is 4th order approximately 1.7km downstream of the proposed workings and beyond the study area boundary.

Cataract Creek contains 1st and 2nd order tributaries draining into 3rd order channels, upstream of the freeway, which becomes 4th order downstream of the freeway.

In addition, only ephemeral, first order tributaries of Cataract River and Bellambi Creek overlie the proposed Wonga East (Area 2) workings.

Cataract Creek, Cataract River and Bellambi Creek drain directly into Cataract reservoir, whilst Lizard Creek and Wallandoola Creek drain into Cataract River, downstream of the Cataract Dam wall.

The Cataract River subsequently flows to the Macarthur Water Treatment offtake at Broughton’s Pass Weir.

As discussed in (GeoTerra, 2012) the valley fill and headwater upland swamps are located upstream of the waterfalls and Hawkesbury Sandstone incised reaches at Wonga West, as well as on the more steeply sloping flanks of Cataract River, Cataract Creek and Bellambi Creek at Wonga East.

No valley fill swamps are present within Wonga East.

Although the streams and swamps are hydraulically interconnected, the reader is directed to the assessment of upland swamps detailed in the groundwater report (GeoTerra, 2012) and swamp assessment (Biosis, 2012) for the proposal.

The Study Area also contains increasingly incised valleys in the central and northern (downstream) reaches of Wallandoola and Lizard creeks, downstream of waterfalls L1 and W1. Less incised, although steeper gradient, streams and hills are present in the Wonga East Area.

Cataract River is regulated by Cataract Dam, which is upstream of the Lizard Creek / Wallandoola Creek confluences, as well as by Broughton's Pass Weir, which is approximately 6.25km downstream of the junction with Lizard Creek, and 1.2km downstream of Wallandoola Creek. The Cataract River is partially diverted through Cataract Tunnel or the Macarthur Water Treatment Plant for the metropolitan water supply at Broughtons Pass Weir.

The proposed Wonga East workings underlie the Cataract Creek, Bellambi Creek and Cataract River catchments in essentially undeveloped bushland, apart from limited fire access and power transmission access trails, whilst the Wonga West catchments of Lizard and Wallandoola creeks also contain mine surface infrastructure and access road associated with the Gujarat NRE No. 1 Colliery No. 4 and No. 5 shafts.

Risk Management Zones (RMZ) have been defined according to the Southern Coalfield inquiry (NSW Department of Planning, 2008) and Bulli Seam PAC (NSW Planning Assessment Commission, 2010) which laterally extends to either side of Wallandoola, Lizard, Cataract and Bellambi creeks, as well as Cataract River (upstream of the reservoir) for 400m from the creek centre line.

A 600m wide "potentially significant feature" zone has also been defined as shown in **Drawing 4**.

No private farm or domestic dams are present within the Study Area.

Previous underground mining in and adjacent to the proposed workings has been conducted through longwalling the Bulli Seam to the west, east and beneath Cataract reservoir, by Gujarat as well as in the BHPBIC Cordeaux lease area to the west / south of the Study Area.

Multi seam mining has been conducted where the Bulli Seam was extracted by bord and pillar as well as pillar extraction methods.

In addition, longwalls have been extracted in the underlying Balgownie Seam, whilst one longwall has been mined in the Wongawilli Seam (WE-A2-LW4) at Wonga East.

Predominantly bord and pillar mining, and to a lesser degree, longwall extraction, has also been conducted in the old BHPBIC Bulli Colliery workings to the north of the Wonga East Area.

The previous Bulli Seam mining has caused both conventional and non-conventional subsidence consequences on stream flow and / or water quality in Lizard Creek and Wallandoola Creek at Wonga West as detailed later in this document, with the streams no longer providing a continuum of stream flow or connected pools after extended dry periods.

No adverse consequences have been observed on stream flow or water quality in Cataract Creek, Bellambi Creek or Cataract River, upstream of the reservoir.

2. SCOPE OF WORK

This study is intended to provide a baseline, pre-mining and post mining assessment of the potentially affected surface water systems within the proposed Wonga East and Wonga West catchments in accordance with the Environmental Assessment approvals process as administered by the Department of Planning.

This document does not discuss surface water aspects of the Gujarat NRE1 colliery pit top and infrastructure areas, which is covered by separate authors.

In accordance with the Director Generals Requirements for Application No. 09_0013, (20/3/2009), the requirements for the surface water 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 surface water resources in the project area, paying particular attention to the Upper Nepean River sub-catchment (Metropolitan Special Area), the discharge of mine water and surface runoff into Bellambi Gully Creek and Bellambi Lagoon* (Note this second part is dealt with in an associated water management report prepared by Beca (2010).

GeoTerra Pty Ltd were commissioned by Gujarat NRE Coking Coal Ltd to assess the existing baseline status and to address any potential surface water impacts relating to the proposed extraction and associated subsidence of the Wongawilli Seam extraction in the Wonga East and Wonga West areas.

The stream and swamp monitoring was conducted to assess the;

- functional nature of flow in streams over the panels;
- creek bed and bank erosion and channel bedload;
- stream and upland swamp water quality;
- stream bed and bank vegetation;
- sediment bedload;
- presence and appearance of pools;
- the presence or absence of bedrock, stream bed or bank cracking;
- any observed or inferred groundwater discharge zones, and the;
- presence of hydrocarbon gas.

3. GUIDELINES AND LEGISLATION

3.1 Guidelines and Policies

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

- National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000a).
- National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ, 2000b).
- Using the ANZECC Guideline and Water Quality Objectives in NSW (Department of Environment and Climate Change [DECC], 2006a).
- State Water Management Outcomes Plan.
- NSW Government Water Quality and River Flow Environmental Objectives (DECC, 2006b).
- Managing Urban Stormwater: Soils & Construction (Landcom, 2004).
- Managing Urban Stormwater: Treatment Techniques (NSW Environment Protection Authority [EPA], 1997).
- Managing Urban Stormwater: Source Control (EPA, 1998).
- Floodplain Management Manual (Department of Natural Resources [DNR], 2005).
- Floodplain Risk Management Guideline (DECC, 2007).
- Technical Guidelines: Bunding and Spill Management (DECC).
- National Water Quality Management Strategy: Guidelines for Sewerage Systems - Effluent Management (ANZECC/ARMCANZ, 1997).
- National Water Quality Management Strategy: Guidelines for Sewerage Systems - Use of Reclaimed Water (ANZECC/ARMCANZ, 2000c).
- Environmental Guidelines: Use of Effluent by Irrigation (DEC, 2004).
- Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (Department of Environment and Conservation [DEC], 2004), and;
- A Rehabilitation Manual for Australian Streams (Land and Water Resources Research and Development Corporation and Cooperative Research Centre for Catchment Hydrology [LWRRDC and CRCCH, 2000).

3.2 NSW Water Management Act, 2000

The *NSW Water Management Act, 2000* (WMA, 2000) replaced the *Water Act, 1912* in the Study Area on July1, 2011 following gazettal on the 25th of February, 2011 of the;

- Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011, and the;
- Water Sharing Plan for the Greater Metropolitan Region Groundwater Water Sources 2011;

The statutory requirements of the WMA, 2000 include for it to:

" provide for the sustainable and integrated management of the water sources of the State for the benefit of both present and future generations and, in particular:

(a) to apply the principles of ecologically sustainable development, and

(b) protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity and their water quality, and

(c) recognise and foster the significant social and economic benefits to the State that

result from the sustainable and efficient use of water, including:

(i) benefits to the environment, and

(ii) benefits to urban communities, agriculture, fisheries, industry and recreation, and

(iii) benefits to culture and heritage, and

(iv) benefits to the Aboriginal people in relation to their spiritual, social, customary and economic use of land and water,

(d) recognise the role of the community, as a partner with government, in resolving issues relating to the management of water sources,

(e) provide for the orderly, efficient and equitable sharing of water from water sources,

(f) integrate the management of water sources with the management of other aspects of the environment, including the land, its soil, its native vegetation and its native fauna,

(g) encourage the sharing of responsibility for the sustainable and efficient use of water between the Government and water users, and to;

(h) encourage best practice in the management and use of water.

The provisions of the WMA 2000 apply to regulation of access to available waters in all rivers, wetlands and groundwater sources in New South Wales.

Any extraction, interception or diversion from either surface and/or groundwater requires access licences under the provisions of the WMA 2000, including the take of water by means of redistributing or diverting water from a water source, as provided in the definition of take of water in the *Water Management Amendment Act, 2010*.

Lizard, Wallandoola and Cataract Creeks are located within the Upper Nepean River Tributaries Headwaters Management Zone (UNRTHMZ) of the Upper Nepean Water Source. The creeks provide water for environmental requirements and enhancement of flows augmenting regulated releases in the Cataract River to the Broughton's Pass Weir off take, and downstream to the Nepean River.

The NSW Office of Water (NOW) considers the diversion of water from surface water sources to sub-surface fracture zones, or redistribution within groundwater sources as a "take" under the WMA 2000, and as a result, licences must be obtained to account for the take of water from the respective water source.

Specific access and protection rules that may apply to water sources within the assessment area of the proposal are outlined in the following sections.

Protection to surface and associated groundwater sources is a critical to be achieved through a rigorous assessment of the values, risks and environmental consequences resulting from mining-induced subsidence and strains to features within water sources, which will lead to quantifiable, rigorously assessed, achievable outcomes in project approvals.

Such outcomes are required to ensure that equitable sharing of water to all users, including environmental water requirements, is, not diminished by mining developments.

3.2.1 Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011

Under the UNRTHMZ access rules for the environmental flow protection rule, pumping is not permitted when there is no visible flow at a pump site.

Trading rules indicate that trading;

- into the management zone is not permitted;
- within the management zone is permitted, subject to assessment, with no trade allowed from below to above the SCA dams, or vice versa, and;
- conversion to a high flow access licence is not permitted

3.2.2 NSW Aquifer Interference Policy

For a description of the surface water related issues in this policy refer to (GeoTerra, 2012).

3.3 Sydney Water Catchment Management Act, 1998

The proposed mining is within the SCA managed Metropolitan Special Area.

The SCA roles, objectives and functions as detailed in the Sydney Water Catchment Management Act 1998 (SWCM Act) can be summarised as to;

- manage and protect catchment areas and catchment infrastructure works (such as dams and water storages)
- protect the water quality of stored waters; and
- maintain the ecological integrity of the land.

3.4 State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011

SEPP (Sydney Drinking Water Catchment) 2011 applies to land within the hydrological catchments that contribute to Sydney's drinking water supply. The aims of this Policy are:

- *to provide for healthy water catchments that will deliver high quality water while permitting development that is compatible with that goal;*
- *to provide that a consent authority must not grant consent to a proposed development unless it is satisfied that the proposed development will have a neutral or beneficial effect on water quality; and*
- *to support the maintenance or achievement of the water quality objectives for the Sydney drinking water catchment.*

The WMP area is designated as a *Schedule 1 Restricted Access Area (Metropolitan Special Area)* under the *Sydney Water Catchment Management Act 1998* and is managed by the Sydney Catchment Authority (SCA). Consequently this SEPP applies.

In deciding whether or not to approve the Project under Part 3A, the Minister may take into account Clause 9 and 10 of the SEPP. Clause 9 states that:

1) *"any development or activity proposed to be carried out on land to which this Policy applies should incorporate the Authority's current recommended practices and (*performance) *standards*;

2) If any development or activity does not incorporate the Authority's current recommended practices and (performance) *standards, the development or activity should demonstrate to the satisfaction of the consent authority or determining authority how the practices and performance standards proposed to be adopted will achieve outcomes not less than those achieved by the Authority's current recommended practices and standards."*

Clause 10 states that:

1) "*A consent authority must not grant consent to the carrying out of development under Part 4 of the Act on land in the Sydney drinking water catchment unless it is satisfied that the carrying out of the proposed development would have a neutral or beneficial effect on water quality;*

2) *For the purposes of determining whether the carrying out of the proposed development on land in the Sydney drinking water catchment would have a neutral or beneficial effect on water quality, the consent authority must, if the proposed development is one to which the NorBE Tool applies, undertake an assessment using that Tool."*

The *Neutral or Beneficial Effect Tool* (NorBE Tool) identified in Clause 10 of SEPP (Sydney Drinking Water Catchment) 2011 describes how to assess a neutral or beneficial effect (NorBE) on water quality for development applications made to consent authorities for land in the Sydney drinking water catchment, as defined in the SEPP.

The NorBE Tool is detailed in Appendix 1 of the *Neutral or Beneficial Effect of Water Quality Assessment Guidelines 2011* (NorBE Guidelines).

The NorBE Guidelines supports the implementation of the SEPP by providing clear direction on what a neutral or beneficial effect means, how to demonstrate it, and how to assess an application against the neutral or beneficial effect on water quality test using the NorBE Tool.

Although not specified in the SEPP, the NorBE Guideline may provide a framework to consider major infrastructure and other projects under Part 3A of the EP&A Act. The Minister for Planning and Infrastructure determines these projects and which water quality test will be applied.

Monitoring to date indicates that the proposed works will not have significant impact on water quality within lands to which the Sydney Drinking Water Catchment SEPP applies.

4. SOUTHERN COALFIELDS INQUIRY AND PLANNING ASSESSMENT COMMISSION STUDIES

In addition to the policies and guidelines outlined in Section 2.0, the three following reports have guided the NRE No.1 surface water assessment;

- NSW Department 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;
- NSW Planning Assessment Commission, 2010 Bulli Seam Operations PAC Report

The above mentioned reports, hereafter referred to as the Southern Coalfield Strategic Review (SCSR), the Metropolitan PAC and the Bulli PAC, indicate that surface water monitoring regimes and impact assessments should be based on the following (paraphrased) issues that were expanded upon in the Metropolitan and Bulli PAC reports.

As a general conclusion, the PAC reports indicated a proposed project should achieve "negligible environmental consequences", which includes;

- no diversion of flow,
- no change in the natural drainage behavior of pools,
- minimal iron staining,
- minimal gas releases, and
- continued maintenance of water quality at its pre-mining standard.

Where the predicted subsidence impacts could lead to unacceptable environmental consequences for significant natural features, the PAC adopted a strategy of specifying outcomes to be achieved for a significant feature, rather than prescribing limits for subsidence effects and/or impacts, or setting arbitrary mining setbacks. The Proponent is responsible for satisfying the Consent Authority and regulators that the proposed strategies will achieve these outcomes.

The SCSR and PAC reports defined *subsidence impact, subsidence effect* and *environmental consequence* as outlined below;

effect describes the subsidence itself

impact any physical change to the fabric or structure of the ground or its surface

consequence any change in the amenity or function of a feature that arises from an impact. Some consequences may give rise to *secondary consequences.* Consequences related to natural features are referred to as *environmental consequences.*

As an example, tensile strain due to the ground surface being `stretched' as a result of undermining is an *effect,* a crack resulting from the tensile strain is an *impact,* loss of water down the crack is *a consequence,* and the drying of a water dependent ecosystem as a result of this loss of water is *a secondary consequence.*

The key surface water related issues within the predicted 20mm subsidence zone highlighted in the above reports that were recommended to be addressed are outlined in the following sections.

Further detailed discussion on the relevant surface water issues is contained within this report.

4.1 Catchment Yield

The PAC assessments have determined that a proponent should derive and calibrate a rainfall runoff model for the relevant streams and storages from dam water level and flow records and compare the data with rainfall runoff modeling to ascertain if there is a departure between the modeled and observed data that indicates an existing loss of water from the catchment.

The possibility that the quality of water reaching Cataract reservoir or Broughton's Pass Weir may be reduced as a consequence of subsidence induced cracking in the waterways and catchment should be assessed.

It should be ascertained if there will be any measurable reduction in runoff to the water supply system operated by the Sydney Catchment Authority or to otherwise represent a threat to the water supply of Sydney or the Illawarra region, as well as any reduction in runoff, including downwards leakage to mining operations, especially where a shallow depth of cover prevails or a structural feature provides a conduit for flow.

4.2 Stream Health

The potential for cracking of stream beds and the underlying strata should be assessed which can lead to:

- loss or redirection of surface water flows;
- changes in water quality, particularly ferruginous springs and/or development of iron bacterial mats that can form flocs, discolouration of water in pools or staining of rock surfaces, as well as generation of elevated levels of manganese and aluminium;
- loss of ecosystem functionality, such as loss of pool integrity, pool connectivity, changes in water quality or loss of visual amenity.

The proponent should conduct mapping and logging of the density and spatial variability of existing subsidence impacts correlated with characteristics of the rock strata in the bed to allow extrapolation of the likely nature and extent of future impacts.

4.3 Stream Flow Reduction

The proponent should compare flow data from gauging stations and, by observation of the shape of recessions and persistence of low flows over a 12 month period, discern if there is any evidence of flow reduction resulting from existing longwall mining under the streams through;

- comparison of daily flows between stations;
- comparison of 5 day moving averages of flow at the stations;
- derivation of rainfall runoff coefficients for the stations

4.4 Risk Management Zones

The SCSR outlined that Risk Management Zones (RMZs) should be identified to focus assessment and management of potential impacts and to manage subsidence effects on significant natural features. The SCSR considered RMZs are particularly appropriate for non conventional subsidence effects.

RMZs should be identified for all significant environmental features which are sensitive to valley closure and upsidence, including rivers, significant streams and valley fill swamps.

Risk Management Zones should be applied to all streams of 3rd order or above in the Strahler stream classification and be defined from the outside extremity of the surface feature, either by a 40° angle from the vertical down to the coal seam which is proposed to be extracted, or by a surface lateral distance of 400m, whichever is the greater.

The Metropolitan PAC report pointed out that defining a RMZ was not, of itself, a determination of `significance', nor does it suggest a need to exclude mining, although it does mean that careful assessment may lead to management consequences.

The Metropolitan PAC report recommended that RMZs be incorporated into a broader risk framework along with assessment of a set of values to assist in determining the nature and level of any protection that might be required.

5. PREVIOUS RELATED STUDIES

Stream flow and stream water quality status of Wallandoola Creek has been assessed in:

- September 2001 (Seedsman Geotechnics Pty Ltd, 2001) at two sites within Wallandoola Creek, approximately 500m downstream of the V Mains Project Area;
- November to December 2001 (GeoTerra Pty Ltd, 2002) at three sites within the main channel and a tributary of Wallandoola Creek, downstream of V Mains. This was in preparation for a proposed expansion of longwall mining to the west of the existing Bulli Seam workings, which, in the end, did not proceed; and
- Between July 2007 and the present within Wallandoola Creek in the vicinity of the proposed Bulli Seam V Mains extraction area.

The stream flow and water quality of Lizard Creek has also previously been assessed in:

- March 2001 (Australian Water Technologies, 2001) at two sites (LC2 and LC8);
- September 2001 (Seedsman Geotechnics Pty Ltd, 2001) at numerous sites within Lizard Creek and its tributaries downstream of V Mains;
- November to December 2001 (GeoTerra Pty Ltd, 2002) at numerous sites within the main channel and tributaries of Lizard Creek, adjacent to and downstream of V Mains in preparation for a potential expansion of longwall mining to the west of the existing Bulli Seam workings (which did not proceed);
- Between July 2006 and the present (Ecoengineers Pty Ltd, 2008) in two unnamed tributaries of Lizard Creek over the current extraction area at T and W Mains, and;
- Between July 2007 and the present in the vicinity of the proposed Bulli Seam V Mains extraction area.

6. PREVIOUS MINING AND SUBSIDENCE

The following discussion on previous mining and subsidence is generated from Seedsman Geotechnics (2012).

6.1 Wonga East

Longwall mining in the Balgownie Seam as well as bord and pillar extraction of the Bulli Seam under Cataract Creek, Bellambi Creek and the Cataract River (upstream of the reservoir) has previously been conducted, with no record of adverse impacts on the stream bed or banks or upland swamps.

At Wonga East, the Bulli Seam overlies the Balgownie Seam by approximately 6 - 8m, whilst the Balgownie Seam overlies the Wongawilli Seam by approximately 10 - 15m.

6.1.1 Bulli Seam Bord and Pillar, Pillar Extraction

As shown in **Drawing 5**, the Bulli Seam has been mined in adjoining workings by BHP Billiton (and its predecessors) at the;

- Cordeaux Colliery to the immediate south and west of the Gujarat lease using longwall extraction, and;
- Bulli Colliery to the immediate north and east of the Gujarat lease area by predominantly bord and pillar methods, with pillar extraction.

The Bulli Seam was initially mined within the NRE No. lease area up to 125 years ago in a relatively disordered bord and pillar pattern with roadways driven approximately 5m wide with approximately 25m wide pillars, which in some cases were split diagonally as shown in **Drawing 5**.

Subsequent pillar extraction of up to 490m wide occurred, with the actual extent being as accurate as historical survey records permit.

It was noted during subsequent extraction of the Balgownie longwalls that the ground conditions matched the recorded mine workings in the Bulli Seam.

As the Cordeaux and Bulli mine workings have the potential to directly influence the groundwater system within the Study Area, the adjacent underground Bulli workings are summarised in **Table 1**.

Table 1 Adjacent Mining Operations

MINE	Operator	Extraction Method	Max Depth (mbg)	Max Mine Inflow (ML/yr)	Status
Cordeaux (d)	BHP	Longwall	455	n/a	flooded
Bulli (d)	BHP	Bord and pillar	405	n/a	flooded

NOTES: LW longwall d decommissioned mbg m below ground n/a not available

The Bulli Seam was mined by BHP Billiton (and its predecessors) at the Cordeaux Colliery to the immediate south of the Gujarat lease using longwall extraction from 1979, with the mine currently being closed on a care and maintenance basis.

BHPBIC also mined the Bulli Seam via bord and pillar extraction between the Cordeaux longwalls and the Bulli Seam workings in the Wonga East area.

The Bulli bord and pillar workings to the east of the NRE1 500 series longwalls and north of the Wonga East area were extracted as shown in **Drawing 5**, with the workings extending to the east, with and a number of portals through to the Illawarra Escarpment.

Longwall extraction in the Bulli Seam has been, and is currently occurring at least 2.6km to the north of the Gujarat lease on the northern, opposite side of the Cataract River in the BHP Billiton Illawarra Coal Westcliff, Northcliff and Appin workings as well as in the Helensburgh Coal Metropolitan mine. These workings are far enough to the north to be of no influence on the Gujarat lease area.

6.1.2 Balgownie Longwalls

The Balgownie longwalls were extracted after and beneath the Bulli Seam in the 1970s and 1980s. The Balgownie Seam was approximately 1.35m thick, although the mining height may have been slightly greater. Panel widths ranged from 144 - 186m and pillars were 25 - 40m as shown in **Drawing 6** for a 280 - 290m depth of cover, with the mining face being relocated around a north-west trending dyke.

Monitoring over the 150 - 190m wide longwalls indicated subsidence of approximately 0.55m above the chain pillars and sag over the panels of up to 0.8m, for a maximum of 1.4m. Strains up to 3mm/m were measured above large Bulli pillars and up to 6mm/m above Bulli Seam extraction areas, with tilts up to 10mm/m.

Following extraction of the Balgownie Seam, subsidence between 0.6 – 0.8m developed where large pillars and barriers were left in the Bulli Seam, with sag between the pillars and above the Balgownie longwalls of approximately 0.2m.

Vertical subsidence above the pillars averaged about 0.55m.

6.1.3 Wongawilli Seam Longwall WE-A2-LW4

The Wongawilli Seam longwall WE-A2-LW4 at Wonga East was mined between 19/04/2012 and 18/09/2012.

The panel was located at 310 – 340m below surface, with a 150m width and an extraction height of 3.1m.

No streams and one swamp (Ccus6) overly the predicted 20mm subsidence zone.

Maximum subsidence of 1.3m, along with maximum strain of 4.3mm/m (tensile) and 3.4mm (compressive) and a maximum tilt of 26.8mm/m were observed over the panel, whilst tensile cracking was observed near the longwall centreline, parallel to the longwall face, and in the pavement of Mt Ousley Road.

It was observed that subsidence was constrained within the panel footprint, with the Bulli and Balgownie seams being mined immediately above WE-A2-LW4. This implies that the previous mining has reduced the bridging characteristics of the overburden to make it more compliant and less able to span the single panel.

Total cumulative subsidence is estimated to be;

- 1m from the Bulli Seam
- 0.5 – 1.3m from the Balgownie Seam (depending on the actual location), and;
- 1.3m from WE-A2-LW4, for a total of up to 3.6 m.

No evidence of pillar run is present for the Bulli Seam, whilst the pillar extraction areas in the Bulli Seam are fully subsided (SCT Operations, 2012).

The observed cracking is consistent with general experience of mining in steep terrain and is likely to be associated with an equal amount of compression across Cataract Creek, with movement likely to have been taken up on a horizontal shear plane at or near the base of the valley.

An inspection of Cataract Creek, in October 2012 did not reveal evidence of stream bed cracking, loss of pool holding capacity, development of ferruginous springs or changes in stream water quality.

No adverse effect on tributary stream outflow, groundwater levels or stream / groundwater quality was observed on swamp Ccus6 or tributary CT1 due to the subsidence or cracking over WE-A2-LW4.

The groundwater related aspects of WE-A2-LW4 are discussed in (GeoTerra, 2012).

The observations from mining WE-A2-LW4 were incorporated into an updated subsidence prediction assessment for the Wonga East longwalls (Seedsman, 2012).

6.2 Wonga West

The Bulli Seam was extracted using 142 -188m wide longwalls in the north/south aligned 200 and 300 series panels.

The 200 series longwalls were extracted between July 1979 (LW202) and October 1993 (LW212), whilst the 300 series were extracted between November 1981 (LW301) and March 1993 (LW309). Longwall 310 was completed in January 2002.

Pillar widths ranged from 19 - 35m, with some experiments at 51m for a depth of cover between 400 - 450m and a 2.5m seam thickness.

The panels underlie both Lizard and Wallandoola Creeks.

The 500 series were extracted between July 1993 (LW501) and September 2000 (LW518) under Cataract Reservoir, between the proposed Wonga East and Wonga West areas.

The longwalls utilised large, stable pillars with narrow panels, whilst workings closer to the dam wall (LW514 onwards) were based on 150m wide panels with 65m wide pillars, which generated a maximum subsidence of 240mm.

Monitoring of the first four longwalls in the 300 series indicates greater deformation above the chain pillars and subsidence of approximately 1m, tilts up to 4.5 mm/m and strains up to 1.5mm/m.

The available subsidence data has been utilised to give an indicative contour plan of the vertical subsidence across the first 4 panels and was processed to visualise the likely subsidence across the full western area.

6.3 Proposed Adjacent Mining

The Environmental Assessment for the BHP Billiton Bulli Seam Operations initially contained longwall workings in the Appin Area 2 Extended and Appin Area 3 Extended areas, which were located at least 1100m north of the Gujarat Lease (BHPB, 2009).

In a subsequent revision, these workings were removed from the Bulli Seam Operations Preferred Project Report (BHPB, 2010).

No other mining is currently proposed in the vicinity of NRE No.1.

7. PROPOSED NRE NO.1 MINING

7.1 WONGA EAST

The proposed north east / south west trending Wonga East panels are subdivided into Area 1 to the east and Area 2 to the west of Mount Ousley Road, with the gap designed to avoid subsiding the freeway.

Based on the current understanding of coal quality, the proposed eastern mining edge is approximately 560m from the crest of the Illawarra Escarpment (defined as 320m ASL).

As summarised in **Table 2**, Area 1 comprises three, 105m wide panels with 40m wide pillars that underlie steeply sloping, northerly draining, 1st and 2nd order intermittent tributaries of Cataract Creek, with a depth of cover to the Wongawilli Seam of approximately 237 - 255m. The tributaries join at Mt Ousley Road into the 4th order, steeply sloping, easterly draining channel of Cataract Creek.

Area 2 comprises eight, 145 - 150m wide panels with 60m wide pillars that underly the 4th order channel as well as 1st and 2nd order tributaries of Cataract Creek with approximately 267m to 320m depth of cover.

The western end of Panel 10 in Area 2 also underlies the 289.87m AHD high water mark of Cataract Creek in the upper backwaters of Cataract Reservoir, which may marginally overlie the panel edge during high water periods as shown in **Drawing 2**.

Fourteen upland swamps that meet the definition of the Coastal Upland Swamp Endangered Ecological Community lie within the predicted 20mm subsidence zone. Of those, seven were assessed to be of “special significance” according to the NSW Office of Environment and Heritage criteria (OEH, 2012), and of those, five are predicted to be potentially subject to subsidence effects (Biosis, 2012), including;

- Crus1 as well as Ccus1, 4, 5 and Ccus10

The longwalls are positioned so that vertical subsidence under 3rd or higher order streams will be restricted to generally less than 250mm, except over WE-A2-LW8, where subsidence may extend up to 1.0m in Cataract Creek.

The proponent has provided an undertaking that it will terminate mining beneath Cataract Creek if subsidence and ground movements are predicted to exceed 250 mm and the creek experiences greater than minimal impact.

All panels will be extracted down dip from south to north.

A plan of the proposed workings in relation to previous workings is shown in **Drawings 5** and **6**.

Table 2 Wonga East Panel Dimensions and Wongawilli Seam Depth of Cover

Panel	Width (rib to rib) (m)	Pillar Width (m)	Length (m)	Depth of Cover (m)
Area1 LW1	105	40	1040	237 - 242
Area1 LW2	105	40	1080	243 - 247
Area1 LW3	105	40	1150	247 - 253
Area2 LW4	150	60	1325	267 - 284
Area2 LW5	150	60	1435	272 - 288
Area2 LW6	150	60	1120	277 - 293
Area2 LW7	150	60	1230	282 - 304
Area2 LW8	150	60	1375	283 - 310
Area2 LW9	150	60	1280	287 - 316
Area2 LW10	150	60	1020	287 - 318
Area2 LW11	150	60	780	288 - 321

NOTE: Shading indicates previously extracted longwall

The proportion of catchment areas to be undermined is shown in **Table 3**.

Table 3 Wonga East Proportion of Catchment Within Potential Subsidence Areas Compared to Total Catchment Area

Stream	Total Catchment (km^2)	Within 20mm Subsidence Zone (km^2)	% of Catchment
Cataract Creek	5.2	2.5	48.1
Bellambi Creek	9.3	0.05	0.5
Cataract River	11.6	0.4	3.4

Source: WRM Water and Environment (2012) in Appendix A

7.2 WONGA WEST

The Wonga West panels are subdivided into Area 3, to the west of Lizard Creek, and Area 4, to the east of Lizard Creek, with the panel layout designed to avoid subsidence related cracks developing in the main channels of Lizard or Wallandoola Creeks.

No extraction is proposed under the main channels of Lizard Creek or Wallandoola Creek, and no extraction is proposed at Wonga West under the Cataract Reservoir.

The proposed Area 4 panels are at least 1km from the Cataract Dam wall, and are positioned to avoid generating a hydraulic connection between the 20mm subsidence zone and Cataract Reservoir.

Five 374 – 390m wide, up to 2690m long, north-south panels with 65m wide chain pillars are proposed in Area 3, along with two 155m wide and up to 1738m long panels separated by 65m wide pillars in Area 4 as summarised in **Table 4**.

Table 4 Wonga West Panel Dimensions and Depth of Cover

Panel	Width (rib to rib) (m)	Pillar Width (m)	Length (m)	Depth of Cover (m)
Area3 LW1	374	65	1626	480 - 512
Area3 LW2	381	65	2186	482 - 510
Area3 LW3	379	65	214	472 - 510
Area3 LW4	383	65	2357	457 - 497
Area3 LW5	390	65	2690	457 - 488
Area4 LW6	155	65	1652	457 - 490
Area4 LW7	155	65	1738	465 - 485

The proposed Wonga West main headings will be aligned with and located in close proximity to, or underneath, Lizard Creek as shown in **Drawing 3**.

The proposed panels, underlie ephemeral 1st to intermittent 2nd order tributaries of Lizard Creek and Wallandoola Creek. In addition, the 3rd order reach of the Lizard Creek tributary (LCT1) overlies WW-A3-LW3, along with a short reach of 3rd order channel in LCT2 over WW-A3-LW5.

The depth of cover to the Wongawilli Seam ranges from approximately 455 - 510m in Area 3, with 460 - 495m in Area 4.

Thirty six swamps that meet the definition of the Coastal Upland Swamp Endangered Ecological Community lie within the predicted 20mm subsidence zone. Of those, eight were assessed to be of “special significance” according to the NSW Office of Environment and Heritage criteria (OEH, 2012), as shown in **Drawing 3**, and of those, seven are predicted to be potentially subject to subsidence effects (Biosis, 2012), including;

- Lcus1, 6, 8, 27 as well as Wcus4, 7 and Wcus 11

Figure 1 indicates the relationship between the previous Bulli Seam and the proposed Wongawilli Seam workings, which will all be extracted down dip from south to north.

Figure 1 Proposed Wonga West Longwalls and Old Bulli Seam Workings

The proportion of catchment areas to be undermined is shown in **Table 5**.

Table 5 Wonga West Proportion of Catchment Area Within Potential Subsidence Areas Compared to Total Catchment Area

Stream	Total Catchment (km^2)	Catchment Within 20mm Subsidence Zone (km^2)	% of Catchment
Lizard Creek	17.1	6.3	36.8
Wallandoola Creek	33.2	2.0	6.0

Source: WRM Water and Environment (**Appendix A)**

7.3 Anticipated Mining Schedule

Intital development of access and ventilation drifts as well as water drainage of the workings has been conducted at Wonga East, and will be required for access to and development of the remaining workings in Wonga East and Wonga West.

It is currently planned that Longwall 5 in Area 2 will be mined, followed by Longwalls 6 to 11 in Wonga East, then the workings in Wonga West.

Table 6 Proposed Underground Mining Schdule

MINING AREA	Estimated Duration of Drift Installation, Pre Drainage and Longwall Mining (Years)
Wonga East Area 1	2.0
Wonga East Area 2	4.5
Wonga West Area 3	7.0
Wonga West Area 4	1.25

8. PREDICTED SUBSIDENCE

8.1 Wonga East

The Cataract Creek, Cataract River and Bellambi Creek catchments have previously been undermined by multi-seam extraction, comprising the Bulli Seam bord and pillar, as well as pillar extraction workings, the Balgownie Seam longwalls and Wongawilli Seam longwall WE-A2-LW4.

The possible subsidence effects at Wonga East shown in **Drawings 7** to **9** were determined using Surface Deformation Prediction System (SDPS) software and default parameters, with the prediction taking into account the subsidence over WE-A2-LW4 (Seedsman Geotechnics, 2012).

Subsidence under the main channel of Cataract Creek is predicted to be generally less than 250mm, along with valley closure of up to 100mm and upsidence of up to 60mm. However, subsidence of up to 0.8m may occur over Longwall WE-A2-LW8 in the bed of Cataract Creek.

Following the Failure Mode and Effects Analysis (FMEA) review (Olsen Environmental Consulting, 2010), it was considered good practice to double these estimates in the context of an impact risk assessment (Seedsman Geotechnics, 2012).

The proponent has provided an undertaking that it will terminate mining beneath Cataract Creek if subsidence and ground movements are predicted to exceed 250mm and the creek experiences greater than negligible impact

A summary of predicted maximum subsidence, strain and tilt is shown in **Table 7**. Subsidence predictions for sub-sections of the creeks are shown in **Appendix B**.

Table 7 Maximum Predicted Wongawilli Workings Subsidence (Wonga East)

	Subsidence (m)	Tilt (mm/m)	Strain (mm/m)	Upsidence (mm)	Valley Closure (mm)
Overall Wonga East Area 1 Mining Domain	1.10	17.0	-13 to 11	120	200
Overall Wonga East Area 2 Mining Domain	1.10	17.0	-14 to 15	120	200
Cataract Creek Main Channel	0.25	4.0	-2 to 8	120	200
Cataract River Main Channel	0	0	0	<60	<100
Bellambi Creek Main Channel	0	0	0	0	0

NOTES: compressive strain = -ve values, tensile strains = +values (Seedsman Geotechnics, 2012)

8.2 Wonga West

The predicted subsidence due to extraction of the Wongawilli Seam (only) is shown in **Drawings 10 to 12,** whilst the combined subsidence of the Bulli Seam and Wongawilli Seam mining is shown in **Figure 2**.

A summary of predicted maximum subsidence, strain and tilt is shown in **Table 8**. Subsidence predictions for sub-sections of the creeks are shown in **Appendix B**.

It should be noted that the Wonga West area has been back analysed to have undergone up to 1m of subsidence following extraction of the 200 and 300 series longwalls, and that both Wallandoola Creek and Lizard Creek, their associated tributaries, as well as upland and valley fill swamps have been previously undermined by the Bulli Seam workings.

Both Wallandoola Creek and Lizard Creek have also been previously undermined by the SW-NE oriented longwall panels of the BHPBIC Cordeaux workings to the south of the Gujarat lease.

Valley closures of up to 100mm and upsidence of about 60mm are predicted. However, following the FMEA review, it was considered good practice to double these estimates in the context of an impact risk assessment (Seedsman Geotechnics, 2012).

No published studies have been conducted on the subsidence effects at Cordeaux on stream flow, water quality or upland swamps. As a result of the lack of pre or post mining data, it is not possible to indicate whether, or not, subsidence has had an adverse effect on the surface water system over the Cordeaux panels.

Table 8 Maximum Subsidence (Wonga West)

	Subsidence (m)	Tilt (mm/m)	Strain (mm/m)	Upsidence (mm)	Valley Closure (mm)
Overall Wonga West Area 3 Mining Domain					
Wongawilli Seam + Bulli Seam	3.5	23	n/a	n/a	n/a
Wongawilli Seam only	2.5	17.5	-12 to 14	-	-
Overall Wonga West Area 4 Mining Domain					
Wongawilli Seam + Bulli Seam	2.5	n/a	n/a	n/a	n/a
Wongawilli Seam only	1.5	12.5	-10.5 to 6.5	-	-
Lizard Creek Main Channel					
Wongawilli Seam + Bulli Seam	1.5	n/a	n/a	n/a	n/a
Wongawilli Seam only	0.5	4.0	7.0	120	200
Wallandoola Creek Main Channel					
Wongawilli Seam + Bulli Seam	1.5	n/a	n/a	n/a	n/a
Wongawilli Seam only	0.5	4.0	6.0	120	200

SOURCE: Seedsman Geotechnics, 2012 n/a not available

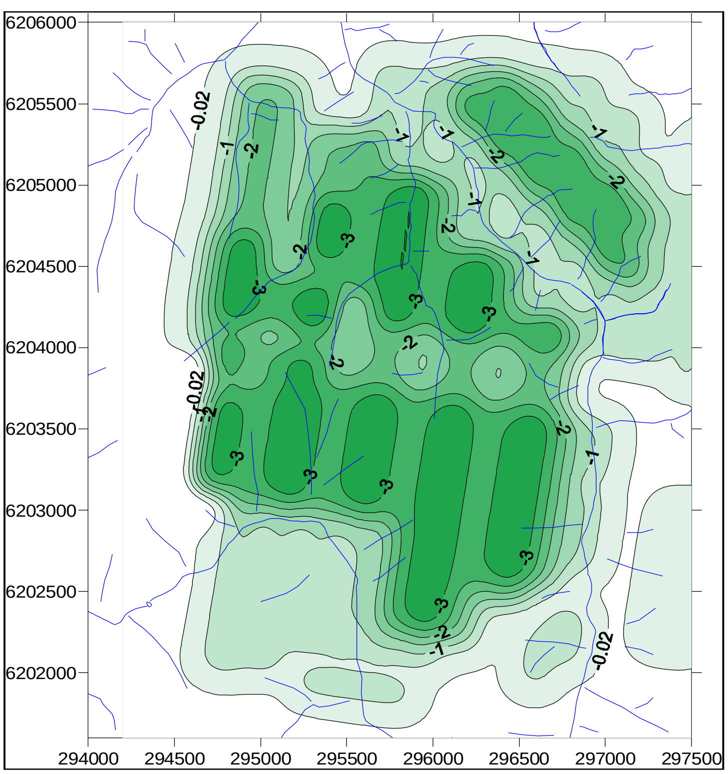


Figure 2 Combined Potential Wongawilli and Bulli Seam Subsidence at Wonga West

9. GENERAL STUDY AREA DESCRIPTION

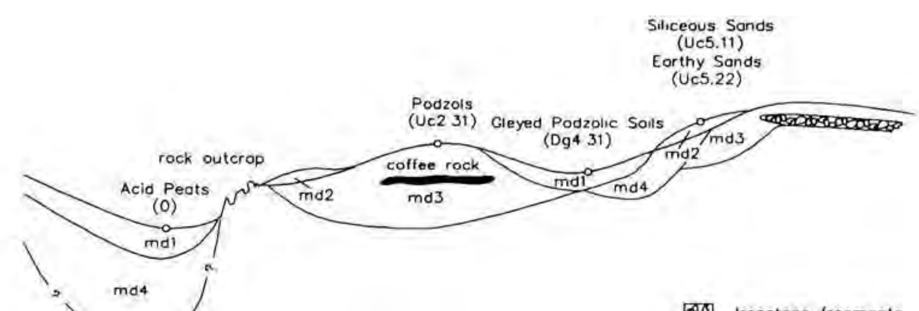
9.1 Land Use

The Study Area is located within the Sydney Catchment Authority restricted access Metropolitan Special Area, which is principally an undeveloped bushland. The region features a limited number of fire and mine site access trails, current and decommissioned mine ventilation shafts as well as men and materials access shaft and infrastructure sites.

9.2 Soil Landscapes

The area comprises three main soil landscapes (Hazelton, 1990) as shown in **Figures 3** to **5**. In general, the upper watershed portions of the catchment are within the Maddens Plains landscape, which migrates into the Lucas Heights landscape, whilst the Hawkesbury landscape is located in the lower, downstream incised valleys as described below.

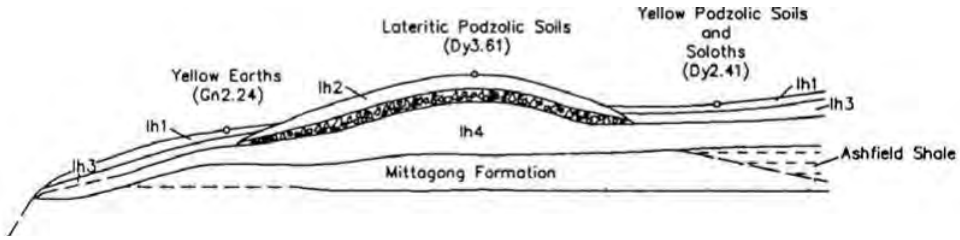
- **Maddens Plains:** moderately to gently undulating rises on plateau surfaces with widespread upland swamps / wetlands. Local relief ranges up to 1-10m with valley slope gradients of 1-10%. The dominant landform elements are broad, usually waterlogged drainage depressions with scattered rock outcrop. The landscape is present within the study area along the channels of Wallandoola and Lizard Creeks.



Source: Hazelton, P.A, Tille, P.J, 1990

Figure 3 Maddens Plains Soil Landscape

- **Lucas Heights:** gently undulating plateau surfaces and ridges 200-1000m wide, with level to gently inclined slope gradients of <10%. Local relief is less than 30m and rock outcrops are absent. Lateritic podzolic soils can be present within the Lucas Heights profile, which would be a source of dissolved iron into stream waters. The landscape is present on the plateau areas.



Source: Hazelton, P.A, Tille, P.J, 1990

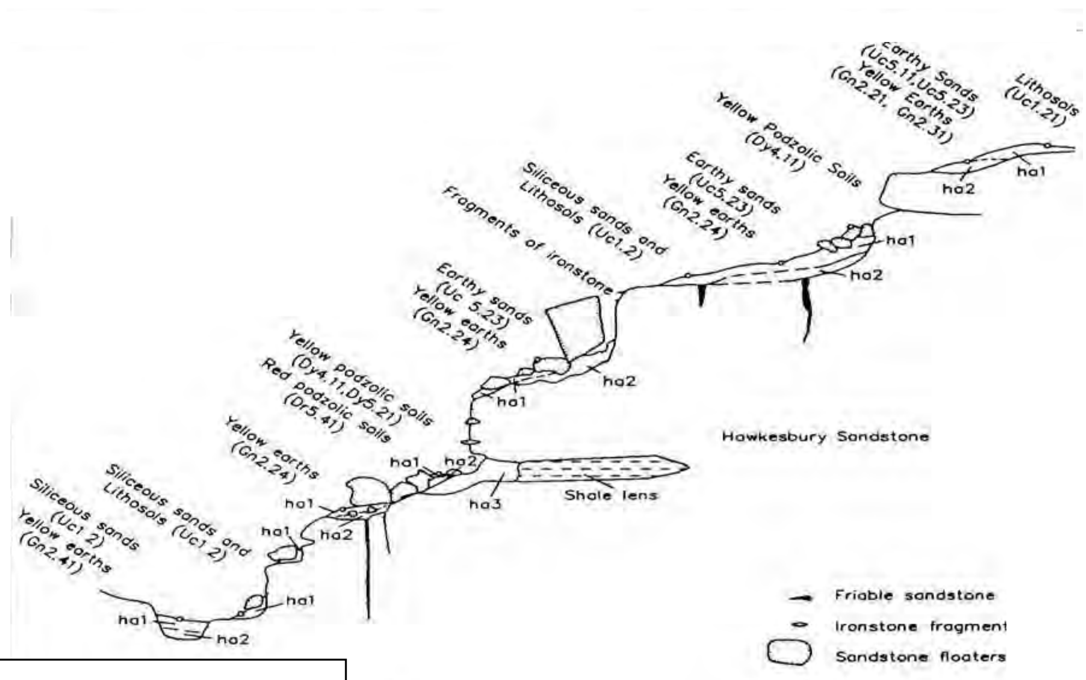
Figure 4 Lucas Heights Soil Landscape

Hawkesbury: Rolling to very steep hills. Local relief of 100 - 200m with slope gradients of 20-70%. Crests and ridges are convex and narrow and <100m wide. Slopes are moderately inclined to precipitous. Valleys are narrow (20-100m) and incised. Rock outcrop is common and occurs as horizontal benches and broken scarps up to 10m high. Rock outcrops and surface boulders and cobbles up to 50% of the ground surface.

Ironstone fragments are present in the profile, which would be a source of dissolved iron into receiving streams.

Cliffs associated with the Hawkesbury landscape have been mapped and discussed in a separate report (SCT Operations, 2012).

The Hawkesbury landscape is present within the steeper, incised sections of Lizard and Wallandoola Creeks.



Source: Hazelton, P.A, Tille, P.J, 1990

Figure 5 Hawkesbury Soil Landscape

9.3 Surficial Geology

For details refer to (GeoTerra, 2012).

9.4 Local Hydrogeology

For details refer to (GeoTerra, 2012).

9.5 Climate

The study area is in a warm temperate region however, it has significant variation in temperature and precipitation due to topographic effects and its proximity to the Illawarra Escarpment and the coast.

Rainfall varies from a maximum of 1800mm/year in the east to 1000mm/year in the west of the Study Area, with maximum rainfall in the Autumn to Winter period.

A plot of rainfall recorded at Cordeaux Colliery since January 2002, which is located to the immediate north of the NRE No. 1 lease area is shown in **Figure 6**.

The plateau generally experiences cooler temperatures than the coast, below the escarpment. Average diurnal temperature ranges from 21.5^{o}C in January to 12.5^{o}C in Winter.

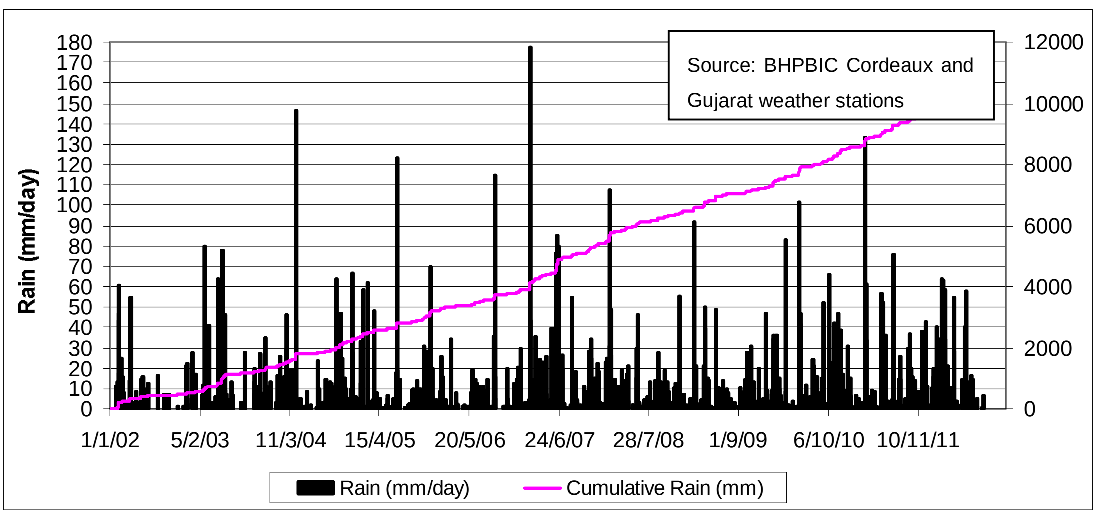


Figure 6 Local Daily Rainfall

10. STREAM CATCHMENTS

The regulated Wonga East Cataract Creek, Cataract River and Bellambi Creek catchments are located upstream of Cataract Reservoir, whilst the Wonga West Lizard and Wallandoola Creeks are unregulated and drain to the Cataract River downstream of the Cataract Dam wall.

Downstream of the junction with the two creeks, the Cataract River flows to a regulated section of the river at Broughtons Pass Weir.

10.1 Wonga West Streams

Lizard Creek and Wallandoola Creek vary along their reach from being “losing-disconnected streams” in the southern headwaters where the shallow groundwater system is recharged from stream flow seeping vertically from the base of the creek, to “gaining” streams in the middle and northern portions of the NRE No.1 lease where the creeks are incised into Hawkesbury Sandstone.

Although it has not directly been observed, variable rates of seepage from the Hawkesbury Sandstone is interpreted to enter the creeks, downstream of waterfalls L1 and W1, and can maintain a low volume baseflow, depending on the interaction between rainfall runoff / recharge and groundwater level applying at any one time.

Differentiation between the distribution of “losing” and “gaining” streams also varies depending on the amount of rainfall recharge into the sandstone plateau and the resultant standing water levels within the regional groundwater system.

Upstream of the incised stream sections and waterfalls, the two catchments are separated by a 15 - 25m high watershed, with the watershed height increasing significantly downstream of the waterfalls, where 55 – 85m deep valleys are located in the northern, downstream section of the lease.

Four channel types are present:

- valley fill upland swamps with an indistinct channel;
- narrow indistinct overgrown channels associated with a low sedge / heath and a relatively thick sandy riparian soil with a streambed consisting of weathered bedrock and/or sandy material;
- rock platforms of variable width which are usually smooth except for minor depressions on joint planes and occasional potholes. These platforms normally grade into a thinly vegetated sandy soil on either bank and can exhibit deposition of hydrated iron oxide observed as orange to black discolouration of the rock surface, or;
- incised channels in sandstone which exhibit rough riffle like surfaces, usually with accumulations of boulders and other sediments. These channels are usually bound by solid rock outcrop.

Four pool types can also be present:

- shallow, linear, small pools located in depressions formed by joint systems or cross-bedding and sometimes associated with potholes. Accumulated water is usually less saline than in surrounding pools and have minor to no interaction with the local groundwater system;
- linear pools associated with narrow erosion channels in sandy soil. The soil is usually vegetated with heath like species, whilst the downstream end is constrained by a rockbar or outcrop;
- larger pools constrained by a downstream rockbar which can be undercut by

erosion and exhibit signs of chemical weathering, or;

- larger pools constrained downstream by sediments. The sediments may extend for a considerable distance downstream.

10.1.1 Wallandoola Creek

Wallandoola Creek flows in a northerly, then westerly direction at Area 3.

The creek has previously been undermined by longwalling in the Bulli Seam by both the BHPBIC Cordeaux and Gujarat NRE No.1 workings as shown in **Drawing 5**. It does not overlie the proposed Wongawilli Seam panels, although is contained within the predicted 20mm subsidence envelope to the south of Area 3, longwalls 3 and 4, as shown in **Drawing 9**.

The main channel of Wallandoola Creek within the Wonga West 20mm subsidence zone is a Schedule 2, 3rd order stream (DIPNR, 2005) with ephemeral 1st and intermittent 2nd order tributaries, and becomes increasingly incised into Hawkesbury Sandstone at and downstream of Waterfall W1.

Wallandoola Creek joins the Cataract River approximately 8km (or 11km along the stream reach) to the north northwest of the Study Area, downstream of the Cataract Dam wall, whilst its headwaters are located south of the Gujarat lease over the previously longwalled BHPBIC Cordeaux Colliery workings.

The creek is not regulated by any dams or weirs within the Study Area. Wallandoola Creek stream monitoring site location details are shown in **Table 9** and **Drawing 3**.

Table 9 Wallandoola Creek Stream Monitoring Sites

SITE	E (MGA)	N (MGA)	DESCRIPTION
WC1	296155	6200724	Upstream of the proposed Wonga West workings and overlying the BHPB Cordeaux workings.
WC2	295854	6201546	Over the proposed V Mains workings on southern NRE No.1 lease boundary
WC3	295560	6202488	Located in a long linear pool to the south west of the proposed panel A3 LW2
WC4	294830	6202802	Upstream of waterfall W1 to the south of the proposed panel A3 LW5
WC5	294792	6202671	In a plunge pool downstream of waterfall W1, downstream of the Wonga West panels
WCT1	295038	6201404	Generally dry tributary which discharges into Wallandoola Creek between WC2 and WC3

NOTE: WC6 was monitored from Sept 2007 to June 2008, whilst WC7 and 8 were irregularly monitored in 2001, but are not discussed in detail in this report as they are significantly downstream of the Wonga West subsidence area Co-ordinates supplied from GPS

Outside of the “spot” monitoring conducted in 2001, regular stream water quality and water level monitoring commenced at each location as shown in **Table 10**.

Table 10 Wallandoola Creek Monitoring History

Location	Monitoring Start Date
WC1	July 2007
WC2	November 2008
WC3	July 2007
WC4	November 2009
WC5	November 2009

The stream gradient generally increases with distance downstream in the Wonga West (Area 3) as shown in **Table 11** and **Figure 7**.

Table 11 Wallandoola Creek Gradient

Stream Reach	Vertical Fall (m)	Distance (m)	Gradient
WC1 - WC2	7	1115	0.006
WC2 - WC3	5	650	0.008
WC3 - WC4	6	1190	0.005
WC4 - WC5	34	780	0.044

As shown in **Appendix C**, Wallandoola Creek at Wonga West is characterised by a long linear pool and rock bar at WC1 and a downstream valley fill swamp which overlies the BHPBIC Cordeaux longwall subsidence area, upstream of the Gujarat lease boundary.

WC2 is located within a valley fill swamp with no discernible stream channel in the sedge dominated channel to the immediate south, and outside of, the NRE No.1 lease boundary.

WC3 is located within an approximately 1.25km long linear pool, whose water level is maintained by a rock bar at the downstream end.

Downstream of WC3, Wallandoola Creek reverts back to an approximately 110m long valley fill swamp, then transposes into an approximately 300m long linear pool followed by a restricted channel flowing over exposed sandstone, at the downstream end of which is a distinctly iron hydroxide orange coloured pool. The coloured pool terminates at a rock bar with a less than 3m high shallow “step”, with a “clear” approximately 1.7km long pool situated immediately upstream of the less than 5m drop into a plunge pool at WC4.

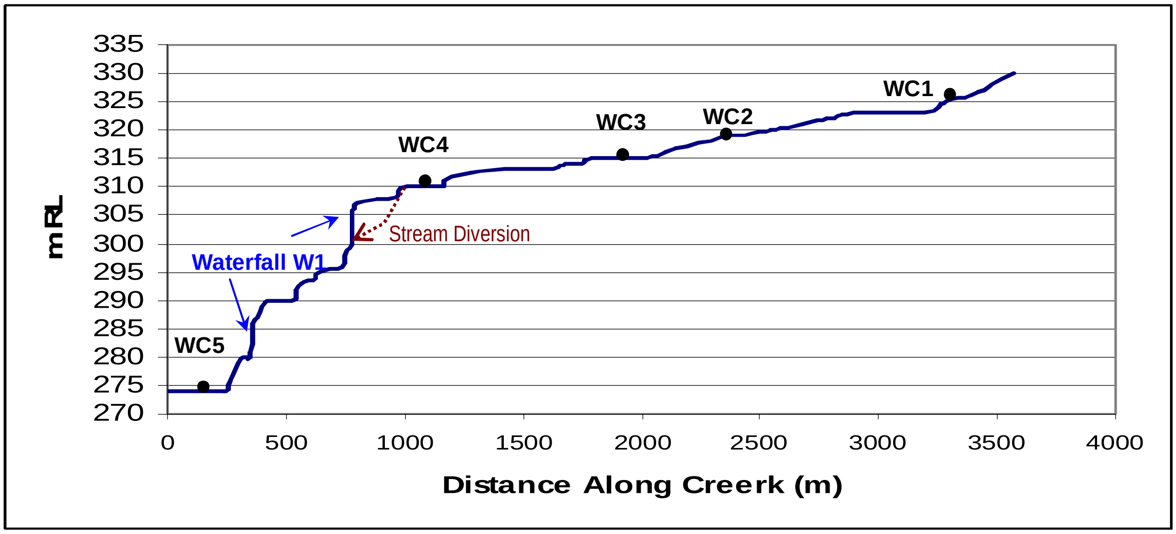


Figure 7 Wallandoola Creek Stream Reach

No evidence of stream bed cracking or enhanced pool drainage is observed between Sites WC1 and WC4.

The WC4 pool water level is constrained by a rock bar with evident cracking located approximately 100m upstream of Waterfall W1, where the pool level and extent is affected by enhanced drainage of the pool through the downstream cracked sandstone streambed.

Waterfall W1 has two major “steps” of 11m and 16m, for a total drop of approximately 30m over a 1.1km stream reach. Downstream of the waterfalls, and outside of the 20mm subsidence zone, the stream gradient flattens out to a series of extended pools constrained by rock bars.

The waterfall is also affected by cracking in the sandstone, as the stream has not been observed to flow over the falls during “dry” periods.

The sandstone streambed located approximately 100m upstream of Waterfall W1 is situated over the western edge of the old Bulli Seam workings subsidence area, and it is assessed that the stream bed cracks are due to mine subsidence.

Downstream of the waterfall, the plunge pool containing Site WC5 maintains a consistent pool, with a distinctly orange ferruginous colour.

The valley fill swamps dissipate out approximately 200m upstream of the WC4 pool, with shrubs, grasses and trees dominating along the creek banks at and downstream of WC4.

The stream bed and banks of the plateau streams are well vegetated, and do not show significant erosion or bank instability.

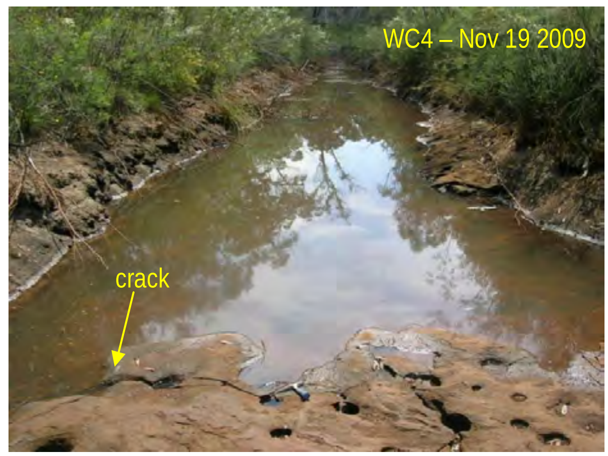


PLATE 1 Wallandoola Creek Monitoring Sites

10.1.2 Lizard Creek

Lizard Creek flows to the north to north west between the proposed Wonga West Area 3 and Area 4. The creek has previously been undermined by Bulli Seam longwalls in both the BHP Cordeaux and Gujarat NRE No.1 leases.

Lizard Creek does not overlie the proposed Wongawilli longwalls, although it is contained within the 20mm subsidence envelope as shown in **Drawing 10**.

The main channel of Lizard Creek is a Schedule 2, 3rd order stream (DIPNR, 2005) with ephemeral 1st to intermittent 2nd order tributaries, which becomes increasingly incised into Hawkesbury Sandstone as it drains downstream of Waterfall L1.

Lizard Creek joins the Cataract River approximately 6km (or 7km along the stream reach) to the north of the Study Area, downstream of the Cataract Dam wall, whilst its headwaters are located to the south over the BHPBIC Cordeaux longwalls.

The creek is not regulated by any dams or weirs.

Lizard Creek stream monitoring site details are shown in **Table 12**.

Table 12 Lizard Creek Monitoring Sites

SITE	E (MGA)	N (MGA)	DESCRIPTION
C10	295475	6204030	In a 1st order tributary of Lizard Creek tributary LCT1
C11	295800	6204475	Downstream of C10 in a 2nd order tributary
LC1	296982	6200704	In valley fill swamp over Cordeaux workings, south of Project Application Area
LC2	296773	6201510	Upstream of Wonga West 20mm subsidence zone, north of lease boundary, downstream of main road access bridge
LC3	296947	6202290	Upstream of Wonga West 20mm subsidence zone, southeast of A3 LW1, upstream of Fire Road 8 creek crossing
LC4	296972	6203921	Southeast of A3 LW1, downstream of Waterfall L1
LC5	296918	6204276	Between proposed panels A3 LW1 and A4 LW7, over first workings driveage
LC6	296174	6205204	Between proposed panels A3 LW3 and A4 LW7
LC7	295293	6206428	Downstream of Wonga West 20mm subsidence area, upstream of LCT2 tributary
LC8	295408	6206686	At Gujarat lease northern boundary, downstream of 20mm subsidence zone
LC9	295534	6207794	Downstream of Gujarat lease, downstream of 20mm subsidence zone, upstream of Lizard Creek Waterfall 2
LCT2A	294836	6204153	Within Swamp Lcus25, over panels A3 LW4 and A3 LW5, on Fire Road 8
LCT2B	294280	6205173	To the west of A3 LW5, on Fire Road 8
LCT2	295185	6206397	Downstream of LCT1 and LCT2 tributaries and enters Lizard Creek immediately downstream of LC7

NOTE: LC1 was monitored irregularly up to June 2008 and LC9 was discontinued after March 2010 as it is outside the Gujarat lease Co-ordinates supplied from GPS

Outside of the "spot" monitoring conducted in 2001, regular stream water quality and water level monitoring commenced at each location as shown in **Table 13**.

Table 13 Lizard Creek Monitoring History

Location	Monitoring Start Date
C10	July 2006
C11	July 2006
LC1	July 2007
LC2	July 2007
LC3	July 2007
LC4	November 2008
LC5	November 2009
LC6	November 2009
LC7	August 2008
LC8	March 2010
LC9	August 2008
LCT2A	August 2008
LCT2B	August 2008
LCT2	August 2008

The stream gradient varies with distance downstream and the presence of extended pools, rock bars, boulder fields or a 26m high waterfall / stepped zone to the west of No. 5 shaft as shown in **Table 14** and **Figure 8**.

Table 14 Lizard Creek Gradient

Stream Reach	Vertical Fall (m)	Distance (m)	Gradient
LC1 - LC2	7	675	0.010
LC2 - LC3	6	795	0.008
LC3 - Waterfall	18	1350	0.013
Waterfall - LC4	20	300	0.067
LC4 - LC5	25	375	0.013
LC5 - LC6	5	1270	0.004
LC6 - LC7	15	1580	0.009
LC7 - LC8	32	1475	0.022

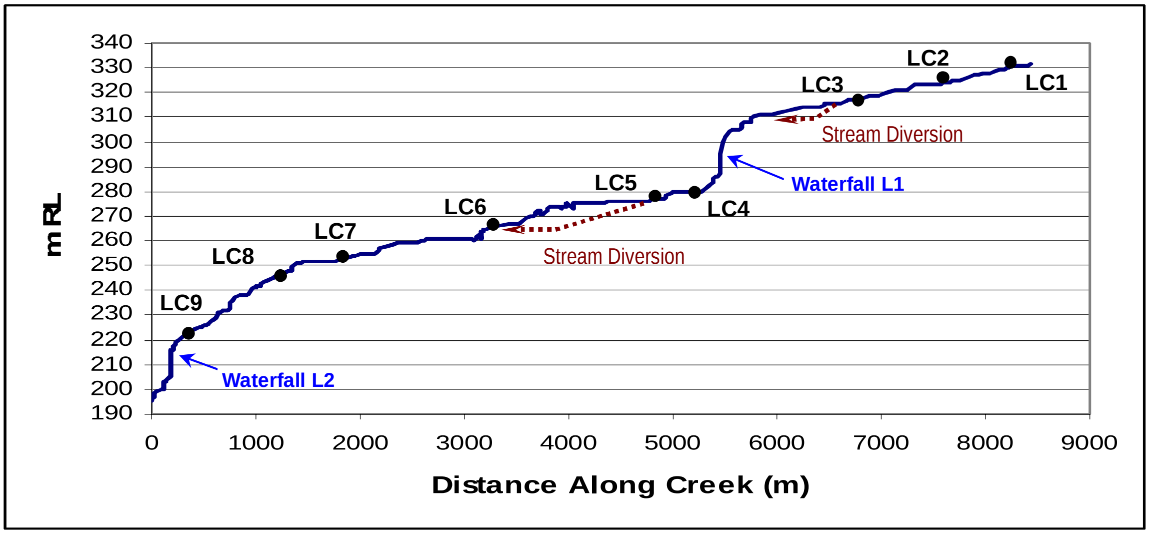


Figure 8 **Lizard Creek Stream Reach**

As shown in **Appendix C**, Lizard Creek in the Wonga West area is characterised by a series of valley fill upland swamps and pools between LC1 and approximately 50m downstream of LC3. The pool levels are supported behind exposed sandstone rock bars, often with less than a 0.5m drop between pools which range up to approximately 500m long.

The pool at Site LC3 is predominantly full and overflowing, however on one occasion for a few weeks, the stream flow temporarily ceased after an extended lack of rainfall / runoff in the catchment.

The upland swamp fringed stream banks can be up to 0.5 to 1.0m high within a reasonably well defined channel in the upstream section, which becomes more defined toward LC3. The creek can have up to approximately 50m of flanking riparian sedge / upland swamp vegetation along each bank, with the sedge / swamp areas grading upslope, out of the channel into either headwater swamps or Scribbly Gum Woodland.

The valley fill swamp Lcus4 terminates in an area of headward erosion near the junction with headwater swamp Lcus6.

Shrubs, grasses and trees dominate along the creek banks downstream of LC3 where the stream becomes increasingly more incised into sandstone.

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

A 26m high waterfall / stepped zone (Waterfall L1) is located between LC3 and LC4.

Downstream of the waterfall, the stream flows through a sequence of elongated pools, rock bars, boulder fields and rock shelves to LC4 and onto LC5.

The creek has been observed to dry out after extended low rainfall periods between LC5 and LC6 over approximately 1.3km of stream reach in an area of sequential pools, rock bars, boulder fields and sandy sediment based pools.

Permanent stream flow and pool depth is re-instated at LC6, where the water is highly orange iron hydroxide affected.

Between LC6 and downstream of LC7, the stream gradient flattens out where permanent elongated pools held behind rock bars are prevalent.

The northern boundary of the Gujarat lease is located at LC8, which is located in a permanent elongated pool held back by a sandstone rock shelf.

From the lease boundary to LC9, the creek gradient steepens, with a series of pools held behind rock bars and elongated sandstone shelves, ending in a 20m high step / waterfall zone, approximately 30m downstream of LC9. Downstream of the waterfall, Lizard Creek subsequently flows into Cataract Creek.

The stream bed and banks of the plateau streams are well vegetated, and do not show significant erosion or bank instability.

PLATE 2A Lizard Creek Monitoring Sites

PLATE 2B Lizard Creek Monitoring Sites

10.1.3 Lizard Creek 3rd Order Tributaries

Two 3rd order tributaries flow into Lizard Creek in the vicinity of the proposed Wonga West longwalls.

Tributary LCT1 has its headwaters over proposed Area 3 longwalls LW2 and LW3, with the 3rd order reach overlying the northern end of Longwall 3, downstream of monitoring point C11. Swamp Lcus18 is located in its headwaters.

All of the 1st, 2nd and 3rd order components of Tributary LCT1 have previously been subsided by the Bulli Seam longwalls, with stream bed cracking, subsurface transfer of stream flow and ferruginous seeps present in the channel. During extended dry periods, the 3rd order reach of the tributary is dry.

Tributary LCT2 headwater's originate in swamp Lcus25, which overlies the proposed Area 3 longwalls LW4 and LW5, as well as swamp Lcus26, which lies to the west of the proposed longwalls. The 1st and 2nd order tributaries flow over Area 3 Longwalls LW4 and LW5, joining as a 3rd order stream in the northwest corner of the proposed LW5, which then becomes 4th order over the proposed first workings.

Tributary LCT2A and swamp Lcus25 have predominantly been undermined by first workings in the Bulli Seam, although the downstream end of Lcus25 has also been partially undermined by longwall 310.

Tributary LCT2B and swamp Lcus26 have not been undermined.

The 3rd and 4th order reach of tributary LCT2 generally contains flowing or ponded water and does not have significant ferruginous precipitates, although it tends to be ponded during extended dry periods.

PLATE 3 LIZARD CREEK TRIBUTARIES

10.2 Wonga West Waterfalls

10.2.1 Waterfall L1

Waterfall L1 has one major drop off with an upper stepped zone of up to 26m high, and is located to the west of No. 5 Shaft.

Downstream of the waterfall the stream gradient flattens out to a series of extended sand based pools constrained by sandstone rock bars.

The waterfall is not observably affected by previous subsidence related cracking as it is located over an area of low subsidence Bulli Seam first workings, however significant underflow / throughflow is observed to exit the face of the waterfall through bedding planes and joints.

The waterfall exhibited ferruginous overland flow in the channel bed as well as a more substantive ferruginous seepage from bedding discontinuities on the western flank of the waterfall as shown in **Plate 4**.

Downstream of the waterfall, the plunge pool maintains a consistent pool, with no distinctive water discolouration.

PLATE 4 Waterfall L1

10.2.2 Waterfall W1

Waterfall W1 has two major "steps" of 11m and 16m, for a total drop of approximately 30m over a 1.1km stream reach. Downstream of the waterfalls, and outside of the 20mm subsidence zone, the stream gradient flattens out to a series of extended pools constrained by rock bars.

The waterfall is also affected by cracking in the sandstone, as the stream has not been observed to flow over the falls during "dry" periods.

The sandstone streambed located approximately 100m upstream of Waterfall W1 is situated over the western edge of the old Bulli Seam workings subsidence area, and it is assessed that the stream bed cracks are due to mine subsidence.

Downstream of the waterfall, the plunge pool containing Site WC5 maintains a consistent pool, with a distinct orange colour as shown in **Plate 5**.

PLATE 5 Waterfall W1

10.3 Wonga East Streams

10.3.1 Cataract Creek

A LIDAR survey was flown with an accuracy of 0.55m and contored at 1m intervals to determine the current surface topography in the study area as shown in **Figure 9.**

Cataract Creek flows to the west into Cataract Reservoir at Wonga East Area 2.

The Schedule 2, 4th order (DIPNR, 2005) Cataract Creek channel does not overlie the secondary extraction areas of longwalls WE-A2-LW4 or LW5 as shown in **Figure 9**.

The main channel and tributaries have been undermined by longwalls in the Balgownie Seam as well as bord and pillar and pillar extraction in the overlying Bulli Seam.

The main channel of Cataract Creek has eroded sequentially into the Hawkesbury Sandstone, Newport and Garie Formations and Bald Hill Claystone, with the Bald Hill Claystone and Bulgo Sandstone being exposed in the lower reach of the creek, upstream of the reservoir.

Cataract Creek flows directly into Cataract Reservoir over the western section of Wonga East, Area 2, whilst its headwaters are located immediately to the west of the Illawarra Escarpment.

The creek is not regulated by any dams or weirs.

The creek is relatively steep, particularly in its headwaters, with a reducing gradient with distance downstream, and flows through a series of short pools, sandy reaches, rock bars and boulder fields as shown in **Table 15** and **Figure 10**.

Table 15 Cataract Creek Gradient

Stream Reach	Vertical Fall (m)	Distance (m)	Gradient
Headwater to CC2	87	865	0.101
CC2 to CC3	8	535	0.015
CC3 to CC5	1	110	0.009
CC5 to CC6	4	635	0.006
CC6 to CC9	5	1250	0.004
CC9 to CC10	4	435	0.009
CC10 to Cataract Dam	1	375	0.003

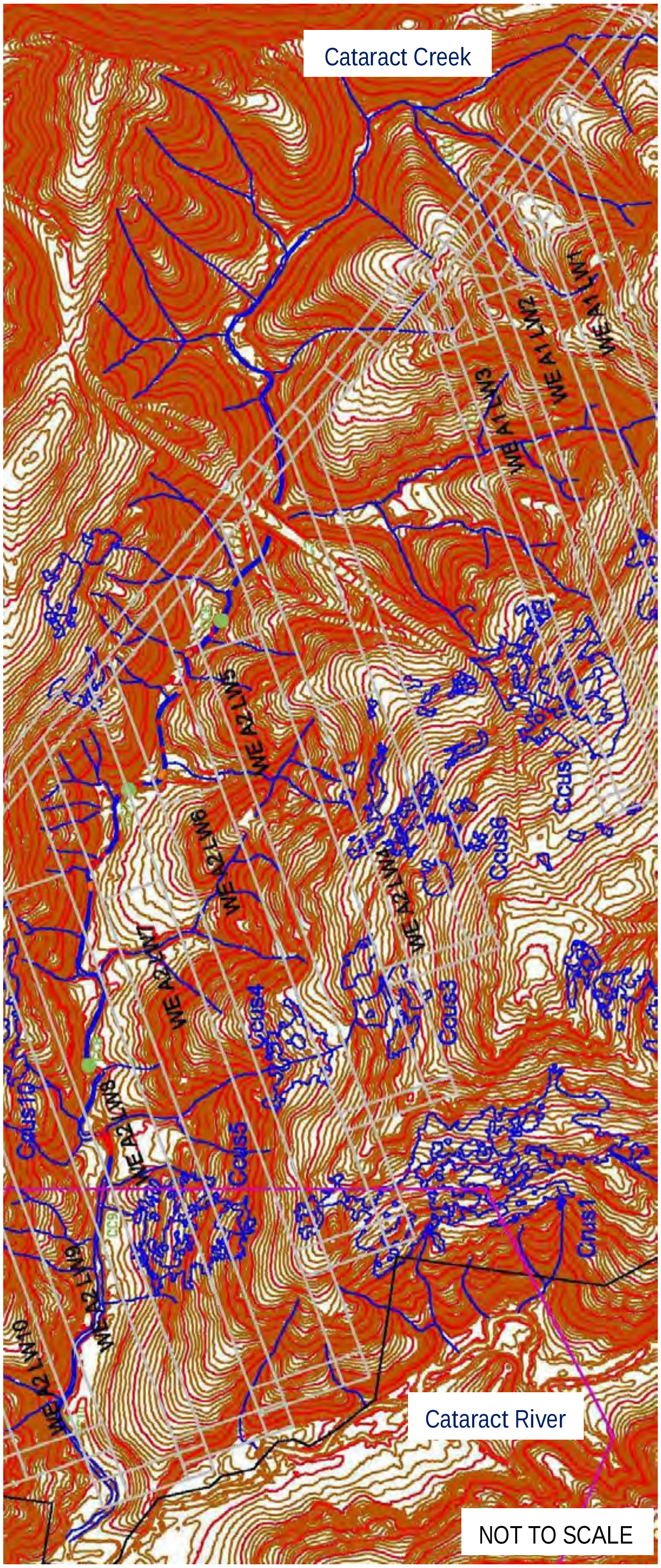


Figure 9 Wonga East 1m Contour Topography

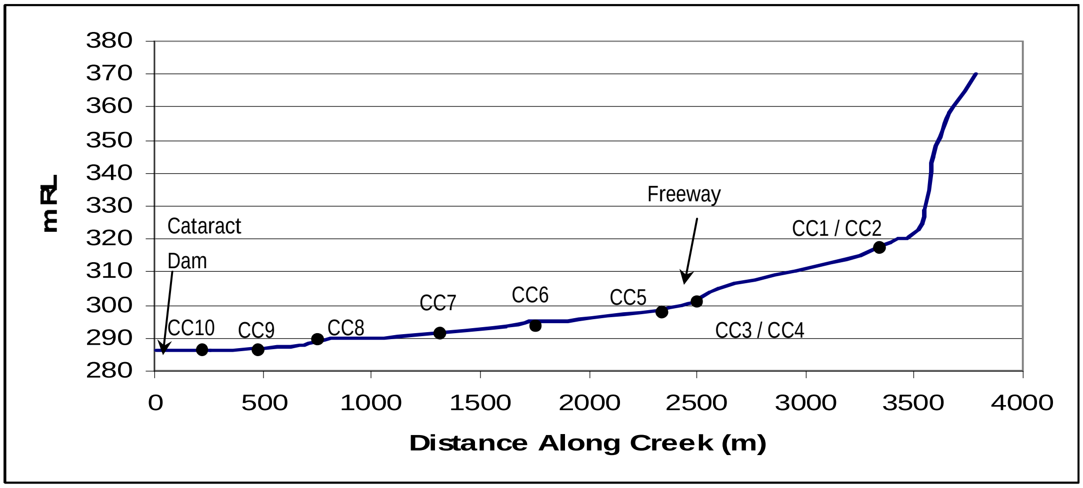


Figure 10 Cataract Creek Stream Reach

Cataract Creek is characterised by two steeply sloping headwater valleys monitored by Sites CC1 and CC2, which flow to sites CC3 and CC4 before joining as a single stream at Site CC5.

The headwater tributaries have eroded through the Hawkesbury Sandstone and, in the deeper eroded areas, through to the Bald Hill Claystone and the underlying Bulgo Sandstone.

Detailed stream bed mapping between CC5 and CC9 identified a series of long elongated pools that are constrained by low (<0.5m high) shallow rock bars, which predominate in the upper to mid section, along with occasional, gravel sized riffle sections that also predominate in the upper to mid section of the study reach.

Significant reaches of sandy based substrate dominate between CC7 and CC9, which has developed in an eroded, interspersed shale and sandstone sequence compared to the Hawkesbury Sandstone.

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

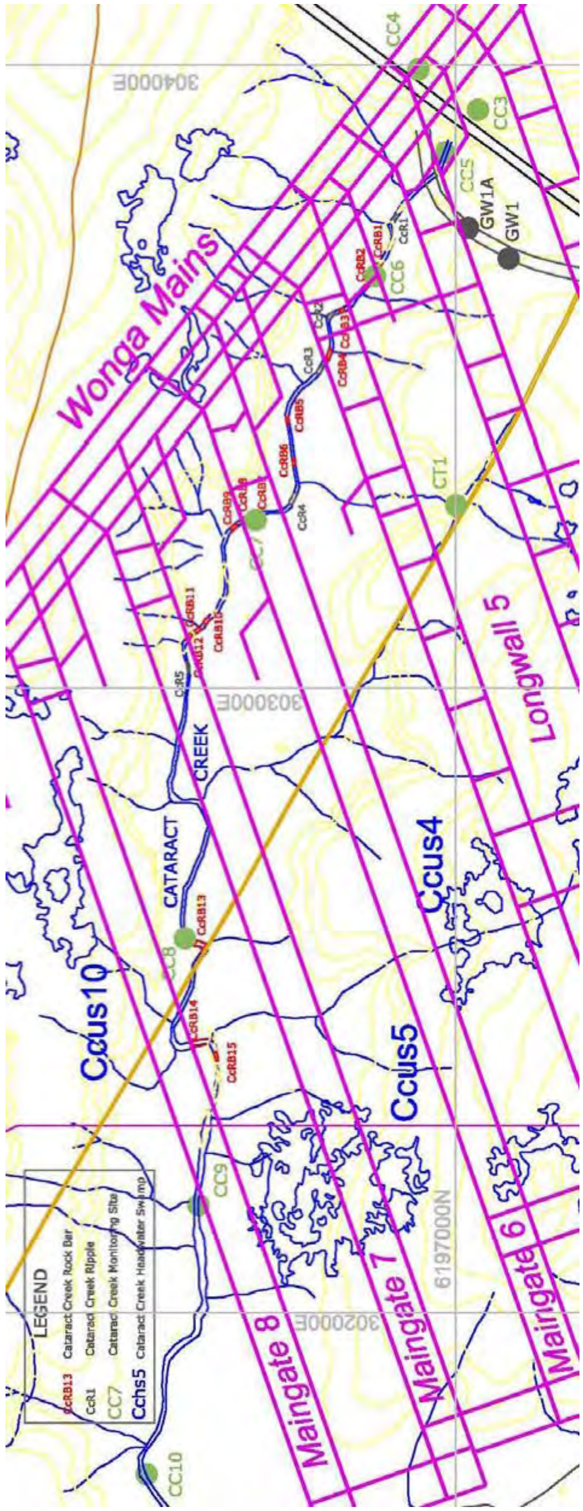


Figure 11 Cataract Creek Wonga East Area 2 Stream Monitoring Sites

Well developed, primarily rainforest based shrubs, grasses and trees dominate along the creek banks.

No waterfalls or highly stepped zones are present in the creek.

The stream bed and banks of the plateau streams are well vegetated and do not show significant erosion or bank instability. Heavily vegetated rainforest is developed from the edge of the escarpment to downstream of the freeway, which transgresses into heavily wooded forest between the freeway and the dam.

The photographs shown in **Plate 6** indicate the typical nature of the rock bars and riffles and pools in the reach between CC5 and CC9.

PLATE 6 Typical Cataract Creek Rock Bars, Riffles and Stream Reach

Details of the regular stream water quality and water level monitoring locations in Cataract Creek are shown in **Table 16**, with photographs shown in **Plate 7**.

Table 16 Cataract Creek Stream 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
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
Crus1c	302195	6196635	Surface water discharge from swamp Ccus1
Ccus3c	302860	6196935	Surface water discharge from swamp Ccus3
Ccus4c	302560	6197015	Surface water discharge from swamp Ccus4
SP1c	303275	6196995	Surface water runoff down slope of shallow piezometers SP1
CD1	301257	6198280	Cataract Reservoir to north of Cataract Creek, outside of the Application Area

NOTE: Co-ordinates supplied from GPS

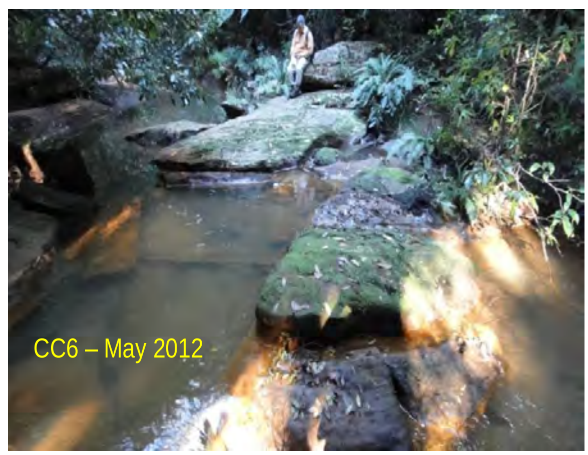


PLATE 7A Cataract Creek Monitoring Sites

PLATE 7B Cataract Creek Monitoring Sites

The CC1 – CC5, CC9, CC10 and CD1 monitoring sites were installed by GeoTerra Pty Ltd (GeoTerra) in August 2008, and were regularly monitored on a bi-monthly basis up until Gujarat NRE Coking Coal Pty Ltd (Gujarat) took over continued monitoring, management and implementation of the NRE1 project field work in July 2010.

CT1 was installed in a 2nd order tributary by Gujarat in April 2012.

Stream water level, flow and water quality stations are in the process of being installed by Gujarat between CC6 and CC8.

Monitoring at CC10 was initially installed in 2008 and then discontinued shortly thereafter when it was assessed the site was within the high water mark of the dam.

The Ccus2, 3, 4, 5, 6, Crus1 and Bcus4 swamp and 1st order creek monitoring sites were installed by GeoTerra in March 2012, with ongoing management of field work and laboratory analysis being conducted by Gujarat.

10.3.2 Cataract River

Stream flow, height and water quality monitoring installations were installed by Gujarat on 12 April 2012 at locations shown in **Drawing 2**, and as summarised in **Table 17** with photographs shown in **Plate 8**.

Table 17 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 Crhs1
CR4**	301780	6196770	Within high water section of Cataract Reservoir

NOTE: Co-ordinates supplied from GPS CR4 is currently not monitored as it is currently in the dam

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

Plate 8 Cataract River Stream Monitoring Sites

10.4 Stream Flow and Pool Depths

10.4.1 Lizard Creek

Volumetric stream flow monitoring has been conducted in Lizard Creek since mid September 2009 at LC3 near the southern boundary of the Gujarat lease.

Limited volumetric stream flow monitoring was conducted for dry flow periods at site LC7 near the northern lease boundary until it was established a natural diversion through a washed out bedding plane in the sandstone enabled approximately 30% of the stream flow to divert around the flow monitoring site. As a result, flow monitoring was discontinued, although stream pool height monitoring has continued.

Accurate stream flow monitoring for use in comparing upstream and downstream catchment volumetric flows is logistically difficult to achieve in Lizard Creek for the following reasons;

- lack of sites where all stream flow is present as overland flow due to;
    - natural diversions through fissures, joints and washed out bedding planes in the sandstone, or
    - diversion underneath the stream bed through subsidence cracks that developed over the Bulli Seam longwalls
- lack of constriction points where stream flow is constrained into a single channel, rather than being split in a number of sub – flow paths, such as in boulder fields or exposed sandstone shelves, or flow through / out of fissures and washed out bedding planes

As shown in **Drawing 5**, Site LC3 is located over essentially unsubsided main headings within the Bulli 200 series workings. Site LC5 is located over the subsided Bulli panel LW303, whilst Site LC6 is located over the subsided LW307. Site LC7 is located in an unsubsided stream reach to the north and approximately 750m downstream of LW309 and Site LC8 is located in unsubsided ground near the northern lease boundary.

Stream pool height monitoring has been conducted as shown in **Figure 12**.

Volumetric stream flow monitoring has also commenced using the manual cross section / flow velocity method at the LC3, 4, 5, LC7, LCT1 and LCT2 rock bar constrictions during field logger download events under the field data management of Gujarat. Extrapolation of the future and historic pool height transducer data to volumetric flow will be conducted when flow / duration curves over a sufficient range of flow events have been developed.

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

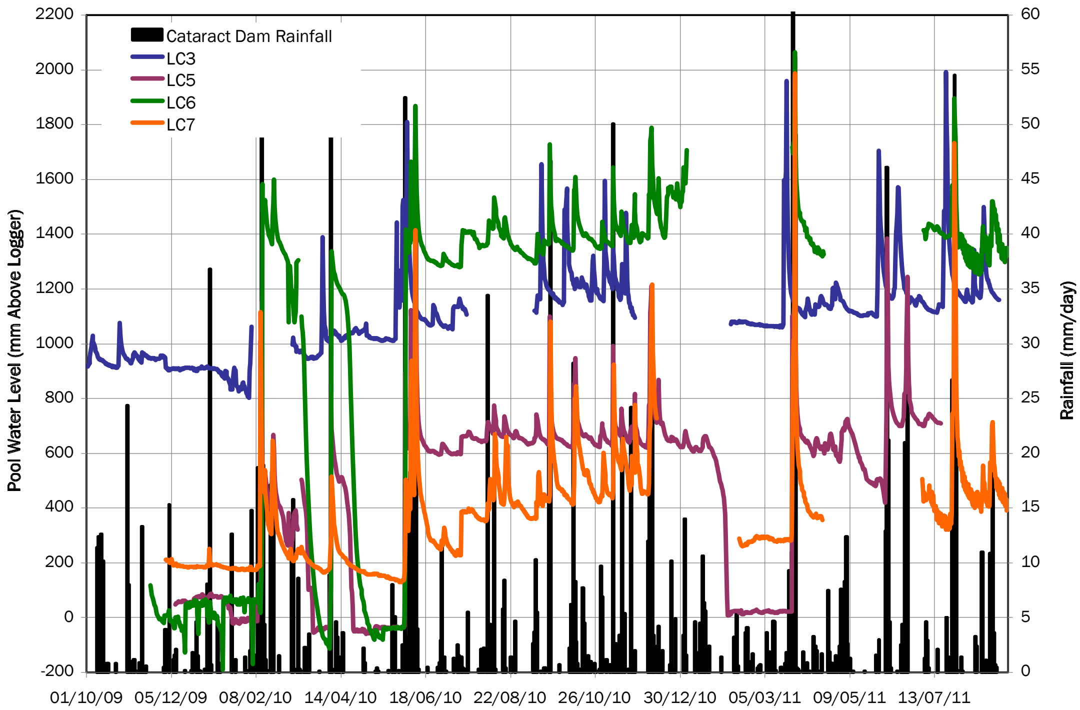


Figure 12 Lizard Creek Pool Depths

10.4.2 Wallandoola Creek

Pool height water level monitoring has been conducted at sites WC1, WC3 and WC4 as shown in **Figure 13**.

Volumetric stream flow monitoring has also commenced using the manual cross section / flow velocity method at the WC1 and WC4 rock bar constrictions during field logger download events under the field data management of Gujarat. Extrapolation of the future and historic pool height transducer data to volumetric flow will be conducted when flow / duration curves over a sufficient range of flow events have been developed.

As shown in **Drawing 5**, Site WC1 overlies the Cordeaux Colliery Bulli longwall subsidence area, WC3 is within an elongated pool between valley fill swamps Wcus1 and Wcus4 over Longwalls 206 and 207, whilst WC4 overlies the western periphery of the NRE No.1 Bulli longwall 20mm subsidence zone.

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

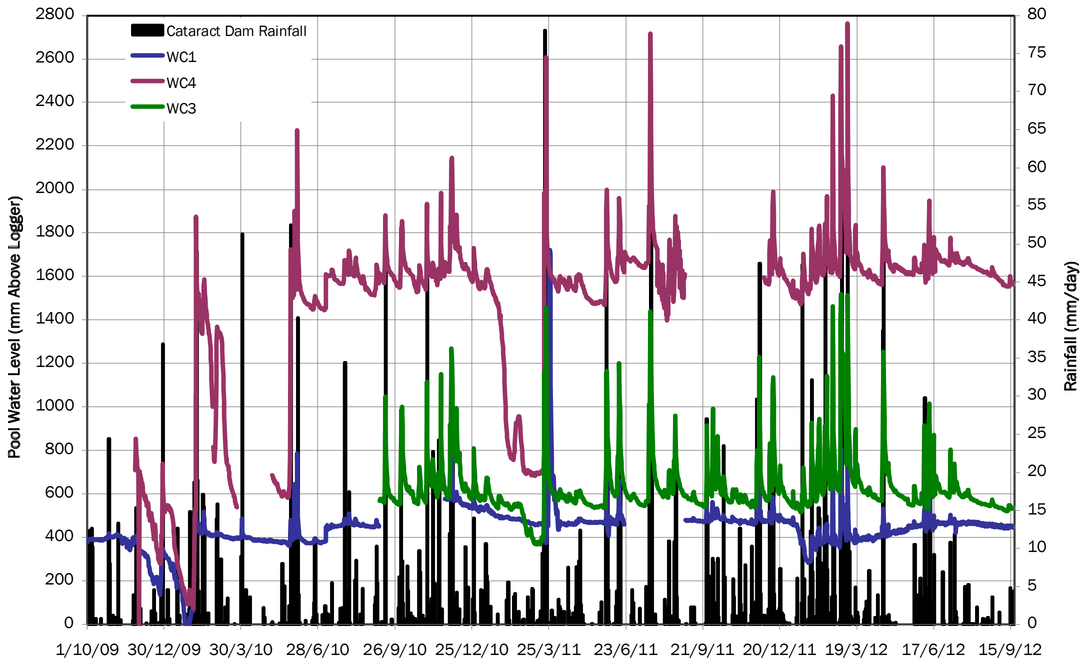


Figure 13 Wallandoola Creek Pool Depths

10.4.3 Cataract Creek

The 2nd order tributaries between Sites CC1 - CC4 and CC2 - CC3 have not been observed to dry out since monitoring began in July 2008, although they usually contain ferruginous precipitates.

The fourth order stream channel between CC5 and CC9 has also been continuously flowing.

Downstream of CC5 the creek water becomes sequentially clearer, although ferruginous precipitation can be observed along the entire reach down to the headwaters of the dam.

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.

No obvious mining induced cracking of rock bars and loss of pool holding capacity has been observed between CC5 and CC9.

Pool height water level monitoring, which commenced in November 2010 under the management of Gujarat, is conducted at sites CC3, CC4 and CC7, whilst CT1 was initiated in April 2012 as shown in **Figure 14**.

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. Additional sites are currently being installed by Gujarat at CC6, 7 and 8. The future and historic pool level data will be converted to volumetric flow once flow / duration curves have been sufficiently developed.

Sites CC3 and CC4 overly the Bulli seam pillar extraction and the Balgownie longwalls, whilst CT1 overlies Bulli seam bord and pillar workings.

All pools between Sites CC1 and CC9 do not show an enhanced pool drainage rate, and have not dried up during the monitoring period.

The tributary monitored by CT1, which drains off the Longwall 4 and 5 catchment area has been observed to dry out after extended lack of runoff, however the pools still generally hold low pond levels and do not show total drainage due to subsurface cracking.

Recently, Cataract Reservoir has inundated Cataract Creek to approximately 100m upstream of CC9, although it has extended to approximately 75m downstream of CC9 since regular monitoring began in July 2008. As a result, flow monitoring at CC9 was temporarily discontinued until the dam level fell below the monitoring site.

Since July 2008, CC10 has been permanently inundated by the dam and has not been regularly monitored.

The dam spill height is at 289.87m AHD (T Schultz, pers comm.)

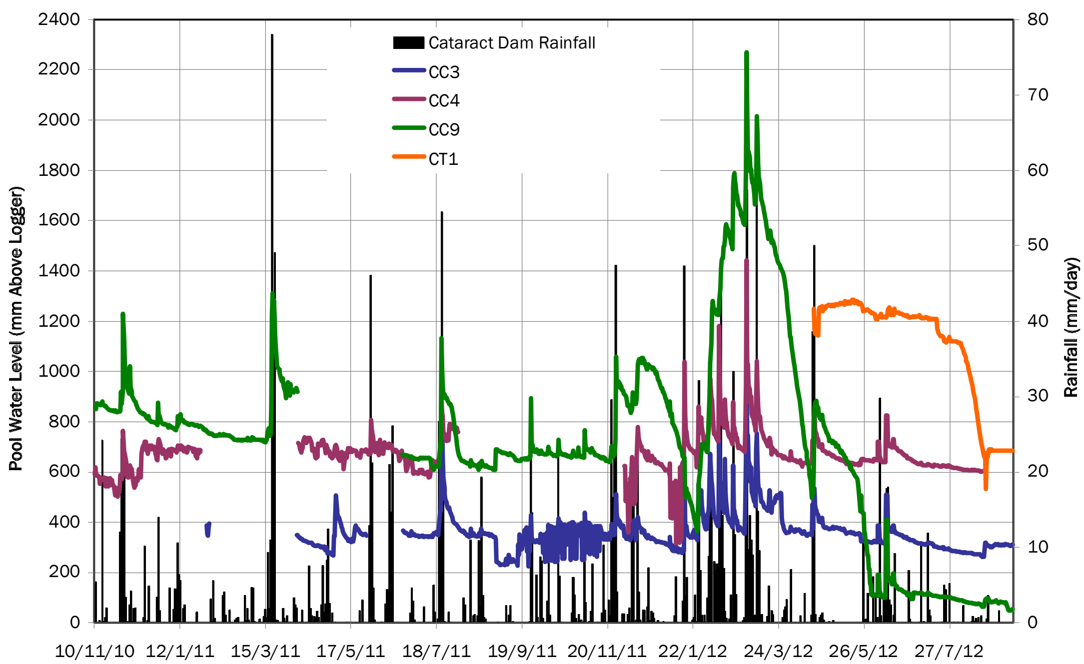


Figure 14 Cataract Creek and Tributary Pool Depths

10.4.4 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, 2 and CR3 as shown in **Figure 15**.

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. The pool level data will be converted to volumetric flow once flow / duration curves have been sufficiently developed.

Site CR4 was installed, but has not yet been used as it is currently under the high water mark of Cataract Reservoir.

Site CR1 lies within the Gujarat lease area and does not overly any previous mining. Sites CR2, 3 and 4 overly 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.

The dam spill height is at 289.87m AHD (T Schultz, pers comm.)

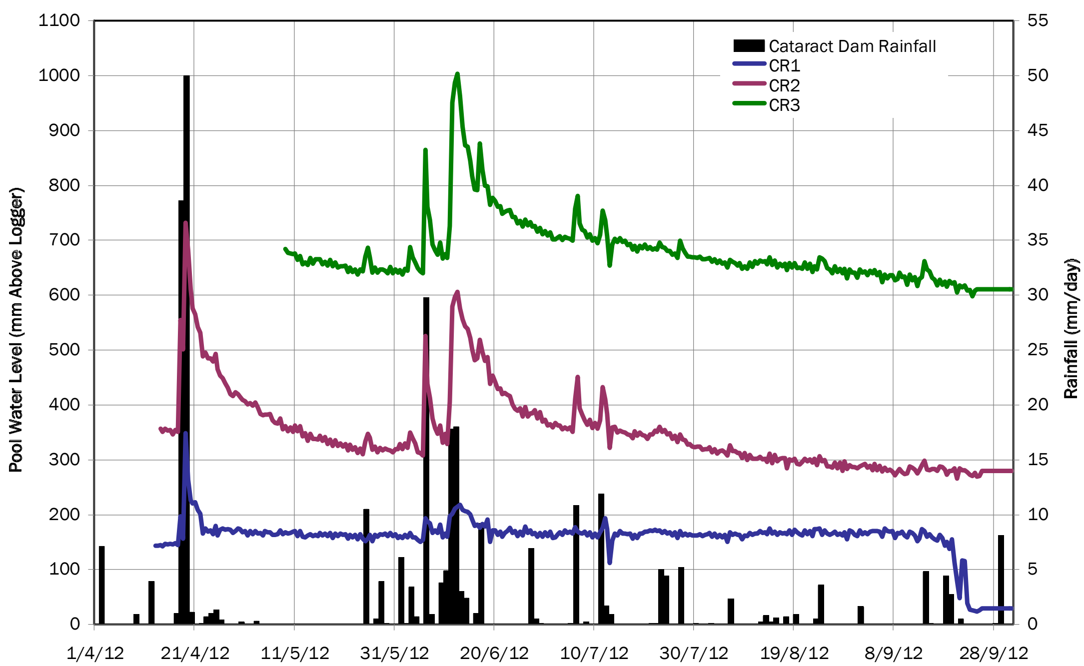


Figure 15 Cataract River Pool Depths

10.5 Stream Water Quality

10.5.1 Lizard Creek

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

Lizard Creek's overall pH ranges from 2.50 to 7.1, with a median range from 4.6 – 6.5 as shown in **Figures 16** and **17**.

It shows a trend to less acidity (increasing alkalinity) downstream, except between LC5 and LC6 during low flow periods, where the stream has a subterranean flow and downstream upwelling component.

Lizard Creek's pH is outside the ANZECC 2000 South Eastern Australia Upland Stream criteria, and, since July 2007, has had an overall reduction in acidity by approximately pH 0.5 to1.0 units.

It is generally the case that the stream pH is more acidic as it discharges out of the humic and fulvic acid dominated swamp areas, then becomes more alkaline as it flows down the main stream, with no significant acidification downstream of upwelling seepage re-entry locations in the streams.

The creek's overall salinity ranges from 19 - 290µS/cm and generally rises by approximately 60µS/cm between LC2 and LC8, outside of the LC5 to LC6 reach.

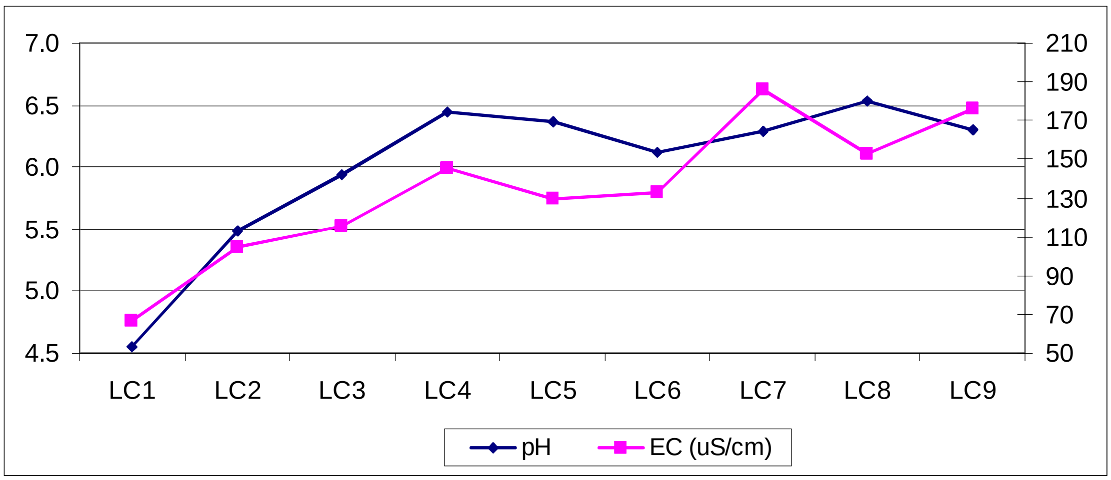
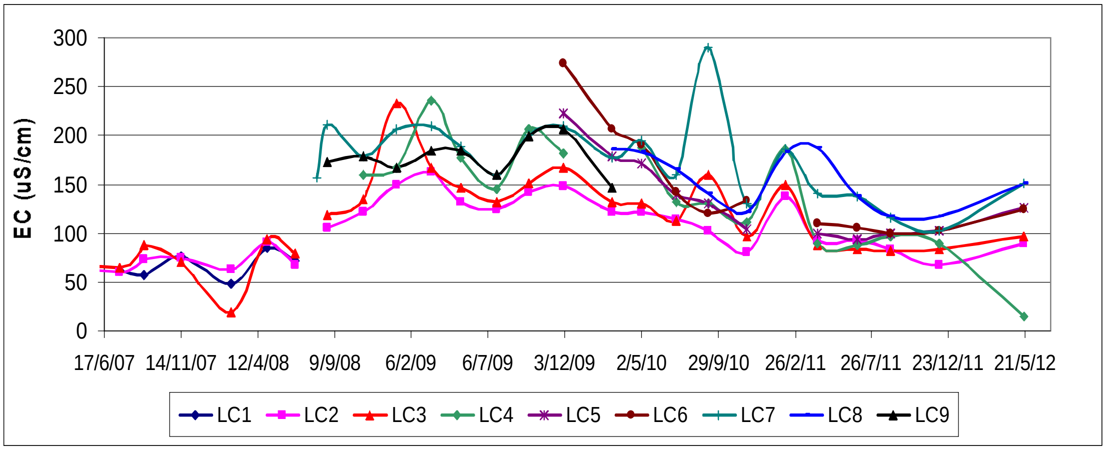


Figure 16 Lizard Creek Median pH and Salinity

The main channel of Lizard Creek has a predominantly perennial flow, although the WC4 pool to the base of Waterfall WL1 can temporarily dry up.

The first and second order tributaries are ephemeral to intermittent and generally dry or ponded, with short term flow after sufficient rain.

Since regular monitoring began in July 2007, the stream's salinity generally rises with distance downstream by approximately 90µS/cm as shown in **Figure 17**.



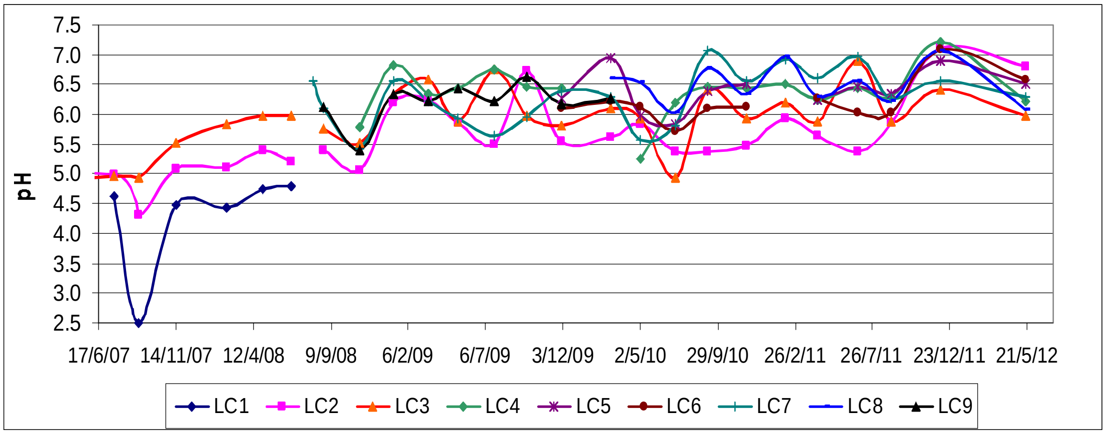


Figure 17 Lizard Creek Field Water Chemistry

Figure 18 indicates the median filtered iron has a relatively flat profile with distance downstream, although total iron peaks at LC6, where the underflow seeps back into the creek.

The median total and filtered iron discharging into the Cataract River at, and downstream of LC8, are 0.64mg/L and 0.17mg/L respectively.

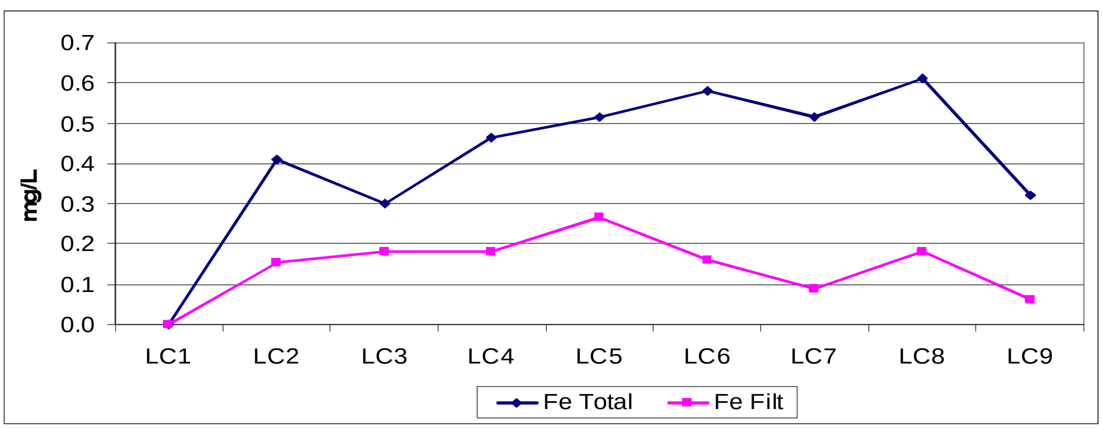


Figure 18 Lizard Creek Median Iron Levels

Figure 19 indicates the median manganese in the creek shows a relatively flat profile, although with a peak of up to 0.13mg/L at LC8.

Total and filtered median manganese levels discharging into the Cataract River (at and downstream of LC8) are 0.13mg/L and 0.12mg/L respectively, compared to the ANZECC 2000 criteria of 1.9mg/L, although at LC9, upstream of the Cataract River, the levels fall to 0.01mg/L.

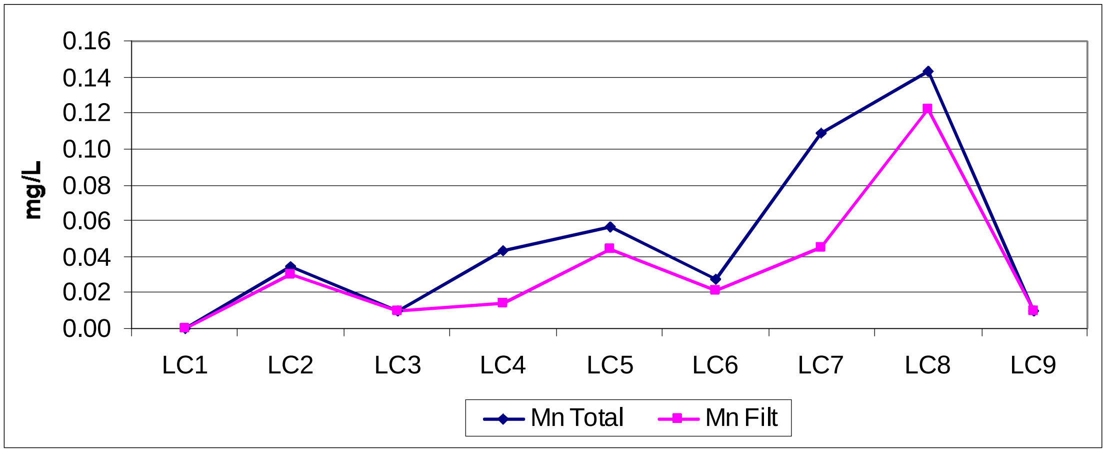


Figure 19 Lizard Creek Median Manganese Levels

A peak in sulfate is generally identified at LC4 and LC5, downstream of Waterfall L1 as shown in **Figure 20**, after which, sulfate falls at LC6, then gradually rises downstream.

The rise in sulfate would relate to a marginal rise in sulfuric acid generation through iron sulfide weathering as a result of enhanced subsurface flow through the cracked Hawkesbury Sandstone over, and downstream of, the subsided Bulli longwalls.

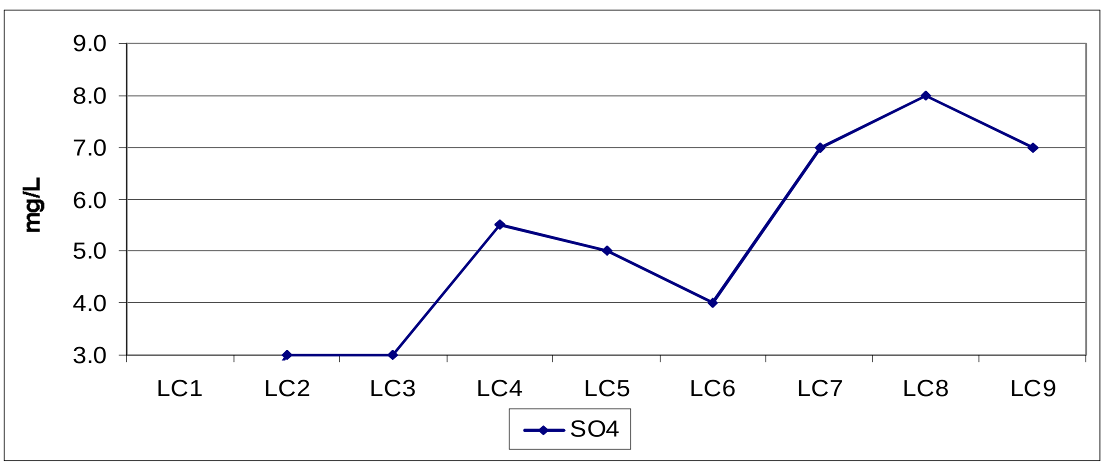


Figure 20 Lizard Creek Median Sulfate Levels

Monitoring indicates the creek is within the acceptable range for potable water, however it is generally outside the ANZECC 2000 South Eastern Australia Upland Stream criteria for pH. 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 occasionally at all sites, with a high variability
- total nitrogen and total phosphorous at all sites, infrequently;
- occasionally, filtered copper, nickel, and;
- aluminium, very infrequently, where it exceeds both the criteria of 55µg/L and pH 6.5.

In the reach between LC3 and LC4, where the headward erosion of valley fill component of swamp Lcus4 is observed as well as desiccation of the sandstone based stream bed can occur, ferruginous deposits are observed in the permanent pool immediately upstream of Waterfall L1, as well as on the waterfall face, but not in the waterfall plunge pool and downstream to LC4.

In the LC3 to LC4 reach, the median water quality of above ANZECC 2000 criteria parameters is as discussed below, where the median;

- filtered zinc reduces from 0.006 – 0.003mg/L,
- filtered aluminium reduces from 0.03 – 0.02mg/L, and
- total phosphorous rises from 0.01 – 0.02mg/L
- whilst pH rises from 5.88 – 6.42 and salinity rises from 130 - 172µS/cm

Between LC4 and LC5 no adverse effects on stream flow, ponding or water quality is observed.

Between LC5 and LC6, where the creek has an enhanced drying out rate in the pools, the above criteria parameter changes observed are where the median;

- filtered zinc reduces from 0.005 – 0.004mg/L,
- total nitrogen reduces from 0.3 – 0.015mg/L, and
- total phosphorous remains static around 0.02mg/L
- whilst pH acidity remains static around 6.12 and salinity rises from 175 - 198µS/cm

From LC6, where there is a distinctive ferruginous precipitation at the point of upwelling and a continuum of flow with no adverse effects on pool water levels, to where the stream bed is not underlain by Bulli workings and has no associated subsidence effects at LC7, LC8 and LC9 (which is upstream of Waterfall L2), the median

- filtered zinc reduces from 0.004mg/L at LC6 to 0.002mg/L at LC9,
- total nitrogen reduces from 0.15mg/L at LC6 to 0.1mg/L at LC9
- total phosphorous reduces from 0.02mg/L at LC6 to 0.01mg/L at LC9
- whilst pH rises from 6.11 – 6.31 and salinity reduces from 198 - 176µS/cm

Where Lizard Creek discharges out of the Study Area at LC8, the above (or outside) criteria parameters can be;

- pH, which is occasionally below pH 6.5;
- filtered zinc (<0.036mg/L), occasionally, and;
- total nitrogen (<0.4mg/L) and total phosphorous (<0.16mg/L), rarely.

10.5.2 Wallandoola Creek

Water quality monitoring initially commenced during September 2001, with regular data monitoring initiated in July 2007.

The pH in Wallandoola Creek ranges from 3.35 to 6.83, with the median pH ranging from 5.49 – 6.19 as shown in **Figures 21** and **22**, with the pH being outside the ANZECC 2000 South Eastern Australia Upland Stream criteria.

It is generally the case that the stream pH is more acidic as it discharges out of the humic / fulvic acid dominated swamp areas, then becomes more alkaline as it flows down the main stream, with no significant acidification downstream of upwelling seepage re-entry locations in the streams.

The creek's salinity ranges from 53 - 199µS/cm and generally rises by approximately 70µS/cm between WC1 and WC6.

Since regular monitoring began in July 2007, the stream's median salinity generally rises with distance downstream, then becomes less saline downstream of Site WC5, as shown in **Figures 21** and **22**, which is downstream of Waterfall W1.

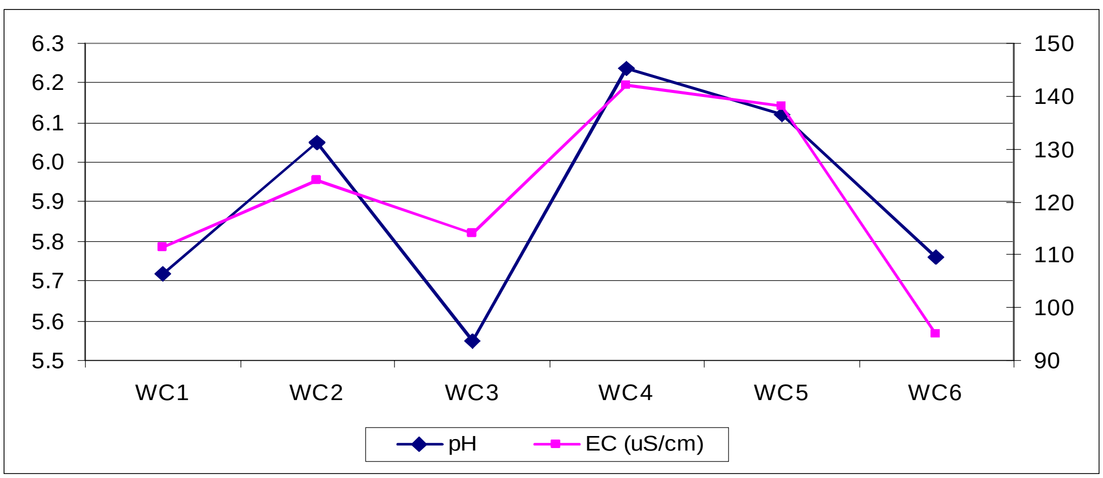


Figure 21 Wallandoola Creek Median Field pH and Salinity

The main channel has an intermittently ponded to perennial flow, whilst the first and second order tributaries are generally dry or are pooled, with short term flow after sufficient rain.

Plots of the field water quality parameter trends are shown in **Figure 22**.

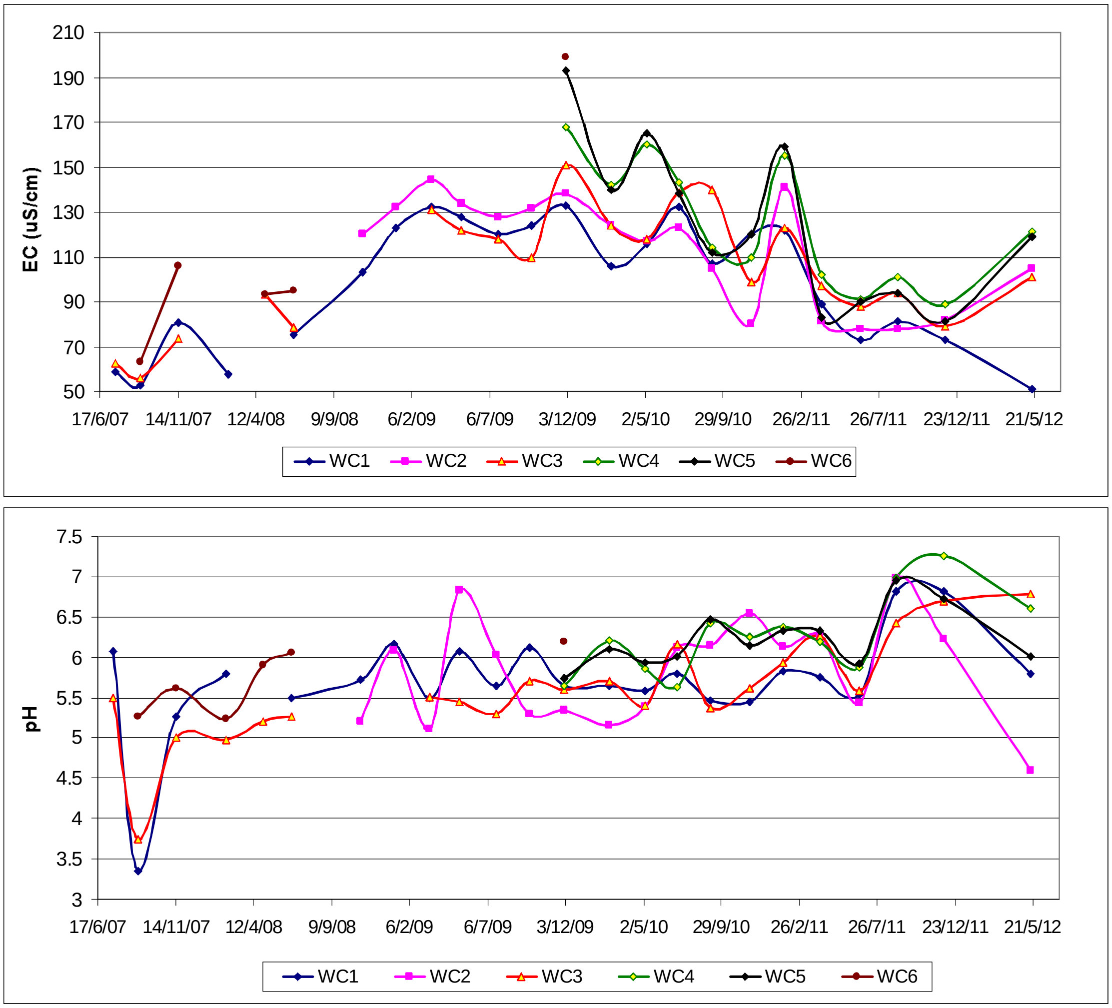


Figure 22 Wallandoola Creek Field Water Chemistry

As shown in **Figure 23**, total iron levels in the creek do not show any significant recurring trend with distance downstream apart from a peak in total iron through oxy-hydroxide precipitation at WC5 over Longwalls 209 and 210 near the major bend in the creek. A slight rising trend can be seen in filtered iron with distance downstream.

Total and filtered median iron discharging from downstream of the subsided Bulli workings in Wallandoola creek is 0.50mg/L and 0.19mg/L respectively.

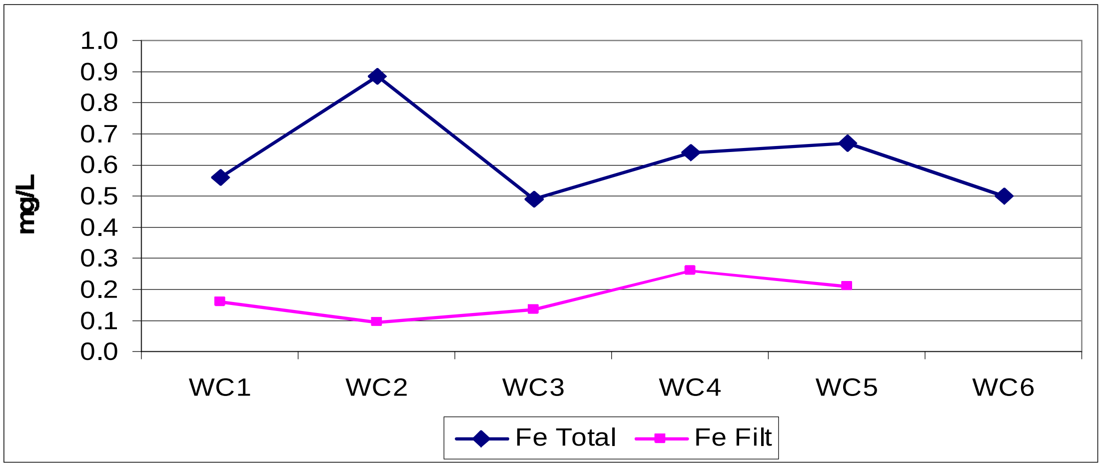


Figure 23 Wallandoola Creek Median Iron Levels

Figure 24 illustrates that manganese decreases from WC1 to WC3, then rises downstream of WC3 over Longwalls 209 and 210 near the major bend in the creek.

Total and filtered manganese levels discharging downstream of the Bulli workings are 0.07mg/L and 0.06mg/L respectively, which is well below the ANZECC 2000 criteria of 1.9mg/L.

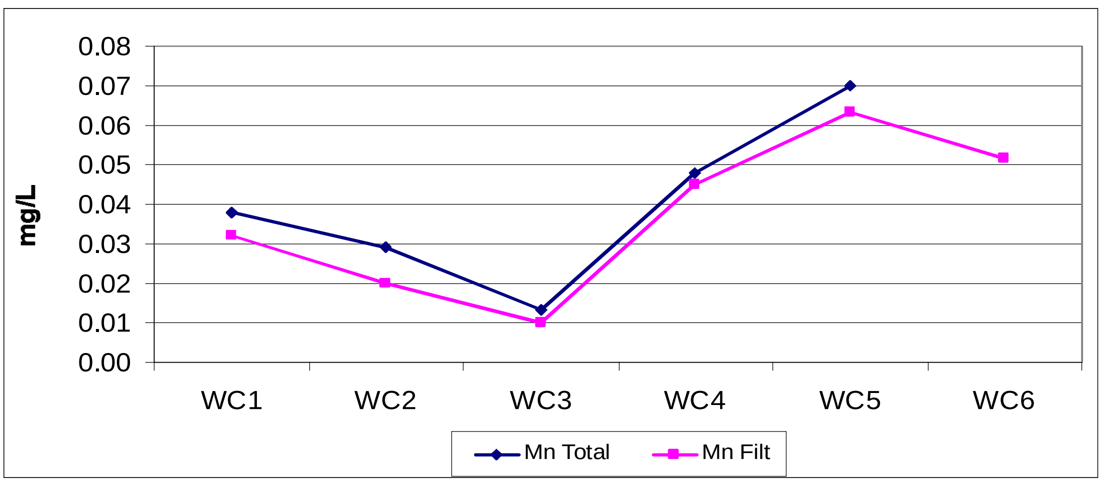


Figure 24 Wallandoola Creek Median Manganese Levels

Figure 25 indicates that the median sulfate levels marginally from WC2 to WC4, then rises again downstream of WC5.

The rise in sulfate would relate to a marginal rise in sulfuric acid generation through iron sulfide weathering as a result of enhanced subsurface flow through the cracked Hawkesbury Sandstone over, and downstream of, the subsided Bulli longwalls.

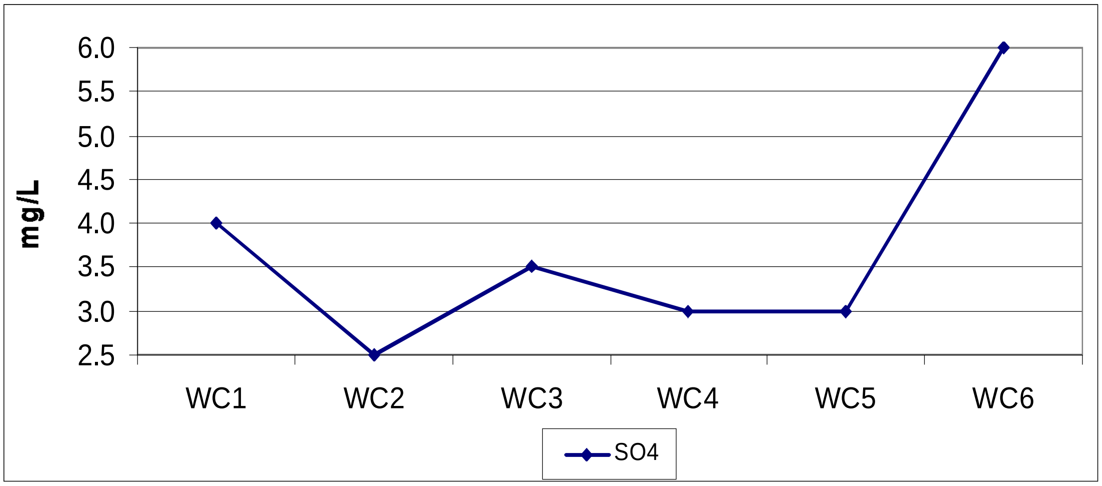


Figure 25 Wallandoola Creek Median Sulfate Levels

Monitoring indicates the creek is within the acceptable range for potable water, however it can exceed the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for the following parameters, depending on the flow conditions at the time of sampling;

- filtered zinc at all sites for the majority of the time,
- total nitrogen at some sites for part of the time with no regular pattern,
- total phosphorous occasionally at each site, with no regular pattern and
- filtered copper, occasionally

In the reach between WC3 and WC4, where ferruginous deposits are generally observed, the median filtered zinc and total nitrogen, which are the only above criteria parameters in this stretch, generally improve with flow downstream as shown below, where the median;

- filtered zinc reduces from 0.014 – 0.005mg/L, and
- total nitrogen increases from 0.2 – 0.25mg/L, whilst
- pH becomes more alkaline, rising from 5.43 – 5.76 and salinity rises from 118 - 151µS/cm

Between WC4 and WC5, where subsidence related cracking is evident around Waterfall W1, the above criteria parameter changes are where the median;

- filtered zinc rises from 0.005 – 0.013mg/L, and
- total phosphorous reduces from 0.24 – 0.08mg/L, whilst
- pH rises from 5.76 – 5.97 and salinity is relatively constant

Where Wallandoola Creek discharges out of the Study Area at WC5, the above criteria parameters can be;

- pH, which is generally below pH 6.5;
- filtered copper (<0.004mg/L), very rarely;
- filtered zinc (<0.03mg/L), occasionally;
- total nitrogen (<0.7mg/L), rarely, and;
- total phosphorous (<0.19mg/L) occasionally.

10.5.3 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 took over ongoing management and implementation of the NRE1 project 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 Gujarat 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 trip.

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

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 of from 6.1 to 6.3 as shown in **Figures 26** and **27**.

It is generally the case that the stream pH is more acidic as it discharges out of the humic / fulvic acid dominated swamp areas, then becomes more alkaline as it flows down the main stream, with no significant acidification downstream of upwelling seepage re-entry locations in the stream.

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 **Figures 26** and **27**.

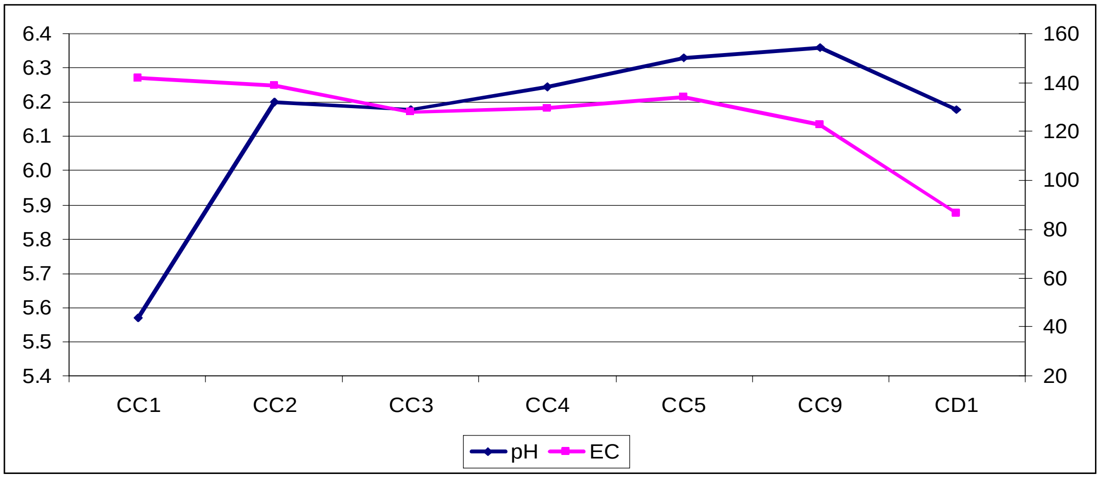


Figure 26 Cataract Creek Median pH and Salinity

All 2nd order or higher tributaries and the main channel of Cataract Creek have been observed to have intermittent to perennial flow.

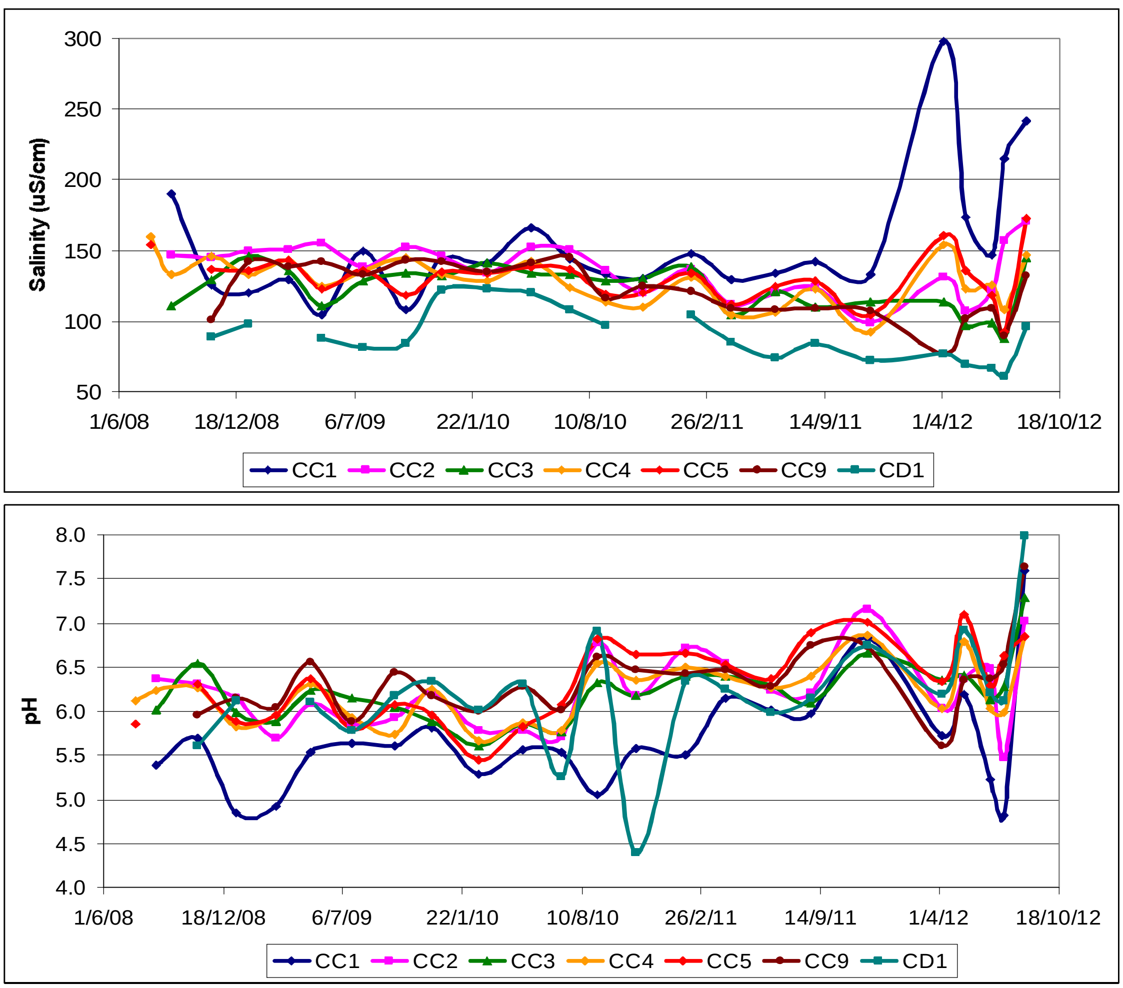


Figure 27 Cataract Creek Field Water Chemistry

As shown in **Figure 28**, filtered iron levels are generally unchanged with flow downstream.

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

Due to the lack of pre mining data, it is not possible to ascertain whether the ferruginous seeps are caused by, or related to, historic mine subsidence.

Total and filtered median iron discharges into Cataract Reservoir at LC9 are 0.96mg/L and 0.26mg/L respectively.

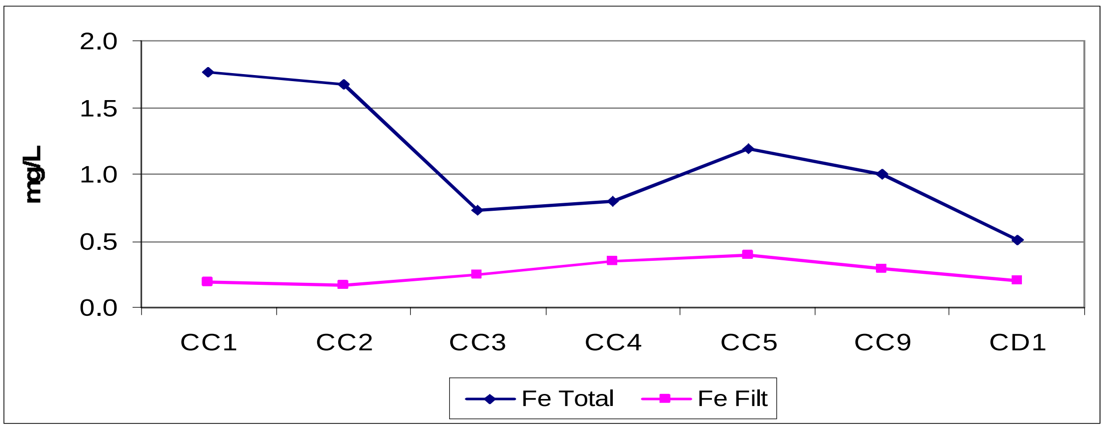


Figure 28 Cataract Creek Median Iron Levels

Figure 29 illustrates that median total manganese peaks at CC2, whilst filtered manganese has a general reduction with flow downstream.

Total and filtered median manganese discharge at CC9 into Cataract reservoir is 0.08g/L and 0.01mg/L respectively, compared to the ANZECC 2000 criteria of 1.9mg/L.

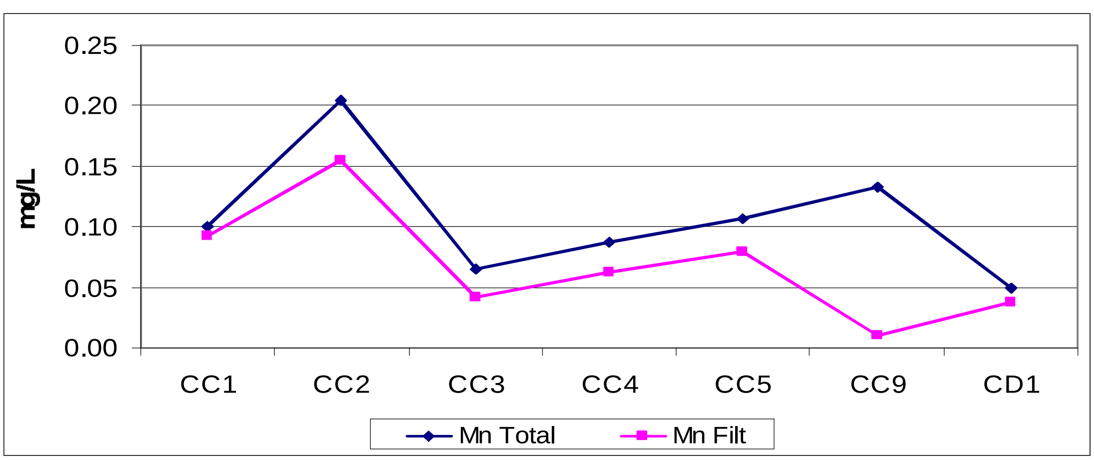


Figure 29 Cataract Creek Median Manganese Levels

A peak in sulfate is present in the CC2 / CC3 tributary as shown in **Figure 30** which could represent the dissolution of sulfuric acid following iron sulfide weathering as a result of shallow subsurface flow through cracks in the subsided and cracked basement strata, and / or weathering of the exposed Bald Hill Claystone and overlying shale / claystone dominated units.

A peak is also present at CC5 where the (CC1 - CC4 and CC2 - CC3) tributaries join.

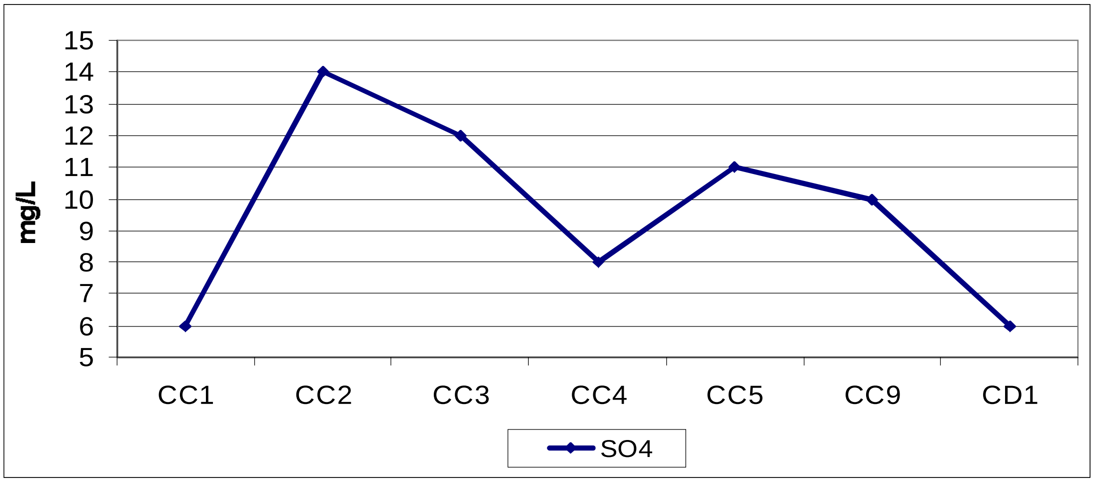


Figure 30 Cataract Creek Median Sulfate Levels

In summary, monitoring to date indicates the creek is within the acceptable range for potable water, however is generally outside the ANZECC 2000 South Eastern Australia Upland Stream Criteria for pH. It is generally the case that the stream pH is more acidic as it discharges out of the humic / fulvic acid dominated swamp areas, then becomes more alkaline as it flows down the main stream, with no significant acidification downstream of upwelling seepage re-entry locations in the streams. The 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 200 criteria as they are below pH 6.5.

No adverse effects on stream flow continuity or stream ponding have been observed in Cataract Creek, however, 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 0.1, 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.

10.5.4 Cataract River

The CR1 – CR4 monitoring sites were installed by Gujarat 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 trip.

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

Cataract River's pH ranges from 5.1 – 6.4, whilst salinity ranges from 52 - 117µS/cm as shown in **Figure 31**.

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.

Insufficient data has been collected to date to discuss longer term trends for iron, manganese and sulfate.

Monitoring to date indicates the creek is within the acceptable range for potable water, however is generally outside the ANZECC 2000 South Eastern Australia Upland Stream Criteria for pH and can 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, total phosphorous and total nitrogen.

Where Cataract River discharges out of the Study Area, and subsequently 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.

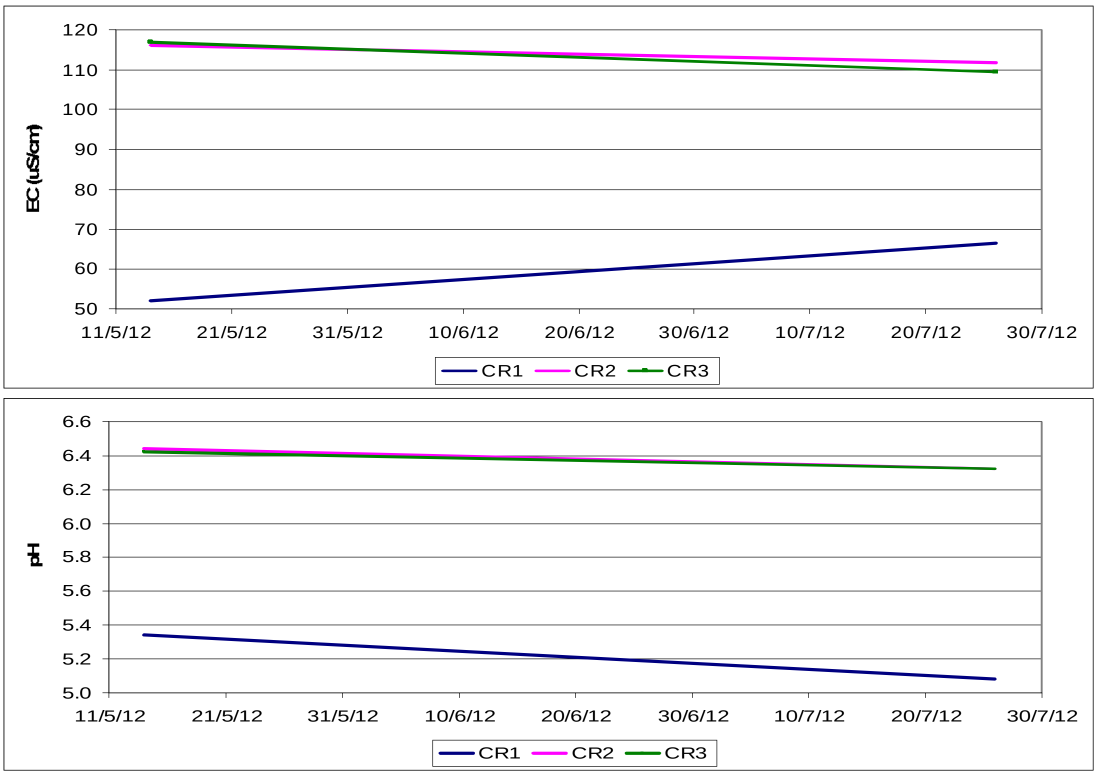


Figure 31 Cataract River Field Water Chemistry

11. PREVIOUS SUBSIDENCE EFFECTS ON STREAMS

The previous operators of NRE No.1, as well as Cordeaux Colliery, have extracted Bulli Seam longwalls under both Lizard and Wallandoola Creeks at Wonga West.

Cataract Creek was undermined by bord and pillar and pillar extraction in the Bulli seam as well as narrow longwalls in the Balgownie workings at Wonga East.

Up to 1.3m of subsidence was generated by extraction of the Bulli Seam in the 200, 300 and 500 series longwalls at Wonga West (Seedsman Geotechnics, 2012).

Bord and pillar, as well as pillar extraction of the Bulli Seam, along with longwalls in the Balgownie Seam was conducted to the east of Cataract Reservoir at Wonga East as shown in **Drawing 5**.

In the 200 series longwalls, no subsidence was measured with 190m wide panels and 35m wide chain pillars, whilst the same layout to the north in the 300 series, 0.9m of subsidence was recorded.

Longwall mining generated a maximum subsidence of 1.1m for the 155m wide longwalls with 30m wide pillars to the east of Cataract reservoir, whilst the 205m wide panels at Cordeaux Colliery, with 30m wide chain pillars, generated up to 1.3m of subsidence (Seedsman Geotechnics Pty Ltd, 2012).

Microseismic monitoring at Bellambi West indicated rock fracturing extended to approximately 100m above the Bulli Seam, whilst vibrating wire piezometer monitoring between longwalls 501 and 502 indicates that the hydraulic integrity of the Bulli Seam and Hawkesbury Sandstone was not adversely affected (Seedsman Geotechnics Pty Ltd, 2011).

No publicly available pre and post mining surveys of the creek flow and water quality are known to be available over the BHPB Cordeaux longwalls.

The following sections outlined the observed effects of subsidence due to the previous extraction of the Bulli Seam at Wonga East and Wonga West, as well as the underlying Balgownie longwalls and the Wongawilli longwall WE-A2-LW4 at Wonga East.

11.1 Lizard Creek

As shown in **Drawing 5**, from south to north within the Gujarat lease, Lizard Creek overlies the north south oriented access drives (to the east of the longwall 202A) and directly overlies the subsidence goaf of longwalls 202B and 202.

Between the southern lease boundary and downstream of LC3, Lizard Creek has been observed to be continuously ponded and predominantly flowing. At the southern end of valley fill swamp Lcus4, downstream of LC3 where a 2m to 3m deep rock bar constrained pool is present, the creek is continuously ponded and generally flowing, with low ferruginous precipitation.

The downstream end of Lcus4 has headward eroded valley fill swamp sediments as well as a rock bar constrained pool as shown in **Plate 9** that can dry out after extended lack of rainfall and runoff.

PLATE 9 Downstream end of Swamp Lcus4

Two sandstone based pools, overlying an un-subsided area between the previously mined Longwalls 202B and 202, are observed to have a single north south oriented crack along the eastern side of the creek in each pool.

The pools can be dry in the immediate vicinity of each crack after extended lack of rainfall, but predominantly contain shallow ponds on the eastern side of the channel in each pool where it is not cracked.

Downstream of the cracked pools, the creek over the southern two thirds of Longwall 202, to the north of Longwall 202B, can be dry and stained with ferruginous deposits after extended dry periods, although no cracks were observed in the exposed sandstone creek bed as shown in **Plate 10**.

PLATE 10 Downstream of Lcus4 and Upstream of Waterfall L1

The northern third of Lizard Creek over Longwall 202 and over the east west oriented access drives between the 200 series and the 300 series contain a ferruginous predominantly ponded and generally flowing pool, which subsequently cascades with a predominantly permanent flow over Waterfall L1.

The waterfall exhibited ferruginous overland flow in the channel bed as well as a more substantive ferruginous seepage from bedding discontinuities on the western flank of the waterfall as shown in **Plate 11**.

PLATE 11 Pond Upstream of Waterfall L1 and Waterfall L1

Downstream of Waterfall L1, over the access drives between the Series 200 and 300 Bulli Seam workings, the plunge pool and extended pool that contains LC4 is generally flowing, although not significantly ferruginous, although can contain pooled, flowing relatively clear water downstream to LC5, which overlies the southern goaf of Longwall 303.

After extended dry periods, water can be observed flowing into a cracked sandstone substrate immediately downstream of LC5 as shown in **Plate 12**.

PLATE 12 Monitoring Site LC5

The creek bed between LC5 and LC6 can dry out after extended lack of rainfall where the creek bed overlies Longwalls 303 to 307. This reach has both sandy and exposed sandstone sections as shown in **Plate 13**.

This reach contains observable stream bed cracks and uplifted sandstone plates, however the majority of the reach does not have obvious cracking.

The reach between LC5 and LC6 has been observed to be completely dry on three occasions since December 2009 as shown in **Figure 12**, with the dry spells lasting for;

- 6 days between 21/3/10 – 27/3/2010.
- 37 days between 19/4/2010 – 26/5/2010, and;
- 45 days between 2/2/2011 – 19/3/2011

PLATE 13 LC5 to LC6 Stream Reach

The creek water is highly ferruginous where it seeps back into the stream at LC6 as shown in **Plate 14**, then becomes sequentially clearer with flow downstream.

Between LC6 and LC7, over Longwalls 308 and 309 and downstream from LC7 to LC9, Lizard Creek is continuously ponded and generally perennial.

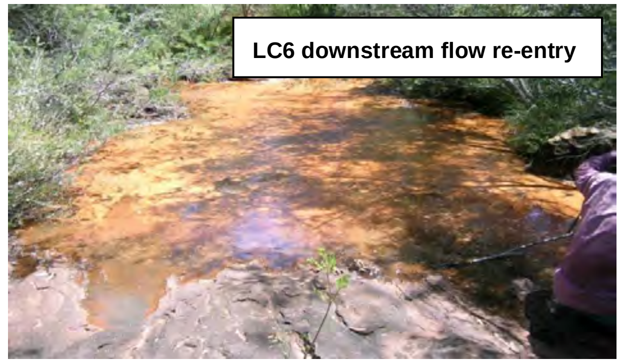


PLATE 14 Site LC6

11.2 Lizard Creek Tributaries

11.2.1 LCT1

Monitoring conducted since August 2006 over T and W Mains in the Bulli Seam, which are located in the headwaters of tributary LCT1 between the 200 and 300 series longwalls, has not observed any adverse geomorphological, hydrological or water chemistry changes due to subsidence (Ecoengineers, 2011).

The intermittent C10 - C11 tributary that overlies T and W Mains has been observed to have dry weather groundwater baseflow seeping from a sandstone headwall (Ecoengineers, 2009).

The ephemeral to intermittent tributary containing headwater swamp Lcus18 has not been observed to have adverse effects from subsidence on stream flow or stream water quality.

The 3rd Order reach downstream of site C11 lies over the western end of the Bulli Seam longwall 308 and 309 has been observed to have unaffected stream flow and water quality to approximately 350m upstream of the Lizard Creek junction.

Downstream of that point over the mid panel section of Bulli Seam longwall 307 as shown in **Drawing 5**, which was mined during 1990, the stream can contains ponded ferruginous water with intermittent flow after extended dry periods (ERM, pers comm.), although without any observable stream bed cracking as shown in **Plate 15.**

In closer proximity to Lizard Creek, also over the mid panel section of the Bulli Seam Longwall 307, contains ponded ferruginous water with an enhanced desiccation rate, although no distinctive stream bed cracking is evident.

PLATE 15 350m upstream of Lizard Creek in Tributary LCT1

11.2.2 LCT2

The ephemeral to intermittent first order tributary LCT2A that contains swamp Lcus25 in its headwaters has had no adverse subsidence effects observed on stream flow or stream water quality.

Tributary LCT2B is also ephemeral to intermittent, and only flows for a short period of hours to days after significant storms, although a sandstone based shallow pond used for water sampling 30m north of the fire road holds and maintains ponded water for weeks, and only dries out due to evaporation. No evidence of subsidence cracks in the sandstone have been observed in this tributary.

The LCT2B 3rd order tributary does not overlie any old Bulli Seam workings and does not show any adverse stream flow or water quality effects.

11.3 Wallandoola Creek

As shown in **Drawing 5**, from south to north within the Gujarat lease, Wallandoola Creek sequentially overlies the Bulli Seam east west oriented longwall panel "P", and subsequently the north south oriented Bulli Seam Longwalls 208 to 211.

Between the southern lease boundary and downstream to site WC4, Wallandoola Creek has been observed to be at least continuously ponded and generally flowing between WC1 and WC4 since 2001.

The creek is primarily clear up to the major bend in the creek to the south of proposed longwalls 3 and 4 in Area 3, then becomes ferruginous over and downstream of the Bulli Seam longwall 209, downstream of WC3.

The southern end of the WC4 pool can be dry, or have low water levels after extended low rainfall, with the pond draining into a crack in the sandstone creek bed as shown in **Plate 16**.

PLATE 16 Pools Upstream and Downstream of Site WC4

The sandstone stream bed overlying the western edge of Longwall 211 can be dry down to an upper "step" of Waterfall W1 after extended dry periods, where the water re-emerges as a ferruginous overland flow combined with numerous ferruginous seeps from sandstone bedding planes and at the base of the waterfall as shown in **Plate 17**.

PLATE 17 Upstream of Waterfall W1

Downstream of Waterfall W1, over the unmined area to the west of the previously mined Longwall 211, the plunge pool and at WC5 is usually flowing, although contains significant ferruginous precipitation as shown in **Plate 18.**

Immediately downstream of Waterfall W1, Wallandoola Creek is perennial, although is always ferruginous.

The creek water becomes sequentially clearer with flow downstream from WC5.

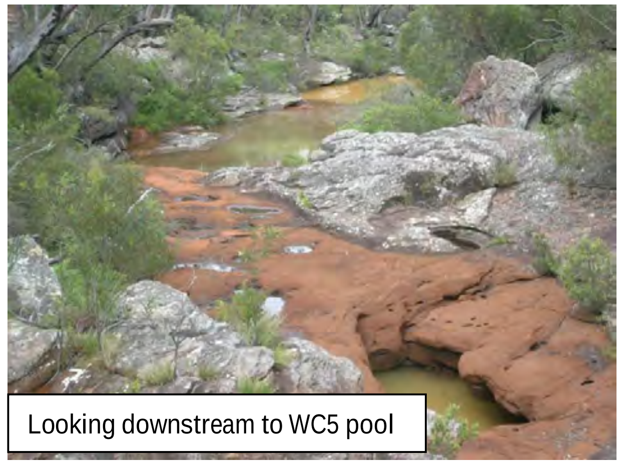


PLATE 18 Downstream of Waterfall W1

11.4 Cataract Creek

As shown in **Drawing 5** 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 longwall WE-A2-LW4 in the Wongawilli Seam.

The 1st and 2nd order tributaries between Sites CC1 - CC4 and CC2 – CC3 have been continuously flowing during all site visits and have not been observed to dry out, and usually contain ferruginous precipitates.

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.

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

11.5 Stream Water Quality Above ANZECC 2000 Criteria

In general, where adverse subsidence effects are noted on stream flow and ponding, there is an associated precipitation of an orange brown coloured iron hydroxide floc, which raises the total and filtered iron content of the stream water.

Although higher concentrations of associated metals and sulfate can occur in the iron floc areas, it is generally not significant, as discussed in **Section 10**.

11.6 Stream Bed and Bank Erosion

No enhanced stream bed or bank erosion has been observed within Lizard, Wallandoola or Cataract Creeks, apart from the headward erosion at the downstream end of the valley fill swamp section of swamp Lcus4 in Lizard Creek.

11.7 Upland Swamps

Refer to (GeoTerra, 2012) for further details.

12. STREAM SIGNIFICANCE

The PAC recommended the proponent should assess the waterway/s condition through describing the:

- natural features likely to be at risk of negative environmental consequences from subsidence impacts;
- permanence of stream flow;
- regional significance of the stream to the catchment water supply and scale of the watercourse;
- stream water quality;
- ecological importance of key aquatic communities;
- connectivity with swamp complexes;
- riparian vegetation environmental quality;
- stream physical form;
- stream visual amenity;
- community value of the stream;
- potential risk to those features from the mining proposal;

as well as

- identifying options for dealing with significant risk;
- determining which of these options will form part of the management plan;
- monitoring the subsidence impacts and consequences for the feature and outcomes from the management strategies;
- outlining if there are techniques available to prevent consequences or to remediate them effectively;
- deriving contingency options and planning to deal with exceedances, and where appropriate, and;
- auditing the risk management process.

The assessment should indicate the qualities of a waterway that characterise its environmental and aesthetic value. Application of one of the standard assessment approaches could provide a consistent basis for comparing the condition of the waterway before and after the impacts of mining.

The Metropolitan PAC report noted that assessment of the significance of individual watercourses in the context of acceptability of the risk of subsidence impacts and consequences is difficult, and also noted the absence of objective measures of significance and the lack of policy guidance on this issue.

The following steps were suggested by the Metropolitan PAC report to ensure adequate relevant information is available to the decision maker and to focus attention on key issues:

Step 1 Identify the mine characteristics (depth, geology, mining method, mining height, mine layout, percentage extraction) and types of subsidence impacts likely to be experienced

Step 2 Identify and describe significant natural features that might be at risk from subsidence impacts. In terms of surface water it should include at least rivers and significant streams, upland swamps, endangered ecological communities and threatened species habitat.

Step 3 Assess any features identified in Step 2 that warrant special significance status in any proposed risk management plan.

Steps 1 to 3 should be completed as part of the preparation of the initial Project Application to inform the early mine planning work and also assist in discussions between the Proponent, regulators and stakeholders.

Steps 4 and 5 provide a more refined analysis based on the possible mining parameters and depend on detailed predictions of subsidence impacts for features in question and where possible, an assessment of the potential consequences of those impacts. These steps form the core of the risk assessments and management options required in an Environmental Assessment.

Step 4 Using the criteria set out in the SCI Report for deriving RMZ boundaries, draw a RMZ around those features from Step 2 and Step 3 and assess the risk to the feature or relevant part of the feature, and

Step 5 Proposed risk management plans will be required for those features of special significance identified in Step 3 where a risk of impact is a real possibility or for features identified in Step 2 where a risk of *significant* impact is a real possibility.

The following stream significance assessment has been conducted in accordance with the procedures outlined in the Bulli Seam Operations environmental assessment and Planning Assessment Commission reports.

Only stream reaches within the predicted 20mm subsidence zone were considered in this assessment.

Due to the effects of previous mine subsidence in sections of Lizard and Wallandoola Creeks, and to relate to separate operational areas of the proposed workings, the significance of the streams has been assessed both in sections, and as an overall connected linear network.

A discussion of the stream significance is outlined in the following sections, and summarised in **Appendix B.**

12.1 Lizard Creek

Lizard Creek, between LC3 and LC7 (over the proposed subsidence reach), conforms to some of the “special significance” criteria in that it;

- has potential regional significance to water supply at Broughtons Pass Weir, downstream of Cataract Reservoir;
- has Endangered Ecological Community (Coastal Upland Swamp) within its channel and tributaries;
- provides potential habitat for the Giant Burrowing Frog and the Red Crowned Toadlet;
- provides potential habitat for Adams Emerald Dragonfly, although the dragonfly has not been identified in the stream, and;
- has a stream discharge out of the predicted subsidence area, and subsequently into Cataract Creek (downstream of the reservoir) generally within the ANZECC 2000 criteria, except for;

- o pH, which is occasionally below pH 6.5;
- o filtered zinc (<0.036mg/L), occasionally, and;
- o total nitrogen (<0.4mg/L) and total phosphorous (<0.16mg/L), rarely.

However, it does not conform to other criteria, in that;

- the connected linear network of the stream is disrupted as it does not have perennial flow between the LC3 to Waterfall L1, and the LC4 to LC6 reaches (excluding the actual waterfall) due to previous subsidence effects between 1979 and 1992 (i.e. 31 to 18 years ago) and can be totally dry in this reaches after extended lack of rainfall;
- the stream is ferruginous where the through flow from the upstream reaches discharges back into Lizard Creek, downstream of LC6, and;
- it does not have a high degree of “naturalness” in the affected reaches.

On the basis that the connected linear network of Lizard Creek and its “naturalness” is “*diminished by the effects of previous mining*”, the Bulli PAC did not consider Lizard Creek to qualify for “special significance” (NSW Planning Assessment Commission, 2010).

As a result, the third order or higher reach of the main channel of Lizard Creek within the Study Area is not deemed to have special significance.

12.1.1 Waterfall L1

Waterfall L1 is located on the downstream end of the potential Wonga West 20mm subsidence zone between LC3 and the waterfall.

The waterfall has not been observed to be adversely affected by loss of stream flow or water level reduction in the downstream plunge pool.

It has an absence of adverse effects due to a lack of subsidence as it overlies an area of only first workings in the Bulli seam, although it does have elevated ferruginous precipitates in its vertical seepage face.

As a result, Waterfall L1 is considered to qualify for “special significance”. (SCT, 2012)

12.1.2 Lizard Creek Tributary 1

Lizard Creek Tributary 1 conforms to some of the “special significance” criteria in that it;

- has potential regional significance to water supply at Broughtons Pass Weir, downstream of Cataract Reservoir;
- has Endangered Ecological Community (Coastal Upland Swamp) within its channel and tributaries;
- provides potential habitat for Adams Emerald Dragonfly, although the dragonfly has not been identified in the stream, and;
- has a stream discharge into Lizard Creek which is generally within the ANZECC 2000 criteria, except for;
  - o pH, which is generally below pH 6.5;
  - o filtered zinc (<0.046mg/L) and;
  - o total nitrogen (<2.08mg/L) and total phosphorous (<0.24mg/L), occasionally.

However, it does not conform to other criteria, in that;

- the connected linear network of the stream is disrupted as it does not have perennial flow between the C11 and LCT1 due to previous subsidence effects between 1979 and 1992 (i.e. 31 to 18 years ago) and can be totally dry in this reach after extended lack of rainfall;
- the stream is ferruginous, and;
- it does not have a high degree of “naturalness” in the affected reaches.

On the basis that the connected linear network of Lizard Creek Tributary 1 and its “naturalness” is “*diminished by the effects of previous mining*”, the Bulli PAC did not consider Lizard Creek to qualify for “special significance” (NSW Planning Assessment Commission, 2010).

As a result, the third order reach of Lizard Creek Tributary 1 is not deemed to have special significance.

12.1.3 Lizard Creek Tributary 2

Lizard Creek Tributary 2 conforms to some of the “special significance” criteria in that it;

- has potential regional significance to water supply at Broughtons Pass Weir, downstream of Cataract Reservoir;
- has Endangered Ecological Community (Coastal Upland Swamp) within its channel and tributaries;
- provides potential habitat for Adams Emerald Dragonfly, although the dragonfly has not been identified in the stream, and;
- has a stream discharge into Lizard Creek which is generally within the ANZECC 2000 criteria, except for;
  - pH, which is generally below pH 6.5;
  - filtered zinc (<0.048mg/L) and;
  - total nitrogen (<3.4mg/L) and total phosphorous (<0.13mg/L), occasionally.
- it has a high degree of “naturalness”.

However, it does not conform to other criteria, in that;

- the stream has ferruginous reaches.

As a result, the third order reach of Lizard Creek Tributary 2 is deemed to have special significance.

12.2 Wallandoola Creek

Wallandoola Creek, between WC3 and WC7 (over the proposed subsidence reach), conforms to some of the “special significance” criteria in that it;

- has potential regional significance to water supply at Broughtons Pass Weir, downstream of Cataract Reservoir;
- has Endangered Ecological Community (Coastal Upland Swamp) within its channel and tributaries;
- provides potential habitat for the Giant Burrowing Frog, the Heath Frog and the Adams Emerald Dragonfly, although they have not been identified in the stream,

and;

- has a stream discharge out of the predicted subsidence area, and subsequently into Cataract Creek (downstream of the reservoir) generally within the ANZECC 2000 criteria, except for;
  - o pH, which is generally below pH 6.5;
  - o filtered copper (<0.004mg/L), very rarely;
  - o filtered zinc (<0.03mg/L), occasionally;
  - o total nitrogen (<0.7mg/L), rarely, and;
  - o total phosphorous (<0.19mg/L) occasionally.

However, it does not conform to other criteria, in that;

- the connected linear network of the stream is disrupted as it does not have perennial flow between the WC4 and WC5, including Waterfall W1 due to previous subsidence effects between 1988 and 1992 (i.e. 22 to 18 years ago) and can be totally dry in this reaches after extended lack of rainfall;
- the stream is ferruginous where the through flow from the upstream reach discharges back into Wallandoola Creek, downstream of Waterfall W1, and;
- it does not have a high degree of “naturalness” in the affected reach;

The Bulli PAC considered Wallandoola Creek, downstream of the Study Area, to be both important and rare, and based on its “naturalness” was considered a candidate for “special significance” status. However, it is not apparent whether the WC4 – WC5 reach was considered in the Bulli PAC assessment.

On the basis that the of Wallandoola Creek and its “naturalness” is diminished by the effects of previous mining in the WC4 to WC5 reach, that reach is not considered to have special significance.

However, although the stream has been impacted by previous mining subsidence which has diminished the naturalness of the creek in the WC4 to WC5 reach, the catchment is essentially undisturbed and has a high level of naturalness, except where mining subsidence is present.

12.2.1 Waterfall W1

The WC4 to WC5 reach is adversely affected by previous subsidence through dessication of the creek bed and Waterfall W1 after extended dry periods, and through ferruginous seepage into the creek at and downstream of the waterfall.

As a result, Waterfall W1 is not considered to qualify for “special significance” in terms of its interrupted connected linear network between WC4 and WC5.

It is noted, however, that Waterfall W1 is considered to be of ‘special significance’ as a cliff structure (SCT 2012).

12.3 Cataract Creek

Cataract Creek, upstream of Cataract reservoir, is considered to have special significance because;

- of the presence of Endangered Ecological Community (Coastal Upland Swamp) within tributaries;
- it provides habitat for Macquarie Perch, Silver Perch and an unidentified freshwater cod (potentially the threatened Murray Cod, Trout Cod or a hybrid of these species (Cardno Ecology Lab 2012);
- provides potential habitat for Adams Emerald Dragonfly and potential breeding habitat for the Stuttering Barred Frog, although neither species has been identified in the stream;
- has perennial flow in the lower reaches and provides a regionally significant water supply function to Cataract reservoir;
- has a high degree of “naturalness”;
- has a stream discharge into Cataract Reservoir that generally is within the ANZECC 2000 criteria, except for;
    - pH (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.

12.4 Cataract River

Cataract River, upstream of Cataract reservoir, is considered to have special significance because;

- of the presence of Endangered Ecological Community (Coastal Upland Swamp) within tributaries;
- it provides habitat for Macquarie Perch, Silver Perch and an unidentified freshwater cod (potentially the threatened Murray Cod, Trout Cod or a hybrid of these species (Cardno Ecology Lab 2012);
- it provides breeding habitat for Giant Burrowing Frog (confirmed) and Heath/Littlejohn’s Tree Frog in tributaries;
- provides potential habitat for Adams Emerald Dragonfly and the Stuttering Barred Frog although neither species has been identified in the stream;
- has perennial flow in the lower reaches and provides a regionally significant water supply function to Cataract reservoir;
- has a high degree of “naturalness”;
- has a water quality discharge into Cataract Reservoir that generally is within the ANZECC 2000 criteria, except for;
    - 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.

13. RISK ASSESSMENT, POTENTIAL STREAM EFFECTS, IMPACTS AND CONSEQUENCES

In accordance with the Bulli Seam PAC findings, a stream risk and an associated potential stream effects, impacts and consequences assessment was conducted through comparing findings and predictions summarised in previous sections, along with observations from field inspections and monitoring.

13.1 Stream Flow and Pool Levels (General)

Stream flow and pool levels are maintained in a stream when there is sufficient runoff in a subject catchment, as well as through contribution groundwater baseflow and upland swamp seepage.

Stream flow is separated into ‘baseflow’ from delayed groundwater, swamp seepage and release from stream bank storage, as well as ‘quickflow’, which is a direct and short term response to rainfall that includes overland flow, rapid lateral movement in the soil (interflow) and direct precipitation onto the stream surface.

The relative contribution of baseflow and quickflow changes through a streams hydrographic record.

Potential geomechanical effects and impacts on streams generated in areas with exposed Hawkesbury Sandstone, Bald Hill Claystone or Bulgo Sandstone due to subsidence can include:

- bending, delamination or lifting of discrete surface sheets of rock into an inverted V due to compression at right angles to the axis of the V, particularly above and immediately behind an active extraction area;
- horizontal stress concentration or mobilisation of natural horizontal stress, mainly in areas of localised topographic highs such as rock bars, with surface shearing, usually along bedding planes or sliding of one sheet above the other with measurable horizontal and relative vertical displacement of the sheets;
- horizontal and low angle shearing, particularly in cross-bedded sandstone;
- isolated thin sheet shear and failure;
- tensile failure of upper beds, mainly perpendicular to the direction of compression, and;
- vertical hairline fracturing perpendicular to the axis of horizontal shearing, usually with significant horizontal opening up to several centimetres, but usually with short vertical penetration into the strata. The fracturing can be characterised by iron rich seeps that oxidise on exposure to the air which are a visible precursor to progressive fracturing in creeks close to mining activity.

Based on experience gained during longwall mining in other Southern Coalfield operations, mining under a creek or river can result in horizontal separation of strata in the base of the valley and redistribution of existing horizontal stresses in the walls and base of the valleys.

If the redistributed stress exceeds the bulk shear strength of the strata, then relative horizontal shear can produce uplift of the valley floor.

Localised weathering patterns may significantly influence the geometry of deformation.

In general terms, the range of possible consequences due to subsidence are:

- loss of water from pools due to rockbar fracturing where surface water is temporarily diverted through near surface fractures;
- full or partial re-emergence of diverted stream flow further downstream;
- loss of surface water inflow to pools due to upstream diversion into the shallow substrate beneath a stream;
- reduced water retention in isolated pools, or sequential pools;
- modification of surface water quality through geochemical and biochemical interactive changes with exposed fresh mineral surfaces following fracturing;
- increased salinity and / or alteration of water quality following slumping, erosion and modified sediment transport;
- adverse impacts on ecosystems by changes in surface water flow, pool water retention and / or changes in water quality, or;
- changes to aquatic habitats due to lower pool water levels, drying of riffle zones, sedimentation etc.

Subsidence and valley uplift is usually associated with shallow horizontal fracturing and diversion of surface water to the shallow substrate beneath a stream bed, which may or may not be hydraulically connected to the underlying regional groundwater system.

Although horizontal stress redistribution can result in localised instability within steep valley slopes, minimal influence on geomorphic features on the plateau or slopes is expected.

The majority of adverse effects or consequences on stream flow and pool water holding capacity in stream beds is due to non-conventional subsidence.

It is noted that the mine layout as proposed has been developed to reduce and limit the potential for these impacts to develop on and within the primary channels of the major creeks within the study area.

With respect to the Catratct Creek, the proponent has provided an undertaking that it will terminate mining beneath Cataract Creek if subsidence and ground movements are predicted to exceed 250mm and the creek experiences greater than negligible impact.

The Bulli PAC assessed that it is well established that, the vertical and lateral extent of upsidence fracture networks increases with the level of upsidence, which in turn increases with the level of closure. However, impact categories have yet to be assigned to measured closure or upsidence effects because:

- upsidence does not correlate well with closure due to difficulties in measuring upsidence accurately and different amounts of upsidence can be induced by the same amount of closure, depending on rock type;
- different levels of impact can be associated with the same level of upsidence, depending primarily on local rock type, rock fabric and structure (massive, laminated, cross bedded, jointed etc) and the orientation of the structure relative to the direction of valley closure, and;
- in the case of some features, some high consequence impacts occur at very low levels of movement. Further increases in the magnitude of the effect (movement) do not always result in an incremental increase in the magnitude of the impact and its consequences, albeit that they might increase other impacts and consequences. Field observations reveal that this is the case in particular for watercourses controlled by rock bars.

The Bulli Seam EA assessed that no pool impacts had been observed where valley closure was less than 200mm.

Total valley closure is critical for features in the base of a valley where most of the displacement occurs, along with the high compressive strains in the valley floor, which is observed as upsidence.

The Bulli PAC determined it is more appropriate if valley closure movements were assessed in terms of compressive strains that could be correlated with subsidence impacts.

The Bulli PAC also noted that although impacts at rockbars in previous studies were based on predicted valley closure, this approach was illogical and unsatisfactory as it is based on correlation between predicted closure (an estimate) and observed impact (a fact) and that there is generally a poor correlation between measured closure and observed impact.

The Bulli PAC concurred with using closure strain as a risk criterion, where closure is a measure of the absolute amount of horizontal displacement across a valley and the impact of the movement is determined by its distribution between the valley sides, that is, by the strain arising from this movement. The Bulli PAC noted that strain distribution changes across the closure profile, with peak strain occurring in the centre of a valley.

Based on the Bulli PAC's findings, total diversion of surface flow into a subsidence induced subsurface fracture system requires higher total compressive strains that are dependent on geological factors such as strata composition, thickness and bedding laminations. Limited measurements indicate a threshold total compressive strain for diversion of flow in sandstone environments of 7mm/m (NSW Planning Assessment Commission, 2010), where conventional compressive strain can make a significant contribution to total compressive strain.

Due to the variable manner in which upsidence can develop and is measured, the Bulli PAC had concerns using upsidence as a risk criterion as its measurement is susceptible to the manner in which the rock surface fails and the location of survey stations.

As a result of the Bulli PAC findings, this assessment of potential effects on stream flow and pool water holding capacity of the subject streams places the emphasis on predicted strains in creek valleys, rather than predicted valley closure.

These aspects are discussed further in the following sections.

13.2 Stream Water Quality (General)

Previous observations in similar geomorphological, hydrological and mining environments within the Southern Coalfields, have assessed that water quality can be adversely affected through:

- increased groundwater discharge to a stream following direct undermining and subsidence;
- lowered dissolved oxygen, lowered pH, elevated dissolved Fe / Ni / Zn / Mn / Al as well as elevated sulfate and salinity from flow through fresh cracks in cliff and stream bed sandstone following subsidence which manifests as orange-brown, low dissolved oxygen plumes in receiving waters, and;

- pool depth reduction and enhanced stagnation and evaporative concentration which enhances low dissolved oxygen and elevated salinity.

The main observable change in streams results from dissolution of freshly exposed diffused iron sulfide and carbonate minerals (such as marcasite, pyrite or siderite) from cracked sandstone which subsequently precipitates on discharge to a receiving water body as an orange-brown iron hydroxide floc, along with the generation of sulfuric acid and increased levels of dissolved iron, manganese, aluminium, nickel and zinc species.

Mine subsidence can delaminate erosion surfaces and bedding planes within and between strata which occurs preferentially along the interface between materials with different elastic properties. Delamination, dilation and interfacial permeability enhancement is likely along the sub-horizontal interface between sub-cropping sandstone and outcropping shales.

The effects of ferruginous springs is generally aesthetic and does not pose an adverse risk to stream ecology due to the relatively short length and high gradients of the streams in the Study Area as well as the substantial dilution and dispersion that would occur at the confluence with the Cataract River (downstream of the dam) or in Cataract reservoir itself.

Where a seep discharges into a stream, the stream can be slightly more acidic and brackish downstream of a subsidence affected area, which, with in-stream diffusion and mixing, subsequently reduces with flow downstream.

An increase in dissolved aluminium may be due to dissolution from kaolinite in the fractured bedrock or, being remobilised from precipitated hydrous iron, manganese or aluminium oxides due to dissolution by humic and fulvic acids in organic rich upland swamps.

In addition, enhanced armouring of stream bed substrate with precipitated iron hydroxide has been observed at discharge areas, however this effect has also be observed in natural, non mining affected streams in the NRE1 lease area.

The generation of ferruginous seeps into a stream decreases over a time frame of years due to armouring of marcasite and siderite with iron oxyhydroxide precipitates (Nicholson et al, 1990).

The diversity and abundance of aquatic species within the Study Area may be affected by the comparitively acidic pH (which is often natural in Hawkesbury Sandstone streams), as well as dissolved aluminium and zinc. Sulfate and dissolved humic and fulvic acids may also be insufficient concentration to form complexes with dissolved aluminium and reduce the stream water ecotoxicity.

If additional adverse seepage to a stream occurs, it is usually diluted in a short distance, with a reduction of pollutant concentration downstream from the point of emergence. This assumes, however, the discharge occurs at an isolated location, whereas it is often observed that the seepage is disseminated along a stream, depending on the subsidence induced flow regime, with the resultant dilution, precipitation and adsorption effects as described above.

Studies at Elouera Colliery (currently operated as the Gujarat NRE Wonga Pty Ltd Wongawilli Colliery) in a similar geomorphological and hydrological environment to the Study Area, indicate there are no residual ecotoxic effects (as opposed to physical subsidence effects on flow) from acidic pH, aluminium, nickel or zinc, with the effects of undermining at Eloura requiring less than 10 years to be ameliorated (Comur Consulting, 2007).

It has also been observed in stream over the Elouera workings that natural attenuation of an affected stream reach can occur up to 750m downstream of the seepage location (BHP Billiton, 2009).

The effect of acidity is reduced mainly through dilution with receiving waters as well as buffering from alkaline solutes such as bicarbonate ($HCO3^-$) and, to a lesser degree, hydroxide species (OH^-).

The increased acidity and lower dissolved oxygen in receiving waters is generally only observed close to the discharge point, and depends on the flow rate and volume at the discharge point.

Dilution of the discharge as well as precipitation of iron and manganese hydroxides, adsorption of dissolved Ni and Zn onto the iron hydroxides, as well as binding or adsorption onto dissolved / total organic carbon can significantly improve water quality downstream from the emergence point.

Further downstream from the seepage point, a stream can be affected by moderately elevated salinity, however this also quickly diminishes with mixing downstream.

Monitoring in the Study Area has identified numerous ferruginous seeps within both the main channel and tributaries of all three creeks.

The potential effects, impacts and consequences are discussed in the following sections, with reference to the predicted subsidence as outlined in **Table 18**.

Table 18 Stream Reach Maximum Subsidence

	Subsidence (m)	Tilt (mm/m)	Strain (mm/m)
Wonga East (Cataract Creek)			
CC1 - CC4 tributary (nth catchment)	<0.02	<1.0	<1.0 to -1.0
CC2 - CC3 tributary (sth catchment)	0.16	3.0	<1.0 to <-1.0
CC5 – CC9	0.8	<1.0	5.0 to -9.5
Wonga East (Cataract River and Bellambi Creek)			
Cataract River and Bellambi Creek	<0.02	<0.1	<1.0 to <-1.0
Wonga West (Lizard Creek and Tributaries)			
LC1 – LC3	<0.02	<1.0	<1.0 to <-1.0
LC3 – Waterfall L1	0.2	3.0	2.0 to -1.0
Waterfall L1	0.12	2.9	+3.5
Waterfall L1 – LC4	0.2	<1.0	<1.0 to <-1.0
LC4 – LC5	<0.02	<1.0	<1.0 to <-1.0
LC5 – LC6	0.25	3.0	5.0 to <-1.0
LC6 – LC7	0.25	<1.0	3.0 to <-1.0
LCT1 (3rd order reach)	2.5	13.0	-7.0 to 7.0
LCT2 (3rd order reach)	1.9	9.0	4 to -6
Wonga West (Wallandoola Creek)			
WC2 – WC3	0.02	<1.0	2.0 to <-1.0
WC3 – WC4	0.5	3.0	6.0 to <-1.0
WC4 – Waterfall W1	<0.02	<1.0	<1.0 to <-1.0
Waterfal W1	<0.02	<1.0	<+1.0
Waterfall W1 – WC5	<0.02	<1.0	<1.0 to <-1.0

NOTES: source: Seedsman Geotechnics, 2012 -ve strain = compression +ve strain = extension

13.3 Lizard Creek

13.3.1 Stream Flow

Due to the designed set back of the longwalls from the main channel of Lizard Creek (and the associated lack of subsidence and uplift), the proposed Wongawilli Seam layout is designed to avoid potential adverse effects on the main channel of Lizard Creek.

A low potential risk to the integrity of stream flow and connectivity in Lizard Creek could be present in the area that may potentially undergo 6 - 7mm/m of tensile strain to the north of WW-A3-LW2 and south of the northern end of WW-A4-LW5.

It should be noted however that stream flow in this reach is already adversely affected by subsidence over the Bulli longwalls, with the quantum, duration and connectivity of flow in Lizard Creek being dependent upon rainfall and runoff in the catchment, as the main creek bed can dry up in two areas, including a:

- 950m reach upstream of Waterfall L1, and;
- 1300m reach between LC5 and LC6.

It is assessed there will be no adverse impacts, effects or consequences in the Lcus1 or Lcus4 valley fill swamps as well as in the sandstone based and rock bar constrained pools due to the predicted 20mm to 0.25m of subsidence (Seedsman Geotechnics, 2012) along the length of Lizard Creek at Wonga West Areas 3 and 4.

Between LC1 and LC5, the predicted strains along Lizard Creek are predominantly less than 3mm/m, which is also not expected to generate any adverse effects impacts or consequences on stream flow.

To the north of WW-A3-LW2, mid way between LC5 and LC6, maximum strains of between 3 - 7mm/m are predicted over a stream reach of approximately 300m (Seedsman Geotechnics, 2012), which could generate cracking in the Hawkesbury Sandstone creek bed.

The LC5 – 6 reach has shown through monitoring to completely dry up for periods of between 6 to 45 days since December 2009. Lizard Creek at this location was undermined by Bulli Seam longwalls 304 to 306 between 1986 and 1989 (i.e. up to 24 years ago).

If subsidence consequences do occur on the bed of Lizard Creek in this reach, it could manifest through additional rock bar leakage, enhanced transfer of stream flow to the underlying sandstone substrate or by an enhanced pool drainage rate.

The degree and extent of predicted cracking can not be determined with accuracy, however, as the predicted strains are not large, and as the stream flow and pool holding capacity has been adversely impacted by previous subsidence, it is not anticipated that any significant change will be observed in the creek.

Valley closures of up to 200mm and upsidence up to 120mm may occur. Notwithstanding this, no significant, observable uplift or valley closure is anticipated within the channel of Lizard Creek. Because of the decision to eliminate longwall extraction under named 3rd order creeks, the systematic strains in these creeks can only be tensile. Because of block rotations above the longwall extraction panels there may be some compressive strains transferred to the creeks.

As is observed with current stream flow conditions in this reach, it is expected that if any subterranean flow transfer occurs due to subsidence or uplift cracking in the stream bed from the proposed workings, stream flow will re-emerge downstream, without loss of total stream discharge from the subsided catchment.

Groundwater modelling indicates a potential 12m reduction in groundwater level, and an associated 0.02 ML/day baseflow reduction after the end of Stage 1 (V Mains and Area 1 and 2) and 0.10ML/day at the end of Area 4 mining to Lizard Creek (GeoTerra, 2012). It is assessed that this would generate negligible environmental consequences except potentially during extended dry periods due to depressurisation in the upper Hawkesbury Sandstone aquifer in the gaining portions of the stream, downstream of Waterfall L1.

No reduction in stream flow is anticipated in the hydraulically separated reach of the creek upstream of the waterfall.

As there is no predicted change, based on the subsidence predictions, to the semi-confining properties of the Bald Hill Claystone following extraction of the proposed Wonga West panels, it is assessed that the modelled stream flow reduction of 0.02 – 0.1ML/day would be accommodated within the secondary porosity generated through bedding plane separation and fracturing after subsidence of the mid to upper Hawkesbury Sandstone.

The additional stored connate water would flow under the regional gravity profile, and, with a delay, discharge either to a downstream reach of Lizard Creek or to an adjoining downgradient catchment, such as the Cataract River as baseflow recharge to the streams.

Based on the modelled outcome that no additional significant water passes through the Bald Hill Claystone into the underlying Narrabeen Group or Illawarra Coal Measures following extraction of the Wongawilli West longwalls, as well as at Wonga East where the claystone is not eroded away in the valley of Cataract Creek, it is assessed there would be no net loss to the water volume flowing into the Cataract River.

Stream flow modelling (WRM Water & Environment, 2012) indicates the average daily flow from Lizard Creek to the Cataract River is 17.0ML/day. Therefore, a 0.02 – 0.1ML/day flow reduction represents approximately 0.1 – 0.6% of the Lizard Creek flow into Cataract River.

13.3.2 Waterfall L1

Waterfall L1 is predicted to undergo less than 0.12m of subsidence and less than 3.5mm/m of extensional strain.

No adverse subsidence effects, impacts or consequences are anticipated at Waterfall L1 and as such, it is predicted to have a low risk of subsidence related cracking and a low risk of enhanced stream bed throughflow.

13.3.3 Rock Bars

A low potential risk to the integrity of rock bar constrained pools could be present in the area that may potentially undergo 6 - 7mm/m of tensile strain to the north of WW-A3-LW2 and south of the northern end of WW-A4-LW5.

It should be noted however that the pool holding capacity in this reach is already adversely affected by subsidence over the Bulli longwalls, with the pool depths and duration being dependent upon rainfall and runoff in the catchment, as pools in the following two areas have been observed to dry out in low flow periods between the:

- 950m reach upstream of Waterfall L1, and;
- 1300m reach between LC5 and LC6.

Monitoring of the LC5 – 6 reach has shown it to be completely dry up for periods of between 6 to 45 days since December 2009.

13.3.4 Tributaries

The first, second and third order tributaries which overly the proposed 20mm subsidence zone are at 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 Lizard Creek.

It is not anticipated, however, that the total volume of water entering Lizard Creek will be adversely affected.

Adverse impacts, effects or consequences are possible on the sandstone based pools due to the predicted 2.5m of subsidence (Seedsman Geotechnics, 2012) in the 3rd order reach of LCT1 and up to 1.9m of subsidence along the 3rd order reach of LCT2 at Wonga West Area 3. The 3rd order reach of LCT1 was undermined by Bulli longwalls 306 to 308 between 1989 and 1991 (i.e. up to 20 years ago), whilst the 3rd order reach of LCT2 was not undermined by the Bulli longwalls.

The predicted strains in the 3rd order reach of LCT1 may range up to 7mm/m (tensile) to -7mm/m (compressive), whilst the 3rd order reach of LCT2 may experience up to 4mm/m to -6mm/m, which could generate stream bed cracking. The degree and extent of cracking can not be determined with accuracy, however, as the stream flow and pool holding capacity has already been adversely impacted by the pre-existing effects of previous subsidence in the 3rd order reach of LCT1, it is not anticipated that any significant change will be observed in that tributary. Adverse effects may occur, however, in LCT2.

If subsidence consequences do occur on the tributaries, it could manifest in the tributaries through additional rock bar leakage, enhanced transfer of stream flow to the underlying sandstone substrate, by an enhanced pool drainage rate or through enhanced discharge of ferruginous seepage.

It is expected that if any subterranean flow transfer occurs due to subsidence or uplift cracking in the stream bed from the proposed Wongawilli Panels, the flow will re-emerge downstream in Lizard Creek, without loss of total stream discharge from the subsidence area.

13.3.5 Upland Swamp Outflow

A detailed significance and risk assessment of the Lizard Creek swamps is contained in (Biosis, 2012).

The predominantly headwater swamps overlying the proposed Wonga West subsidence area have the potential to undergo subsidence related bedrock cracking. The Lcus8 swamp overlying WW-A3-LW1 is anticipated to be at low risk of adverse subsidence related effects (Biosis 2012) while Lcus1, Lcus6 and Lcus27 anticipated to be at a negligible risk of adverse subsidence related effects (Biosis 2012).

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

The valley fill swamps along Lizard Creek, to the south of the proposed subsidence zone, are not anticipated to be at significant risk of adverse effects

13.3.6 Stream Water Quality

The main stream reach to the north of the proposed longwalls 1 in Area 3 is currently affected by ferruginous precipitates, as well as reduced stream flow and pool holding capacity due to pre-existing effects from the Bulli Seam longwall subsidence.

If additional stream bed cracks form to the north of the proposed panel, along with enhanced diversion of stream flow through the underlying sandstone substrate, ferruginous orange discolouration of the water and elevated total / filtered iron, along with zinc and possibly copper and aluminium could occur, along with increased opacity of the water and reduced dissolved oxygen. However, it is unlikely that any observable, adverse effect on stream water quality will occur in addition to the existing water quality in that stream reach.

Due to the minimal predicted subsidence and strain in the main channel of Lizard Creek, and therefore the associated lack of potential for generation of additional stream bed cracking and substrate through-flow, no observable adverse effect on stream water quality is anticipated, outside of the longwall 1 and 2 stream reach.

13.3.7 Tributary Water Quality

Tributary LCT1 is currently affected by ferruginous precipitates, as well as reduced stream flow and pool holding capacity due to pre-existing effects from the Bulli Seam longwall subsidence.

The 3rd and 4th order reach of LCT2 has not been undermined, and is not affected by subsidence, although the LCT2A 1st and 2nd order headwaters, as well as swamp Lcus25 have been undermined by the 300 series longwalls.

If stream bed cracks form in the LCT1 or LCT2 3rd order or higher channels, along with enhanced diversion of stream flow through the underlying sandstone substrate, orange discolouration of the water and elevated total / filtered iron, along with zinc and possibly copper and aluminium could occur in LCT1 or be generated in LCT2 and potentially discharged into Lizard Creek, along with increased opacity of the water and reduced dissolved oxygen.

As a result, observable, adverse effects on stream water quality in the 3rd order or higher channels of LCT1 and LCT2, as well as the receiving waters of Lizard Creek, could occur.

13.4 Wallandoola Creek

13.4.1 Stream Flow

Due to the designed set back of the longwalls from the main channel of Wallandoola Creek (and the associated lack of subsidence and uplift), the proposed Wongawilli Seam layout is designed to avoid potential adverse effects on the main channel of Wallandoola Creek.

A potential risk to the integrity of stream flow and connectivity in Wallandoola Creek could be present in the area that may potentially undergo up to 0.5m of subsidence and 6mm/m of tensile strain to the south of WW-A3-LW3 and LW4

It should be noted however that stream flow in this reach is already adversely affected by subsidence over the Bulli longwalls, with the quantum, duration and connectivity of flow in Wallandoola Creek between WC4 and WC5 being dependent upon rainfall and runoff in the catchment, as the main creek bed can dry up in this reach.

Based on the less than 20mm of predicted subsidence and associated low strains, it is assessed that there will be no adverse consequences in the Wcus1 and Wcus4 valley fill swamps and associated sandstone based / rock bar constrained elongated pools up to the main bend in Wallandoola Creek, downstream of WC3 at Wonga West Area 3.

The predicted strains of up to 6mm/m in the reach up to midway between WC3 and WC4 is not expected to generate adverse effects on stream flow as the channel is dominated by either sandy based sediments or thick valley fill swamp vegetation, which can absorb low strain levels without generating connected stream bed cracking and the associated loss of stream flow or enhanced pool drainage.

At the northern extent of the main bend in Wallandoola Creek, to the south of proposed longwalls WW-A3_LW3 and LW4, upstream of WC4, the predicted stream bed subsidence ranges from 0.25 – 0.5m (Seedsman Geotechnics, 2012). Although it could cause adverse consequences, is not anticipated to occur based on similar, previous subsidence effects observed over the Bulli 200 series longwalls, with similar previous subsidence and strains.

The predicted strains of up to 6mm/m in the stream bed directly south of proposed WW-A3-LW3 and LW4 longwalls could generate cracking in the exposed Hawkesbury Sandstone. The degree and extent of cracking is difficult to determine, however it could potentially enable enhanced drainage of the approximately 100m long pool upstream of the rock shelf.

If subsidence effects do occur, it could manifest through rock bar leakage or transfer to the underlying sandstone substrate through the pool base.

Cracks generally form in the base of a stream and are generally prevalent in more incised reaches where sandstone bedding planes lift and "dilate". Based on observations in similar topography to Wallandoola Creek, the cracked zone can extend up to 10m below surface. Studies into the depth of dilation of a river bed due to upsidence and closure of Waratah Rivulet at Metropolitan Colliery indicate that cracking occurred to 9m within a zone monitored to 27m below surface in a 60m wide valley which subsided by up to 1.3m, with 140mm of vertical dilation of the strata due to uplift (Mills and Huuskes 2004).

If cracking occurs directly beneath the subject reach of the stream, and as the creek bed upstream of Waterfall W1 is not anticipated to be hydraulically connected to the underlying regional groundwater system based on extrapolation of drilling observations, it is assessed that any through flow into the cracks will re-surface downstream.

Due to the sequential and migratory development of uplift as mining progresses due to panel by panel extraction, the development of stream bed cracking may also migrate downstream as mining advances from WW_A3-LW2 to LW4. If cracks develop, water flow to the new voids may occur as the strain sequentially develops along the creek bed, with the rate of inflow controlled or modified by the;

- time frame of uplift
- location of uplift
- depth and width of cracking in the bedrock, and
- degree of filling in cracks with sediment

Modification of stream flow can affect the function and integrity of ecological systems, whilst enhanced recharge from streams to shallow temporary aquifers can raise the groundwater table and potentially dry up restricted portions of a stream if a hydraulic connection between the two systems is present.

It is possible, although not anticipated to be likely, that cracking could occur in the creek bed to the south of WW-A3-LW3 and LW4, which could lead to loss of flow into the underlying dilated strata or enhanced drainage of pools, however, if it did occur, the cracking is not anticipated to generate a net loss of water volume discharge from subsidence affected creek systems since the subterranean flow, if it occurred, would re-emerge under gravity drainage further downstream in the catchment.

After heavy rain, the majority of runoff would flow along the creek bed, with a lesser proportion flowing through the dilated, subsided strata, whilst during low flows, a greater proportion of water would move as underflow through the shallow stream bed substrate.

It is not anticipated that the predicted strains of between 1 - 3mm/m and subsidence of 0.02 – 0.25m at the rock shelf constrained pool immediately upstream of WC4, to the south of WW-A3-LW5 will be sufficient to adversely affect the stream flow or water holding capacity of the subject pool.

Based on the subsidence assessment, valley closures of up to 200mm and upsidence of up to 120mm could occur, which are double the predicted closure and upsidence values predicted by Seedsman Geotechnics (2012) in accordance with the FMEA assessment.

No adverse subsidence effects, impacts or consequences are anticipated at or downstream of Waterfall W1 due to minimal predicted levels of subsidence and strains at that location.

Groundwater modelling indicates a potential 12m reduction in groundwater levels, and an associated 0.06ML/day baseflow reduction after the end of Stage 1 (V Mains and Area 1 and 2 and 0.25ML/day (at the end of Area 4) to Wallandoola Creek.

It is assessed that this would generate negligible environmental consequences, except potentially during extended dry periods due to depressurisation in the upper Hawkesbury Sandstone in the gaining portions of the stream, downstream of Waterfall W1.

No reduction in stream flow is anticipated in the reach upstream of the waterfall.

As there is no predicted change in the semi-confining properties of the Bald Hill Claystone, based on the subsidence predictions, following extraction of the proposed panels, then it is assessed that the modelled stream flow reduction of 0.06 – 0.25ML/day would be accommodated within the secondary porosity generated through bedding plane separation and fracturing after subsidence of the mid to upper Hawkesbury Sandstone.

The additional stored water would flow under gravity, and with a delay, discharge either to a downstream reach of Wallandoola Creek or to an adjoining downgradient catchment, such as the Cataract River.

Based on the modelled outcome that no additional significant water flow passes through the Bald Hill Claystone into the underlying Narrabeen Group or Illawarra Coal Measures following extraction of the Wongawilli West longwalls, it is assessed there would be no net loss to the water volume flowing into the Cataract River.

Stream flow modelling (WRM Water & Environment, 2012) indicates the average daily flow from Wallandoola Creek to the Cataract River is 33.0ML/day. Therefore, a 0.06 – 0.25ML/day flow reduction represents approximately 0.2 – 0.8% of the Wallandoola Creek stream flow into Cataract River.

13.4.2 Waterfall W1

Waterfall W1 is predicted to undergo less than 0.02m of subsidence and less than 1mm/m of extensional strain.

As such it is predicted to have a low risk of subsidence related cracking and a low risk of enhanced stream bed throughflow.

13.4.3 Rock Bars

A low potential risk to the integrity of rock bar constrained pools could be present in the area that may potentially undergo 6mm/m of tensile strain to the south of WW-A3-LW3 and LW4.

It should be noted however that the pool holding capacity in this reach is adversely affected by previous subsidence associated with the Bulli seam longwalls, with the pool depths and duration being dependent upon rainfall and runoff in the catchment, as the WC4 pool has been observed to dry out in low flow periods.

13.4.4 Tributaries

The first and second order tributaries which overly the proposed 20mm subsidence zone are at 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 Wallandoola Creek.

It is not anticipated, however, that the total volume of water entering Wallandoola Creek will be adversely affected.

13.4.5 Upland Swamp Outflow

A detailed significance and impact assessment of the Wallandoola Creek swamps is contained in (Biosis 2012).

The headwater swamps overlying the proposed Wonga West subsidence area have the potential to undergo subsidence related bedrock cracking. In particular, the headwater swamp of the Wcus4 complex, which overlies WW-A3-LW2, is anticipated to be at moderate risk of adverse subsidence related effects, while Wcus11 also over WW-A3-LW2 is anticipated to be at a low risk of environmental consequences (Biosis 2012).

The valley fill swamp along Wallandoola Creek (Wcus7), to the south of WW-A3-LW3 and LW4 is anticipated to be at risk of adverse subsidence related effects (Biosis 2012). The valley fill swamp along Wallandoola Creek of the Wcus4 complex, to the south of WW-A3-LW2 is anticipated to be at negligible risk of adverse effects.

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

13.4.6 Stream Water Quality

The stream reach to the south of the proposed longwalls WW-A3-LW3 and LW4 is currently affected by ferruginous precipitates.

If stream bed cracks form to the south of the proposed panels, along with diversion of stream flow through the underlying sandstone substrate, orange discolouration of the water, generation of bacterial mats along with elevation of total / filtered iron, zinc and possibly copper and aluminium could occur, along with increased opacity of the water and reduced dissolved oxygen.

Due to the minimal or lack of predicted subsidence and strains, and therefore the associated low potential for stream bed cracking and substrate through-flow, no adverse effect on stream water quality is anticipated outside of the longwall 3 and 4 stream reach.

13.5 Cataract Creek

13.5.1 Stream Flow

As a worst case scenario, the potential risk to the integrity of stream flow and connectivity in Cataract Creek could be present in the area:

- to the west of longwalls WE-A2-LW5, 6, and LW7, that may potentially undergo <0.02m of subsidence and <1mm/m of tensile strain;
- over LW8, where the creek may potentially undergo up to 0.8m of subsidence and up to 5mm/m tensile and 9.5mm/m compressive strain;
- over LW9, where the creek may potentially undergo up to 0.26m of subsidence and up to 1.3mm/m of tensile and 2 mm/m of compressive strain, and;
- over LW10, where the creek may potentially undergo up to 0.04m of subsidence and up to 1.1mm/m of tensile strain.

Valley closure of up to 100mm and upsidence of up to 60mm may occur at Wonga East (Seedsman Geotechnics, 2012).

The proponent has provided an undertaking that it will terminate mining beneath Cataract Creek if subsidence and ground movements are predicted to exceed 250 mm and the creek experiences greater than negligible impact

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

Cataract Creek has eroded into the Bald Hill Claystone above the proposed longwalls WE-A2-LW9 and WE-A2-LW10. During periods of high water, this could potentially generate recharge from the reservoir to the exposed Bulgo Sandstone, which could occur both before any mining occurred in the area, and afterwards. During lower dam water levels, recharge would still occur as baseflow recharge from Cataract Creek.

Stream reaches flowing over the Newport and Garie Formations, as well as the Bald Hill Claystone, may not experience the same degree of surface cracking as observed over the sandstone reaches, due to the enhanced ductility of the clay based lithologies.

Beneath the plateau area of the multi seam mined Bulli and Balgownie workings, between Cataract Creek and Bellambi Creek, extraction of the proposed workings is modelled to generate up to 4m of depressurisation in the upper Hawkesbury Sandstone at the end of mining Area 2 and V Mains (GeoTerra, 2012). The modelled, localised reduction is anticipated to reduce the regional phreatic surface gradient from the plateau to the creek, as well as toward Cataract reservoir, thereby potentially reducing baseline seepage volumes to the creek and dam. It is also possible that, if they exist, the location of seepage points in the stream bed may be relocated up to 4m lower in elevation in the catchment.

Based on interpreted local groundwater contours (GeoTerra, 2012) the 4m modelled reduction in the phreatic surface over the proposed workings represents a change in gradient toward Cataract reservoir from 0.0212 to 0.0196.

On the basis that there is no direct free drainage flow path to the workings, which is supported by water balance investigations and assessment of the post subsidence response in the pressure head and packer test data from GW1 and GW1A bores adjacent to the mined panel WE-A2-LW4 (GeoTerra, 2012), the water level decline is anticipated to be temporary, as the water table is anticipated to recover once the mining at Wonga East has been completed.

Groundwater modelling predicts a 0.06ML/day reduction in stream flow in Cataract Creek at the end of mining Area 2 / V Mains, rising to 0.07ML/day after Area 4 is completed.

As there is no predicted vertical drainage connection from the stream bed to the proposed workings (Seedsman Geotechnics, 2012), and where the Bald Hill Claystone is not eroded into, or through, and with no change in its semi-confining properties following extraction of the proposed panels, it is assessed that the modelled stream flow reduction of 0.06 – 0.07ML/day would be accommodated within the secondary porosity generated through bedding plane separation and fracturing of the Hawkesbury Sandstone and upper Bulgo Sandstone.

The additional stored connate water would flow under gravity, and with a delay, discharge either to a downstream reach of Cataract Creek, Cataract River or Bellambi Creek and subsequently into Cataract Reservoir as baseflow recharge to the streams.

Based on the assessment that no free drainage to the workings is generated following extraction of the Wongawilli East longwalls, it is assessed there would be no net loss to the water volume flowing into the SCA water storage at Cataract Reservoir.

Stream flow modelling (WRM Water & Environment, 2012) indicates the average daily flow from Cataract Creek to Cataract reservoir is 11.73ML/day. Therefore, a 0.06 – 0.07ML/day flow reduction represents approximately 0.5 – 0.6% of the Cataract Creek flow into Cataract Reservoir.

13.5.2 Rock Bars

Low potential risk to the integrity of rock bar constrained pools could be present in the area adjacent to longwalls WE-A2-LW5, 6, 7 and LW10.

A potential risk to the integrity of rock bar constrained pools is present in the area overlying WE-A2-LW8 that may potentially undergo up to 5mm/m tensile and 9.5mm/m compressive strain. However, based upon the proponent’s commitment to limit subsidence impacts on the Cataract Creek, the potential for cracking can be minimised.

No rock bar constrained pools are present over WE-A2-LW9.

13.5.3 Tributaries

The first and second order tributaries which overly the proposed 20mm subsidence zone are at 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 Creek.

It is not anticipated, however, that the total volume of water entering Cataract Creek will be adversely affected.

13.5.4 Upland Swamp Outflow

A detailed significance and impact assessment of the Cataract Creek swamps is contained in (Biosis, 2012).

The headwater swamps overlying the proposed Wonga East subsidence area have the potential to undergo subsidence related bedrock cracking. In particular, Ccus1 over WE-A1-LW3 and Ccus5 over WE-A2-LW5 are identified as being at risk of negative environmental consequences; while Ccus5 and Ccus10 are identified as being at low risk of negative environmental consequences (Biosis 2012).

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

13.5.5 Stream Water Quality

The Cataract Creek catchment upstream of CC5 is currently affected by ferruginous precipitates, however, no significant adverse effects on stream flow, pool holding capacity, water opacity or reduced dissolved oxygen are apparent from monitoring conducted to date after the previous multi seam mining.

Due to the predicted lack of stream bed cracking, no observable adverse effects on stream water quality are anticipated in Cataract Creek, upstream of Cataract Reservoir.

The Cataract Creek catchment flows over Hawkesbury Sandstone in its upper flanks, then subsequently over the clay dominated Newport and Garie Formations, Bald Hill Claystone and the upper Bulgo Sandstone in the more eroded reaches of the catchment as it drains to Cataract Reservoir as shown in **Figure 7**.

As a result, the ferruginous seeps in the upper catchment could represent the effects of enhanced interface drainage between the layered lithological sequence.

13.6 Cataract River and Bellambi Creek

13.6.1 Stream Flow

No potential risk to the integrity of stream flow and connectivity in Cataract River and Bellambi Creek is present. In particular, Crus1 over WE-A1-LW5 is identified as being at low risk of negative environmental consequences; while Crus2 and Crus3 are identified as being at negligible risk of negative environmental consequences (Biosis 2012).

Negligible stream flow effects, impacts or consequences are anticipated to occur in Cataract River or Bellambi Creek, upstream of Cataract Reservoir, due to the low to absent levels of predicted strains and subsidence.

Due to the Cataract River or Bellambi Creek not being undermined, or mined in near proximity to the streams, valley closures of less than 100mm and upsidence of less than 60mm are anticipated (Seedsman Geotechnics, 2012).

Groundwater modelling indicates there is negligible anticipated potential reduction in recharge or stream flow to the overall Cataract River and Bellambi Creek catchments as a result of the proposed Wonga East mining (Golder Associates, 2012).

13.6.2 Rock Bars

No potential risk to the integrity of rock bar constrained pools in Cataract River and Bellambi Creek is present.

13.6.3 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.

As a result, it is anticipated that the total volume of water entering Cataract River or Bellambi Creek will be negligibly affected.

13.6.4 Upland Swamp Outflow

A detailed significance and risk assessment of the Cataract River and Bellambi Creek swamps is contained in (Biosis 2012).

The headwater swamps overlying the proposed Wonga East subsidence area have the potential to undergo subsidence related bedrock cracking.

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

13.6.5 Stream Water Quality

The headwaters of the first and second order streams draining off the proposed 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.

13.7 Stream Bed and Bank Stability

13.7.1 Wonga West

Due to the lack of significant predicted subsidence in Wallandoola Creek (<0.25 - 0.5m) and Lizard Creek (<0.5m), along with the highly vegetated swamps and the exposed sandstone dominated stream beds, no adverse effects on stream bed or bank stability is anticipated in the 3rd order or higher main channels.

Up to 2.5m of subsidence in the 3rd order or higher tributary of LCT1 is predicted, which could cause a reduction in stream bed and bank stability, however this reach is currently significantly affected by previous subsidence over the Bulli longwalls, and it is not anticipated there will be additional, adverse effects from extraction of the proposed Wongawilli Seam longwalls

Up to 1.9m of subsidence in the 3rd order or higher tributary of LCT2 is predicted, which could cause a reduction in stream bed and bank stability in the 3rd order reach, but not in the 4th order reach, which does not overlie the proposed workings.

13.7.2 Wonga East

Due to the lack of significant subsidence in Cataract River and Bellambi Creek (no subsidence), along with the highly vegetated swamps and the exposed sandstone dominated stream beds, no adverse effects on stream bed or bank stability is anticipated in the 3rd order or higher main channels.

As a worst case scenario, subsidence of up to 0.8m may occur in Cataract Creek over longwall WE-A2-LW8, which may make it potentially prone to stream bed and bank instability, whereas the stream bed over or adjacent to the other panels at Wonga East are not anticipated to be at risk of stream bed or bank instability. However, based on the proponent’s commitment to limit subsidence impacts through adaptive management of the mine workings, the potential for cracking in Cataract Creek can be minimised.

13.8 Gas Emissions

Dilation in the strata immediately beneath the base of a stream due to valley bulging is restricted to the shallow strata, up to 20m below the surface, and does not provide a direct conduit for the release of gases from underlying, deeper strata.

Due to the pre-existing subsidence and crack development in the overburden over Wonga East and Wonga West, emission of gases at the surface is not anticipated to be an issue of concern.

13.9 Cataract Reservoir Water Storage and Quality

No reduction to the surface water or groundwater quality contribution to Cataract Reservoir is anticipated from the Cataract Creek, Cataract River or Bellambi Creek catchments.

A 0.06 – 0.07ML/day (or 5 - 6%) reduction of flow from the Cataract Creek to Cataract Reservoir is predicted at the end of Mining Wonga East Area 2. However, this quantum is insignificant when compared to the average daily evaporation from the reservoir, and taking into account the numerical difficulties involved in using the surface water and groundwater models to estimate creek flows, groundwater seepage and inflow to the workings.

Based on the variability of input parameters used in the modelling assessments and the high degree of interpretation required, it is assessed there is a low risk of reduced water yield to Cataract Reservoir.

Surface water modelling **(Appendix A)** and groundwater modelling (GeoTerra, 2012) indicate there is a low risk for potential loss of water or change to the water holding capacity of Cataract Reservoir.

It is worth noting that the Planning Assessment Commission report for the Metropolitan Coal project indicated that;

"analyses based on standard flow measurement techniques at discrete points are not capable of providing a definitive position on the likelihood or otherwise of water loss from a catchment (ie, Woronora Reservoir at Metropolitan), nor is a definitive position provided by hydrologic modeling. However, the local and regional groundwater conditions coupled with the mine parameters would suggest that the likelihood of water being lost from the surface water system as a consequence of mining, and then by passing (Woronora Reservoir) is very low."

As the issue was not beyond reasonable doubt, the PAC recommended that a program of monitoring should be developed between the proponent and the SCA to further investigate the existence or otherwise of catchment yield impacts.

The proposed workings have been positioned at sufficient distance from the Cataract Reservoir and there are no known geological structures which could cause a mining induced hydraulic connection between the workings and the base of the reservoir.

14. POTENTIAL CUMULATIVE IMPACTS

14.1 Lizard and Wallandoola Creeks

The description of potential subsidence effects on Lizard and Wallandoola Creeks due to extraction of the Wongawilli Seam as outlined in **Section 13** includes a discussion of the potential cumulative effects on those creeks, and the reader is referred to this section for further detail.

14.1.1 Creek Bed and Bank Stability and Pool Levels

The Bulli Seam underlying both Lizard and Wallandoola creeks has been mined in the Gujarat and Cordeaux leases by longwall extraction, with up to 1.5m of subsidence.

The proposed Wongawilli Seam extraction at Wonga West will generate up to 2.5m of predicted additional subsidence in the catchments of Lizard and Wallandoola Creeks at Wonga West.

The main channel of Lizard Creek is predicted to undergo up to an additional 0.25m of subsidence, whilst the main channel of Wallandoola Creek is predicted to undergo up to an additional 0.5m of subsidence.

Outside of the cumulative effect of previous Bulli workings subsidence, combined with the potential predicted subsidence within the overall catchments, no site specific, cumulative effect on the creek bed and bank stability or pool levels is anticipated due to the additional subsidence (at each particular feature).

14.1.2 Tributary, Upland Swamp and Main Channel Stream Flow Connectivity

A potential cumulative effect of subsidence on the stream flow from first and second order streams, which may or may not also contain upland swamps is possible if the subsurface transfer of the tributary / swamp water outflows does not report back into the lower reach of the tributary, before it discharges into the main third order channel of Lizard or Wallandoola Creek.

In our experience, although the upper tributaries / swamps can transfer overland flow to subsurface throughflow in subsided areas, they discharge the stream flow back into the third order flow system of the main creeks at or near their confluence with the main stream, so negligible volumes of tributary / swamp outflow is “lost” to the system.

Significant ferruginous precipitates have been observed in tributaries LCT1 and LCT2 over previously mined areas, which discharge into the main stream of Lizard Creek, however no definitive assessment can be made as to whether they are due to subsidence, or not, as no pre-mining surveys are available.

14.1.3 Stream Water Quality

Where the re-emergent tributary / swamp outflow over subsidence areas re-enters the main stream, ferruginous precipitates, along with lower dissolved oxygen, localised and marginally more acidic pH and slightly elevated salinity seeps can be observed at the point of entry.

However, monitoring conducted in the NRE1 lease area indicates the adverse effects only last for a few tens of metres and that the water quality downstream of the “mixing” zone is only negligibly affected, if at all.

14.2 Cataract Creek

The description of potential subsidence effects on Cataract Creek due to extraction of the Wongawilli Seam as outlined in **Section 13** includes a discussion of the potential cumulative effects on those creeks, and the reader is referred to this section for further detail.

14.2.1 Creek Bed and Bank Stability and Pool Levels

The Bulli, Balgownie and Wongawilli workings, which underly the Cataract Creek catchment have been mined in the Gujarat and Cordeaux leases by longwall extraction with up to 1.4m of subsidence.

The proposed Wongawilli Seam extraction at Wonga East will generate up to 1.2m of predicted additional subsidence in the Cataract Creek catchment.

As a worst case scenario, the main channel of Cataract Creek is predicted to undergo up to an additional 0.8m of subsidence over longwall WE-A2-LW8 (Seedsman Geotechnics, 2012).

Outside of the cumulative effect of previous Bulli, Balgownie and Wongawilli workings subsidence, combined with the potential predicted subsidence within the overall catchments, no site specific, cumulative effect on the creek bed and bank stability or pool levels is anticipated due to the additional subsidence (at each particular feature).

To date, with three seams being mined in the Cataract Creek catchment, there has been no observable adverse effects on stream bed and bank stability or pool levels.

14.2.2 Tributary, Upland Swamp and Main Channel Stream Flow Connectivity

A potential cumulative effect of subsidence on the stream flow from first and second order streams, which may or may not also contain upland swamps is possible if the subsurface transfer of the tributary / swamp water outflows does not report back into the lower reach of the tributary, before it discharges into the main third order channel of Cataract Creek.

In our experience, although the upper tributaries / swamps can transfer overland flow to subsurface throughflow in subsided areas, they discharge the stream flow back into the third order flow system of the main creeks at or near their confluence with the main stream, so negligible volumes of tributary / swamp outflow is “lost” to the system.

To date, with three seams being mined in the Cataract Creek catchment, there has been no observable adverse effects on tributary, upland swamp and the main channel stream flow connectivity.

14.2.3 Stream Water Quality

Where the re-emergent tributary / swamp outflow over subsidence areas re-enters the main stream, ferruginous precipitates, along with lower dissolved oxygen, slightly more acidic pH and slightly more saline seeps can be observed at the point of entry.

However, monitoring conducted in the NRE1 lease area indicate that the adverse effects only last for a few tens of metres and that the water quality downstream of the “mixing” zone is only negligibly affected, if at all.

Significant ferruginous precipitates have been observed in tributary CT1 over previously mined areas, which discharge into the main stream of Cataract Creek, however no definitive assessment can be made as to whether they are due to subsidence, or not, as no pre mining surveys are available.

14.3 Wonga West Interaction with the BHPB Cordeaux Workings

14.3.1 Stream Flow and Connectivity

Due to a lack of pre and post extraction data, the impacts, effects and consequences to stream flow and stream connectivity from the Cordeaux workings, located upstream of the proposed Area 3 and Area 4 mining domains in both the Lizard and Wallandoola Creek catchments, cannot be quantified.

However, observations for this study indicate that the stream flow discharging from the Cordeaux lease area is essentially perennial and contains ferruginous seepages.

No additional workings are currently proposed in the Cordeaux lease or in the BHPBIC lease between the proposed Gujarat workings and the Cataract River, and therefore there are no anticipated additional cumulative effects on stream flow or stream connectivity.

14.3.2 Pool Heights

The Cordeaux lease area located upstream of the Gujarat lease in the Lizard and Wallandoola Creek catchments at Wonga West is predominantly composed of valley fill upland swamps, and as such, any pools which are present are predominantly shallow and of limited extent.

The proposed mining at Wonga West Area 3 and 4 is not anticipated to generate sufficient subsidence, strains or tilts to adversely affect the pools in the Cordeaux lease.

No mining is currently proposed between the Gujarat lease and the Cataract River junction at Wonga West.

14.3.3 Stream Water Quality

The water quality discharging from the Cordeaux lease has a median pH of 6.02 and EC of 124µS/cm in Wallandoola Creek and median pH and EC of 5.44 and 110µS/cm respectively.

Parameters which exceed the ANZECC 2000 water quality criteria discharging from the Cordeaux lease, as monitored at Sites LC2 and WC2, can include:

- copper (up to 0.004mg/L in Lizard and Wallandoola Creeks);
- zinc (up to 0.054mg/L in Lizard & 0.026mg/L in Wallandoola Ck);
- aluminium (up to 0.25mg/L in Lizard & 0.05mg/L in Wallandoola Ck);
- total nitrogen (up to 2.60mg/L in Lizard and 2.5mg/L in Wallandoola Ck);
- total phosphorous (up to 4.2mg/L in Lizard and 0.2mg/L in Wallandoola Ck).

As there is no new mining planned in the Cordeaux lease, and as the Cordeaux catchments are interpreted to have attained a “steady state” (GeoTerra, 2012), there are no new anticipated cumulative impacts on the water quality within and discharging as a result of the proposed Wongawilli Seam extraction.

14.4 Wonga East Interaction with BHPBIC Bulli and Cordeaux Workings

14.4.1 Bellambi Creek

The Bulli Seam underlying Bellambi Creek has been mined by the BHPBIC Bulli mine workings by bord and pillar as well as pillar extraction methods.

14.4.2 Cataract River

The Cordeaux mine has extracted the Bulli Seam with both bord and pillar, as well as longwall mining methods in the Cataract River catchment.

Outside of the pre-existing regional cumulative groundwater depressurisation of the overburden, there are no anticipated cumulative impacts within Bellambi Creek due to the interaction of the BHPBIC Bulli mine workings and the proposed Wongawilli Seam extraction, as the predicted subsidence effects are predominantly contained within the Cataract Creek catchment.

Outside of the pre-existing regional cumulative groundwater depressurisation of the overburden, there are no anticipated cumulative impacts within Cataract River due to the interaction of the BHPBIC Cordeaux workings and the proposed Wongawilli Seam extraction, as the predicted subsidence effects are predominantly contained within the Cataract Creek catchment.

14.5 Potential Vertical and Horizontal Connective Fracturing

The potential cumulative effects of vertical and horizontal, connective fracturing and overburden depressurisation is discussed in (GeoTerra, 2012).

15. MONITORING AND MANAGEMENT

A catchment based Water Management Plan incorporating detailed provisions for surface water and groundwater, monitoring, analysis, data collection, interpretation, reporting, management and rehabilitation should be prepared once approval for the project is achieved.

The monitoring and data interpretation should be best practice for the detection of surface water and groundwater impacts of subsidence within stream beds and the broader sub-catchments, as well as in the shallow and deeper (regional) groundwater systems.

A key aspect of the Plan should deal with the early detection and assessment of subsidence (or uplift) effects within the subject streams and groundwater systems using appropriately sampled and analysed geochemical and physical data to provide early indication of any subsidence related surface water or groundwater effects.

Measurement and/or monitoring of compliance with performance measures and performance indicators will be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods will be fully described in the relevant management plans.

15.1 Management Plans and Trigger Action Response Plans

As subsidence could potentially affect the Study Area streams, the following components within monitoring, management and Trigger Action Response Plans (TARP) should be prepared to manage the risks that cover the following issues;

- stream and tributary flow;
- rock bar constrained and pool water holding capacity;
- stream water quality
- waterfalls, and;
- upland swamps.

15.2 Stream Pools and Flow

Daily automated monitoring of selected pool water depths upstream, within and downstream of the Study Area should be conducted and compared to rainfall in the local area. The monitoring sites would be sited upstream, within and downstream of the proposed 20mm subsidence area, at locations that are permanently wet.

Where the stream bed status, current flow diversions and site logistics allow, the stream monitoring locations should also be monitored for volumetric flow.

Monitoring should assess the inputs from catchment runoff and any flow variations within the Study Area before, during and after the extraction period, particularly for low flows.

The collected data should review any observable changes that develop, and, subsequently develop a plan to manage any adverse issues, if appropriate.

The chemical characteristics and concentrations of stream water quality parameters such as pH, temperature, dissolved oxygen, salinity (EC) and major ions can also be used to assess the flow mechanisms within a major stream.

Use of portable / dismountable flow gauging equipment that does not adversely affect the stream ecology may be required to obtain quantitative flow data for hydrologic assessment.

Baseflow separation analysis is not a suitable method in the Study Area as the method can only be used;

- in ‘gaining’ streams (the upper tributaries and main channels of the Study Area streams are ‘losing’ streams);
- as the swamps also contribute to delayed discharge to the main streams from their storages, and it can only be used to;
- characterise the groundwater discharge regime at the stream gauging site,which provides information on the temporal changes but not the spatial distribution of groundwater inputs along a stream.

15.3 Stream Water Quality

Water quality monitoring should be conducted in Wallandoola, Lizard and Cataract Creeks as well as the Cataract River, upstream of Cataract reservoir, upstream, within and downstream of the Study Area before, during and after the period of extraction.

Water quality related field studies should concentrate on regular visits to main channel sites that would be monitored for identifiable inputs from catchment runoff and all key water quality parameter variations for the duration of mining and for an appropriate period following mining.

Monitoring should be conducted for the following parameters:

- Field pH, electrical conductivity, dissolved oxygen, oxidation / reduction potential and temperature;
- total dissolved solids;
- Na / Ca / Na / K / SO4 /Mg / Cl / F;
- total alkalinity;
- dissolved organic carbon;
- total / filterable Fe, Mn, Al;
- filterable Ni, As, Li, Ba, Sr, Cu, Pb, Zn, and ;
- total nitrogen and total phosphorous.

Stream water level, or spot flow monitoring and sampling should be conducted, where logistically feasible, at all locations on the same day. All samples should be collected in appropriately cleaned and prepared equipment, stored in appropriately cleaned and rinsed sample containers, then transported and analysed according to ANZECC 2000 standards, with 0.45μm filtering and nitric acid preservation to less than pH2 for metals samples.

Trigger values for selected pollutants of concern should be set within the context of a Trigger Action Response Plan (TARP), and where the values are exceeded, the cause and effect of the exceedance should be investigated and a management plan developed if the cause is directly related to mining.

The TARP system provides a simple and transparent snapshot of the monitoring of environmental performance and where required the implementation of management and/or contingency measures.

These should be reviewed following collection of additional baseline data, and additional water quality monitoring sites may need to be established as the monitoring program progresses.

The TARP should illustrate how the various predicted subsidence impacts, monitoring components, performance measures and responsibilities are structured to achieve compliance with the relevant statutory requirements and the framework for management and contingency actions.

15.4 Stream Erosion and Destabilisation

Subsidence may induce minor bed or bank erosion over the proposed panels, particularly in the headward and downstream sections of any subsidence troughs, as well as over the chain pillars.

As the creek banks are well vegetated, no significant change is anticipated and it is not envisaged that stream bank remediation will be required.

Any changes to the current state will be visually monitored after significant stream flow events, and if adverse subsidence / uplift effects occur, a specific management and rehabilitation plan should be developed for the affected areas.

15.4.1 Bedload Movement

If erosion occurs in a stream, it may cause a minor increase in potential bedload movement in and downstream of the subsidence area, which will be visually monitored during and after significant flow events.

Significant bedload movement is not anticipated and therefore stream bed or bank management and rehabilitation is not anticipated to be required.

15.4.2 Stream Gradient

It is not anticipated that significant observable change will occur due to subsidence and that stream gradient rehabilitation measures will not be required in the main stream channels.

15.4.3 Riparian Vegetation

Vegetation in the stream and banks will be visually monitored over the proposed mining area before and after any stream is undermined, particularly after significant flow events.

As no adverse effect on the riparian vegetation is anticipated, no vegetation rehabilitation measures are anticipated.

15.4.4 Waterfalls

The integrity and overland flow of the waterfalls should be monitored, along with specific subsidence measurements to indicate if any adverse effects on the waterfalls may have the potential to more than “negligibly” affect them, and necessitate “adaptive” management” of the planned mining.

15.4.5 Rock Bars

The integrity and pool holding capacity of rockbars in the potential subsidence zone should be monitored, along with specific subsidence measurements to indicate if any adverse effects may have the potential to more than “negligibly” affect them, and necessitate “adaptive” management” of the planned mining.

15.5 Mine Inflows

Mine inflows should be monitored through measurement of all water pumped into and out of the NRE No. 1 workings where underground logistics are suitable.

15.6 Rainfall

Rainfall should be monitored daily at the mine’s and the nearest Bureau of Meteorology weather station, as well as a dedicated rain station within the catchment for the duration of mining.

The quantity and variability of stream flow in Wallandoola, Lizard and Cataract Creeks will be monitored by data loggers to assess the rainfall / runoff relationship, with photography used to monitor flow conditions in both creeks as well as their unnamed tributaries.

15.7 Reporting

An end of panel report should be prepared for the mined panel, which should summarise all monitoring conducted over the period. The report will outline any changes in the surface water or groundwater system over the mined out areas.

If required, a meeting will be convened with the OEH and / or NOW and the SCA at the mine office to discuss requirements for remediation and ongoing monitoring.

All monitoring and management activities will be reported in the Annual Environmental Management Report (AEMR) in subsequent years.

15.8 Ongoing Monitoring

All results should be reviewed one year after each panel has been completed and an updated ongoing monitoring and remediation program will be developed in association with the OEH, NOW and the SCA.

15.9 Quality Assurance and Control

QA/QC will be attained by calibrating all measuring equipment, ensuring that sampling equipment is suitable for the intended purpose, NATA registered laboratories are used for chemical analyses and that site inspections and reporting follow procedures outlined in the ANZECC 2000 Guidelines for Water Quality Monitoring and Reporting.

Field sample collection, storage, despatch, laboratory analysis, interpretation and reporting will be conducted according to ANZECC 2000 requirements.

15.10 Potential Subsidence Impact Contingency Measures

If monitoring indicates there has been significant hydrologic or aquatic ecotoxic effect then management and mitigation measures may be required.

Management measures may involve alterations to the area of extraction or modification to the orientation and/or disposition of future mining.

In the event a subsidence impact water resource or watercourse performance measure is considered to have been exceeded or is likely to be exceeded, Gujarat should implement the following Contingency Plan:

- the likely exceedance of the water resource or watercourse performance measure will be reported to the Technical Services Manager and/or the Environment and Community Manager within 24 hours of assessment completion;
- the Technical Services Manager or the Environment and Community Manager will report the likely exceedance to the General Manager as soon as practicable after becoming aware of the exceedance, and;
- the mine will report the likely exceedance of the water resource or watercourse performance measure to the DoP, SCA and DECCW as soon as practicable after they become aware of the exceedance.

The mine should identify an appropriate course of action with respect to the identified impact(s) in consultation with specialists and relevant agencies, as necessary. For example:

- proposed contingency measures;
- a program to review the effectiveness of the contingency measures; and
- consideration of adaptive management under circumstances where a water resource or watercourse performance measure has been exceeded.

Contingency measures should be developed in consideration of the specific circumstances of the exceedance and the assessment of environmental consequences.

Gujarat should submit the proposed course of action and a program to review the effectiveness of the contingency measures to the DoP for approval and should implement the approved course of action to the satisfaction of the DoP. Potential contingency measures for an exceedance of the water resource or watercourse performance measures could include:

- additional monitoring that increases the monitoring frequency or additional sampling to inform the proposed contingency measures;
- implementation of stream remediation measures to reduce the extent of fracturing;
- implementation of revegetation measures to remediate impacts of gas releases on riparian vegetation;
- provision of a suitable offset(s) to compensate for the reduction in the quantity of water resources reaching Cataract Reservoir or Cataract River, and;
- implementation of adaptive management measures, such as reducing the thickness of the coal seam extracted, narrowing of the longwall panels and/or increasing the setback of the longwalls from the affected area.

Ongoing monitoring should be required to assess whether any subsidence related physical and / or chemical changes to stream flows, stream or swamp water quality and stream or swamp integrity occur, as well as to validate predicted impacts on swamp groundwater levels, mine seepage and swamp groundwater water quality.

All relevant rehabilitation actions will be derived in association with the DoP, OEH, NOW and SCA and will be acted upon as appropriate.

At the end of the subject mining, assessment of the field and laboratory data will be completed to determine whether any unanticipated trends are occurring, and a review of measures will be required to address the issue if a subsidence / uplift related trend is apparent.

15.11 Adaptive Management

Precautionary and 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 stream systems overlying the proposed mining domains.

The adaptive management process is based on the premise that avoidance of adverse impacts is preferential to rehabilitation of adverse consequences to a stream.

Monitoring, evaluation, and reporting on management performance and ecological impact should be integrated into the site's management systems to progress the technical understanding and predictive capability of subsidence effects, impacts and consequences on the potentially affceted 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.

Longwall WE-A2-LW5 is proposed to be mined under a separate approval application (MP 10_0046-MOD 1) which is currently with the DoPI. Longwall WE-A2-LW5 does not overlie the main channel or significant tributaries of Cataract Creek. As such, it will provide a good "baseline" monitoring opportunity to assess the effect of subsidence on fracture propogation and development through the overburden, as well as the;

- height of fracturing,
- development of cracking at surface,
- changes to an upland swamp perched water system in Crus1 and Ccus4, and;
- water quality in Cataract Creek and any mine inflow changes.

Data gained from monitoring a suite of extensiometers, 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 curent geotechnical, hydrogeological and hydrological assessments for the proposed mining and to incorporate, if required, adaptive management measures for future panels.

Adaptive management measures that could be used include;

- monitoring of the predicted and observed subsidence impacts, effects and consequences over the Wonga East workings. Using the data base, update subsidence predictions for the Wonga West panels and if required, modify the mining geometry for Wonga West;
- reducing the thickness of coal seam extracted if subsidence monitoring indicates a change is required;
- narrowing the longwall panels if subsidence monitoring indicates a change is required, or;
- increasing the longwall setback from a stream to limit the subsidence effects, impacts and consequences, or
- changing the start / finish lines of subsequent longwalls in order to manage subsidence impacts

In adaptive management the goal to be achieved is set so there is certainty of the outcome and the conditions requiring adaptive management do not lack certainty. The measures should establish a regime which would permit changes within defined parameters, to indicate how the outcome is to be achieved.

The Bulli PAC outlined that adaptive management measures may be required if the "Precautionary Principle" is triggered when two pre conditions exist. The conditions are that;

- a threat of serious or irreversible environmental damage is present which can be direct or indirect and where incremental or cumulative impacts are included, and;
- if there is scientific uncertainty as to the potential environmental damage

The proposed adaptive management measures will need to assess the:

- existence of the threat of serious or irreversible harm;
- degree of scientific certainty;
- spatial scale of the threat;
- magnitude of possible impacts;
- seriousness or irreversibility of environmental damage
- perceived value of the threatened environment;
- temporal scale, including persistence;
- complexity and connectivity of the possible impacts;
- manageability of impacts, through the availability and acceptability of the proposed measures (assess what is possible in principle, economically and within a reasonable timeframe);
- level of public concern and the basis for that concern;
- scientific or other evidentiary basis for that concern;
- reversibility of the impacts including management or rehabilitation feasibility
- level of precaution required;
- cost of prevention, and the;

- proportionality of the solution

The key elements of an adaptive managemnet plan should include:

- monitoring of impacts based on agreed indicators;
- conducting research to reduce key uncertainties;
- adjustment of the activity based on the results and;
- an efficient and effective compliance system.

A step-wise adaptive management approach to managing the threat should involve an iterative approach involving testing of achievement of defined goals. Through feedback to the management process, the management procedures should be changed in steps until monitoring shows the desired outcome is obtained and that there is statistical confidence in the outcome.

16. POTENTIAL REHABILITATION

If any adverse impacts occur as a result of subsidence on the streams over the proposed Wonga East and Wonga West mining domains, Gujarat should undertake appropriate remediation as agreed to by the SCA, OEH and NOW.

A Stream Rehabilitation Management Plan and Remediation Register should be used to manage implementation of remediation measures in accordance with approval from the SCA, OEH and NOW.

A potential subsidence impact performance criteria could be that negligible environmental consequences, including negligible;

- diversion of flow,
- change in the natural pool drainage behaviour,
- iron staining,
- gas release and;
- increase in water cloudiness

will occur over at least 80% of the length of the main channel of Lizard, Wallandoola and Cataract Creeks that are subject to greater than 20mm of subsidence.

Stream remediation activities should be conducted where monitoring results indicate the subsidence impact performance measure where surface flow and / or pool holding capacity of a pool has been adversely affected due to subsidence, except where the change is due to climatic conditions, has been exceeded. Exceedance of the subsidence impact performance measure will be assessed as a component of the overall Water Management Plan for the proposed longwalls.

Remediation should commence when the rate of valley closure (as measured monthly by ridge to ridge survey points) is less than 20 mm/month following mining of the subsequent longwall.

More than one remedial effort may be required at a pool or rock bar as ongoing incremental impacts may result in association with successive longwalls. In addition, the timing of remediation activities will also be influenced by practical considerations, as entry to the creek bed will require surface flow over a particular rock bar to be absent.

Fracture characterisation should be conducted to measure the depth and lateral extent of the sub-surface fracture network at each location requiring remediation. These could include the drilling of cored holes to a depth of approximately 20m to:

- determine the depth of fracturing;
- measure the relative volume of fine versus large void spaces;
- determine the horizontal connectivity between fractures; and
- use of a borehole calliper to identify the location of individual fractures.

The principal management measure that could be used to restore surface flow and pool holding capacity is polyurethane (PUR) grout injection into the fracture network which should reduce the permeability of the rock by filling voids and reducing subsurface flow diversion paths.

Grouting products that could be used include CarboPur (WFA and WF grades), which are products used for consolidation, stabilisation and/or sealing of strata. A grout curtain could be constructed across a rock bar by drilling a line of holes at regular intervals (approximately 2m) and progressively injecting grout down to 20m below surface.

The design of any remediation and rehabilitation strategy must be cognisent of the overall environmental impacts and as such be developed on a case specific basis.

Direct access to a particular section of a stream will determine the remediation necessary and the extent to which it is implemented.

Other potential remediation techniques include:

- Hand grouting - sealing cracks exposed at surface using hand applicators;
- Shallow pattern grouting - drilling shallow holes with small hand held equipment and low pressure grout injection with a portable pump;
- Deep pattern or curtain grouting - drilling deeper holes with air hammer or reverse circulation drilling rigs and higher pressure grouting techniques, and;
- Deep angle hole cement grouting - remote directional drilling used to access inaccessible sites using the same grouting methods as deep pattern/curtain grouting methods.

The range of techniques will be considered in the design of any stream remediation program. Any technique used will need to be approved by the SCA, OEH, NOW, NSW I&I (Fisheries) and the DoP.

Where remediation activities involve drilling and grout injection into sub-surface fractures, associated activities should involve procedures for the mobilisation, placement and operation of equipment as well as implementation of a necessary environmental management measures. Drilling equipment could include a drill rig and rods, geofabric straw bale filters, tape barriers at access points, air compressors, hoses, compressed air pumps, a Dingo and a drill rig 'A' frame to enable assembly/disassembly for heli lifting.

Injection equipment could include a pneumatic PUR injection pump, diesel-operated compressor, high capacity pressure delivery hoses, static mixing unit/injection gun assembly, injection tubes and packers and a temporary shelter for personnel and equipment.

A range of environmental management measures should be described in the Stream Rehabilitation Management Plan and should be implemented during remediation works. Measures could include:

- management of soil and vegetation disturbance;
- erosion and sediment controls to minimise the potential for downstream effects;
- stream flow diversion and reduction of sub-surface flows during application of grout;
- drill cuttings containment and disposal;
- fuel management;
- management of grouting products and injection operations;
- waste management; and
- transport and handling of equipment and materials.

16.1 Baseflow Offsets

If the agreed performance measures are exceeded and the DRE Director-General determines that it is not reasonable or feasible to remediate the impact or environmental consequence, or remediation measures implemented by Gujarat have failed to satisfactorily remediate the impact or environmental consequence, then Gujarat will provide a suitable baseflow offset to compensate for the impact or environmental consequence, to the satisfaction of the Director-General.

Any baseflow offset will be proportional with the significance of the impact or environmental consequence.

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In preparing this report, GeoTerra has relied upon information and documentation provided by the client and / or third parties. GeoTerra did not attempt to independently verify the accuracy or completeness of that information. To the extent that the conclusions and recommendations in this report are based in whole or in part on such information, they are contingent on its validity. GeoTerra assume the client will make their own 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.

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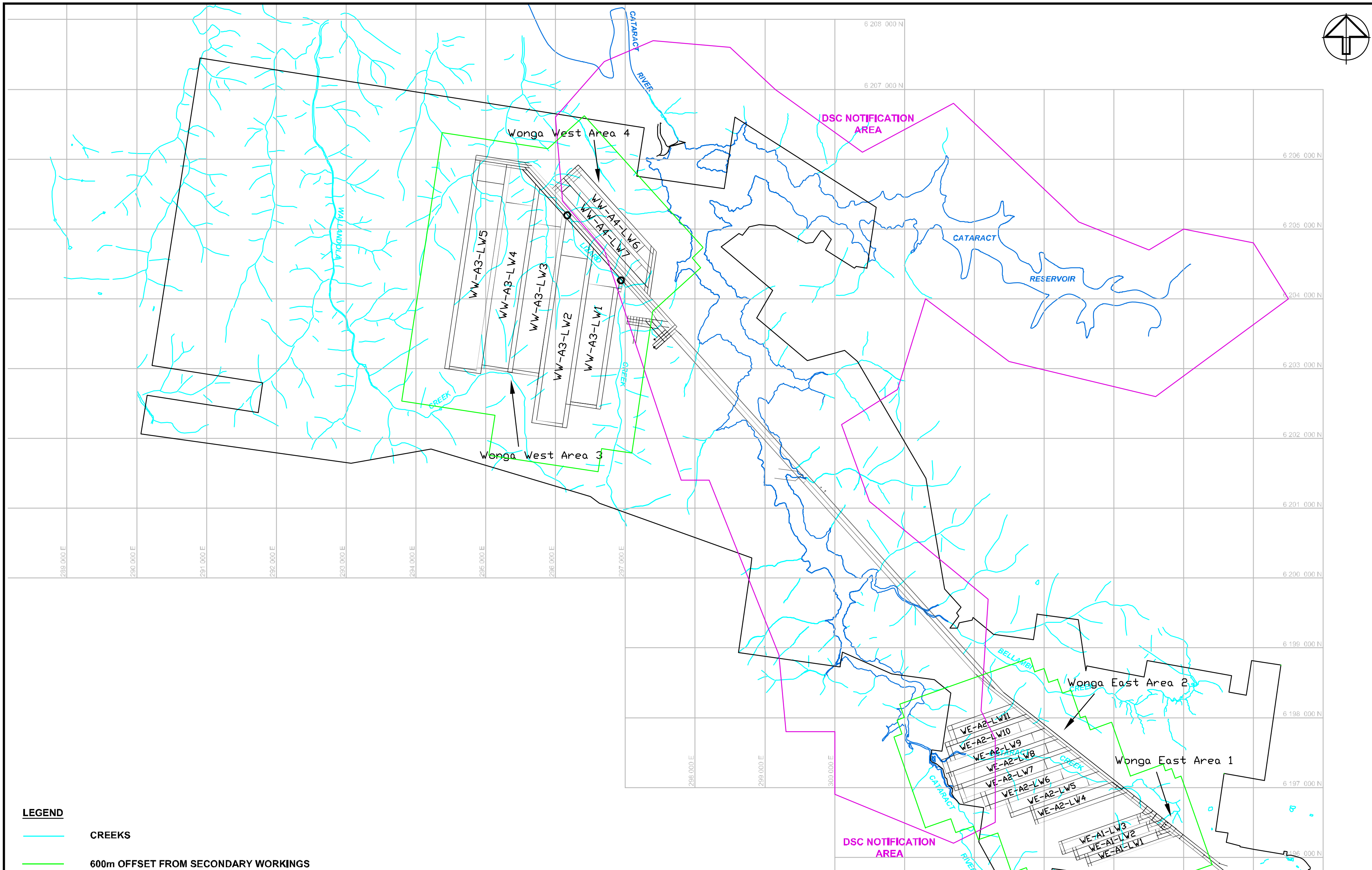
Interpretations and recommendations provided in this report are opinions provided for our Client's sole use in accordance with the specified brief. As such they do not necessarily address all aspects of water, soil or rock conditions on the subject site. The responsibility of GeoTerra is solely to its 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.



LEGEND

CREEKS

600m OFFSET FROM SECONDARY WORKINGS

PROJECT:	GUJ1-G-R1	GUJARAT NRE COKING COAL LTD NRE No.1 COLLIERY	GeoTerra
DRAWN:	A. DAWKINS		
DATE:	26 Oct 2012	PROPOSED WONGAWILLI WORKINGS	DRAWING 1
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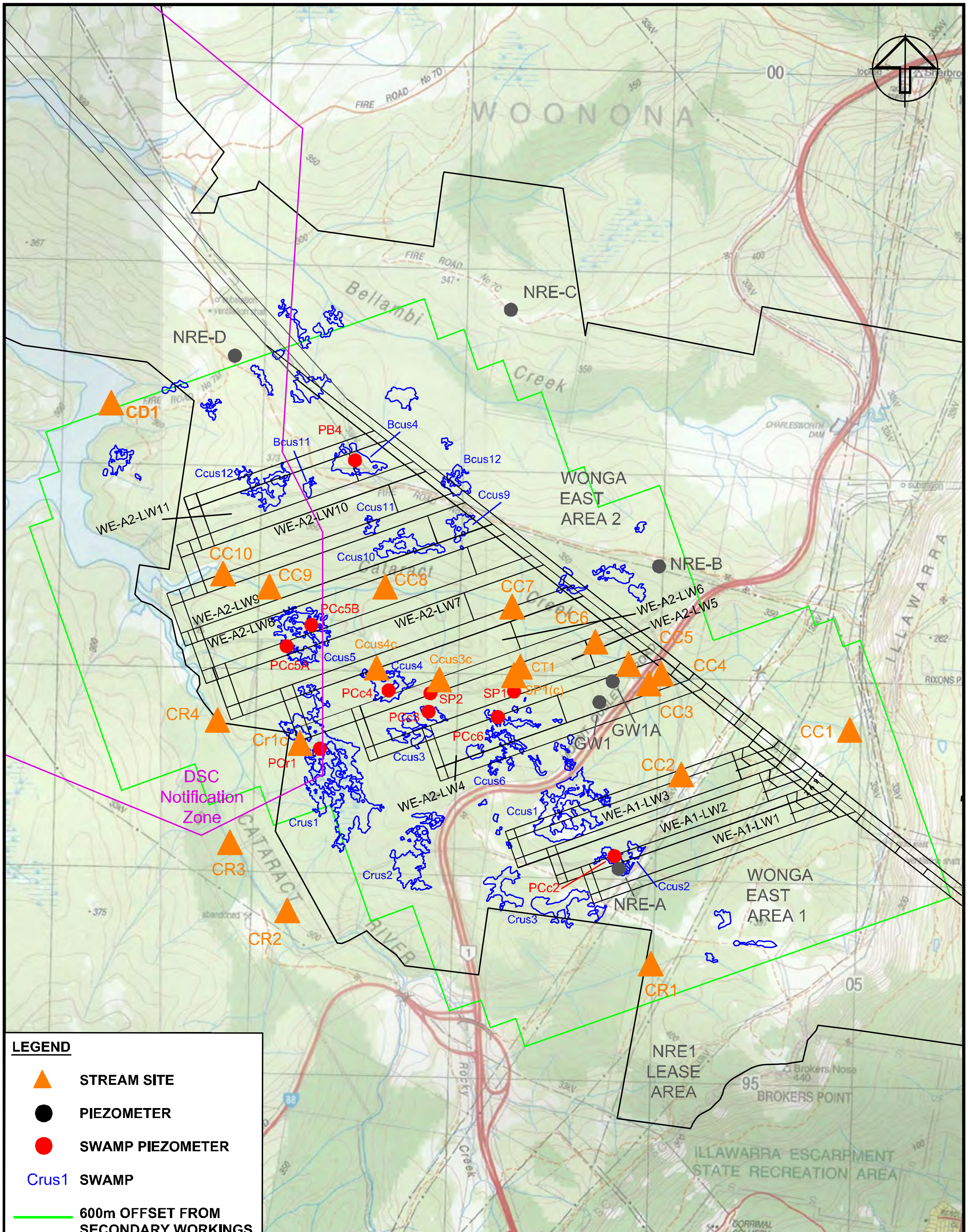

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DRAWN:	A. DAWKINS		
DATE:	26 Oct 2012	**Proposed Wonga East Workings and Monitoring Locations**	**DRAWING 2**
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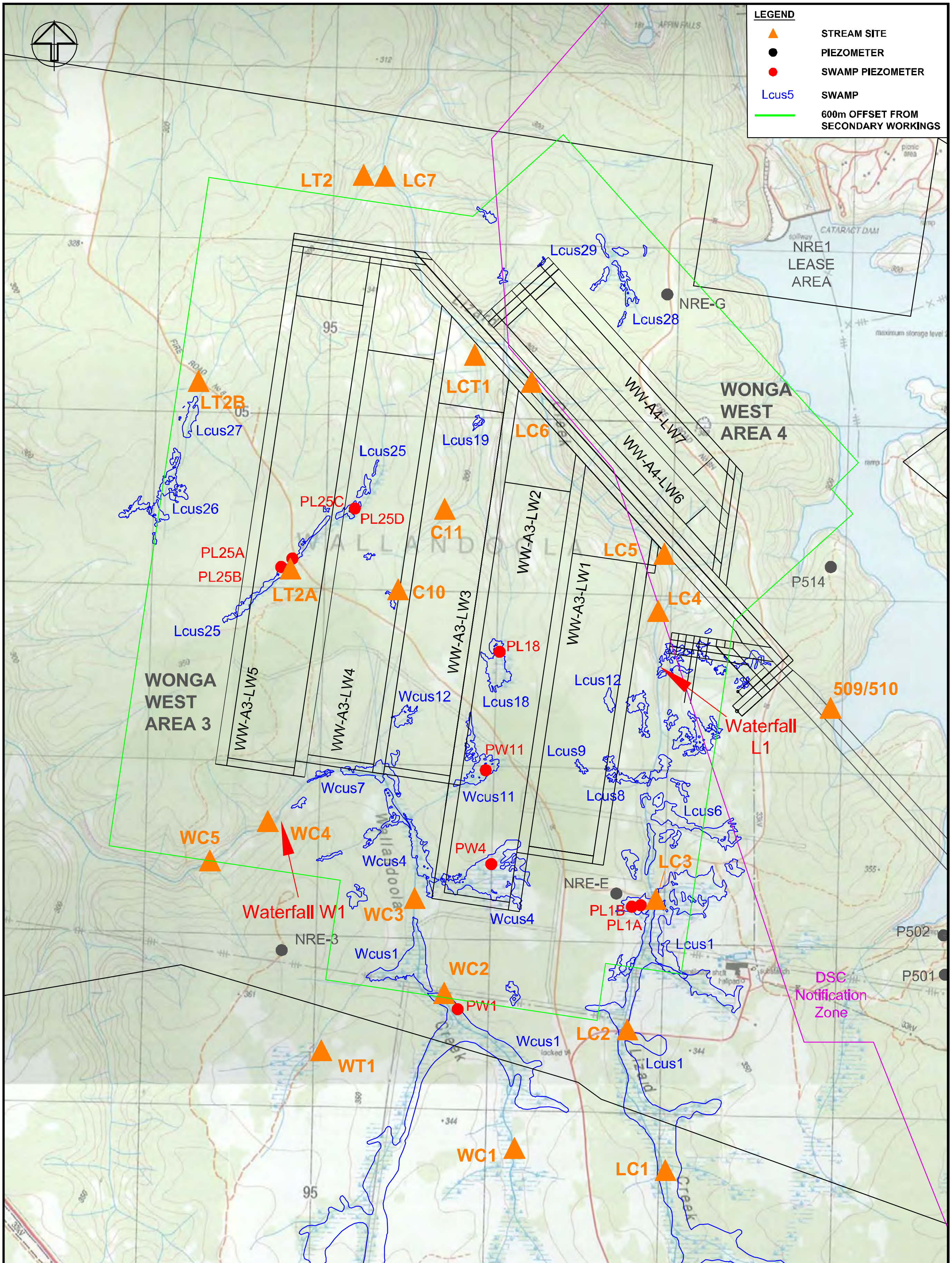

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DRAWN:	A. DAWKINS
DATE:	18 July 2011
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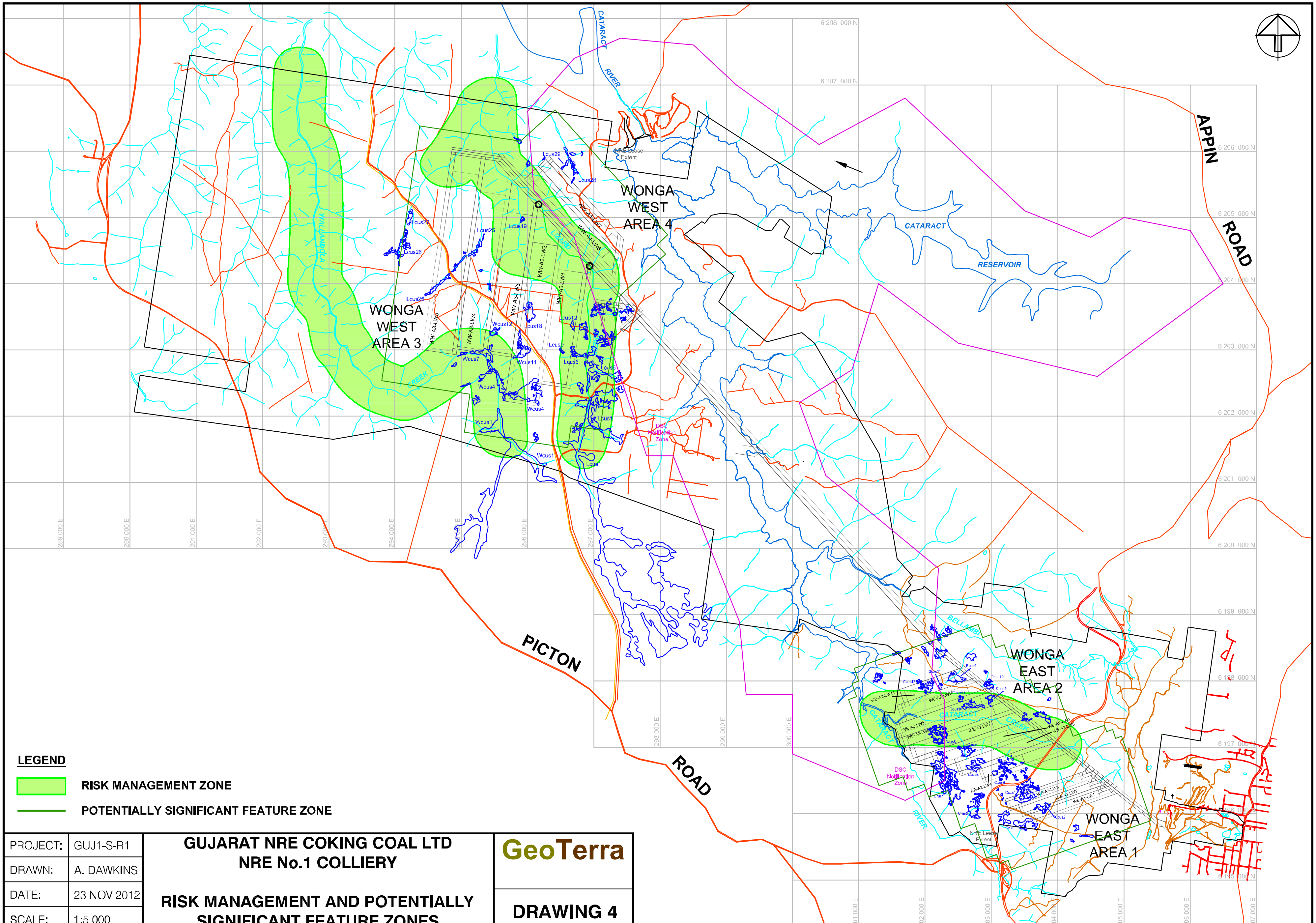
GUJARAT NRE COKING COAL LTD
NRE No. 1 COLLIERY

Proposed Wonga West Workings and Monitoring Locations

GeoTerra

DRAWING 3



LEGEND

RISK MANAGEMENT ZONE

POTENTIALLY SIGNIFICANT FEATURE ZONE

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DRAWN:	A. DAWKINS		
DATE:	23 NOV 2012	RISK MANAGEMENT AND POTENTIALLY SIGNIFICANT FEATURE ZONES	DRAWING 4
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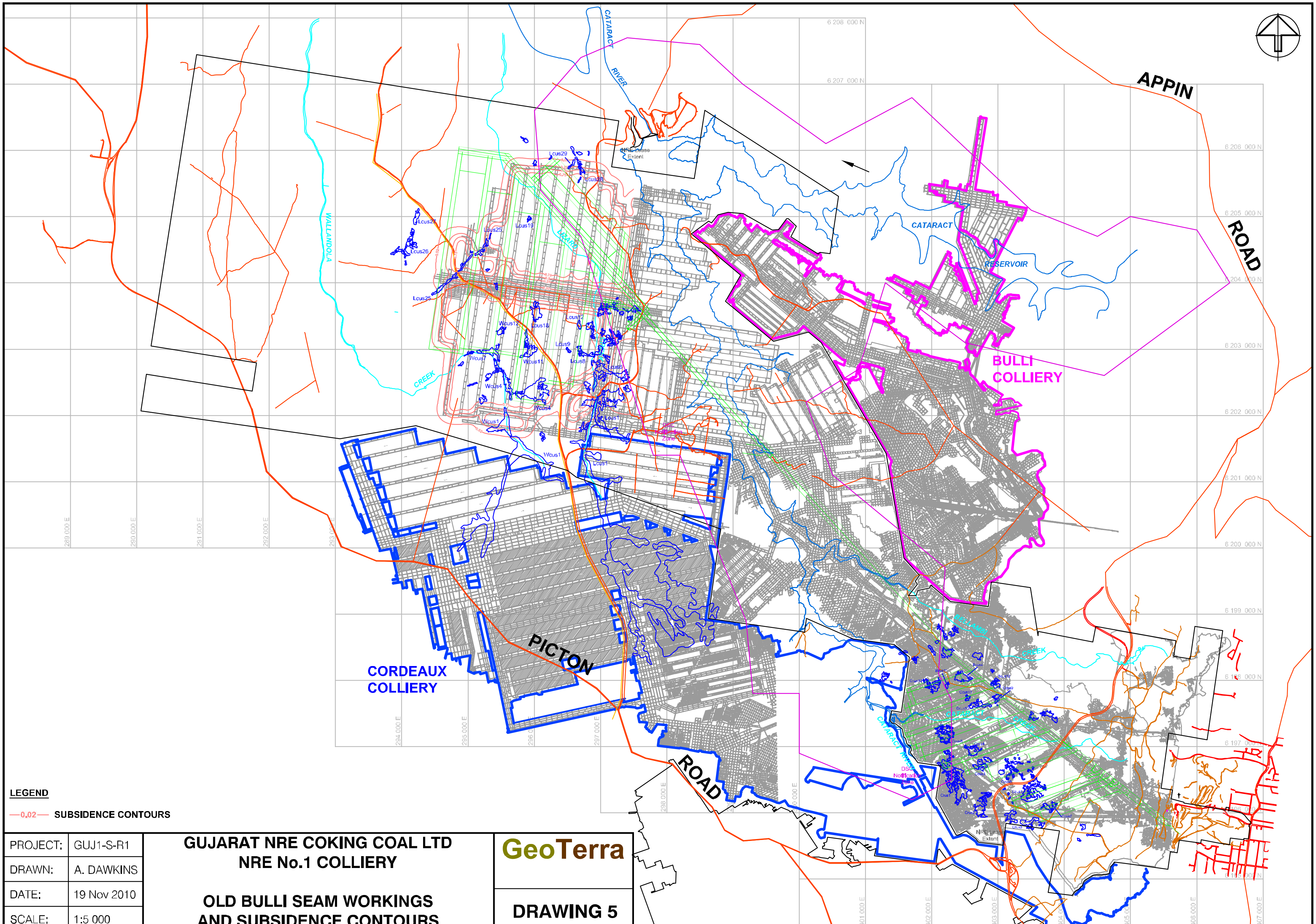

LEGEND

—0.02— SUBSIDENCE CONTOURS

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DATE:	19 Nov 2010		
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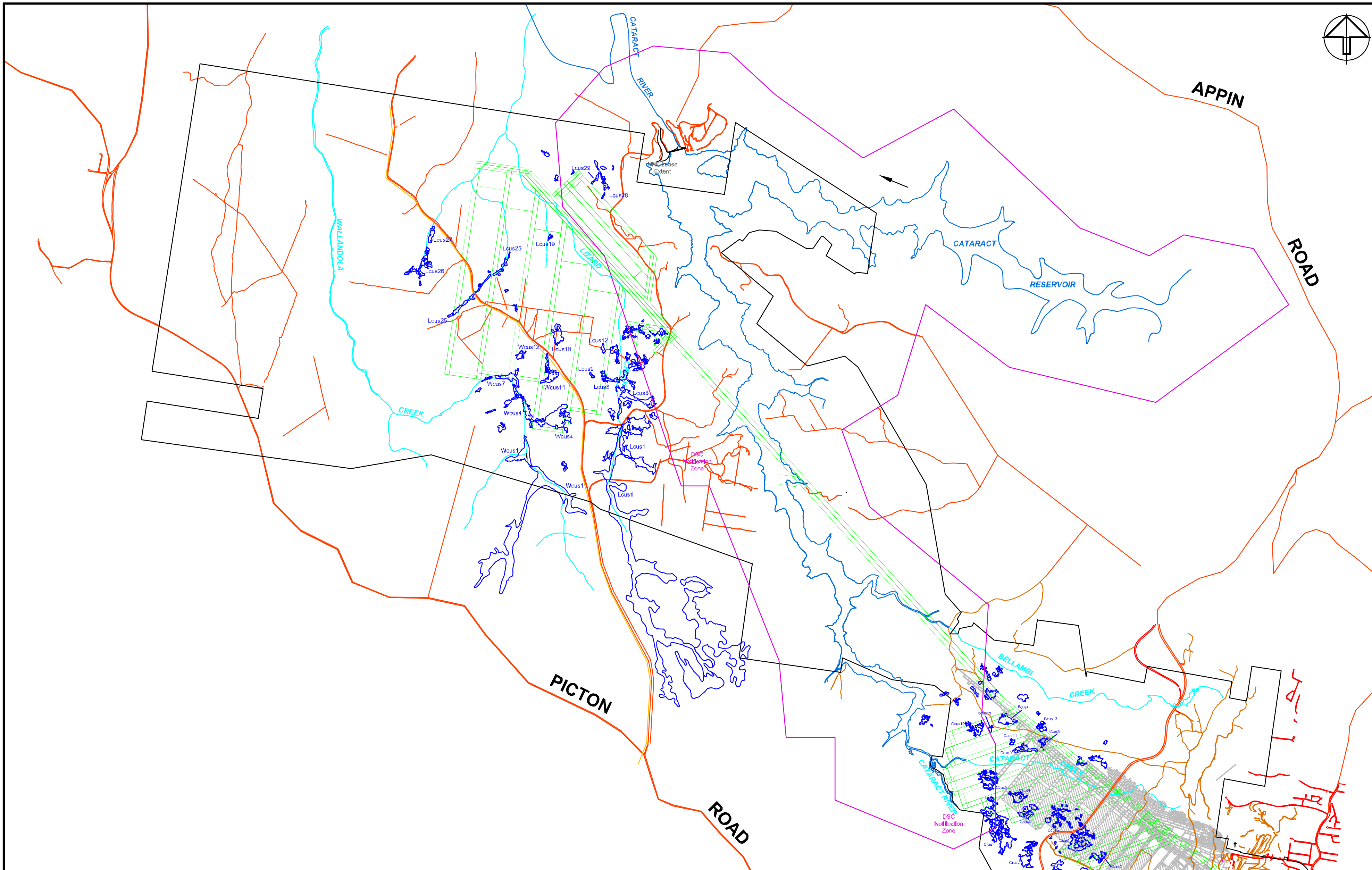


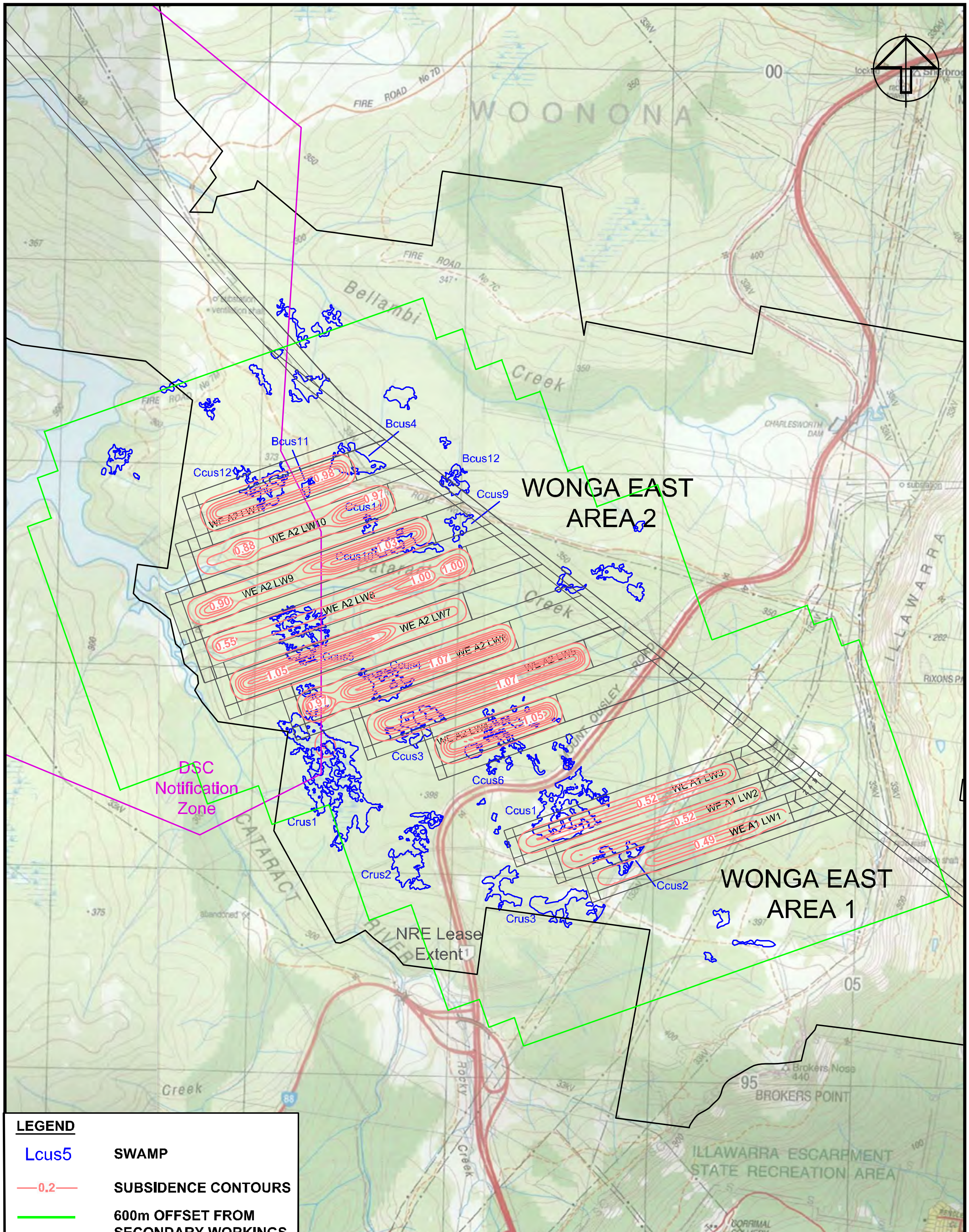
PROJECT:	GUJ1-S-R1
DRAWN:	A. DAWKINS
DATE:	26 OCT 2012
SCALE:	1:5 000

GUJARAT NRE COKING COAL LTD
NRE No.1 COLLIERY

OLD BALGOWNIE WORKINGS

GeoTerra

DRAWING 6



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DRAWN:	A. DAWKINS		
DATE:	26 OCT 2012	**Proposed Wonga East Subsidence**	**DRAWING 7**
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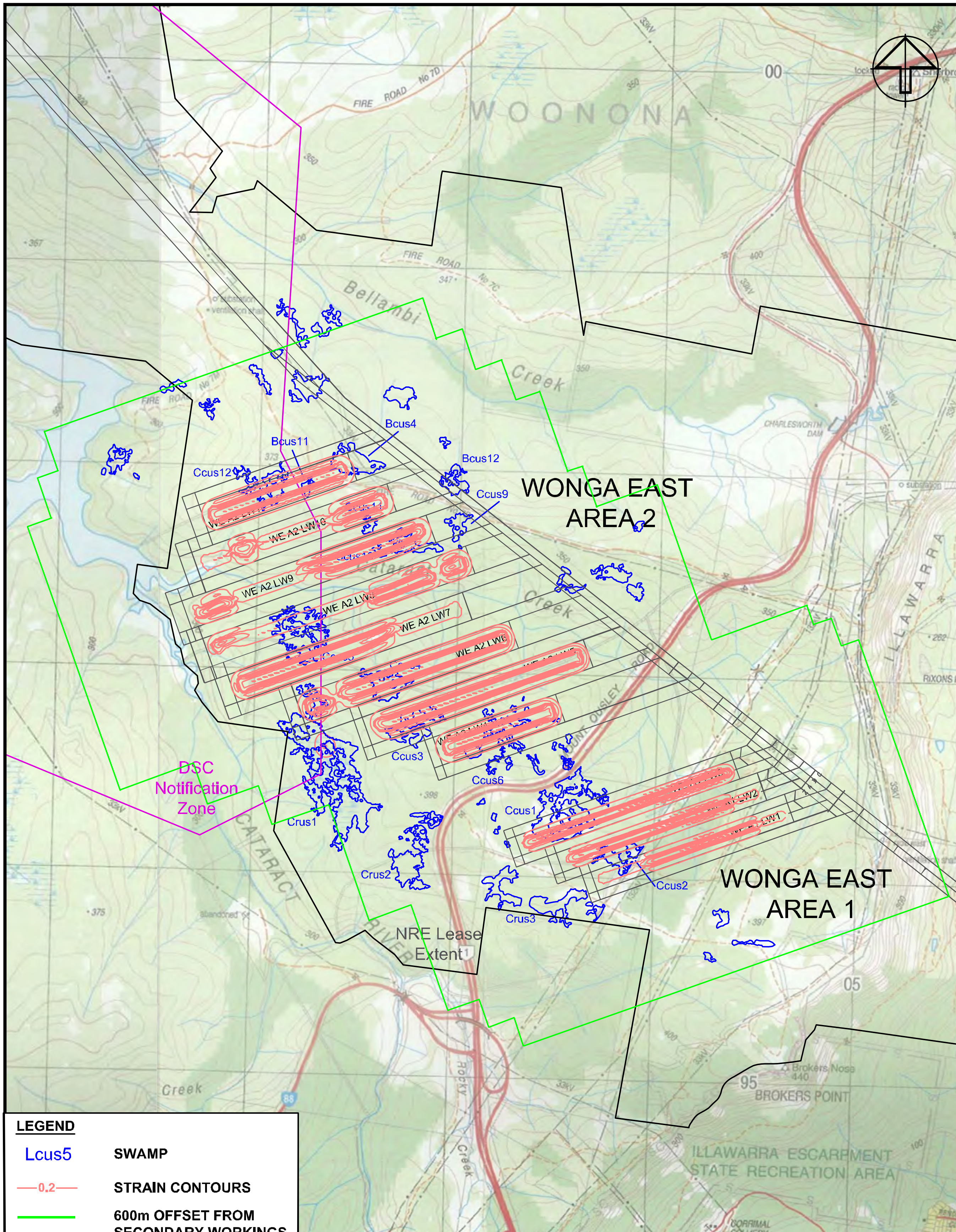

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DRAWN:	A. DAWKINS
DATE:	26 OCT 2012
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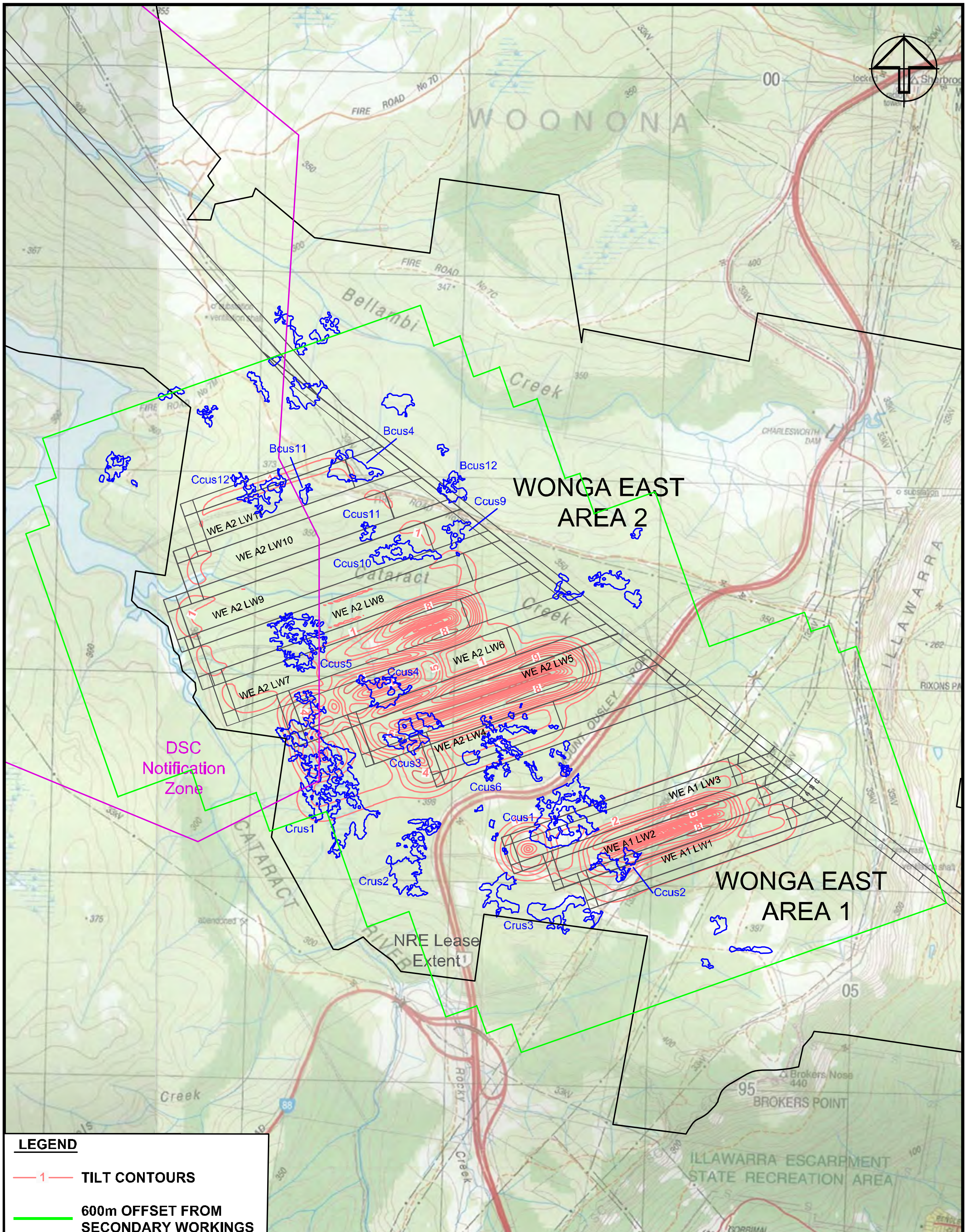
GUJARAT NRE COKING COAL LTD
NRE No. 1 COLLIERY

Predicted Wonga East Strains

GeoTerra

DRAWING 8



LEGEND

—1— TILT CONTOURS

600m OFFSET FROM SECONDARY WORKINGS

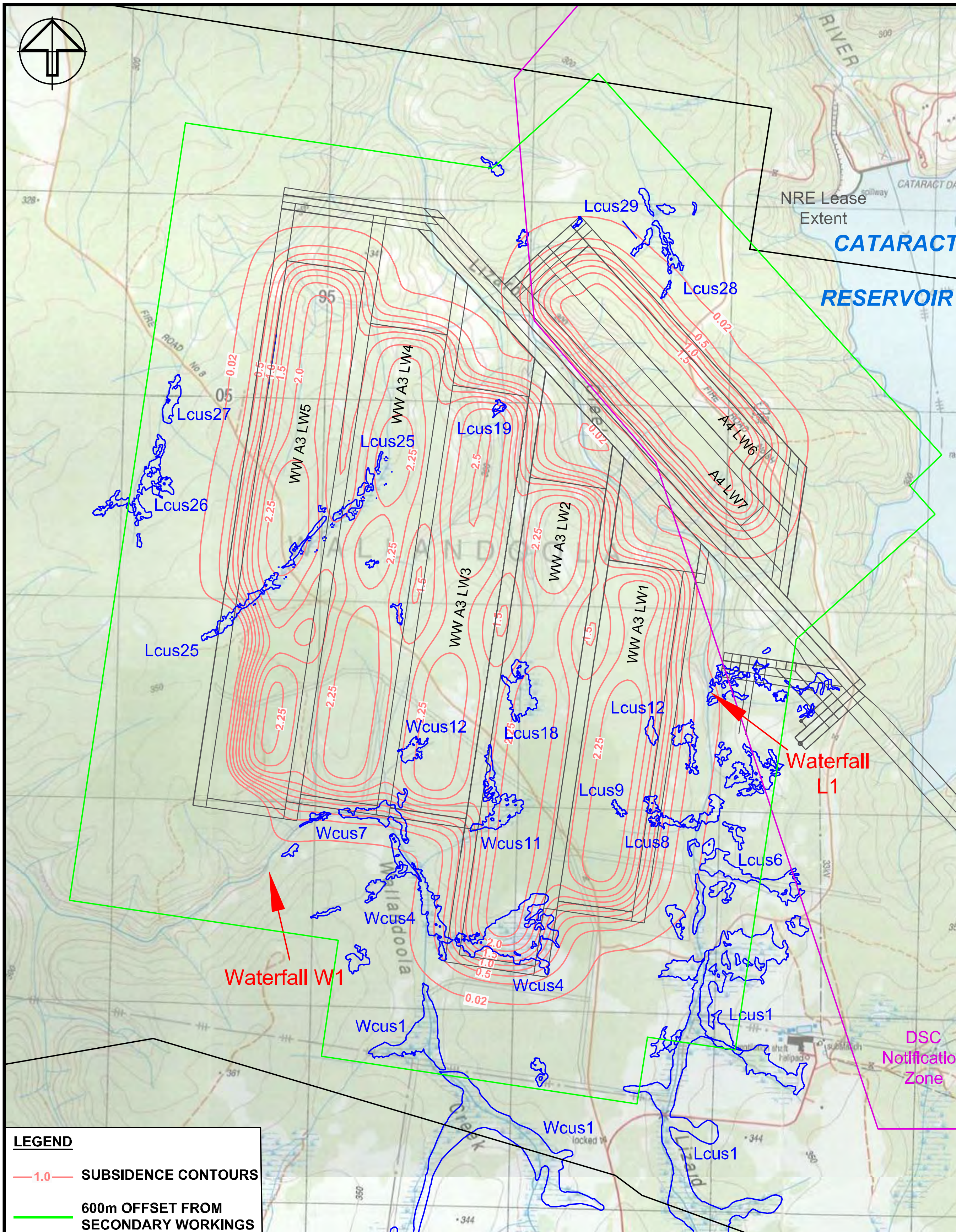
PROJECT:	GUJ1-S-R1
DRAWN:	A. DAWKINS
DATE:	26 OCT 2012
SCALE:	1:250

GUJARAT NRE COKING COAL LTD
NRE No. 1 COLLIERY

Proposed Wonga East Workings and Tilt Contours

GeoTerra

DRAWING 9



PROJECT:	GUJ1-S-R1	GUJARAT NRE COKING COAL LTD NRE No. 1 COLLIERY	GeoTerra
DRAWN:	A. DAWKINS		
DATE:	26 OCT 2012	Proposed Wonga West Workings and Subsidence Contours	DRAWING 10
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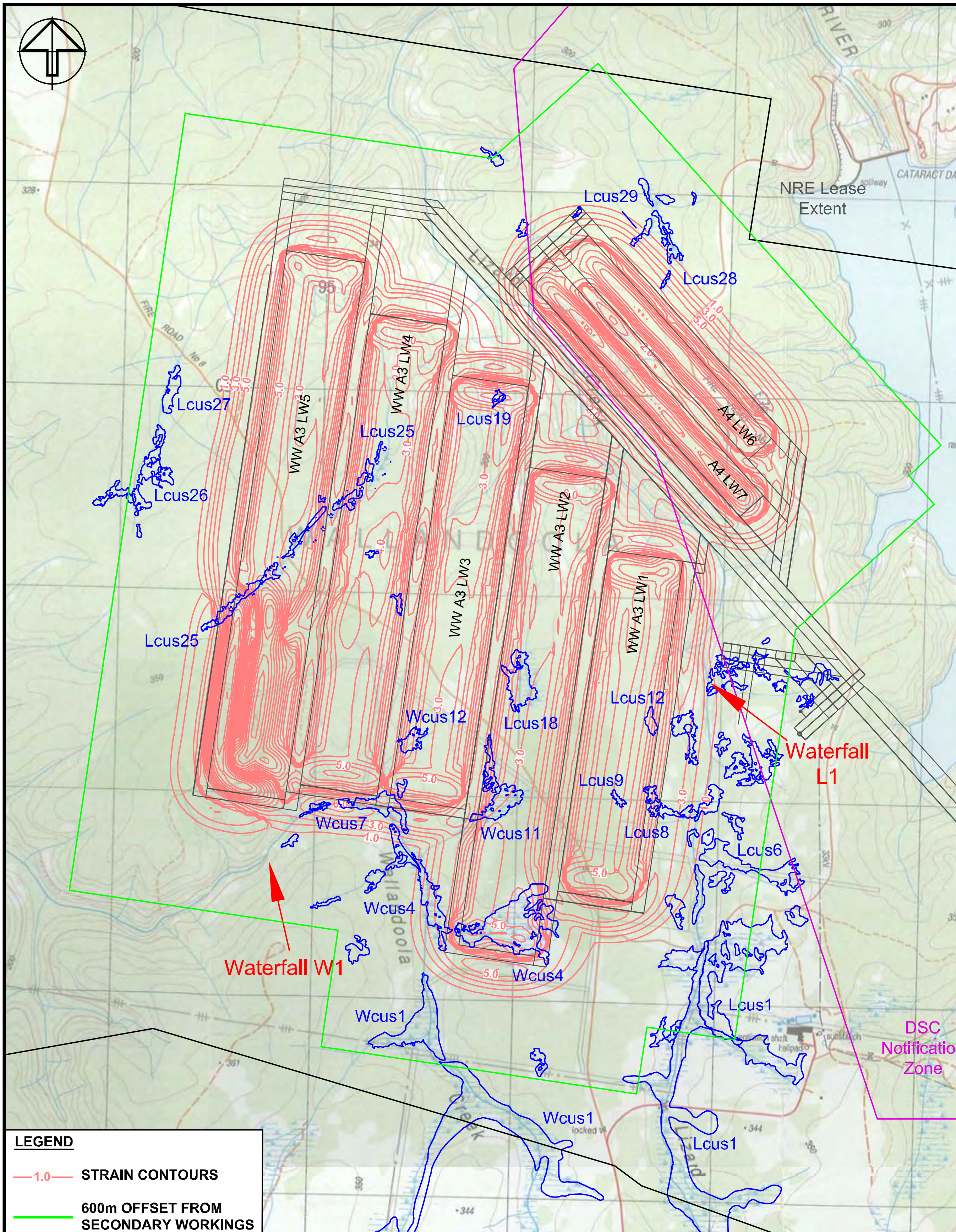

PROJECT:	GUJ1-S-R1	**GUJARAT NRE COKING COAL LTD** **NRE No. 1 COLLIERY**	**GeoTerra**	
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DATE:	26 OCT 2012	**Proposed Wonga West Workings and Strain Contours**	**DRAWING 11**	
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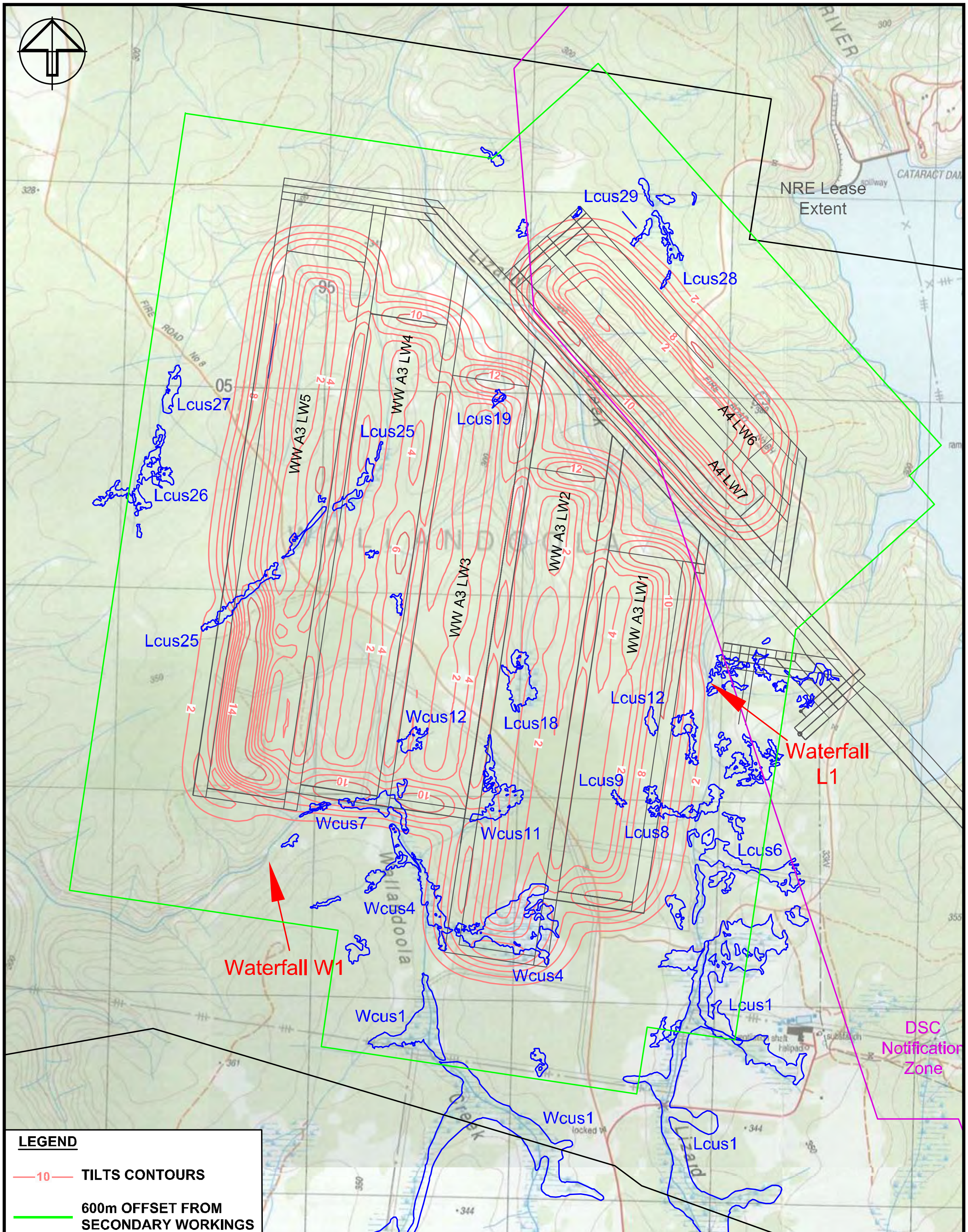

LEGEND

10 TILTS CONTOURS

600m OFFSET FROM SECONDARY WORKINGS

PROJECT:	GUJ1-S-R1	**GUJARAT NRE COKING COAL LTD** **NRE No. 1 COLLIERY**	**GeoTerra**	
DRAWN:	A. DAWKINS			
DATE:	26 OCT 2012	**Proposed Wonga West Workings and Tilt Contours**	**DRAWING 12**	
SCALE:	1:250			

APPENDIX A

WRM WATER AND ENVIRONMENT PTY LTD
SURFACE WATER MODELLING

NRE NO.1 COLLIERY
SURFACE WATER MODELLING

Gujarat NRE Coking Coal Limited
November 2012

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water + environment

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REPORT TITLE: NRE No. 1 Colliery Surface Water Modelling
CLIENT: Gujarat NRE Coking Coal Limited
REPORT NUMBER: 0637-01-B [Rev 7]

Revision Number	Report Date	Report Author	Reviewer
0	16 March 2010	MB	GR
1	13 April 2010	MB	GR
2	7 May 2010	MB	GR
3	12 May 2010	MB	GR
4	6 September 2010	MB	GR
5	21 January 2011	MB	GR
6	16 November 2011	CW	MB
7	26 November 2012	CW	MB

For and on behalf of
WRM Water & Environment Pty Ltd

Michael Batchelor
Principal Civil Engineer

EXECUTIVE SUMMARY

This report describes the geometry of the catchments and streams potentially impacted by mining subsidence induced by the proposed Gujarat NRE No. 1 Colliery longwall mining project. It also outlines hydrological modelling undertaken to determine the relative contribution of the potentially affected catchments to runoff in the receiving waters.

The catchments of Lizard and Wallandoola Creeks will potentially be affected by the proposed Wonga West workings, and the catchments of the Cataract River and Cataract Creek will potentially be affected by the Wonga East workings. The western end of Panel 10 in the Wonga East workings extends under the high water extent of the northern bank of the Lake Cataract backwater in Cataract Creek.

Catchment geometry and stream longitudinal profiles were extracted from an airborne laser scanning survey acquired over the Study Area on 20th October 2009, and are described below:

1. Lizard Creek is approximately 10km long from its headwaters to the confluence with the Cataract River. It is a 3rd order stream for most of its length – with the downstream reaches being 4th order for 1.2km and 5th order for a 1.7km length. Approximately 3.6km of the stream reach is located upstream, 3.5km within and 3.2km downstream of the 20mm subsidence zone. Channel invert elevations fall from approximately 360m AHD to 200m AHD, including a 30m high waterfall located approximately half way along its length, and another 20m waterfall upstream of the Cataract River confluence. Of the total Lizard Creek catchment area of 17.1km^2, 5.2km^2 is located upstream of the potential subsidence zone, 6.3km^2 is within and 3.3km^2 is downstream of the 20mm subsidence zone overlying the proposed workings.

2. Wallandoola Creek is approximately 15.5km long from its headwaters to the confluence with the Cataract River. It is a 4th order stream for most of its length. Approximately 4.0km of the stream reach is located upstream, 1.4km within and 10.2km downstream of the 20mm subsidence zone. Channel invert elevations fall from approximately 370m AHD to 140m AHD including series of waterfalls with a total drop of 50m along a 2.5km reach approximately half way along its length. Of the total Wallandoola Creek catchment area of 33.2km^2, 8.3km^2 is located upstream of the potential subsidence zone, 2.0km^2 is within and 22.5km^2 is downstream of the 20mm subsidence zone overlying the proposed workings.

3. Cataract Creek is approximately 5.5km long from its headwaters to the upstream reaches of Lake Cataract. It is a 4th order stream for most of its length. The proposed Wonga East workings are located between Chainage 1,600m and Chainage 4,700m. Approximately 2.1km of the stream reach is located upstream, 2.0km within and 0.8km downstream of the 20mm subsidence zone. Channel invert elevations fall from approximately 340m AHD to 285m AHD. Of the total Cataract Creek catchment area of 5.2km^2, 2.1km^2 is located upstream of the potential subsidence zone, and 2.5km^2 has been identified as potentially subsided by the proposed workings.

4. Cataract River is approximately 6.7km long from its headwaters to the upstream reaches of the Lake Cataract storage. The proposed Wonga East workings and its associated 20mm subsidence zone do not underlie the Cataract River. The predicted 20mm subsidence zone runs adjacent to the Lake Cataract backwater for a distance of about 600m. It is a 3rd order stream upstream of the Link Road crossing and 4th order from the confluence just downstream of the crossing to the Lake Cataract backwater. Channel invert elevations fall from approximately 430m AHD to 285m AHD. Of the total Cataract River catchment area of 11.6km^2, 0.4km^2 has been identified as potentially subsided by the proposed workings with 11.2km^2 outside of the 20mm subsidence zone.

Lake Cataract will not be undermined by the proposed Wonga West workings. The proposed Wonga East workings underlie the backwater of Lake Cataract on Cataract Creek for a distance of 730m (maximum water depth 3.9m when the water level is at spillway level). Cataract River is not underlain by the proposed workings, or the expected subsidence zone. Of the total Lake Cataract catchment area of 127.8km^2, 3.4km^2 is identified as potentially subsided (Seedsman, 2010).

Rainfall in the study area is highly variable, with mean annual rainfall ranging from less than 1,000mm/a in the west of the Study Area to over 1,800mm/a on the eastern escarpment. Historical records show significant variations in rainfall from north to south during specific events.

Long-term streamflow records are not available for the potentially affected streams. However, data is available from gauges on headwater streams flowing into Lake Cataract: Bellambi Creek at South Bulli No. 1 (<5 years) and Loddon River at Bulli Appin Road (<19 years).

The streamflow records from these two gauges show similar responses to rainfall– with persistent baseflow being a notable feature, but contributing a relatively small proportion total runoff. The streamflow records were extended by simulating catchment behaviour using the AWBM rainfall-runoff model and historical climate data. Given the limited availability of representative rainfall data, the AWBM gave a reasonable representation of catchment behaviour, though it tended to underestimate very low flows.

Daily runoff from other catchments in the upper Study Area was estimated using the AWBM model, with the model parameters transposed from the adjacent calibrated catchments. Climate data specific to each sub-catchment of interest was used to account for spatial rainfall variability.

The catchment models were validated by directing the modelled runoff to a hydrological model of the Lake Cataract system. Simulated stored water levels were compared to historical records provided by the SCA. With the exception of a small number of individual runoff events, the model gave a good representation of historical storage behaviour over the 35 year period for which complete daily records were available.

Based on a catchment yield model calibrated to historical records since 1976, losses of 1ML/d would have had very little impact on Lake Cataract water levels. The maximum reduction in stored volume occurs in mid-2007 and ranges from 940ML for a loss of 0.5ML/d to 1,385ML/d for a loss of 10ML/d. Losses of 10ML/d would not have caused the Lake Cataract Reservoir water volume to fall below 10% of capacity. Such loss rates are very large, and unlikely to eventuate given the underlying geology and proposed mining method.

Subsidence induced cracking could potentially affect streamflow in the reaches overlying and downstream of the proposed workings. Other investigations have concluded that these impacts would normally be restricted to short reaches, where flow infiltrates into cracks in the bed, then remerges further downstream. Based on the available subsidence assessments, it is not possible to directly predict the magnitude of these losses or the lengths of streams likely to be impacted.

In the absence of long-term streamflow records on Lizard and Wallandoola Creek, the impact of losses from the affected reaches due to mine subsidence on the persistence of baseflow was estimated by extracting a constant daily loss rate from a simulated streamflow record. The model parameters were transposed from AWBM models calibrated to adjacent catchment runoff records and validated against portions of the streamflow record at Broughton's Pass Weir. Flows in Lizard Creek and Wallandoola Creek at the reporting locations just downstream of the proposed 20mm subsidence zone, are similar. A loss of 0.5ML/d would reduce the frequency of flows greater than 1.0ML/d from around 38% to 32%. A loss of 1.0 ML/d would reduce the frequency of 1.0ML/d flows to 28%. A loss of 0.5ML/d would reduce the frequency of flows greater than 0.1ML/d from around 70% to 46%. A loss of 1.0 ML/d would reduce the frequency of 0.1ML/d flows to 37%.

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