GeoTerra

West Cliff Colliery

Longwall 38
End Of Panel
Surface Water and Groundwater
Monitoring Report

Sth32_2 R1A
9 May 2016

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Sth32_2 R1A (9 May, 2016)

South 32 Illawarra Coal Holdings Pty Ltd
PO Box 514
UNANDERRA NSW 2526

Attention: Gary Brassington

Gary,

RE: West Cliff Colliery (Area 5) End of Longwall 38 Surface Water and Groundwater Monitoring Report

Please find enclosed a copy of the above mentioned report.

Yours faithfully

GeoTerra Pty Ltd

Andrew Dawkins (AuSIMM CP-Env)
Principal Hydrogeologist

Distribution:	Original	GeoTerra Pty Ltd
	1 electronic copy	South32 Illawarra Coal Holdings Pty Ltd

Authorised on behalf of GeoTerra Pty Ltd:	
Name	Andrew Dawkins
Signature	
Position	Principal Hydrogeologist

Date	Rev	Comments
28/04/2016		Initial Draft
09/05/2016	A	Incorporate Review Comments

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Executive Summary

The following table summarises the potential and observed effects on surface water and groundwater systems within the West Cliff Colliery (Area 5) Longwall 38 subsidence area.

Appendix A contains the Longwall 38 Trigger Action Response Plans (TARPs) and Impact Summary.

Potential Impacts	Observed Impacts Due to Extraction of Longwall 38
Surface Water	
Bedrock cracking and loss of plateau stream flow	*Stream bed cracking has occurred in the tributary creeks, with flow loos in GR108 and GR110*
No adverse ecological changes to plateau streams due to subsidence	*No adverse effect on plateau stream ecology has been observed*
Possible localised ponding may occur in plateau streams	*No localised stream ponding due to subsidence has been observed*
Plateau stream bed incision may occur	*No plateau stream bed incision has been observed*
No adverse effects on plateau stream water quality anticipated	*No adverse effects on plateau stream water quality has been observed apart from some minor iron hydroxide seepage*
Georges River water level to remain essentially unchanged	*Fracturing and flow diversion observed in Rockbar 49. Pool water levels were lower than baseline in Pools 44, 54, 56, 57, 58, 59 and 60. All pool water levels responded to increased mitigative flows from West Cliff mine.*
Methane rich strata gas emissions into the river are likely, with reduced dissolved oxygen levels possible	*No new gas seeps or adverse effects on the Georges River were observed as a result of Longwall 38 extraction*
Low likelihood of ferruginous spring inducement with significant impacts from pH and iron not predicted	*Some ferruginous seepage in Georges River has been observed but it was within the Longwall 37 and 38 TARP trigger levels*

Potential Impacts	Observed Impacts Due to Extraction of Longwall 38
Groundwater	
Adverse interconnection of aquifers and aquitards is not anticipated within 20m of the surface	*No adverse interconnection between aquifers and aquitards was observed within 20m of the surface*
Potential increased rate of recharge into the plateau	*No increased rate of recharge into the plateau was observed*
Temporary lowering of regional phreatic water levels by up to 10m which may stay at that level until maximum subsidence develops	*Depressurisation of WC95 by up to 9m, with a subsequent 4m recovery was observed over Longwall 38*
Groundwater levels should recover over a few months and no permanent post mining reduction in water levels in bores on the plateau unless a new outflow path develops	*Continued depressurisation of WC95 over Longwall 38 by approximately 5m is currently occurring*
The yield and serviceability in registered bores may be affected by subsidence	*Two private bore yields have been affected (GW72454 and K10bh01) over Longwall 38*
Horizontal displacement may make private bores inaccessible	*No private bores reported to have been horizontally displaced due to Longwall 38 extraction*
Strata dilation and subsequent re-filling of secondary voids may temporarily lower standing water levels of private bores	*Two private bore yields have been reportedly adversely affected (GW72454 and K10bh01)*
Interface drainage, ferruginous, brackish seeps may be generated in streams on the plateau	*No interface drainage, ferruginous, brackish seeps have been generated in streams on the plateau*
Increased groundwater seepage inflow into the mine workings should not occur	*No notable increase in groundwater inflow to the mine has been observed*
Strata gas discharge into private bores may occur	*No reported strata gas discharge into private bores has been reported)*

1. INTRODUCTION

South32 Illawarra Coal and its predecessors have extracted the Bulli Seam at West Cliff Colliery by retreat mining of Longwall 38 within the West Cliff Colliery lease (Area 5) between 03/02/2015 to 01/02/2016.

The previous Area 5 workings (Longwalls 30 to 37) are all located to the west, whilst Longwall 38 is at least 45m to the east of the Georges River, within a predominantly uncleared forested area in the southern and central sections and a semi-rural cleared area over the northern longwall area.

Longwall 38 is located approximately 1km north-east of Appin, in the Southern Coalfields of NSW, as shown in **Figure 1**.

This report provides a compilation and interpretation of physical and geochemical groundwater and stream monitoring that was conducted before, during and after extraction of Longwall 38.

Surface water and groundwater features associated within the Longwall 38 (20mm) subsidence zone include:

- the main channel and westerly draining 1st to 2nd order tributaries of the northerly flowing Georges River;
- two NOW licensed private bores (GW72454 and K10bh01), and;
- three licensed piezometers (GR27, GR29 and WC95)

Monitoring of the Georges River and its westerly flowing tributaries within the 20mm subsidence area has been conducted since October 2002 by assessing the;

- ephemeral or perennial nature and flow in streams over and adjacent to the panels;
- creek bed and bank erosion and channel bedload;
- stream and dam water quality, including ferruginous and gaseous seeps;
- stream bed and bank vegetation;
- nature of alluvial land along stream banks;
- presence, size and integrity of dams and their water levels, as well as;
- standing water levels and water quality in groundwater bores.

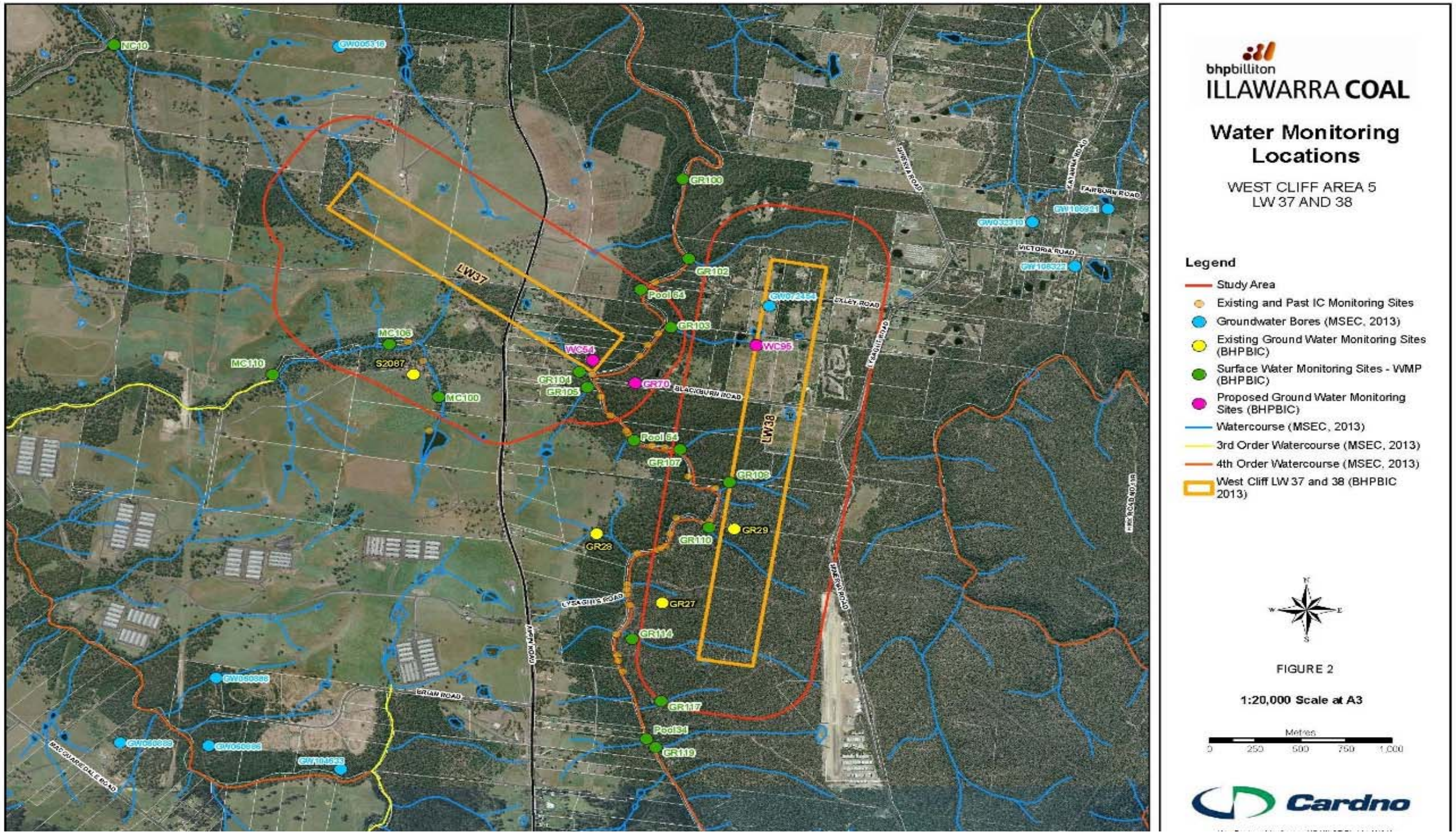


Figure 1 Longwall 37 and 38 Surface Water and Groundwater Monitoring Locations

2. GENERAL DESCRIPTION

2.1 Mine Layout and Progression

Longwall 38 commenced on 03/02/2015 and was completed on 01/02/2016, with mining progressing up-dip in the Bulli Seam from south to north.

The longwall's depth of cover increases to both the southern and northern ends of the panel, whilst the seam thickness varies from 2.5 – 2.7m.

2.2 Land Use and Geomorphology

The land over Longwall 37 is primarily composed of grazing pasture with minor fringing undeveloped woodland to the south.

Longwall 38 is located near the Georges River with undeveloped woodland over the majority of the panel, along with a semi- rural area over the north of the longwall.

2.3 Topography and Drainage

2.3.1 Plateau

The plateau over the Longwall 38 (20mm) subsidence area (aka, the Study Area) rises from the Georges River in the centre to the Hawkesbury Sandstone and Wianamatta Shale dominated plateau on either side of the gorge.

The Georges River gorge is up to approximately 20m deep with steep sided sandstone cliffs and scree slopes in some areas.

Ground levels vary from approximately 165 - 220mAHD and 205 - 245mAHD over Longwall 38.

The headwaters of Mallaty, Nepean and Woodhouse Creeks overlie Longwall 37, which drain to the south-west and north-west into the Nepean River, whilst unnamed 1st and 2nd order watercourses drain to the west into the Georges River over Longwall 38.

There are no upland swamps in the Study Area.

A number of earthen wall dams are located in the creeks and drainage lines over Longwall 37, with limited dams over the northern end of Longwall 38, and they are used as water sources on the rural properties.

The upper reaches of the streams generally have clay based alluvium developed on Bringelly Shale, Minchinbury Sandstone and Ashfield Shale / Wianamatta Shale with Hawkesbury Sandstone in the eroded Mallaty Creek valley, whilst Longwall 38 is dominated by exposed or sub-cropping Hawkesbury Sandstone.

The Georges River gorge is developed within the Hawkesbury Sandstone.

2.3.2 Georges River

The longwalls do not underlie the river gorge, with the closest point of Longwall 37 lying approximately 25m west, whilst Longwall 38 is situated approximately 50m east of the Georges River centreline as shown in **Figure 1**.

The river has dissected the Woronora plateau, forming sandstone dominated scarps on the east and west banks. Cliffs are usually formed in competent sandstone which can contain stratigraphically controlled cavernous zones, with ephemeral seeps in some areas.

Interspersed boulder fields, exposed sandstone bedrock and sandy alluvium are prevalent along the stream bed.

The perennial river flow is derived from catchment runoff and licensed discharges from Appin and West Cliff mines located upstream of the Study Area.

The Georges River and its tributaries within the Study Area do not form part of the SCA Drinking Water Catchment Area and it is not a Declared Special Area.

2.4 Streamflow and Water Levels

2.4.1 Georges River Flow

The land in the eastern part of Longwall 37 generally drains to the Georges River, with the central and western areas draining to Nepean, Mallaty or Woodhouse Creeks, as well as a number of minor tributaries to the Nepean River.

The Study Area associated with Longwall 38 drains west to the Georges River via several 1st and 2nd order tributaries.

The creeks have an approximate gradient between 15 and 40mm/m, with the upper catchments characterised by outcropping Wianamatta Shale, with the landscape types classified as Cumberland Plains Lowlands and Hawkesbury-Nepean River Valley (BHP Billiton Illawarra Coal, 2014).

The Georges River receives water from the following sources:

- Appin Village storm water and waste water overflows and seepage;
- flows sourced from the catchment; and
- flows sourced from the EPA Licensed Discharges at Appin and West Cliff Collieries.

Water flow in the Georges River, upstream of the licensed discharges have been measured since 2002, with the data indicating relatively low flow rates upstream of the licensed discharges. Since the implementation of controlled releases from West Cliff Colliery in August 2004, water flows have been substantially continuous (BHP Billiton IC, 2014).

The primary median flows are from the West Cliff Colliery discharge point. Consequently, current water flows within the Georges River are primarily sourced from the upriver catchment and from the EPA licensed discharges at West Cliff Colliery.

2.5 Georges River Water Chemistry

West Cliff Colliery releases water on an almost continual basis to the Georges River via Brennans Creek from Brennans Creek Dam (BCD). This controlled discharge aims to:

- restrict discharges from License Point 10 to a maximum pH of 9.0;
- steadily reduce salinity levels over time, and;
- provide a stable environmental flow in the Georges River.

The discharge regime has been successful, contributing the major flow component of the Georges River since inception, with salinity of water discharged from West Cliff Colliery being reduced from an average value around 4000µS/cm (2004) to an average value of around 2000µS/cm (2011/2012), despite drought conditions in the three years leading up to 2006 (BHP Billiton IC, 2014).

2.6 Geology

The Bulli Seam dips at an approximate gradient of 0.02 to the south east, with the depth of cover ranging from approximately 490 - 520m over Longwall 37 and 470 - 500m over Longwall 38.

The Hawkesbury Sandstone predominantly outcrops adjacent to and underlies the Georges River gorge, with the western plateau capped by outcropping Wianamatta Shale, whilst outcropping shale is not present adjacent to Longwall 38 as shown in **Figure 2**.

The underlying lithologies are the typical Southern Coalfield sequence of Narrabeen Group and Illawarra Coal Measures.

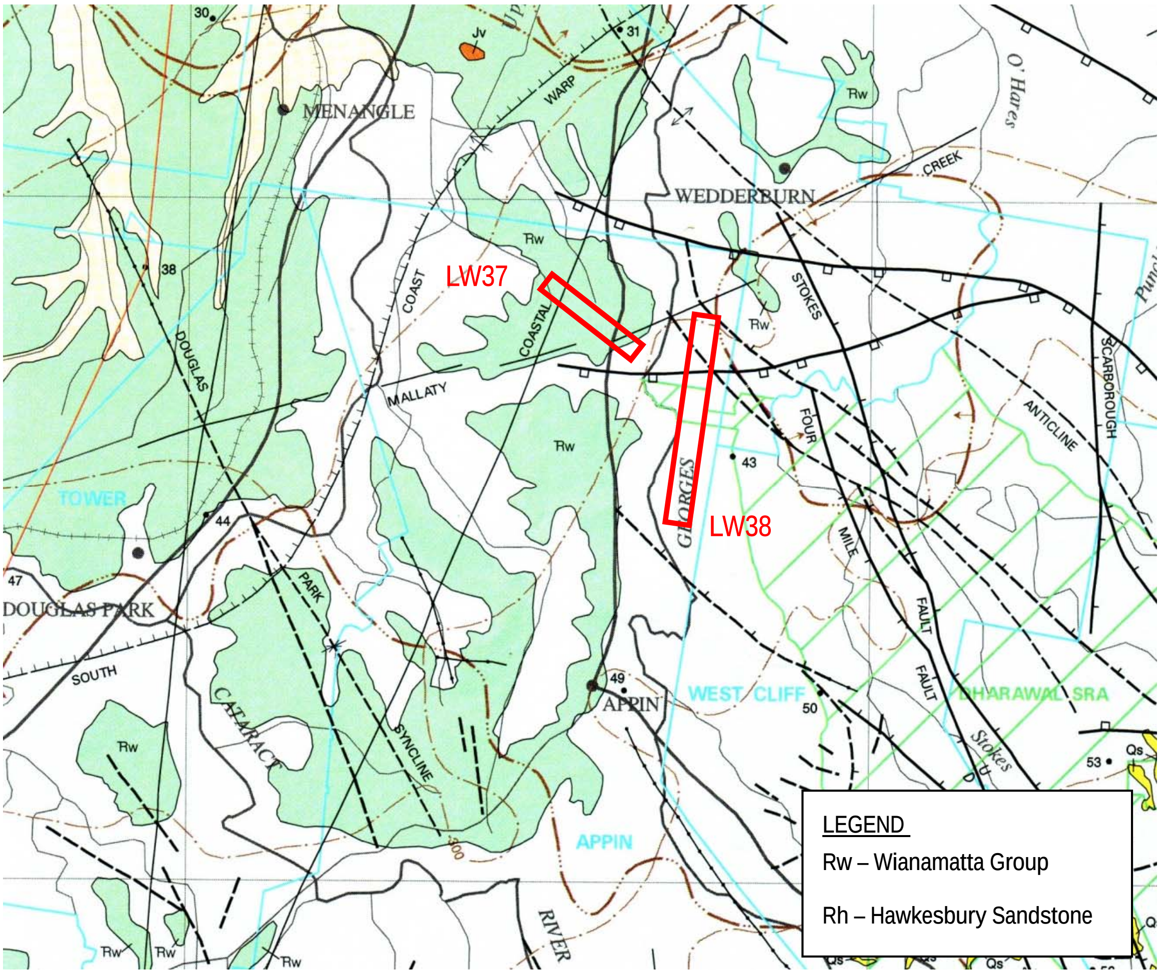


Figure 2 Local Geology

2.6.1 Local Faulting and Structures

The Longwall 37 and 38 workings are positioned to the east of the “South Coast Warp”.

The south east / north west trending “O’Hares Fault” location has been projected from exploration data and may cut across the northern portion of Longwall 38 and to the north of Longwall 37 as shown in **Figure 3** (MSEC 2012).

Surface lineaments due to differential weathering on joint planes are well developed on outcropping Hawkesbury Sandstone as stream courses which are generally controlled by the underlying sandstone joint fabric and regional topography dip to the northwest, but are generally poorly developed in the Wianamatta Shale.

Mapped and inferred geological structures include a north west / south east trending set and an east / west set of faulting which is developed on the eastern plateau of the Georges River.

Major faulting is not apparent at the surface on the plateau or river bed, which does not preclude the presence of structures at depth or minor structures not yet identified by mapping.

In the Southern Coalfield, faulting tends to decrease in displacement vertically upwards through the Narrabeen Group and Hawkesbury Sandstone.

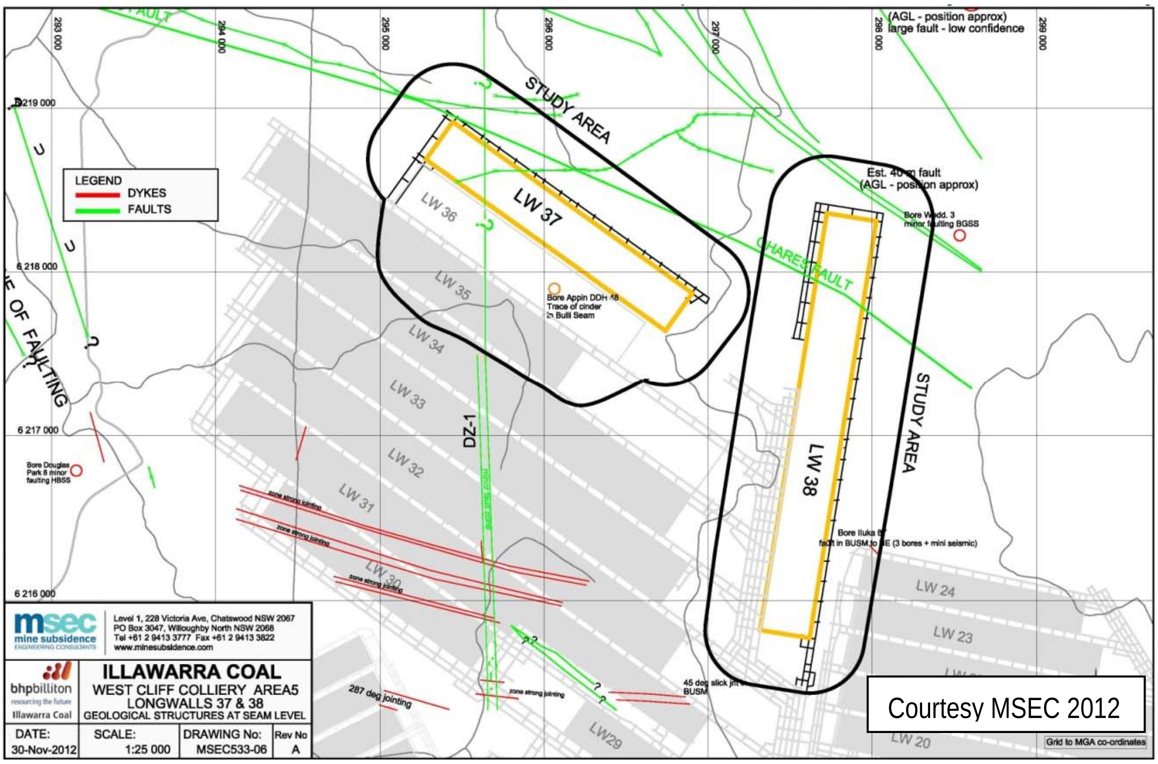


Figure 3 Local Geological Structures

2.6.2 Igneous Intrusions

No dykes or other intrusions of significance are known in the Study Area.

2.7 Hydrogeology

The Georges River is a generally "losing" system during dry periods, along with groundwater flow from the plateau under a regional hydraulic gradient to the river during and following significant rainfall recharge events.

These flows are dominantly horizontal, and are determined by confined flow along discrete layers underlain by fine grained or relatively impermeable strata within the Hawkesbury Sandstone, or along the Hawkesbury Sandstone / Wianamatta Shale interface.

No systematic study of near-surface groundwater systems has been conducted other than in piezometers within or near the Georges River in the south of the Study Area near Longwall 38, with the piezometers designed to measure the combined near surface water system hydraulic potential to 10m below the river.

Past observations and measurements of surface water and the near surface groundwater systems in the Georges River identified:

- natural pre-existing sub-bed flow diversions;
- horizontal permeability enhancement in shallow strata on the flanks of the river due to mining;
- discrete zones of horizontal permeability enhancement due to mining;
- interaction between surface water and the near surface groundwater systems;

- minimal systematic vertical conduits between upper and lower fracture zones;
- pre-extraction permeability profiles which did not necessarily agree with post extraction profiles; and
- the general river system is "losing" during dry periods and "gaining" during wet periods.

It is suspected that the river would consist of a series of disconnected or drained pools during extended periods of low rainfall if the Appin and West Cliff licensed discharges did not enter the river (Ecoengineers, 2012). This is confirmed by data obtained during pre-mining assessments for West Cliff Longwalls 5A1 – 5A4 in 1999 – 2000.

2.8 Existing Private Bores and South32 - IC Piezometers

2.8.1 Private Bores

Four NSW Office of Water (NOW) registered bores are located within or adjacent to the Study Area as shown in **Figure 4**, with selected details in **Table 1**, with one bore (GW 72454) contained within the Study Area.

All private bores were drilled between 152 - 279m below surface, with water obtained primarily from dual porosity sandstone aquifers.

Yields of up to 0.3L/sec were obtained from inflow zones in the sandstone which range from 29.8 - 163m below surface.

The actual intersected aquifer horizon is generally deeper than the measured static water level in a bore, as when a confined aquifer is intersected, the formation water rises up the bore due to confined lithostatic and hydrostatic pressure. Based on this principle, and on assessment of the NOW data, the majority of aquifer intersections over the proposed mining area lie below the elevation of the Georges and Nepean Rivers.

Table 1 Private Bores in the Vicinity of Longwall 38

GW	N	E	SWL (mbgl)	Depth (m)	Drilled	Aquifer (mbgl)	Lithology	YIELD (L/s)	TDS (mg/L)	Purpose
32310	6218596	299161	35.9	152	1969	29.8 – 29.9 60.9 – 61.0	sandstone sandstone	0.1 0.11	n/a	Stock Domestic
72454	6218063	297710	24.0	162	1994	60 - 90	sandstone	0.3	good	Domestic
105921	6218682	299577	44.0	183	2003	163 – 163.1	sandstone	0.2	fresh	Stock Domestic
108322	6218316	299395	41	279	2003	44 - 44.1 151 – 151.1	sandstone sandstone	n/a	fresh	Stock Domestic

Note: n/a not available mbgl metres below ground level TDS total dissolved solids

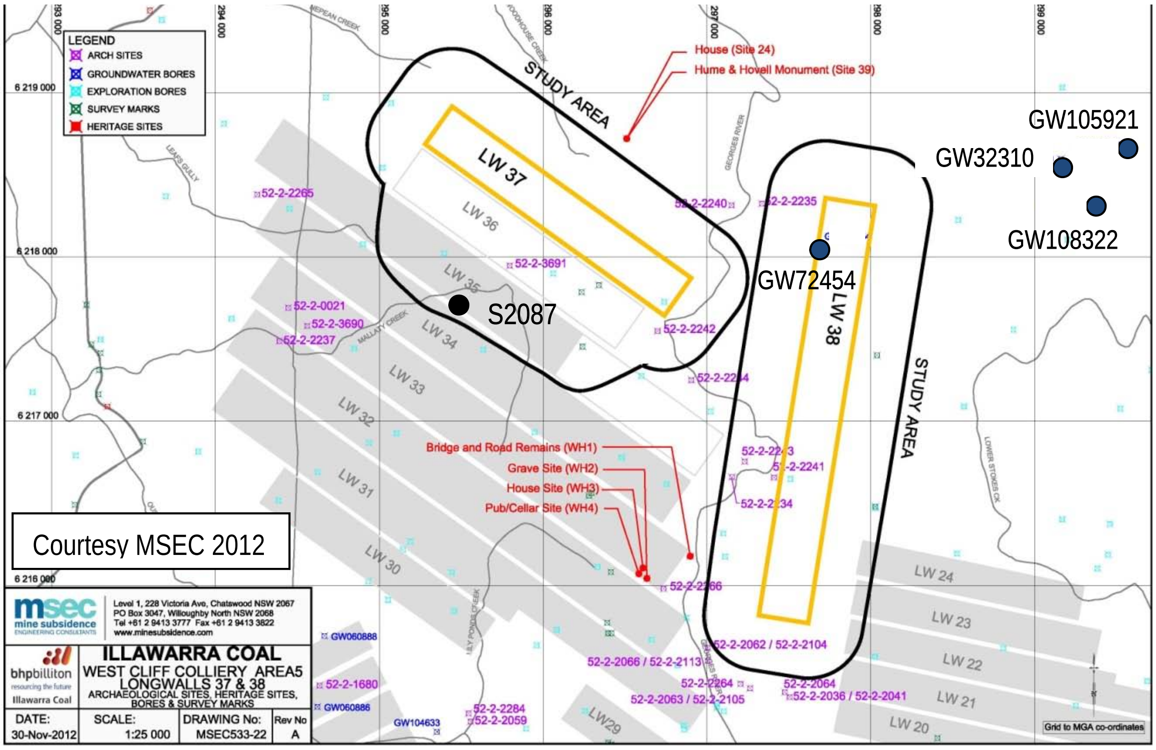


Figure 4 Private Bores and BHPBIC Vibrating Wire Piezometers

2.8.2 Shallow Open Standpipe Piezometers

A suite of Georges River stream bed and flanks piezometers were installed to monitor the Longwall 31 to 33 SMP Area. Some of the piezometers have been rehabilitated and removed (GR25, 26, 66, 68) and are no longer in use.

The shallow piezometers were installed primarily to measure groundwater levels along the plateau and associated Georges River.

Locations of current piezometers are shown in **Figure 1**, as summarised in **Table 2**.

Table 2 South32 IC Piezometers

	Date Installed	Depth (m)	Lithology
GR27	Jan 06	30.1	sandstone
GR28	Dec 01	24.31	sandstone
GR29	Dec 01	33.6	sandstone
GR70	Sept 2014	33.5	sandstone
WC54	Sept 2014	51.5	sandstone
WC95	Sept 2014	25.0	sandstone

2.8.3 Vibrating Wire Piezometer

A VWP array is located in bore S2087 over Longwall 35 in July 2010 as shown in **Figure 4**.

This piezometer array was decommissioned and rehabilitated approximately two years ago.

2.9 Surface Water / Groundwater Interaction

Surface water drainage on the plateau is via ephemeral tributaries which flow into Nepean, Woodhouse and Mallaty Creeks to the west of the Georges River, as well as gullies in the east, adjacent to and over Longwall 38, which drain to the Georges River.

The majority of rainfall infiltrates into the plateau soils.

Recharge to the regional groundwater system occurs with an extended delay after rainfall has infiltrated into the plateau soil as well as the underlying Wianamatta Shale and / or Hawkesbury Sandstone.

Some water may discharge from temporary seeps in the cliff face of the gorge due to the preferential horizontal flow regime in sub-horizontal bedding planes in the sandstone or at the Wianamatta Shale / Hawkesbury Sandstone interface.

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

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

Groundwater under the plateau discharges to the river in a “gaining” system where it flows under gravity to the river, whilst a smaller component of flow moves from high to lower piezometric pressure areas up from the base of the gorge to the river.

Based on field monitoring, the Georges River is observed to be a “losing” system, where stream water flows under gravity to the underlying groundwater system during extended dry periods within Area 5.

Site inspections to date have identified one seepage point adjacent to Longwall 37 and four adjacent to Longwall 38 along the Georges River within the Study Area (Ecoengineers, 2015).

As the Georges River is the largest regional surface water feature in the Study Area, all drainage from surrounding groundwater systems and tributary streams is toward the base of the gorge.

3. MONITORING RESULTS AND DISCUSSION

3.1 Subsidence

The maximum monitored subsidence, tilt and strain following the completion of extraction of Longwall 38 is provided in MSEC (2016).

3.2 Rainfall

Daily rainfall recorded at Douglas Park (St Marys Towers BOM Station 68200) since January 2002 is shown in **Figure 5**.

Mean annual potential evapotranspiration on the plateau averages around 1617 ±64mm/year, whilst annual evapotranspiration is estimated at around 660 ±111mm/year for the 2007 to 2013 period (Ecoengineers, 2014).

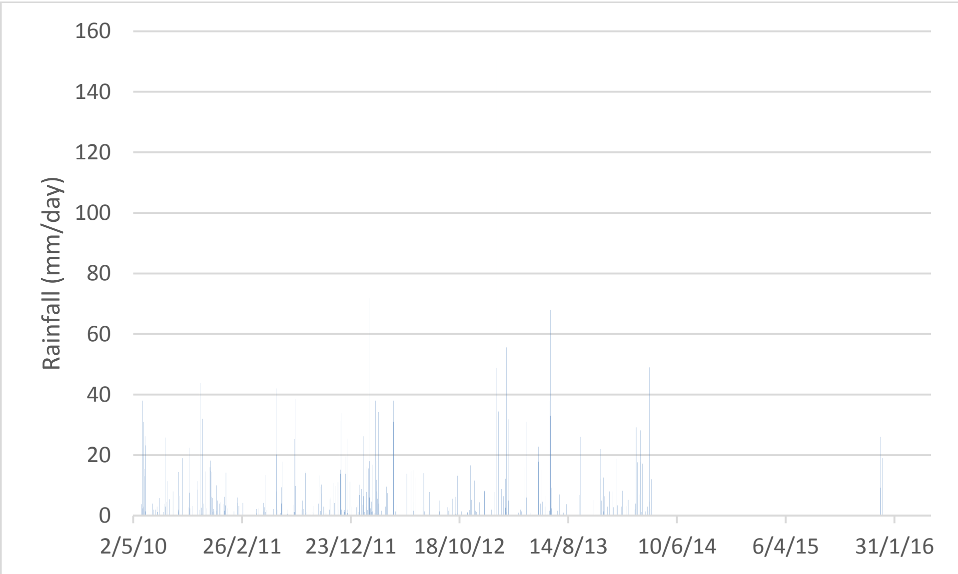


Figure 5 Douglas Park Rainfall

3.3 Georges River and Tributary Monitoring

Stream water level as well as field chemistry and laboratory analysis of river water samples has been conducted by the Illawarra Coal Environmental Field Team (ICEFT) in the Georges River since July 2002 at sites shown in **Figure 1**.

In addition, Georges River tributaries that drain to the west, within the Longwall 38 (20mm) subsidence area, have been monitored by the ICEFT since July 2012.

According to the LW37 / 38 TARP monitoring requirements (BHPBIC, 2014), this assessment focusses on the following stream sites;

Georges River

- Pool 34 - upstream of Longwall 38
- Pool 54 - mid stream reach, adjacent to Longwall 38
- Pool 64 – north stream reach adjacent to Longwall 38 (downstream of Longwall 37)

Westerly Draining Tributaries

- GR102 – northern end (downstream) of Longwall 38
- GR103 – northern section of Longwall 38
- GR107 – mid section of Longwall 38
- GR108 – mid section of Longwall 38
- GR114 – southern section of Longwall 38
- GR117 – south of (upstream) of Longwall 38
- GR119 – south of (upstream) of Longwall 38

3.3.1 Georges River and Tributary Stream Bed Fracturing

During and after the Longwall 38 extraction period, trigger levels for stream bed fracturing, compared to the baseline (pre Longwall 38) value were:

- Level 1 fracturing with no observable surface water diversion;
- Level 2 fracturing with observable surface water diversion, and;
- Level 3 more than negligible diversion of flows or changes in the natural drainage behaviour of pools over more than 20% of the stream length subject to vertical subsidence >20mm.

During the extraction of Longwall 38 the ICEFT identified impacts in the Georges River at GR_Rockbar_49 (impact WCA5_LW38_008). The largest fracture at this site was observed at 10m long and 0.04m wide. Flow diversion was observed.

During the extraction of Longwall 38 the ICEFT identified impacts in Georges River tributaries GR104, GR108 and GR110.

- Tributary GR104 - fracturing and associated uplift was identified at a rockbar in GR104 (impact WCA5_LW38_001). As this impact was located outside the zone of influence of Longwall 38 it is likely to be a result of a previous mining.
- Tributary GR108 - three zones of fracturing and uplift were identified in GR108 during the extraction of Longwall 38. These impacts have been reported as WCA5_LW38_002, WCA5_LW38_003 and WCA5_LW38_005. No flow diversion was noted at WCA5_LW38_005. No flow was present during the inspections of WCA5_LW38_002 and WCA5_LW38_003 therefore changes to flow conditions are undetermined.
- Tributary GR110 - fracturing to the base of GR110 with associated loss of flow was identified (impact WCA5_LW38_007).

Stream impact sites relevant to Longwall 38 are shown in **Figure 6.**

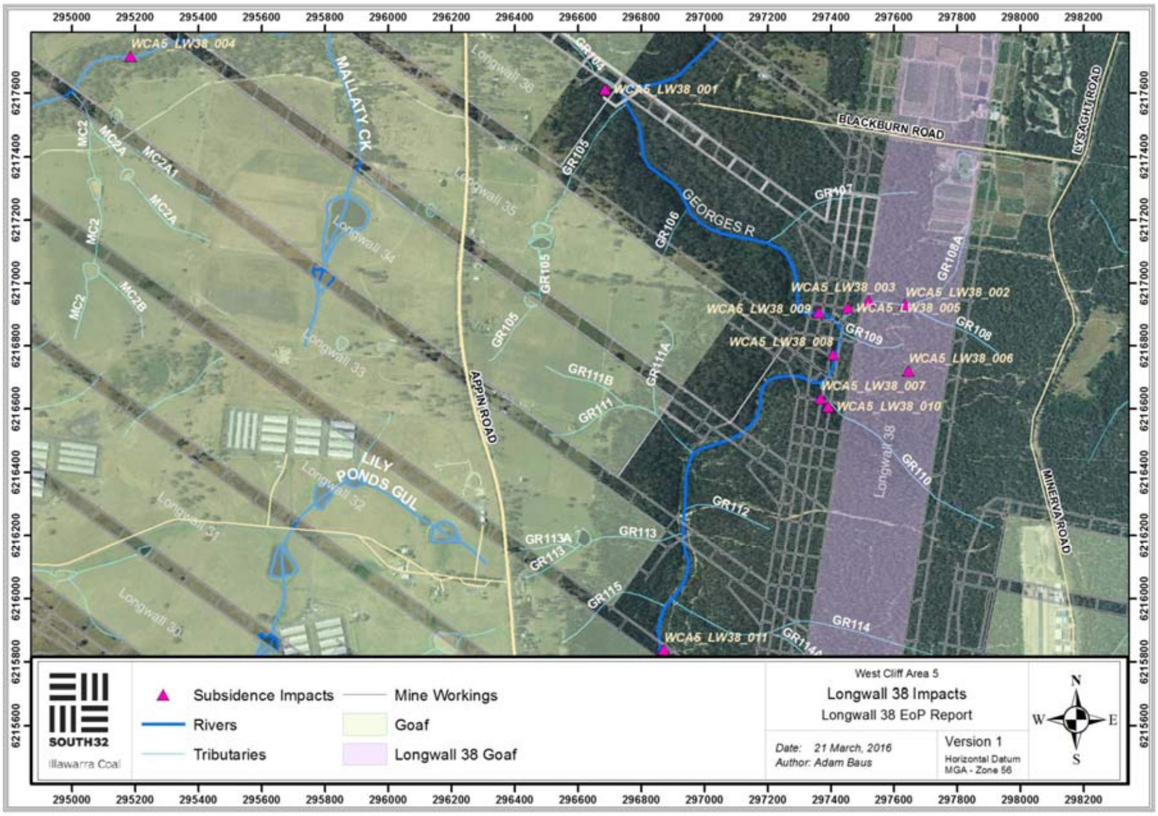


Figure 6 Georges River and Longwall 38 Tributary Impact Sites

The following trigger level exceedances were reported within the Georges River as a result of Longwall 38 extraction:

- *WCA5_LW38_008 Georges River GR_Rockbar 49 Level 2*
- *WCA5_LW38_009 Georges River downstream of Rockbar49 Level 1*

No trigger level exceedances were reported for tributaries draining within the Longwall 38 (20mm) subsidence zone.

3.3.2 Georges River and Tributary Pool Height

During extraction of Longwall 38, below baseline levels were reported for Georges River Pools 44, 54, 56, 57, 58, 59, 60.

These pools were reported during extraction of previous longwalls and were attributed to Longwall 35.

During significant rainfall events and increased mitigatory flow from Brennans Creek Dam these pools continue to show water levels similar to baseline. However, these water levels decrease during periods of low rainfall and reduced releases from Brennans Creek Dam.

As these water level impacts are a result of Longwall 35 they were previously classified under the West Cliff Area 5 Longwalls 34 to 36 Subsidence Management Plan and Georges River Management Plan (2014). Accordingly, they remain as a Level 2 impact.

Triggers relating to water level in the Georges River did not change during the extraction of Longwall 38 (South32 ICEFT, 2016).

River level monitoring commenced in October 2002 in the main river channel as shown in **Figure 7**.

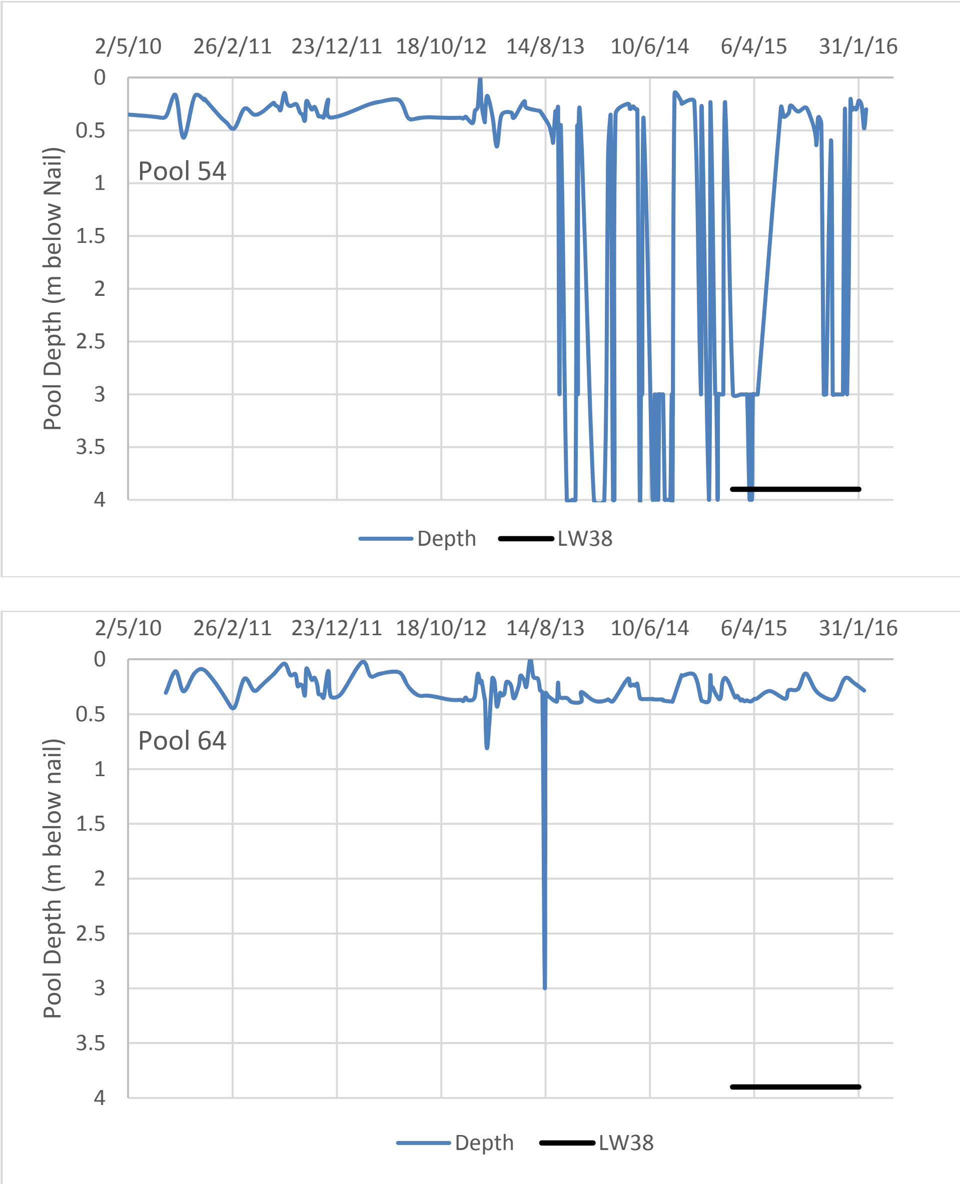


Figure 7 Georges River Depth Monitoring

Stream level monitoring commenced in June 2012 in the westerly flowing first and second order tributaries draining off the Longwall 38 (20mm) subsidence area as shown in **Figures 8** and **9**.

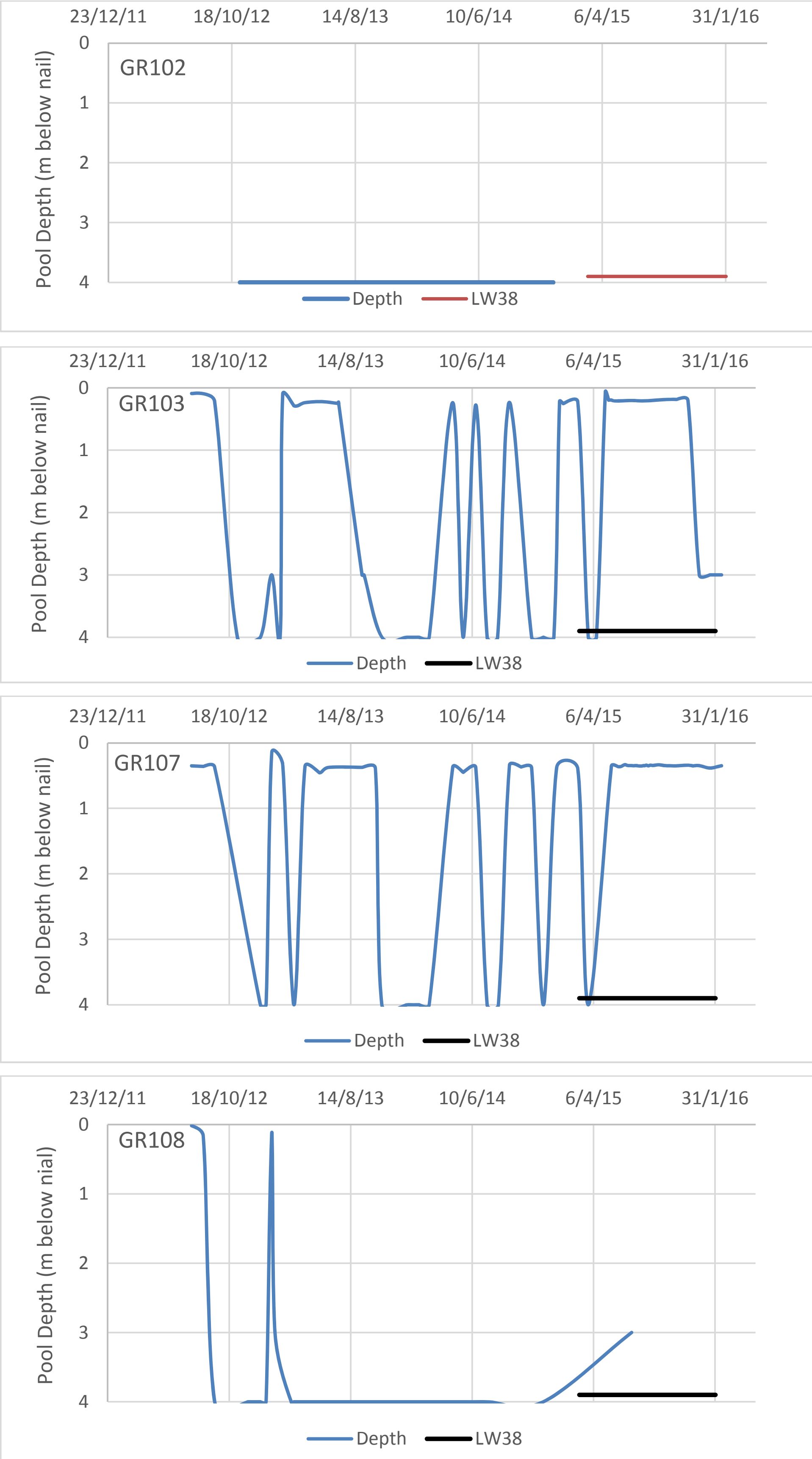


Figure 8 Georges River Tributary Depth Monitoring (A)

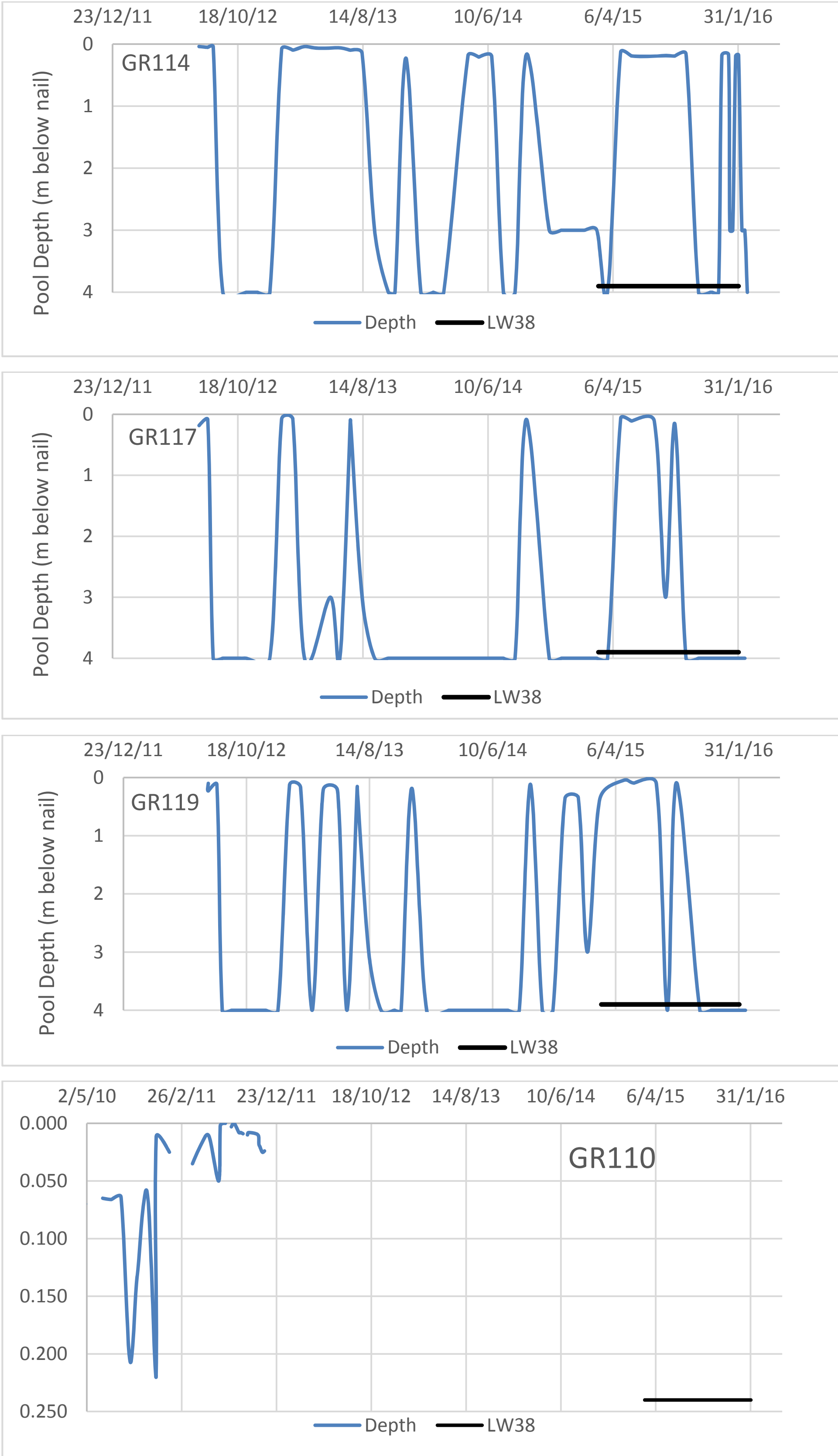


Figure 9 Georges River Tributary Depth Monitoring (B)

Based on the monitoring shown in **Figures 7** to **9**, there have been no periods in the Georges River where dry and / or flooded areas of riverbed were observed during the extraction of Longwall 38 and no pool water levels lower than pre Longwall 38 levels.

In addition, additional drying out, flooding and no pool water levels lower than baseline in the tributaries draining off the LW38 catchment area was observed from GR108 and GR110.

The pool water level TARP trigger was attained in the Georges River at GR_Pool 49.

3.3.3 Georges River and Tributaries Pre Longwall 38 Water Quality Observations

Prior to extraction of Longwall 38, the Georges River was observed to have undergone subsidence associated water chemistry effects such as;

- iron staining of the Georges River between Pool 58 and Pool 67, however, when the river flow retuned to higher levels, no staining was observed.

The key water quality parameters (pH, dissolved oxygen, electrical conductivity and oxidation reduction potential) generally remained within the expected level of <2 standard deviations from the pre Longwall 37 means within the study area (Ecoengineers, 2015).

3.3.4 Georges River and Tributaries pH and Salinity

For the selected monitoring sites, the Georges River has a pH range as shown in **Figure 10**.

During and after the Longwall 38 extraction period, trigger levels for a reduction in stream water quality for pH compared to the pre Longwall 38 values were:

- Level 1 0.5 – 1.0 unit drop for 2 consecutive months;
- Level 2 1.0 – 1.5 unit drop for 2 consecutive months, or;
- Level 3 1.5 unit drop for more than 2 consecutive months.

For the selected monitoring sites, the Georges River tributaries have an electrical conductivity (EC) range as shown in **Figures 11** to **12**.

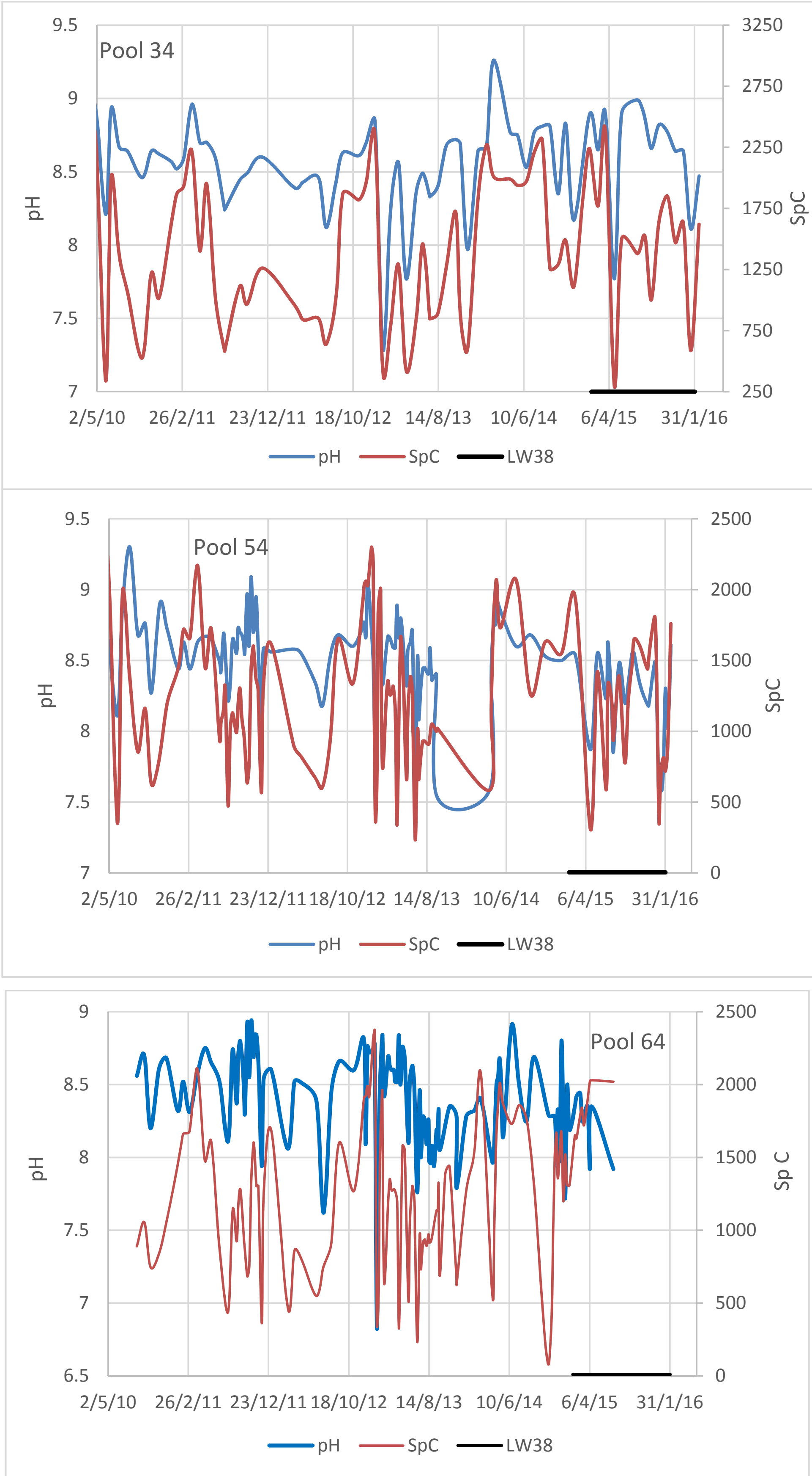


Figure 10 Georges River pH and Salinity

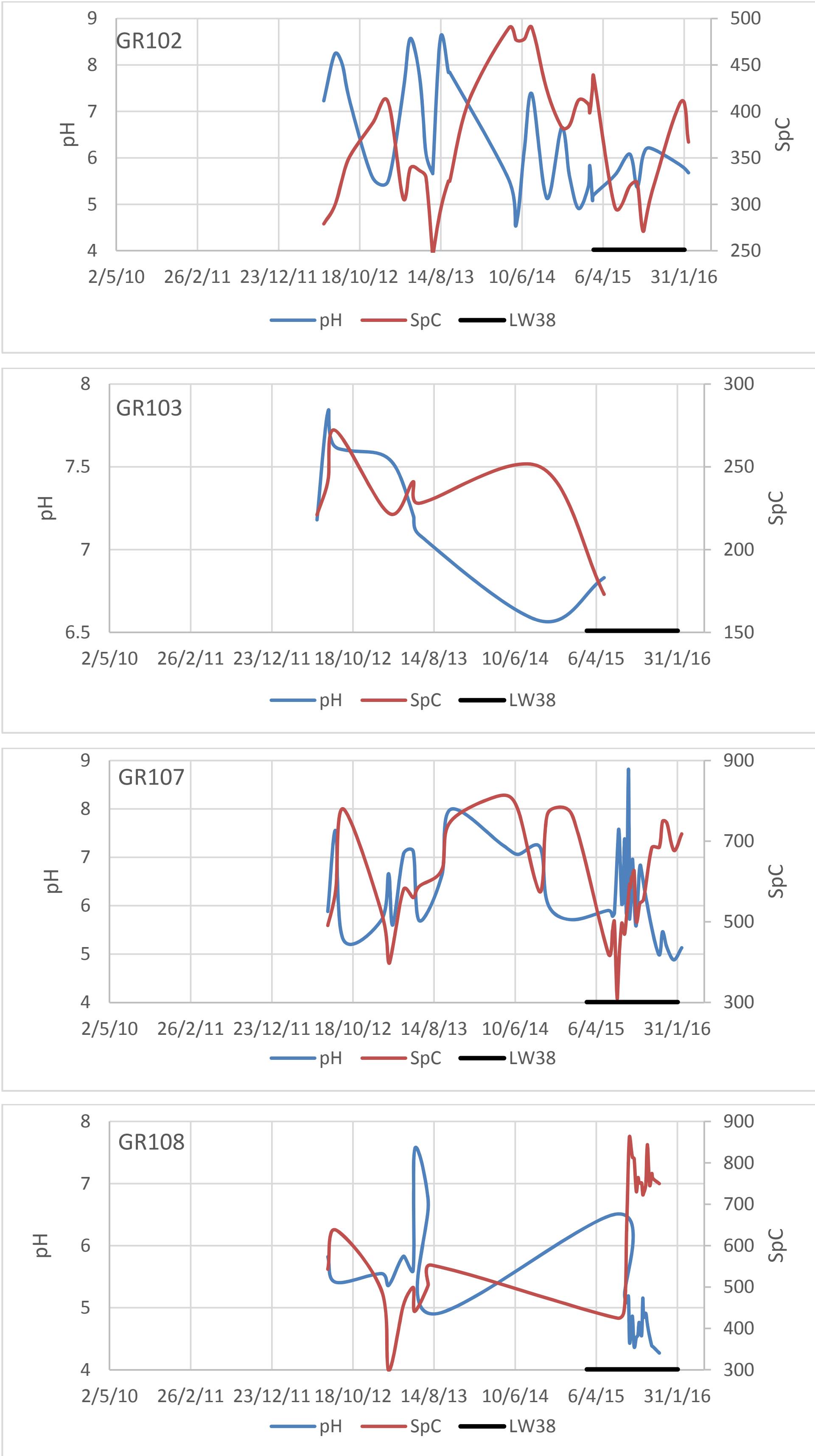


Figure 11 **Georges River Tributaries (A) pH and Salinity**

Figure 12 Georges River Tributaries (B) pH and Salinity

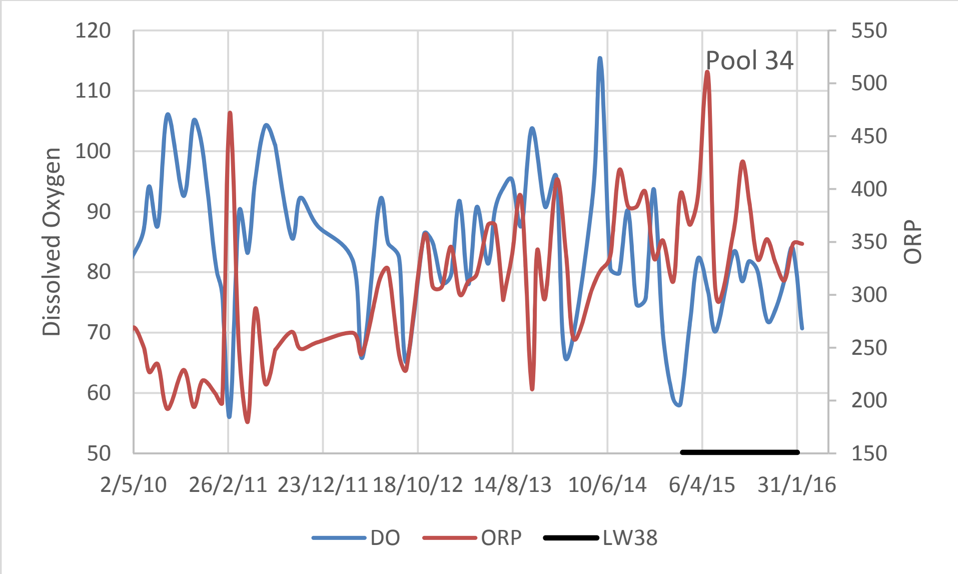
The pH and salinity in the selected Georges River and tributary sites maintained a similar variability, with no significant change to the baseline range, along with no significant change in trend or extended adverse changes being observed as a result of extraction of Longwall 38.

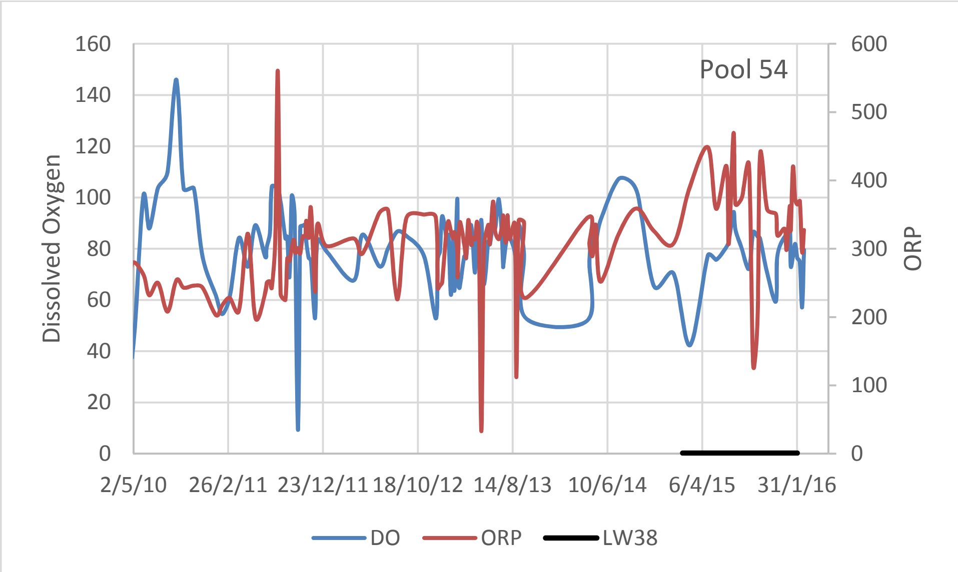
No TARP trigger levels were attained for pH due to extraction of Longwall 38.

3.3.5 Georges River and Tributaries Dissolved Oxygen and Oxidation Reduction Potential

For the selected monitoring sites, the Georges River has a dissolved oxygen (DO) and oxidation reduction potential (ORP) range as shown in **Figure 13**, whilst the Georges River tributaries are shown in **Figures 14** and **15**.

During the Longwall 38 extraction period, the Georges River DO and ORP maintained a similar pre Longwall 38 variability, with no significant change to the observed ranges as a result of extraction of Longwall 38.





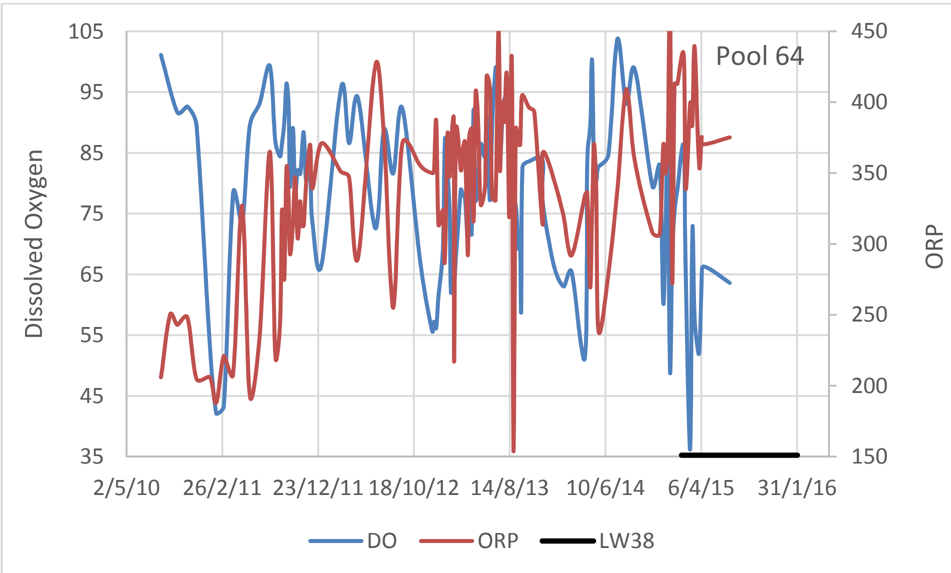


Figure 13 Georges River Dissolved Oxygen and Oxidation Reduction Potential

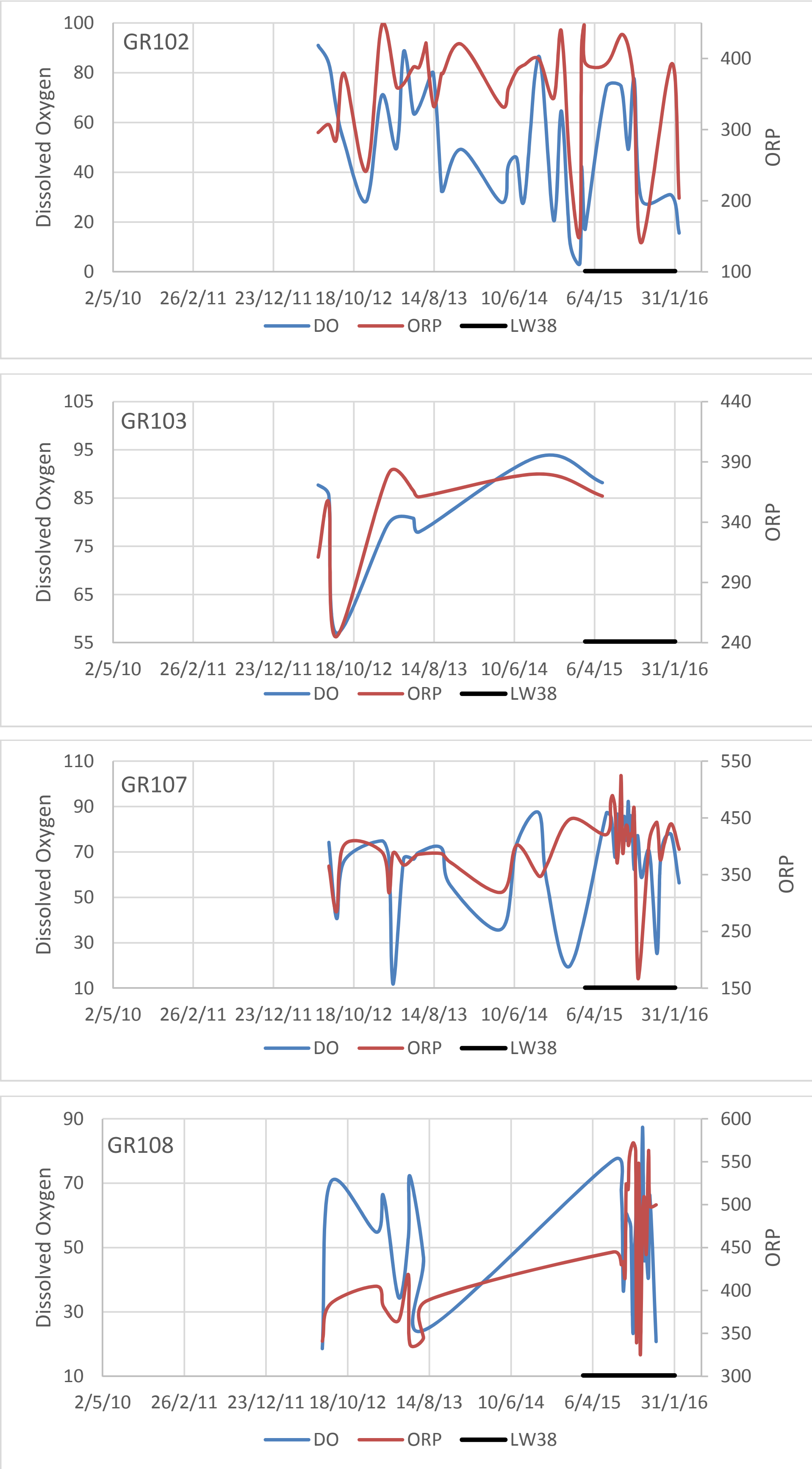


Figure 14 Georges River Tributaries (A) Dissolved Oxygen and Oxidation Reduction Potential

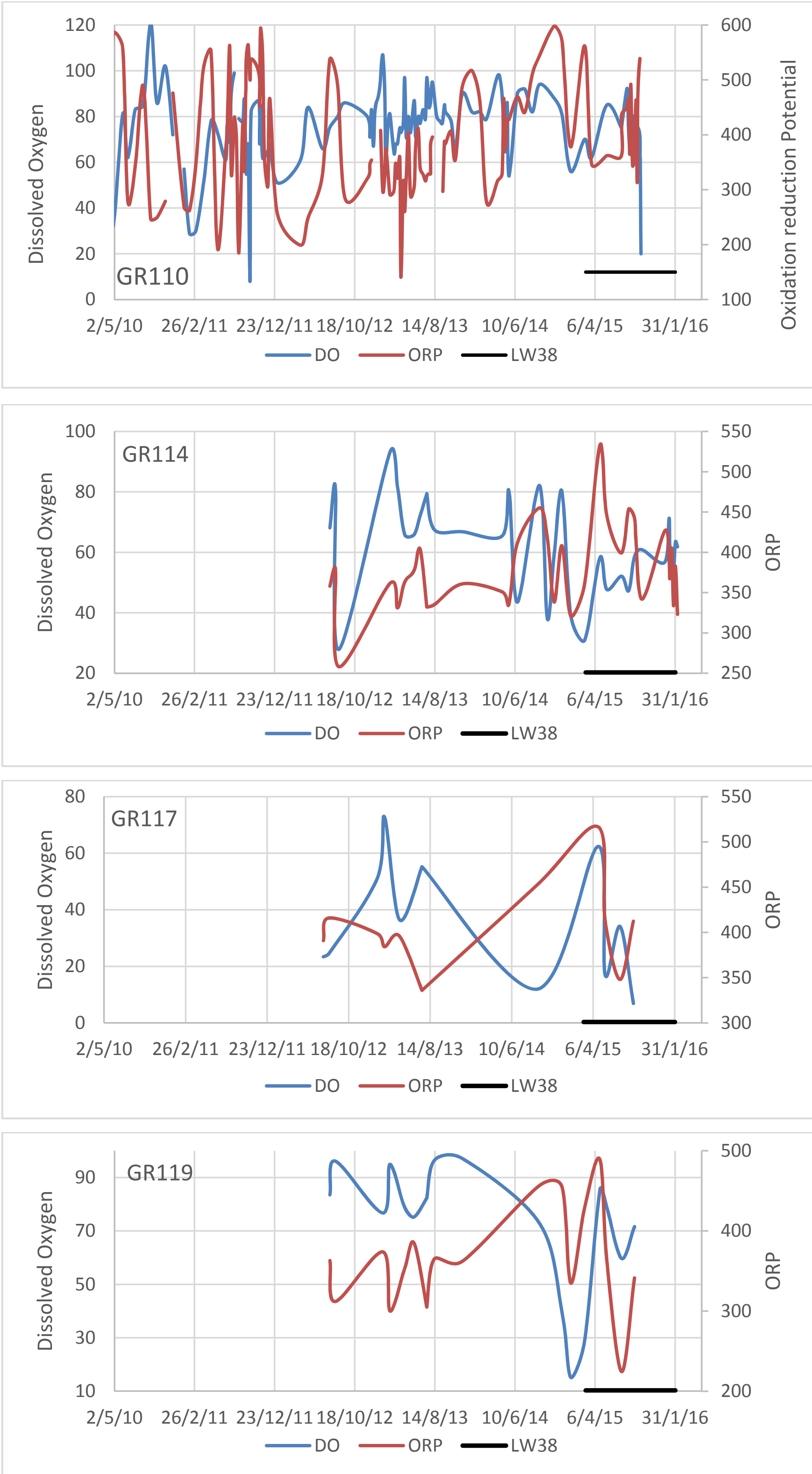


Figure 15 **Georges River Tributaries (B) Dissolved Oxygen and Oxidation Reduction Potential**

3.3.6 Georges River and Tributaries Iron, Manganese, Nickel and Zinc

For the selected monitoring sites, the Georges River has an iron (Fe), manganese (Mn), nickel (Ni) and zinc (Zn) range as shown in **Figure 16**, whilst the Georges River tributaries are shown in **Figures 17** and **18**.

During and after the Longwall 38 extraction period, trigger levels for iron compared to the pre Longwall 38 values were:

- Level 1 increase in iron staining;

During the extraction of Longwall 38, a 20m section of iron staining was observed in the Georges River downstream of GR_Pool 49.

Minor iron staining was noted at impacts WCA5_LW38_002, as well as WCA5_LW38_005 in tributary GR108.

During the Longwall 38 extraction period, the Georges River Mn, Ni and Zn maintained a similar pre Longwall 38 variability, with no significant change to the observed ranges as a result of extraction of Longwall 38.

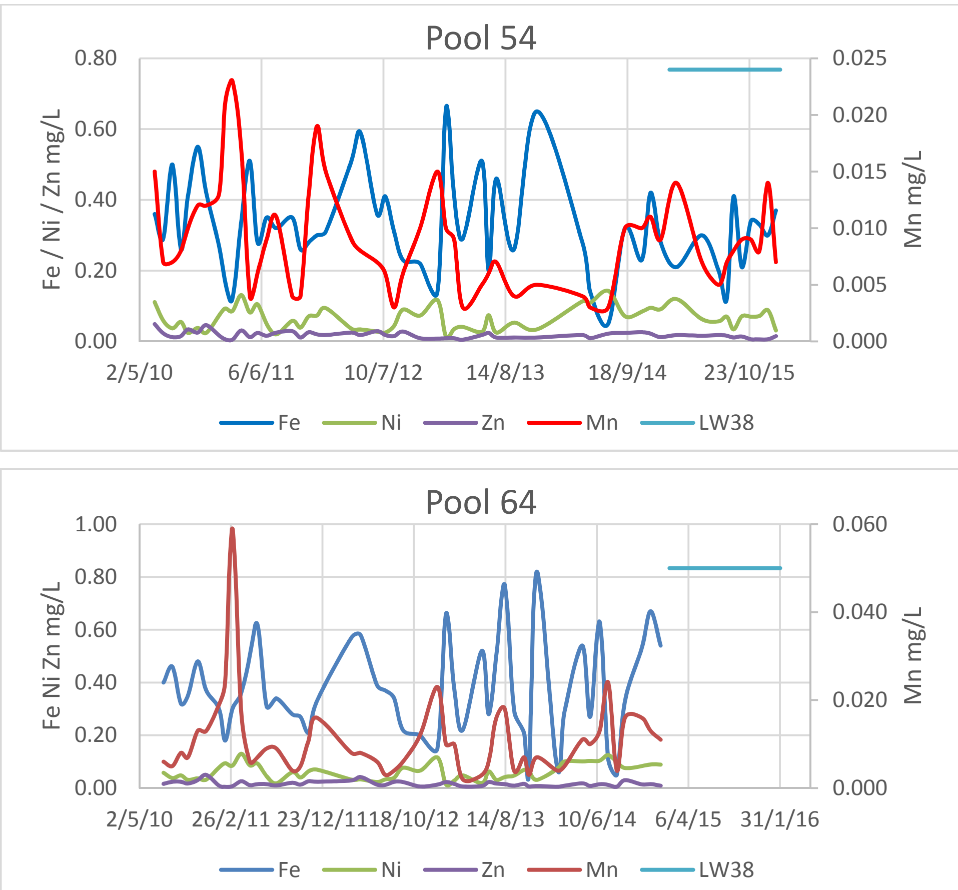


Figure 16 Georges River Iron, Manganese, Nickel and Zinc

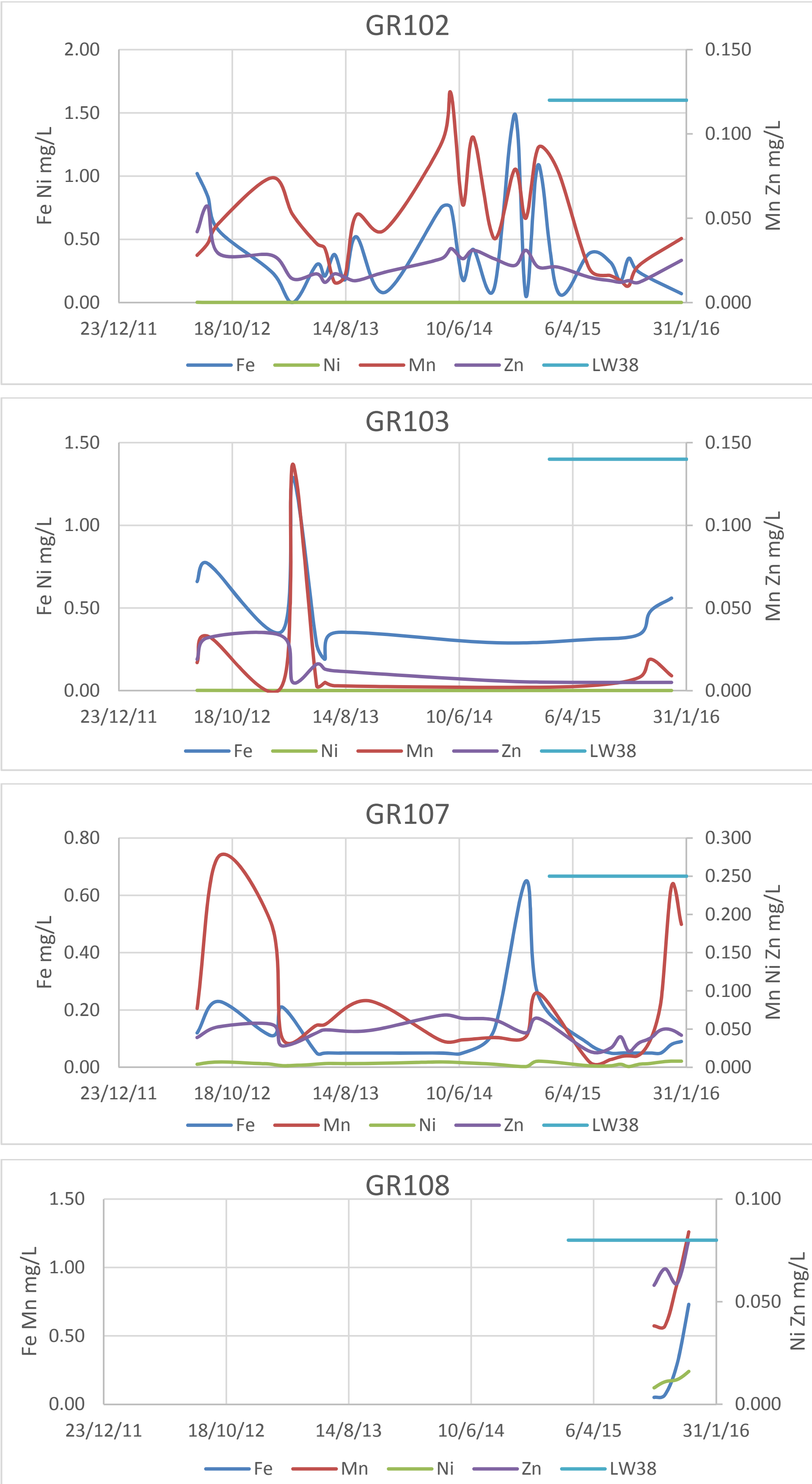


Figure 17 Georges River Tributaries (A) Iron, Manganese, Nickel and Zinc

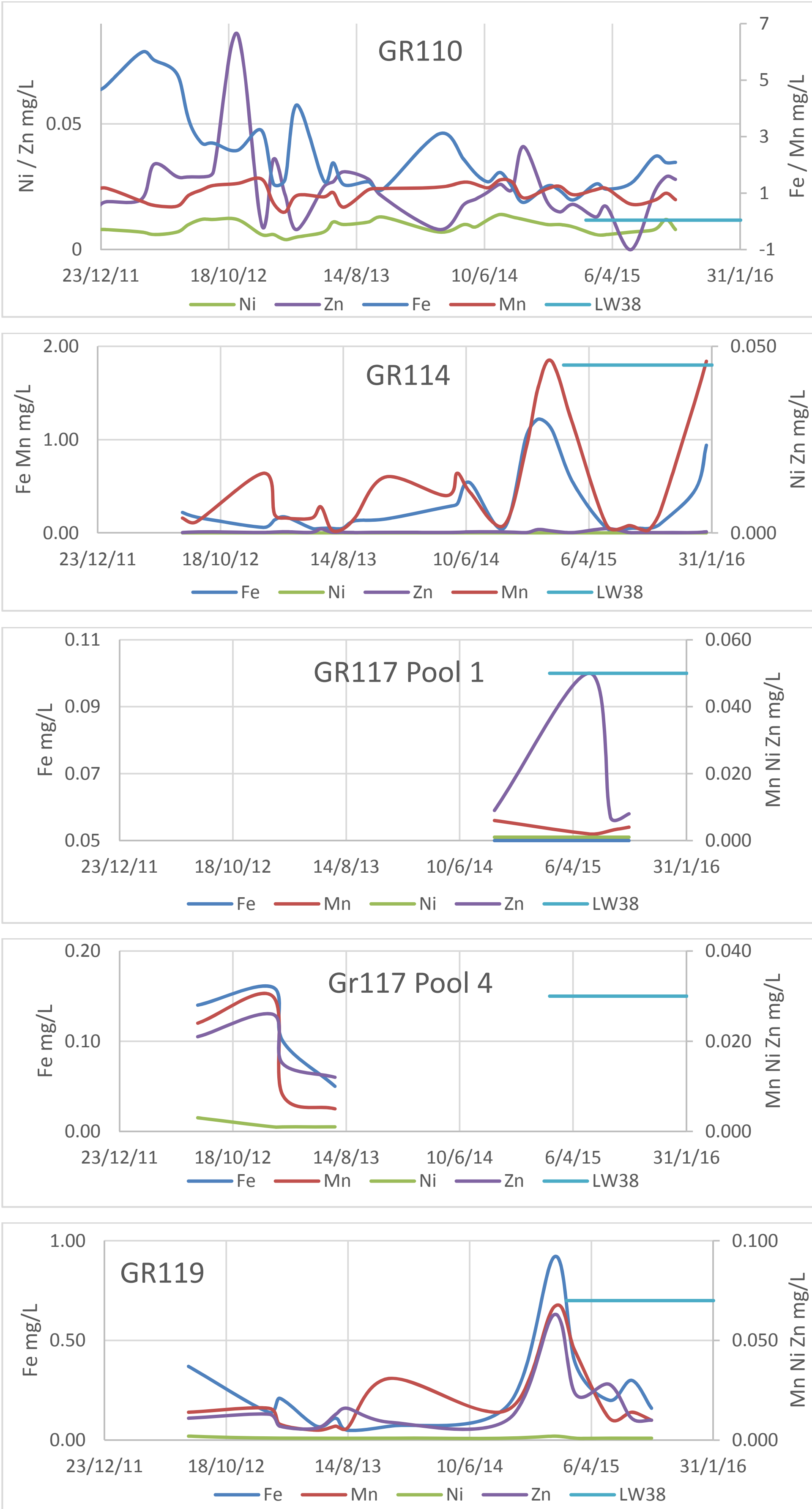


Figure 18 Georges River Tributaries (B) Iron, Manganese, Nickel and Zinc

3.3.7 Gas Seeps into the Georges River and Tributaries

The ICEFT did not observe any new gas releases during extraction of Longwall 38.

3.4 Groundwater

Monitoring has been conducted in the Longwall 38 Study Area to document any observed impacts relating to the "GR" piezometers, as well as the following private boreholes within Area 5. The following bores and piezometers were specifically observed as part of the Longwall 37 and 38 TARP:

- Piezometers - GR27, 28, 29, 70, WC54 and WC95
- Private Bores - GW32310, GW72454, GW105921 and GW108322
- Vibrating Wire Piezometer Array – S2087.

The observed effects during extraction of Longwall 38 are outlined in the following sections.

3.4.1 Aquifer / Aquitard Interconnection

No adverse interconnection of aquifers and aquitards has been observed within 20m of the plateau surface and no increased rate of groundwater recharge into the plateau has been observed as a result of Longwall 38 extraction.

No TARP trigger levels related to aquifer / aquitard interconnection or changes in recharge have been observed to have been reached or exceeded as a result of Longwall 38 extraction.

3.4.2 Groundwater Levels

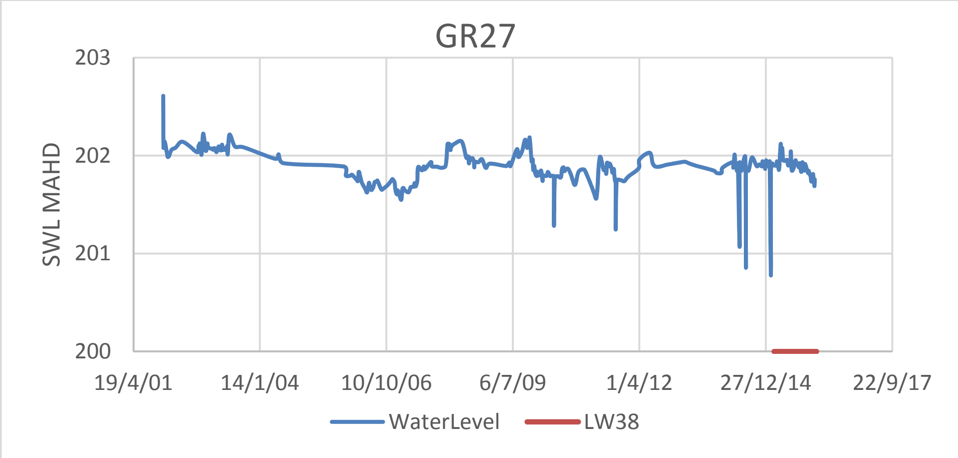
Piezometers GR29 and WC95 along with the Private Bore GW72454 overly Longwall 38.

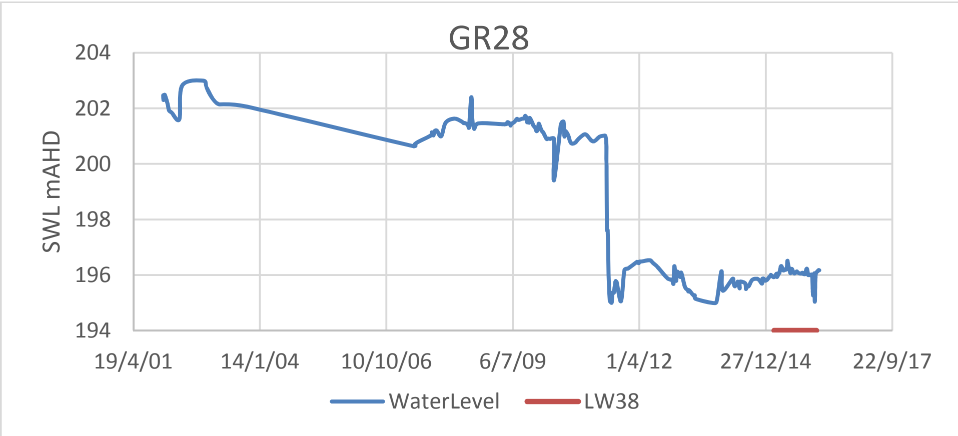
Piezometer GR27 lies within the Longwall 38 (20mm) subsidence zone to the southwest, between Longwall 38 and the Georges River, whilst GR28 lies on the western side of the Georges River.

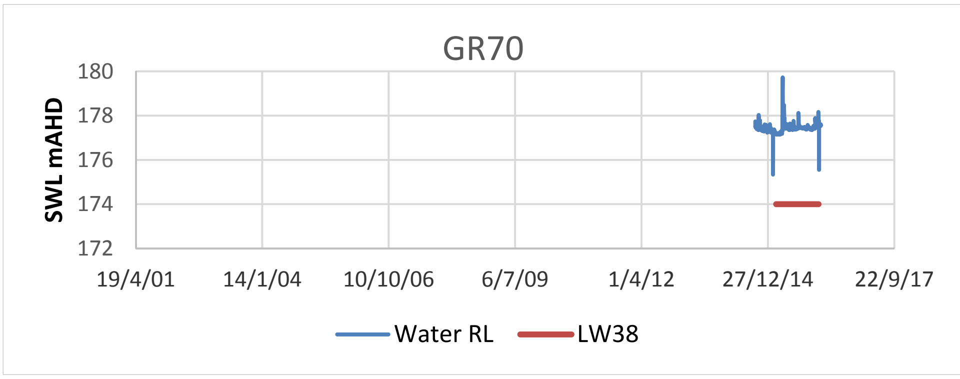
Piezometers WC54 and GR70 are located within the Longwall 37 (20mm) subsidence zone.

Water levels in GR27, GR28, GR70 and WC54 have not been observably affected by subsidence up to the end of extraction of Longwall 38, although GR28 was affected by an approximately 6m drop associated with subsidence in August 2011 as shown in **Figure 19.**

The water level in WC95 fell by approximately 9m between the end of March and late May 2015, then subsequently recovered by approximately 4m up to mid-January 2016 as shown in **Figure 20**.







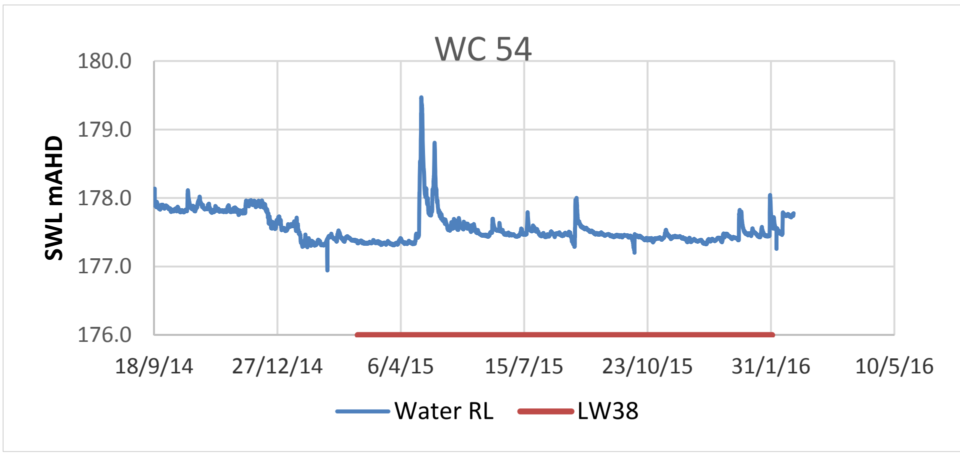


Figure 19 GR and WC Piezo Water Levels

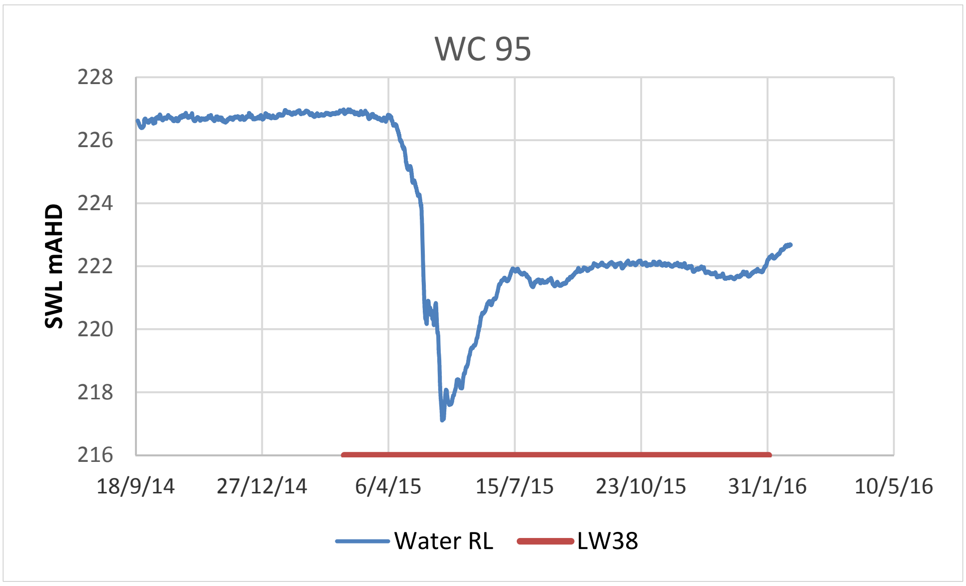


Figure 20 WC Piezo Water Levels

A Level 1 TARP trigger level was triggered by the 9m reduction in water level in piezometer WC95 as the fall was between 5 – 7.5 m greater than the predicted reduction in Hawkesbury Sandstone related depressurisation over a minimum 2 month period.

3.4.3 Vibrating Wire Piezometers

No monitoring of relevance to the extraction of Longwall 38 has occurred in the vibrating wire piezometer array in Bore S2087.

3.4.4 Well Yield and Bore Serviceability

The landowner at No. 75 Exley Road Wedderburn (Lot 10, DP3221) reported an adverse effect on their groundwater pumping supply and iron levels from bore GW72454 in mid-November 2015. The bore is located near the house, next to a shed.

The landowner at No. 41 Exley Road Wedderburn (Lot 81, DP622780) reported an adverse effect on their groundwater supply from bore K10bh01 on 1 March 2016 in that it had not been performing as usual for several months. The bore is located on the southern end of their property.

Two private bores (GW72454 and K10bh01) reported adverse effects on their bore yield or water quality as a result of extraction of Longwall 38.

3.4.5 Groundwater Quality

The groundwater quality monitoring of piezometers GR27, 28 and 70 indicates that no adverse effects on their salinity or pH has occurred as a result of Longwall 38 extraction as shown in **Figure 21**.

Monitoring of the GW72454 bore indicates no change in salinity, a minor alkalisation in pH from 4.78 to 5.27 along with an increase in iron from 0.42 mg/L before undermining to 6.96mg/L after undermining.

Bore K10bh01 had a minor increase in salinity of 104uS/cm before undermining to 331uS/cm after undermining, as well as a change in pH from 5.89 to 4.46.

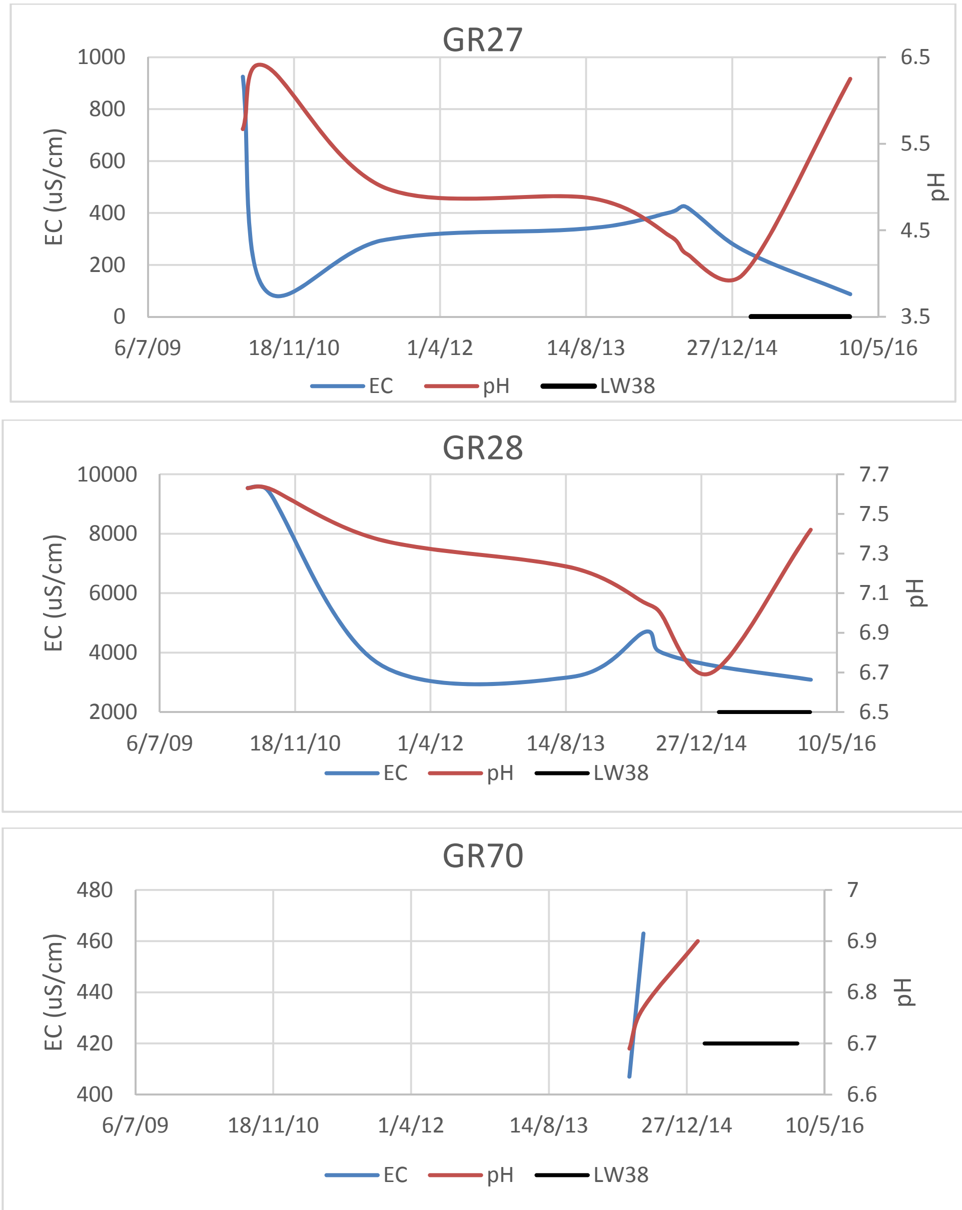


Figure 21 Piezometer Salinity and pH

No groundwater quality TARP triggers were exceeded during or following the extraction of Longwall 38.

3.4.6 Gas Seepage

No bore water quality TARP triggers were exceeded during or after the extraction of Longwall 38 did not result in any gas seepage into a private bore.

3.4.7 Inflow to Mine Workings

*No increased groundwater inflow to the West Cliff mine workings following extraction of Longwall 38 has occurred and no TARP trigger levels have been reached or exceeded, based on the data presented in **Figure 22**.*

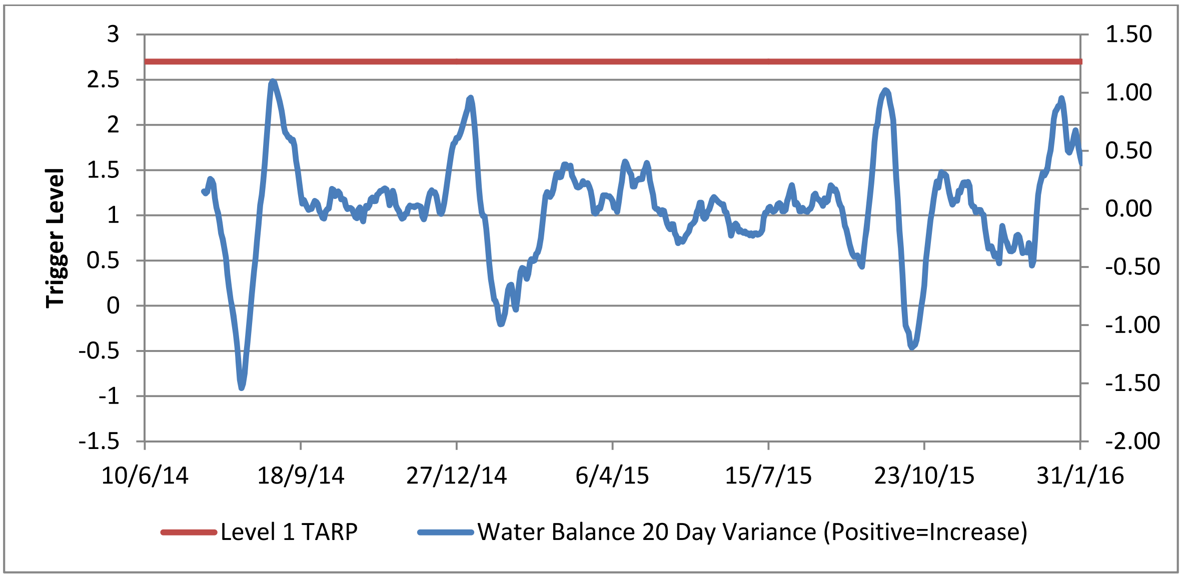


Figure 22 West Cliff Mine Groundwater Inflow

4. CONCLUSIONS

Based on monitoring of the Georges River and tributary streams as well as groundwater piezometers and bores conducted prior to, during and after extraction of Longwall 38, the following conclusions can be made:

- A Level 2 TARP trigger stream bed cracking and associated stream flow diversion was observed in association with extraction of Longwall 38 in the Georges River at the GR_Rockbar 49;
- New stream bed fracturing and associated reduction in stream flow and pool desiccation has been observed over Longwall 38 in the GR104, 108 and 110 tributaries;
- No new gas emission sites in the Georges River were associated with extraction of Longwall 38;
- A Level 1 water quality TARP triggers comprising iron staining over a 20m reach occurred downstream of GR_Pool 49 in the Georges River that was associated with extraction of Longwall 38;
- Up to 9m of depressurisation in the upper Hawkesbury Sandstone was observed in piezometer WC95 bore that overlies Longwall 38;
- Two private bores (GW72454 and K10bh01) reported adverse bore yields as a result of subsidence associated with Longwall 38;

5. REFERENCES

ANZECC 2000 Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Vol 1 & 2

Ecoengineers, 2015 End of Panel Assessment of Surface Water Effects West Cliff Colliery Longwall 37

GeoTerra, 2013 BHP Billiton Illawara Coal Pty Ltd West Cliff Longwalls 37 and 38 Groundwater Assessment, Appin, NSW

Heritage Computing, 2010 Bulli Seam Operations Groundwater Assessment A Hydrogeological Assessment in Support of the Bulli Seam Operations Environmental Impact Statement

HydroSimulations, 2013 Bulli Seam Operations Groundwater Data Analysis to Mid 2013 (Appin and West Cliff Areas)

Mine Subsidence Engineering Consultants, 2012 BHP Billiton Illawarra Coal West Cliff Colliery – Longwalls 37 and 38 Subsidence Predictions and Impact Assessments for the Natural Features and Surface Infrastructure in Support of the Extraction Plan

Mine Subsidence Engineering Consultants, 2016 End of Panel Subsidence Monitoring Report For West Cliff Longwall 38

South32, 2015 Feher / Benes (Lot 10, DP3221) Illawarra Coal – Post Mining Property Inspection, 20/5/15

South32, 2016 West Cliff Longwall 38 End of Panel Landscape Report

South32, 2016A West Cliff Area 5 Impact Report 17th of March 2016

South32, 2016B Lot 81, DP622780 Illawarra Coal Post Mining Property Inspection 18/03/2016

LIMITATIONS

This report was prepared in accordance with the scope of services set out in the contract between GeoTerra Pty Ltd (GeoTerra) and the client, or where no contract has been finalised, the proposal agreed to by the client. To the best of our knowledge the report presented herein accurately reflects the client's requirements when it was printed. However, the application of conditions of approval or impacts of unanticipated future events could modify the outcomes described in this document.

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.

The findings contained in this report are the result of discrete / specific methodologies used in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site in question. Under no circumstances, however, can it be considered that these findings represent the actual state of the site at all points.

Interpretations and recommendations provided in this report are opinions provided for our Client's sole use in accordance with the specified brief. As such they do not necessarily address all aspects of water, soil or rock conditions on the subject site. The responsibility of GeoTerra is solely to its client and it is not intended that this report be relied upon by any third party. This report shall not be reproduced either wholly or in part without the prior written consent of GeoTerra.

APPENDIX A

Longwall 38 TARP Impact Summary

Longwall 38 TARPs and Impact Summary

Feature	Performance Measure*	Potential Impacts	*Exceeding* Prediction	TARP Trigger Level	Observed Impacts	Additional Comments / Recommendations
Water Quality						
Georges River ***Longwall 38*** Upstream monitoring site: • Pool 34 Adjacent monitoring site: • Pool 54 Downstream monitoring site: • GR100	Negligible environmental consequences including: • negligible gas releases and iron staining; and • negligible increase in water cloudiness, over at least 80% of the stream length subject to vertical subsidence >20mm. No subsidence impact or environmental consequence greater than minor	• Fracturing and pool water level loss • Subsidence induced springs • Gas releases • Potential geochemical effects on water quality • Fracturing of rockbars and the stream bed where the subsidence movements are predicted to be highest • Changes in grade of drainage lines are considered small in comparison to natural grades. This is unlikely to result in significant increases in ponding or flooding, although some very localised impacts may occur • Diversion of surface water flows where fracturing coincides with a water controlling feature e.g. rock bar.	• Subsidence impacts or environmental consequences greater than minor	***Level 1*** • Temporary reduction in water quality (observed for 2 consecutive months) at any site when comparing the baseline period to mining period for that site i.e. : - pH drop between 0.5 and 1.0 units from the minimum baseline value	No Level 1 impacts	n/a
				Level 2 • Temporary reduction in water quality (observed for 2 consecutive months) at any site when comparing the baseline period to mining period for that site i.e. : - pH drop between 1.0 and 1.5 units from the minimum baseline value	No Level 2 impacts	n/a
				Level 3 • Reduction in water quality (observed for more than 2 consecutive months) when comparing the baseline period to mining period for that site i.e.: - pH drop of 1.5 units from the minimum baseline value	No Level 3 impacts	n/a

Longwall 38 TARPs and Impact Summary

Feature	Performance Measure*	Potential Impacts	*Exceeding* Prediction	TARP Trigger Level	Observed Impacts	Additional Comments / Recommendations
Tributaries of the Georges River ***Longwall 38*** Upstream monitoring site: • GR119 Adjacent monitoring sites: • GR107, GR108, GR110 Downstream monitoring sites: • GR102, GR103, GR114 and GR117	No greater subsidence impact or environmental consequences than predicted in the EA and PPR.	• Changes in grade of drainage lines are considered small in comparison to natural grades. This is unlikely to result in significant increases in ponding or flooding, although some very localised impacts may occur • Some compressive buckling and dilation of the uppermost bedrock could occur. However, the natural surface soil beds would limit exposure of fracturing at the surface and any minor occurrences are likely to be filled with the natural soils during subsequent flow events.			Rock fracturing, rock displacement or bedding plane extension in Tributaries GR104, GR108 and GR110	All observations within predicted effects, no TARP triggers exceeded
Appearance and Pool Water Level						
Georges River All mapped pools within the mining area	Negligible environmental consequences including: • negligible diversion of flows or changes in the natural drainage behaviour of pools; • negligible gas releases and iron staining; and • negligible increase in water cloudiness, over at least 80% of the stream length subject to vertical subsidence >20 mm.	• Fracturing and pool water level loss • Subsidence induced springs • Gas releases	• More than negligible diversion of flows or changes in the natural drainage behaviour of pools over more than 20% of the stream length subject to vertical subsidence >20mm • More than negligible increase in water cloudiness over more than 20% of the stream length subject to vertical subsidence >20mm • More than negligible	***Level 1*** • Fracturing with no observable surface water diversion • Pool water level lower than baseline in any mapped pool located in the mining area (within 400m of the longwall) • Increase in turbidity, iron staining, algal growth, or other visible water quality parameters determined by comparing baseline	Iron staining along a 20m reach downstream of GR-Rockpool 49	n/a

Longwall 38 TARPs and Impact Summary

Feature	Performance Measure*	Potential Impacts	*Exceeding* Prediction	TARP Trigger Level	Observed Impacts	Additional Comments / Recommendations
	No subsidence impact or environmental consequence greater than minor		increase in iron staining over more than 20% of the stream length subject to vertical subsidence >20mm • Subsidence impacts or environmental consequences greater than minor	photos with photos during the mining period.		
				Level 2 • Pool water level lower than baseline in the majority of mapped pools located in the mining area (within 400m of the longwall) • Fracturing with observable surface water diversion.	Flow diversion at GR_Rockbar 49	n/a
				Level 3 • Pool water level lower than baseline in all mapped pools in the mining area (within 400m of the longwall) • Fracturing with observable water diversion results in any mapped pool becoming dry during a mitigation flow in the River.	No Level 3 impacts	n/a
Groundwater						
IC monitoring bores: • GR27 • GR28 • GR29 • GR70 • WC54 • WC95 Private Bores • GW32310 • GW72454 • GW105921 • GW108322		Reduced bore yield Groundwater quality Generation or enhancement of ferruginous springs Bore gas emissions	Subsidence impacts or environmental consequences greater than minor	***Level 1*** • Increase in water flow from the goaf between 2.7-3 ML/day (20 day average) • 5.0 – 7.5 m reduction in the Hawkesbury Sandstone greater than predicted standing water level or pressure (outside of pumping influences in private bores) over a minimum 2 month period	No increase in water flow to the underground workings 9m reduction in piezometer WC95 over more than 2 months, followed by a 4m recovery Adverse yield reports in bores GW72454 and K10bh01	n/a WC95 reduction within the range of 5.0 - 7.5 m greater than the predicted reduction

Longwall 38 TARPs and Impact Summary

Feature	Performance Measure*	Potential Impacts	*Exceeding* Prediction	TARP Trigger Level	Observed Impacts	Additional Comments / Recommendations
Mine water budget				***Level 2*** • Rise in water flow from the goaf between 3-3.4ML (20 day average) • 7.5 – 10 m reduction in the Hawkesbury Sandstone greater than predicted standing water level or pressure (outside of pumping influences in private bores) over a minimum 2 month period	No Level 2 impacts	n/a
				Level 3 • Abnormal rise in water flow from the goaf >3.4ML (20 day average) • >10m reduction in the Hawkesbury Sandstone standing water level or pressure (outside of pumping influences in private bores) over a minimum 2 month period • Total loss of groundwater level within a private bore	No Level 3 impacts	n/a

* Performance Measure as defined in BSO Development Consent Approval (Table 1).