END OF PANEL

ASSESSMENT OF WATER FLOW

AND QUALITY EFFECTS

APPIN COLLIERY LONGWALL 705

for

BHP BILLITON ILLAWARRA COAL

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ecoengineers Pty Ltd
9 Sunninghill Circuit
Mount Ousley NSW
Australia 2519
T: 61 2 4227 4174
F: 61 2 4227 5154
www.ecoengineers.com
ABN 74 078 666 510

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EXECUTIVE SUMMARY

An assessment has been made of hydrologic and water quality effects on the Nepean River in the Longwall 705 Subsidence Management Plan (SMP) Area following the mining of Appin Longwall 705 which commenced 7 September 2012 and finished 27 March 2014.

Direct flow monitoring of the River in the vicinity of Appin Area 7 is not undertaken as there are no suitable zones of restricted flow, this section of the River being largely flooded by backwater from Menangle Weir.

However, long records exist for the Sydney Catchment Authority-operated gauging stations at Maldon and Menangle Weirs, approximately 5 km upriver and 14 km downriver respectively of the stretch of the River adjacent to Longwall 705. It is generally possible to subtract flows as measured at Maldon Weir from those at Menangle Weir. The difference should be equivalent to runoff from all catchments between these two weirs responding to local rainfall minus any abstractions by licensed pumps in the River, and plus or minus any natural or mining-induced gains or losses of groundwater to/from the River.

In the previous End of Panel Water Reports for Longwalls 701 and 702, the difference between concurrent recessional data for Maldon and Menangle Weirs (during dry to near-dry weather) were used to assess if there was any detectable abnormal rate of loss or gain of River water between the weirs during mining, relative to the late 1990 to late 2007 baseline period. This was done by comparing the equivalent mean slope and its standard deviation of the rate of recession of low flows (i.e. the slope of a plot of flow against the natural logarithm of time) during mining with the pre-mining baseline period.

Due to generally higher river-flows following the cessation (locally) of the Millennium Drought in late 2006 and particularly more recently during the period of Longwall 705 mining, the identification of dry weather, low flow, ‘Menangle minus Maldon’ recessions similar (in terms of initial and final flow rates) to those assessed for the previous Longwall 701 and 702 End of Panel reports was found to not be possible due to invariably higher River flows through this region. By ‘dry weather’ we mean a lack of rainfall at the local BOM weather station at Douglas Park.

Therefore flow data records for Maldon and Menangle Weirs were carefully reassessed, again all the way back to 1990 to identify all dry weather recessions, defined as periods when there was no local daily rainfall as recorded at the BOM Douglas Park weather station close to Area 7.

To further improve the precision of this exercise, daily flow data for spills over Broughtons Pass Weir into the Lower Cataract River (which flows in the Nepean River just upriver of the completed and proposed Area 7 longwalls) were also included to produce ‘Menangle minus Maldon minus Broughton’s’ recession of improved reliability – especially for the post-Millennium Drought period of increased wetness which has applied since Longwall 701 was mined. A macro was written into Excel to ensure that all dry weather recessions over the period 1990 through 2007 were reliably and unambiguously detected.

The reanalysis of all low flow recessions in the River over the entire baseline period from 1990 to 2007 i.e. prior to the mining of Longwall 701 stretching back to 1990 identified a total of 55 such local rainfall-free ‘Menangle minus Maldon minus Broughton’s’ recessions.

This new baseline study also clearly showed that the magnitudes of all log (time)-linear(flow) recession rates exhibit a strong, simple linear correlation between the starting flow rate of recessional periods and the rate of recession, as indicated by the slope of the log-linear recession curve. The R^2 parameter of the correlation was a strong 0.88 indicating that the correlation accounts for 88% of all variance. There are hydrodynamic reasons, associated with the cross sectional profiles in the River which can account for such a correlation.

Next, this relationship was then used to check the 5 recessions which could now be identified (by use of the same macro) during the period of mining of Longwall 705.

These analyses showed that rates of dry weather recession during the mining of Longwall 705 were slightly lower but, well within error, equivalent to those estimated from the study of baseline recessions during 1990 through 2007. The rate of recession during the mining of Longwall 705 ranged from -18.6 - -22.7 ML/day with a mean of -20.9±1.9 ML/day (n=5). The mean rate during the 17 year baseline period was -24.4±16.9 ML/day (n=51).

This exercise therefore indicates that there has been no observable loss or diversion of water from the Nepean River as a result of the mining of Longwall 705.

Appin Area 7 baseline water quality data for the river was obtained by BHPBIC from July 2002, when monitoring commenced, to mid-October 2007 when Longwall 701 commenced. Since then, surface water quality has been monitored weekly and laboratory analysis samples collected monthly.

Field inspections carried out by the BHPBIC Environmental Field Team included monitoring for iron stain zones in the river and tributaries and gas release zones in the river. The relevant iron stain zones were identified during the mining of Longwall 701 and no new iron staining associated with Longwall 705 has been observed.

Iron Stain Zone One in Elladale Creek, activated during the mining of Longwall 701, was short-lived in duration and no staining was observed after October 2009. Iron Stain Zone Two along the bank of the Nepean River currently comprises a spring with iron staining over an approximate 2 x 2 metre area. No changes to this zone were observed over numerous monitoring visits during and since mining of Longwall 705.

Three new gas zones (Gas Zones 16, 17 and 18) were identified during Longwall 705. Of these, only Gas Zone 18 remains active. The gas zone with the highest flow rate was Gas Zone 16, where the flow rate was estimated to be approximately 200 L/min.

Data for pH, Electrical Conductivity, Dissolved Oxygen, Total Iron and Total Manganese were compared at sites upriver and downriver of Longwall 705 in order to identify any significant water quality change due to Longwall 705. Upper and lower limit Trigger Action Response Plans (TARPs) were established by the Management Plan for each parameter for downriver sites.

No TARP monitoring level was reached as a result of water quality observations in the Nepean River, with the exception of the identification of the aforementioned strata gas plumes, which were all Level 1 impacts, due to their flow rates being less than 3000 L/min.

1. INTRODUCTION

Ecoengineers Pty Ltd ('Ecoengineers') was engaged by BHP Billiton Illawarra Coal ('BHPBIC') to provide an assessment of water quality and flow effects in the Nepean River in the vicinity of Longwall 705.

Mining of Appin Area 7 Longwall 705 commenced 7 September 2012 and finished 27 March 2014.

In this report we have defined the area which is potentially affected by Longwall 705 based on the predicted limit of valley-related movements determined by Mine Subsidence Engineering Consultants ('MSEC') (MSEC, 2008). It is such geophysical effects which have the potential to cause the types of hydrologic or aquatic impacts listed above.

Observed valley-related movements are described in MSEC (2014).

Figure 1.1 below shows the general layout of Longwall 705, indicating the relative positions of previously mined longwalls and of the Nepean River, as well as water quality monitoring locations referred to in this report.

Figure 1.1 shows that the closest downriver water quality monitoring location to the defined limit of Longwall 705 effects is site NR11, just downriver of the confluence of Nepean River and Ousedale Creek.

Similarly, the closest upriver water quality monitoring location to the limit of Longwall 705 effects is site NR6, just downriver of the confluence of Nepean River and Cataract River.

As in previous Appin Area 7 Longwall End of Panel reports, we have assessed water quality on both a long-term, site by site basis; and a single day, river transect basis. In our assessments of water quality transects down the River, the transect was generally started at upriver site NR0, just downstream of Maldon Weir, and finished at downriver site NR50, at the Menangle Weir (see **Figure 1.1**).

BHPBIC measured mine subsidence movements at seven ground monitoring lines across the Nepean River valley which they defined as NEPX K-line to NEPX Q-line (refer MSEC 2014 Drawing MSEC583-01). Total observed upsidences and closures were less than predicted at all lines.

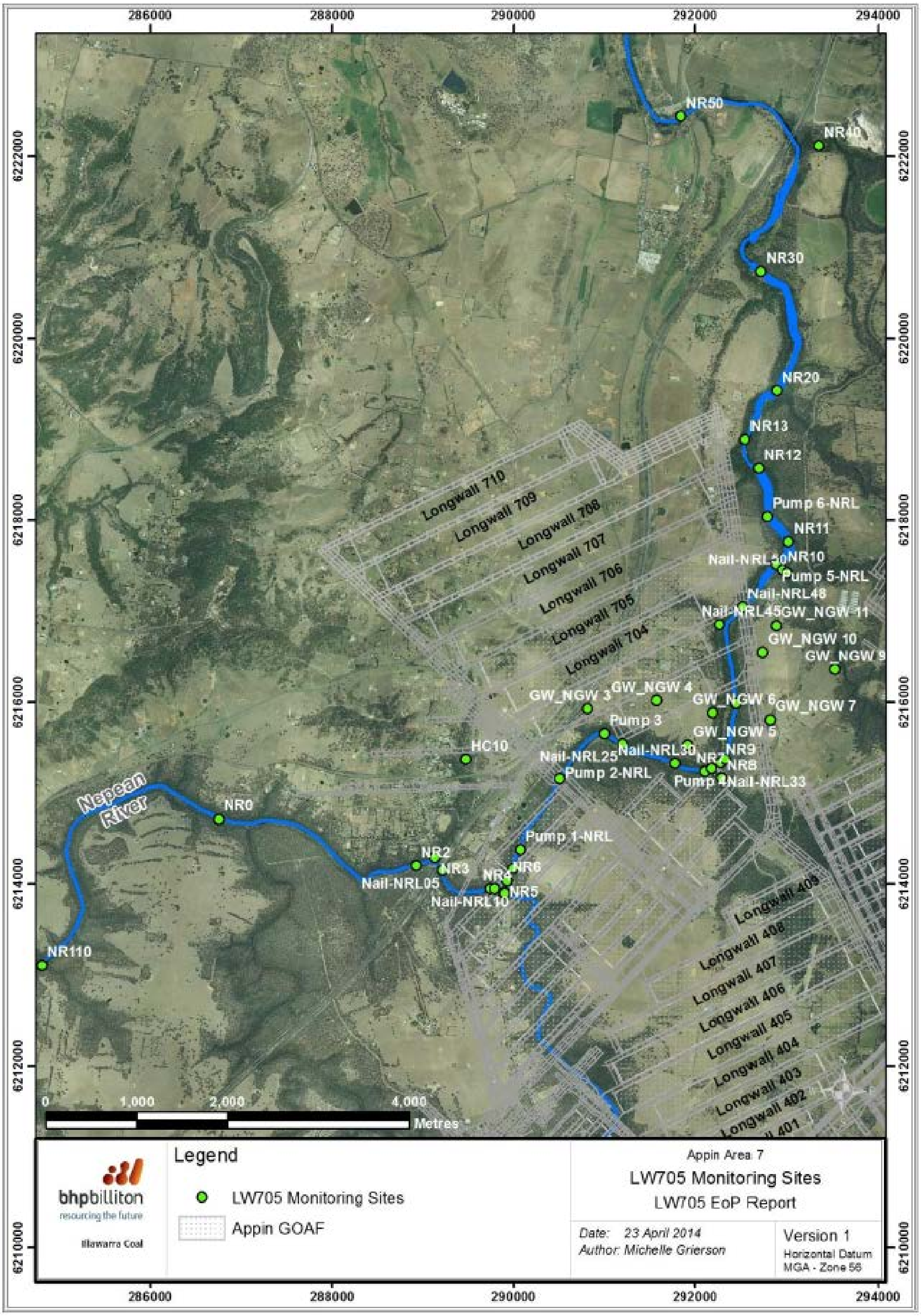

Figure 1.1: Longwall 705 in Relation to Nepean River Water Quality Sampling Locations, Extraction Pumps and Surveyed Water Level Datum 'Nails'.

1.1 REGIONAL CONTEXT AND BASIS OF THIS ASSESSMENT

The Nepean River is part of the Hawkesbury-Nepean River system which begins in the uplands west of Wollongong and flows northward past Camden to its junction with the Warragamba River near Wallacia.

The section of Nepean River adjacent to Longwall 705 can be described as a flooded valley. The water level within the River is predominantly regulated by the downstream weir at Menangle, which acts as a dam. Low water flows upriver of Longwall 705 are regulated by the (ungauged) Douglas Park Weir, which is located approximately 2.5 km south-west of Longwall 705. The section of river between the two weirs is approximately 14 km in length. Both weirs lie well outside the Area 7 Subsidence Management Plan (SMP) Area established by MSEC (2008).

This section of the Nepean River does not form part of a *Catchment Area* or a *Declared Special Area,* as defined by the Sydney Water Catchment Management Regulation 2008 under the Sydney Water Catchment Management Act 1998.

Nevertheless, the Nepean River is considered a significant watercourse which has been subject to many considerations of its value as an important national water resource and of aquatic ecosystem importance over many years (Independent Expert Panel on Environmental Flows for the Hawkesbury Nepean, Shoalhaven and Woronora Catchment, 2002a, b, and c). It was therefore defined as an *area of environmental sensitivity* for the purposes of the Appin Area 7 Longwalls 705 - 710 SMP Application.

There were no regionally specific Water Quality Objectives arising from the Independent Inquiry into the Hawkesbury-Nepean River System by the Healthy Rivers Commission. The Commission recommended the use of the default trigger values in the National Water Quality Guidelines (NWQG, ANZECC/ARMCANZ, 2000a & b).

There are no significant tributaries of the Nepean River in the vicinity of Longwall 705. A small, first order tributary locally called Lyrebird Creek crosses the northeastern end of the longwall as can be seen in **Figure 1.1** above. Another small tributary, Harris Creek, runs south to Nepean River to the immediate west of Longwall 705.

This assessment of surface water flow and quality is based upon past experience in the assessment of water quality effects induced by mining in the Illawarra Region generally, and specifically from hydrologic and water quality monitoring studies conducted in Nepean River.

2. BACKGROUND

2.1 NEPEAN RIVER HYDROLOGY

Water flows in the Nepean River are derived from a number of sources, which include flows from catchment areas, flows from licensed discharges, including Appin Colliery and Tahmoor Colliery (the latter located adjacent to Bargo River), and stormwater runoff from agricultural and urban areas. Excess flows from the Lake Nepean and Lake Avon catchment areas released over Pheasants Nest Weir contribute the majority of flows into the River.

The major tributaries upstream of Longwall 704 below Pheasants Nest Weir are the Bargo, Cordeaux and Cataract Rivers.

Minor amounts of water are directly drawn from the river by licensed water pumps and there are several of these close to Longwall 705 as shown above in **Figure 1.1**. It is understood that the total of licensed extraction allocations adjacent to Appin Area 7 is about 9 – 10 ML/day.

Regular flow monitoring has not been undertaken within the stretch of the river adjacent to Appin Area 7 as there are no areas of restricted flow and it is very difficult to measure flow across flooded channels, especially when the cross section contains both submerged and exposed boulders.

The closest flow gauging station upstream of Appin Area 7 is at Maldon Weir, located approximately 14 km upriver from Longwall 705. The closest flow gauging station downstream of the SMP Area is Menangle Weir, located approximately 5 km downriver of Longwall 705.

The Maldon Weir has a nominal catchment of 865 km^2 when SCA is spilling water over Pheasants Nest Weir (about 25 km upriver of Longwall 705) on the Upper Nepean River. For the approximately 50 percentile (median) and lower flows, when SCA is not spilling water over Pheasants Nest Weir, the Maldon Weir catchment is comprised primarily of the Bargo River catchment (approx. 181 km^2).

Flows at Maldon Weir underestimate flows in the Nepean River adjacent to Longwall 705 by at least 85%, and even more so when Pheasants Nest Weir is spilling.

Relatively consistent discharges to the Nepean River below Maldon Weir come from Stone Quarry Creek (Picton), Allen’s Creek (Wilton), and the Cataract River over Broughtons Pass Weir, as well as irregular flow inputs from creeks such as Harris Creek, together with approximately 1 ML/day from Allen’s Creek via the Appin West Pit Top licensed discharge (Geoterra, 2006).

As noted above, water level in the section of the Nepean River adjacent to Longwall 705 is predominantly controlled by Menangle Weir. The Weir ensures that the River remains fully charged at all times, even when there is little flow in it.

Interpolation between Maldon and Menangle Weir long-term flow records, allows estimates of flows adjacent to Longwall 705 to be made. The flow rate at Menangle Weir is considered to be far more representative of flows adjacent to Longwall 705 than the flow rate at Maldon Weir but it is still biased by flows from tributaries in the River between Maldon and Menangle Weirs, the largest contributor of which is by far the Cataract River catchment below Broughton’s Pass Weir but also including SCA releases and/or ‘natural’ spills over the Weir.

Measured daily mean water flows at Maldon Weir have been provided by SCA for the period between 1 January 2012 and 10 March 2014. The Maldon Weir record has some gaps and covers 749 days out of a total of 800 days.

Measured daily mean water flows at Menangle Weir have been provided by SCA for the period between 1 January 2012 and 17 February 2014. There are some gaps in this record which covers 779 days out of a total of 800 days.

In addition to these two data records, the record of daily mean water flows for Broughtons Pass Weir has now also been provided by SCA and been assessed for the entire period 1 January 1990 to 11 May 2014.

The HYDSTRA ratings of all of this recent data for Maldon and Menangle Weirs (covering the period of Longwall 705 mining) were marked by SCA as having “poor quality theoretical rating using one formal method of extension” which has “not been substantiated by discharge observations.”

Table 2.1 below provides a summary of ranked historical flow data for Maldon, Menangle, and Broughton’s Pass Weirs.

Table 2.1 Percentiles for SCA Flow Frequency Records for Maldon, Menangle and Broughtons Pass Weirs

Percentile	Maldon Flow: Historical Record (ML/day)	Maldon Flow: Post Millennium Drought (ML/Day)	Menangle Flow: Historical Record (ML/day)	Menangle Flow: Post Millennium Drought (ML/Day)	Broughtons Pass Historical Flow Record (ML/day)	Broughtons Pass Post Millennium Drought (ML/day)
60	17.39	44.71	44.04	156.24	0	5.28
50	14.02	33.01	34.40	105.40	0	0.37
40	11.53	24.30	24.86	58.92	0	0
30	9.13	18.22	17.01	42.29	0	0
20	6.74	13.68	9.50	30.98	0	0
10	4.14	7.89	4.81	19.16	0	0
Total Data Days	**5750 (1/1/1990 – 31/12/2006)**	**2375 (1/1/2007 – 10/03/2014)**	**5841 (1/7/1990 – 31/12/2006)**	**2057 (1/1/2007 – 17/02/2014)**	**6068 (1/1/1990 31/12/2006)**	**2672 (1/1/2007 – 11/05/2014)**

Some cessation of flow events have been recorded by the SCA, which reflect periods where more water is extracted from the River than is supplied from upstream, with maximum falls below the weir spill point of 36 mm at Maldon Weir and 295 mm at Menangle Weir. Subtraction of daily Maldon and Broughton's Pass Weir flows from Menangle Weir flows sometimes gave negative values either because of flow gauging errors or the effect of licensed extractions.

Water flows in the Nepean River:

- vary greatly and are highly responsive to rain events due to the significant areas of upriver catchment involved;
- reach very high levels during sustained storm events, while minimum flow is rarely likely to be less than 13 ML/day (approx. a 5 percentile flow at Menangle Weir);
- cease on a small number of occasions, usually only when the rate of pumping out of the river exceeds the rate of inflow under low flow/drought conditions; and
- are characterised by median flow rates in the Nepean River adjacent to Longwall 705 that are likely to be much higher than the median flow rate at Maldon Weir (33.01 ML/day), and about 15% less than the median flow rate at Menangle Weir (105.4 ML/day).

Interpolation between Maldon and Menangle Weir post millennium drought flow records suggests a median (50 percentile) flow rate adjacent to Area 7 of roughly 86 ML/day.

Water levels along the Nepean River were surveyed by BHPBIC in 2003, well after the completion of Tower Longwall 20. That survey showed that water levels fall slightly from a point immediately downstream of Douglas Park Weir (RL 61.10 AHD) to a point immediately upstream of Menangle Weir (RL 60.84 AHD), which represents a gradual fall of approximately 260 mm over a length of approximately 14 kilometres. This slight fall in water level most likely represents friction and head losses occurring along the river.

BHPBIC also conducted a survey of river bed levels in 2003 and measured levels at points representing the approximate deepest parts along the river. This showed that the bed profile changes considerably along the river's length and the river is typically between 2 and 7 metres deep.

Three sections across the Nepean River were measured by Geoterra in 2005. They indicate that the river increases in width as it travels downstream. The river is generally deeper where erosion is greatest on the outside of bends. It also becomes generally deeper as it travels downstream with a depth range from less than 0.25 metres over sand bars to greater than 8 metres in deeper rock based sections (Geoterra, 2006).

2.2 RAINFALL AND EVAPOTRANSPIRATION

Table 2.2 shows annual rainfalls recorded nearby at Douglas Park (St. Mary's Towers) (BOM station code 68200) from 1974. Between 2000 and 2006 the area was in drought. It experienced significantly lower than average rainfalls than had applied over the previous decade. Rainfall during this period was over 30% lower than the long term median annual rainfall at Cataract Dam which, over the more than 100 years since recording commenced in 1904, has averaged 1064 mm.

Monthly rainfall recorded at Douglas Park (St. Mary's Towers) on most months during the mining of Longwall 705 was less than the long term monthly averages (see **Tables 2.3 and 2.4**), however total rainfall during this period was only slightly less than average due to well above average rainfalls in January and June 2013 and March 2014.

The CSIRO Land and Water national grid map for Annual Potential Evapotranspiration (PET) for the most recent largely post-Millennium Drought period 2006 - 2010 indicates that the region currently probably has a mean annual Potential Evapotranspiration (PET) of around 1617 ± 64 mm/year (Donohue et al., 2010).

Annual Evapotranspiration ('ET') in the General SMP Area, which is largely cleared for pasture and generally drains Wianamatta Shale-based soil mantled or outcropping terrain, can be estimated from precipitation (P) and PET using the well-known and now well-established Yang et al. (2008) algorithm i.e. the 'Budyko Framework' approach.

Assuming a default catchment-specific (vegetation, topography, orientation etc.) parameter (n) value of 1.8 in that algorithm (Roderick and Farquhar, 2011) and an average annual rainfall of 755 ± 157 mm/year at Douglas Park, annual ET is estimated to be probably about 660 ± 111 mm/year (1.8 ± 0.6 mm/day) for the seven post Millennium Drought years 2007 to 2013.

Table 2.2 Annual Rainfalls at Douglas Park Since 1974

Year	Rainfall
1974	1040.8
1975	806.9
1976	1115.4
1977	607.6
1978	1210
1979	320.7
1980	424.4
1981	841
1982	393.2
1983	749.2
1984	949.4
1985	845.9
1986	852.8
1987	878.1
1988	1146.4
1989	884.6
1990	1240.1
1991	741.4
1992	659.9
1993	564.2
1994	483.6
1995	806.8
1996	687
1997	620
1998	809.6
1999	947.2
2000	582.2
2001	609.4
2002	496.6
2003	532.9
2004	618
2005	698.6
2006	402.7
2007	998.6
2008	774.3
2009	523.8
2010	794.4
2011	742.4
2012	727.4
2013	860.2
Average 1974 - 2013	**738.7 ± 224.2**
2014 January to March	**219.7**

Table 2.3 Average Monthly Rainfall at Douglas Park Since 1974

Month	Average Rainfall (mm) (1974 – 2013)
January	68.0
February	94.7
March	77.7
April	61.4
May	55.2
June	66.4
July	42.6
August	40.0
September	42.9
October	58.4
November	75.3
December	58.1

Table 2.4 Monthly Rainfalls at Douglas Park during mining of Longwall 705

Month	Rainfall (mm)
September 2012	14.2
October 2012	36.6
November 2012	39.4
December 2012	23.4
January 2013	210.4
February 2013	137.6
March 2013	41.0
April 2013	62.2
May 2013	45.6
June 2013	196.2
July 2013	9.6
August 2013	3.8
September 2013	32.8
October 2013	5.2
November 2013	74.8
December 2013	41.0
January 2014	19.5
February 2014	62.0
March 2014	138.2

2.3 NEPEAN RIVER MONITORING PROGRAM

The monitoring program for Longwall 705 was undertaken in accordance with the SMP requirements for Appin Longwalls 705 – 710 and the approved Appin Area 7 Water Management Plan.

River-related inspections, undertaken by the Illawarra Coal Environmental Field Team (ICEFT), occurred between Douglas Park Weir (NR2) and Menangle Weir (NR50).

The monitoring included: water level monitoring, photographic records, impact monitoring (i.e. strata gas and iron staining), and cliff stability and steep slopes assessments.

Table 2.5 below shows the dates of monthly water quality monitoring and sample collection for detailed laboratory analysis since commencement of mining of Longwall 705, with the respective Maldon, Menangle, and Broughtons Pass Weir flow data.

As can be seen in **Table 2.5**, River flows at Maldon Weir on all but four sampling dates were above or equal to the 50 percentile flow.

Table 2.5 Dates of Nepean River Monitoring and Sampling with Respective Maldon, Menangle and Broughtons Pass Weir Flow Data.

Date	Maldon Weir Flow (ML/Day)	Maldon Percentile Flow (Post Millennium Drought)	Menangle Weir Flow (ML/Day)	Menangle Percentile Flow (Post Millennium Drought)	Broughtons Pass Weir Flow (ML/day)	Broughtons Pass Percentile Flow (Post Millennium Drought)
19/9/12	54.246	65.4	112.261	51.3	0	0 - 45
16/10/12	75.154	71.9	148.635	58.4	1.168	53.7
14/11/12	32.976	50.0	110.820	51.0	12.241	66.4
13/12/12	21.507	36.0	74.035	43.6	0.532	50.9
9/1/13	13.907	20.4	29.795	19.2	1.131	53.6
7/2/13	263.492	90.2	331.947	83.2	1.371	54.1
3/4/13	35.371	52.9	173.939	64.3	43.494	79.7
1/5/13	91.519	77.1	202.793	69.7	10.824	65.5
24/7/13	47.059	61.3	354.317	84.1	13.376	67.2
19/8/13	79.191	73.0	183.310	66.2	6.266	61.2
15/10/13	23.821	39.6	148.985	58.6	34.783	76.9
14/11/13	93.38	77.8	271.380	78.1	51.351	81.6
9/12/13	121.091	81.9	166.996	62.7	2.952	57.2
6/1/14	63.71	68.4	148.055	58.1	1.004	53.0
6/2/14	18.343	30.4	107.748	50.3	0	0 - 45
5/3/14	101.013	79.3	No Data	No Data	66.516	84.8
2/4/14	No Data	No Data	No Data	No Data	231.633	95.0

2.4 WATER QUALITY IN NEPEAN RIVER

The ICEFT conducted *in situ* water quality monitoring and collection of water samples for detailed laboratory analysis at selected sites (**Table 2.6**).

Table 2.6 Appin Longwalls 705-710 Water Quality Monitoring and Sampling Commitments

Monitored Sites Associated With Longwall 705	Monitoring Frequency	Recommended Future Monitoring
Water Quality		
Nepean River Baseline upriver sites for cross- checking for upriver perturbations: ☐ NR0 ☐ NR2 (pre Area 9 mining) ☐ NR110 (New site - post Area 9 mining) ☐ NR4 ☐ NR5 ☐ NR6 Impact monitoring sites adjacent to each longwall: ☐ NR11 ☐ NR12 ☐ NR13 ☐ NR20 ☐ NR30 Other sites ☐ NR7 ☐ NR9 ☐ NR50	☐ Monthly baseline prior to mining (data has been recorded for most sites since 2003). ☐ Weekly observations and field analysis during mining. ☐ Monthly detailed laboratory analysis during mining. ☐ Monthly monitoring for 2 years post mining (or as otherwise required/approved). ☐ If required as a result of assessment of mining impacts.	☐ Monthly observations and field analysis due to distance from mining. ☐ Removal of NR20 and NR30 due to distance from mining and adequate location of NR12, NR13 and NR50.
Ephemeral Watercourses ☐ Lower Harris Creek (NR3) ☐ Elladale Creek (NR8) ☐ Ousedale Creek (NR10) ☐ Menangle Creek (NR40) ☐ Upper Harris Creek (HC10)	☐ Prior to mining of longwall underlying watercourse or mining of any immediately adjacent longwall. ☐ Monthly detailed laboratory analysis during mining. ☐ Following the development of incremental subsidence for each longwall that will impact on the feature.	☐ As per the monitoring program

2.4.1 Baseline Water Quality

The BHPBIC surface water monitoring data has been assessed for the Appin Area 7 baseline period covering 10 July 2002 to 24 October 2007 (when Longwall 701 commenced).

Table 2.7 below lists observed baseline water qualities for the river sites and for lower tributary sites, which were used to establish the Nepean River water quality TARPs for Appin Area 7 (refer **Figure 1.1**).

Table 2.7 indicates very little difference in mean river baseline water quality immediately upriver, adjacent to and downriver of Appin Area 7.

Baseline water qualities in the Nepean River, especially under the ecologically more critical low flow conditions (<50 percentile), are clearly dominated by the following processes:

1. inputs of more acidic water from Cataract River;
2. low flow inputs of more saline water from Harris, Elladale and Ousedale Creeks which have negligible to minor bulk effect on overall river salinity;
3. consistent inputs of low DO water from Cataract River (and Elladale Creek) which is the primary driver of DO in the Nepean River immediately downstream of the Cataract River confluence;
4. a relatively low rate of re-aeration downriver of the Cataract River confluence (the flooded geomorphology of the River is such that it has a low Re-Aeration Coefficient (RAC) adjacent to Appin Area 7); and
5. consistent inputs of Fe and Mn to the river from Cataract River and Elladale Creek.

Analysis of the baseline water quality database, including water quality analyses at depth, showed that the Nepean River near the confluence and downstream of Cataract River, typically exhibits distinctive temperature/dissolved oxygen (DO) stratification, and to a lesser degree, salinity stratification between surface and deeper waters.

Oxygen stratification is most apparent in summer months or during low flow periods when turbulent mixing is limited, with deeper stretches showing low to very low DO.

Table 2.7 Baseline Water Quality Data Nepean River and Lower Tributaries July 2002 – October 2007 [1]

Site	EC (μS/cm)	St. Dev.	pH	St. Dev.	DO (%)	St. Dev.	Tot. Fe (mg/L)	St. Dev.	Tot. Mn (mg/L)	St. Dev.	Ni Filt (mg/L)	St. Dev.	Zn Filt (mg/L)	St. Dev.
River Sites														
NR2	646	222	8.16	0.66	90.2	19.0	0.31	0.52	0.035	0.024	0.025	0.015	0.017	0.032
NR4 [2]	582	239	8.08	0.56	93.8	32.0	0.33	0.30	0.038	0.026	0.020	0.013	0.011	0.009
NR6	578	243	7.99	0.57	94.1	20.9	0.46	0.27	0.056	0.045	0.017	0.013	0.013	0.016
NR7	506	201	8.05	0.55	88.3	28.7	0.30	0.28	0.044	0.035	0.018	0.012	0.009	0.008
NR9	515	203	8.05	0.60	93.9	23.4	0.30	0.24	0.044	0.021	0.018	0.012	0.009	0.006
NR11	496	171	7.69	0.51	87.1	28.3	0.32	0.39	0.050	0.056	0.014	0.009	0.009	0.006
NR20	480	162	7.76	0.60	88.0	23.7	0.29	0.30	0.044	0.054	0.012	0.007	0.013	0.013
NR30	470	146	7.74	0.56	83.9	24.9	0.30	0.29	0.040	0.035	0.017	0.012	0.100	0.466
Tributaries [3]														
NR3	2100	712	7.80	0.16	104.5	27.7	0.29	0.23	0.053	0.051	0.001	0.003	0.013	0.010
NR5	334	182	7.36	0.46	69.4	39.5	1.36	1.28	0.162	0.169	0.003	0.005	0.009	0.007
NR8	3028	1763	7.11	0.31	62.0	32.0	1.06	0.82	1.446	1.562	0.001	0.000	0.012	0.011
NR10	1492	715	7.79	0.46	100.9	27.5	0.45	0.53	0.031	0.048	0.004	0.005	0.015	0.041

[1] EC = Electrical Conductivity, DO = Dissolved Oxygen, Fe = iron, Mn = manganese, Ni = nickel, Zn = zinc, Tot. = total, and Filt = filtered (dissolved).

[2] NR4 is on the Nepean River but probably not adequately up-river of the Cataract River confluence. Under low flow conditions (<25 percentile) NR4 is probably affected by backwater from Cataract inflows.

[3] Tributaries: NR3 = Harris Creek, NR5 = Cataract River, NR8 = Elladale Creek, and NR10 = Ousedale Creek.

Past data also show that during dry weather, when conditions are warm and sunny and flows in the Nepean River remain relatively constant (due to controlled or no release from Maldon Weir), then pH values in the river may occasionally occur naturally in the 8.2 – 9.5 pH range. This applies particularly where the Nepean River passes through an area dominated by farmland and there are pre-existing nutrient inputs (total phosphorus and nitrogen) from fertilizing and livestock waste contaminating small catchments draining into the river.

These nutrient inputs were detected in the large number of sampling campaigns conducted since July 2002. They are especially evident from sites NR11 and others further downriver, especially following significant rain.

Algal primary productivity in river pools is maximized under those circumstances. Algae absorb dissolved CO_2 and bicarbonate ions from water and produce oxygen, thereby driving pH up (when CO_2 and bicarbonate ion concentrations decrease). It is common to observe pH levels in the river rising to maximal levels as high as 9.5 during warm, sunny conditions.

This suggests that to expect the pH of water in the river to lie below 8.5 at all times is unwarranted, and it is very likely that local aquatic biota are well acclimatized to pH levels at least as high as 9.5.

The issue of salinity is relevant to the assessment of potential impact(s) on aquatic ecology for Longwall 705 because of the geochemistry of the Nepean catchment.

Runoff into the Nepean River is dominated by a Cumberland Plain (Lowlands) landscape dominated by a mixture of Hawkesbury Sandstone and Wianamatta Shale outcrops. Even taking into account the Appin West Colliery licensed discharge to Allen’s Creek, salinity of the river water (expressed in Electrical Conductivity (EC) units) is unlikely to ever exceed 1000 µS/cm and chloride and sulfate ion concentrations are unlikely to frequently exceed about 20 mg/L and 100 mg/L, respectively.

In contrast, Elladale and Simpson Creeks arise in Cumberland Plain landscape almost exclusively dominated by Wianamatta Shale. These shale-derived soils are such that salinities in the middle and lower sections of these creeks frequently exceed 3000 µS/cm, and chloride and sulfate ion concentrations are likely to frequently exceed 500 mg/L and 20 mg/L respectively.

The salinity of waters discharged from these shale catchment creeks into the Nepean River is principally based upon the cation sodium (Na^+) and the anion bicarbonate (HCO_3^-).

It is now established that the anion bicarbonate is the principal and most variable driver of <u>salinity-based</u> ecotoxicity in such waters. It is important to note that as the pH of the River water is lowered, the ratio of bicarbonate to carbonate anion concentrations (i.e. $[HCO_3^-]/[CO_3^{2-}]$) rises, causing ecotoxicity due to salinity alone to increase (per unit of salinity). Here decreased pH is due principally to inputs of dissolved Fe and Mn and their oxidation and precipitation as hydrous oxides, and/or the addition of dissolved CO_2 from exogenous sources such as CO_2 in decomposition of natural organic matter.

As noted in **Section 1.1** above, there are no Water Quality Objectives regarding salinity arising from the Independent Inquiry into the Hawkesbury Nepean River System by the Healthy Rivers Commission. The Commission recommended using the trigger values in the NWQG (ANZECC/ARMCANZ, 2000a & b).

It is therefore considered that the Nepean River should be regarded as a lowland river where the default EC trigger value in the NWQG is 2200 µS/cm (ANZECC/ARMCANZ, 2000a & b). This conclusion is based on:

1. studies which have shown that below Bargo River, the river has long been affected not only by discharges from Bargo River, the township of Picton and from Appin West Colliery, but also by agricultural land uses; and the fact that
2. large areas of the River catchment are dominated by Wianamatta Shale-derived soils, the Shale being a marine sediment (Hazelton and Tille, 1990). Such marine sediments continue to provide salinity to runoff and groundwater seepages (interflow, through-flow, etc.) up to the present day.

A number of tributaries of the Upper Nepean River naturally contribute relatively saline water to the River. For example, the long term mean salinity of lower Elladale Creek at site NR8 is 3028 ± 1763 µS/cm (refer **Table 2.8** above) at the one standard deviation level. This catchment is largely mantled by Wianamatta Shale-derived soils and drains to Nepean River.

The salinity of this creek is not only highly variable but most of the time significantly exceeds the default trigger value (2200 µS/cm) even for lowland rivers for southeastern Australia in the NWQG (ANZECC/ARMCANZ, 2000a & b).

Ecological studies have been conducted by The Ecology Lab (2008) in tributary streams of Nepean River and in Tea Tree Hollow Creek, a tributary of Bargo River and Bargo River itself. Those studies consistently found that it is likely that in the lowland rivers of the Southern Coalfield (e.g. Bargo River, Nepean River, and Georges River) most macroinvertebrate taxa (families) are well acclimatized to TDS up to at least 2,000 mg/L (i.e. EC up to approx. 3200 µS/cm).

3. WATER-RELATED EFFECTS

3.1 ASSESSMENT OF FLOW EFFECTS ON THE RIVER

There have been no reported or observed losses of surface water flows as a result of mining near the Nepean River by Appin Longwalls 701, 702, 703, and 704, or by mining near or directly beneath the Nepean River by Tower Longwalls 15 to 20. This includes observations at a monitoring site that was located directly above Tower Longwall 17, which mined directly beneath the river for a length of approximately 800 m.

Any rock bars present along the river bed are completely submerged and any fractures in the bedrock that develop as a result of mining are likely to be immediately filled by water and sediment. The volume of water that fills these fractures is likely to be an extremely small proportion of the total volume of water retained by Menangle Weir.

MSEC (2008) assessed the potential for surface water flow diversion as a result of the extraction of Longwalls 705 to 710 as low.

The Nepean River is invariably a ‘gaining river’ in terms of surface water - groundwater interaction. The potential for infiltration of water into the groundwater system is very low as the Nepean River lies in a well incised gorge (river valley) which represents the regional low point in the piezometric surface.

The potential for sub-bed diversion of surface water in the Nepean River is very low as the river bed is flooded and the gradient of the river is very flat.

Given that the local stretch of the Nepean River is flooded by backwater from Menangle Weir, it is not possible to conduct direct flow gauging of the River in the vicinity of Longwall 705.

However, as noted in **Section 2.1** above, long records exist for both Maldon and Menangle Weirs upriver and downriver respectively of the River adjacent to Longwall 705. It is thus possible to subtract flows measured at Maldon Weir from those measured at Menangle Weir. The difference should be equivalent to runoff from all catchments between these two weirs responding to local rainfall minus any abstractions by licensed pumps in the River.

It is thus possible to search for dry weather recessional phases in the Menangle minus Maldon flow dataset and to check those recessions for normal behaviour, i.e. relative to the record of baseline recessions prior to the commencement of the Area 7 longwalls. Such tests could be, and were, previously successfully conducted for the assessments presented in the Longwalls 701 and 702 End of Panel Reports (Ecoengineers, 2008, 2009). We have recently identified (in retrospect after the End of Panel assessment for 703) only one such recession during the mining of Longwall 703 but none during or immediately after the mining of Longwall 704.

Identification of low flow recessions (for assessing possible riverine hydrologic effects of mining of Longwall 705) was hindered by comparatively high flows during the mining period (see **Table 2.5**), which meant that no recessions of equivalent initial flow rate to those of the baseline studies could be identified. Consequently, in order to assess any potential flow effects on the River we have reanalysed the baseline record for Maldon and Menangle Weirs, and have now included in these analyses the flow record for Broughtons Pass Weir, in order to improve analytical reliability.

These analyses involved the identification of all recessional periods in the Menangle minus Maldon minus Broughtons Pass Weir record which were longer than or equal to eight contiguous days in length, contained no negative values, and had zero rainfall recorded for the period at Douglas Park (St. Mary's Towers).

This study resulted in the identification of 51 baseline recessions since later 1990 (arbitrarily set as the beginning of the baseline assessment period due to quality criteria), 7 recessions during the mining of Tower Colliery longwalls 16 and 17 between 1998 and 2000 and 12 recessions during the period of Appin Area 7 mining thus far, 5 of which occurred during the most recent Longwall 705 mining period. The key data from each of these periods is summarised below in **Table 3.1**.

Table 3.1 Local Dry Weather Recessions Extracted from the Menangle, Maldon and Broughton's Pass Weir Flow Records, 1990 – 2014.

Date Range	Number of Days	Menangle minus Madlon minus Broughtons Pass Flow Maxima (ML/day)	Menangle minus Madlon minus Broughtons Pass Flow Minima (ML/day)	Slope	R^2 Value	Predicted Slope Based on Pre-mining Baseline Data
12 - 19/12/1990	8	18.59	5.14	-5.97	0.93	
21 - 29/12/1990	9	3.75	0.47	-1.53	0.99	
28/01 - 4/02/1991	8	12.85	5.05	-3.63	0.97	
12 - 23/09/1991	12	35.02	0.01	-15.62	0.91	
9 - 17/07/1992	9	73.11	7.73	-28.86	0.95	
20 - 28/10/1992	9	7.13	1.49	-3.06	0.89	
25/02 - 5/03/1993	9	59.54	6.08	-25.27	0.99	
6 - 13/08/1993	8	63.36	12.03	-25.51	0.99	
18 - 27/08/1993	10	109.64	6.02	-40.69	0.86	
4 - 11/11/1993	8	75.88	1.01	-28.65	0.93	
24/01 - 1/02/1994	9	26.05	0.71	-10.67	0.89	
17 - 27/02/1994	11	46.67	2.46	-20.37	0.97	
13 - 24/03/1994	12	97.98	9.07	-36.78	0.99	
3 - 10/04/1994	8	47.80	8.47	-19.11	0.99	
15/04 - 1/05/1994	17	76.50	4.49	-25.63	0.96	
11 - 20/05/1996	10	135.98	37.58	-42.14	0.97	
24/06 - 3/07/1996	10	49.61	18.21	-14.08	0.84	
30/07 - 6/08/1996	8	70.71	29.13	-18.55	0.97	
6 - 17/11/1996	12	51.55	7.25	-17.82	0.91	
1 - 8/02/1997	8	103.45	10.28	-47.81	0.99	
16 - 24/02/1997	9	137.74	21.32	-52.10	0.98	
9 - 23/04/1997	15	38.59	5.14	-11.66	0.87	
10 - 19/08/1997	10	24.83	11.02	-5.38	0.78	
10 - 17/10/1997	8	130.06	17.79	-57.96	0.98	
22/05 - 1/06/1998	11	74.08	8.78	-25.89	0.94	
8 - 15/07/1998	8	23.71	7.35	-8.72	0.87	
Period of Tower 16 mining (28/10/1998 - 22/08/1999)						
9 - 17/03/1999	9	42.25	2.01	-15.07	0.76	-18.05
11 - 19/06/1999	12	60.47	8.31	-23.92	0.91	-23.40
31/08 - 8/09/1999	10	52.85	24.12	-14.50	0.86	-12.89
Period of Tower 17 mining (23/09/1999 - 18/04/2000)						
6 - 14/10/1999	9	96.17	23.89	-31.02	0.82	-32.42
17 - 24/01/2000	8	35.06	10.76	-11.79	0.91	-10.90
16 - 26/02/2000	11	28.82	2.82	-10.87	0.94	-11.66
16 - 24/05/2000	9	155.43	58.51	-52.12	0.83	-43.48
30/09 - 08/10/2000	9	32.91	9.14	-11.81	0.82	
23 - 30/12/2000	8	52.60	24.38	-11.61	0.82	
8 - 15/01/2001	8	46.40	28.81	-8.43	0.82	
11 - 18/04/2001	8	132.43	36.82	-40.68	0.80	
14 - 24/07/2001	11	47.94	27.80	-7.08	0.93	
29/07 - 16/08/2001	19	104.77	17.93	-25.00	0.94	
9 - 16/03/2002	8	37.82	13.42	-11.22	0.90	
2 - 9/04/2002	8	139.08	8.30	-69.94	0.95	
30/04 - 7/05/2002	8	101.81	42.33	-28.04	0.86	
31/05 - 7/06/2002	8	154.00	24.04	-64.66	0.87	
19 - 28/09/2002	10	39.08	6.74	-13.61	0.90	
23 - 30/10/2002	8	35.72	2.54	-15.55	0.91	
25/08 - 7/09/2003	14	128.02	12.09	-39.13	0.89	
14 - 22/09/2003	9	20.44	0.65	-9.09	0.86	
27/02 - 5/03/2004	8	95.26	10.31	-40.15	0.99	
24/03 - 3/04/2004	11	41.02	3.14	-18.44	0.89	
11 - 19/04/2004	9	25.64	3.12	-10.57	0.95	
23 - 30/11/2004	8	59.48	3.32	-31.27	0.84	
16 - 23/12/2004	8	116.23	12.01	-49.89	0.91	
17 - 24/11/2005	8	66.97	8.40	-25.80	0.93	
8 - 18/12/2005	11	58.14	1.73	-23.08	0.97	
22/01 - 7/02/2006	17	93.76	10.51	-27.95	0.97	
2 - 11/04/2006	10	23.59	2.63	-8.24	0.88	
14 - 21/07/2007	8	129.51	34.90	-49.77	0.97	
27/09 - 7/10/2007	11	24.75	1.06	-8.54	0.82	
Pre-mining average (n = 51)		66.77	12.42	-24.37	0.92	
Pre-mining standard deviation (n = 51)		41.02	12.28	16.88	0.06	
Period of 701 Mining (27/10/2007 - 09/05/2008)						
22 - 31/01/2008	10	30.56	4.46	-9.26	0.78	-11.71
27/04 - 8/05/2008	12	32.36	4.45	-9.39	0.82	-12.52
21 - 30/06/2008	10	24.52	9.22	-6.62	0.94	-6.86
Period of 702 Mining (18/09/2008 - 20/05/2009)						
20 - 28/02/2009	9	25.08	1.89	-10.59	0.88	-10.40
21 - 28/09/2009	8	58.86	28.03	-15.33	0.89	-13.83
15 - 23/10/2009	9	50.48	32.76	-8.98	0.89	-7.95
Period of 703 Mining (22/10/2009 - 08/03/2011)						
13 - 20/04/2011	8	119.62	69.83	-23.50	0.88	-22.34
Period of 704 Mining (7/05/2011 - 29/07/2012)						
Period of 705 Mining (7/09/2012 - 27/03/2014)						
26/10 - 2/11/2012	8	76.92	44.28	-18.60	0.84	-14.64
13 - 21/12/2012	9	55.51	16.35	-19.17	0.84	-17.56
27/12 - 3/01/2013	8	67.90	22.17	-22.66	0.89	-20.51
21 - 28/08/2013	8	125.85	75.44	-22.53	0.88	-22.61
28/12/2013 - 5/01/2014	9	125.48	70.24	-21.46	0.83	-24.78

As can be seen from **Table 3.1** above, the 51 local, dry weather, non-mining recessions periods in Nepean River identified via the Menangle minus Maldon minus Broughtons Pass Weirs flow records prior to the mining of Appin Area 7 encompass a wide range of flow maxima and minima and slopes of the inferred log-linear recession curves.

Each of these recession curve slope fits had a good R^2 values, ranging from 0.76 to 0.99. The mean dry weather recession rate, excluding 7 dry weather recessions during and immediately following the mining of Tower Colliery Longwalls 16 and 17 between October 1998 and May 2000 is -24.4±16.9 ML/day. Out of these 51 baseline (non-mining) recessions the slope of only two recessions (02/04/2002 – 09/04/2002 and 31/05/2002 – 07/06/2002), i.e. only ~4% had slopes steeper than -58.1 ML/day i.e. below two standard deviations below the mean. This indicates the sample of 51 baseline recessions is exhibiting normal statistical behaviour

To determine whether there was any accessible relationship between the starting flow rate of a recession and the consequent standard rate of low flow recession (as conventionally indicated by the slope of the log(time) – linear(flow) recession curve) testing identified the following simple linear correlation shown in **Figure 3.1** below.

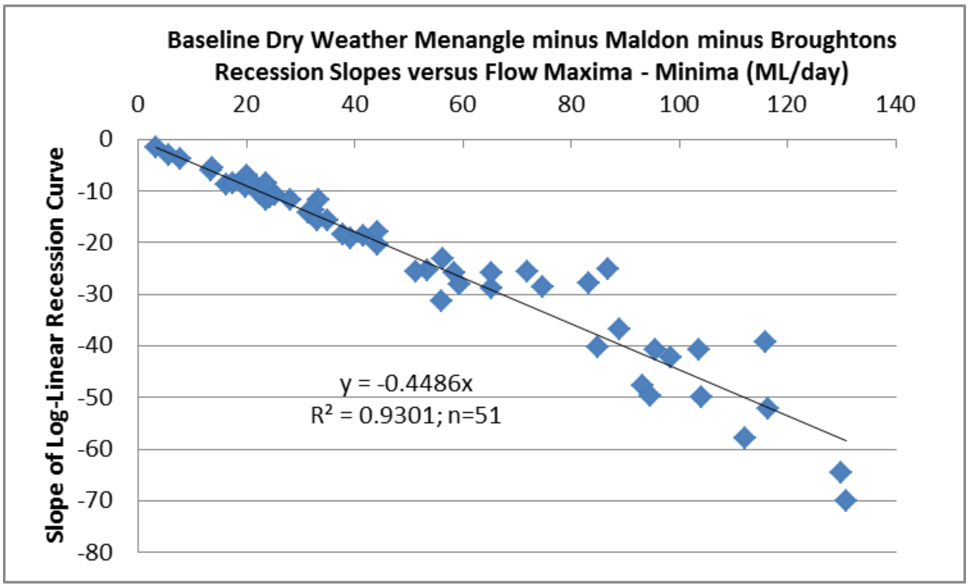

Figure 3.1 Relationship between Dry Weather Menangle minus Maldon minus Broughton's Pass Recessions (starting) Maxima and subsequent Log-Linear Recession Curve Slopes for the Baseline Period January 1990 to October 2007.

Figure 3.1 shows that during the (1990 – 2007) pre-Area 7 mining baseline period, there was a good relationship between the maximal dry weather Menangle minus Maldon minus Broughtons Weir flows and the subsequent rate of recession.

The above correlation graph essentially only increases in scatter at high starting flows where the recessions are 'prematurely' terminated by rainfall/runoff. It is noted that all three weirs are wide and low flows over them have a small depth with high levels of uncertainty in any case. However increased error is also generated in the Menangle minus Maldon minus Broughtons Pass flows at very high flows as the correctly *propagated* error is expected, by definition, to increase markedly towards the highest flow ranges for the recessions.

Correlations of the type shown in **Figure 3.1** above, while not common, are typically associated with flows in man-made canals and deeply incised rivers (usually in Permian and Triassic Sandstone) of relatively fixed cross section. That is; they are a function of the cross sectional hydrodynamics of a choking 'bath tub' shaped channel.

This useful relationship, exhibiting an excellent R^2 value of 0.93 (hence explaining 93% of all propagated variance), allows theoretically predicted recession curve slopes to be calculated for each of the recessions identified during the subsequent period of mining of the Area 7 longwalls. These predicted low flow recession slopes (for the mining periods) have been included in **Table 3.1** above in the rightmost column.

The rate of recession during the mining of Longwall 705 ranged from -18.56 - -22.7 ML/day with a mean of -20.9±1.9 ML/day (n=5). The mean rate during the 1990 – 1998 and 2000 to 2007 year baseline period was a closely similar -24.4±16.9 ML/day (n=51). These values agree within error.

Rates of dry weather recession during the mining of Longwall 705 were therefore; well within statistical error, equivalent to those estimated from the study of 51 non-mining baseline recessions through the 17 year baseline period from late 1990 through to 2007 (excluding the period of mining of Tower Colliery longwalls 16 and 17).

This implies that; the rate at which dry weather flows receded in the Nepean River was closely comparable during the mining of Longwall 705 to that which was observed during the nearly seventeen years of baseline recessional behaviour prior to the commencement of mining of Appin Area 7 including; the six years of the local expression of the Millennium Drought 2001 – 2006 but excluding the 3 year period of mining of Tower Colliery Longwalls 16 and 17 from 1998 to 2000.

This exercise therefore indicates that there has been no observable loss or diversion of water from the Nepean River as a result of the mining of Longwall 705.

3.2 NEPEAN RIVER WATER QUALITY TARPS

Data for pH, EC, DO, Total Fe and Total Mn at the baseline upriver (of Longwall 705) site NR2, and the downriver sites NR11, NR12, NR13, NR20 and NR30 were compared in order to identify any change (as defined by the TARPs) in water quality that may have resulted from the mining of Longwall 705.

TARPs have been established for each parameter for downriver sites by the Area 7 Management Plan. These TARPs are based on ± 1 and ± 2 standard deviations from the baseline mean for each parameter, observed for 2 or more consecutive months.

For sites NR12 and NR13, for which monitoring begun in May 2012 (i.e. during the Longwall 704 mining period), the baseline means and standard deviations from the nearby upstream site NR11 have been use for the TARP assessments.

For these assessments, if a TARP is exceeded at one of the downriver sites (NR11, NR12, NR13, NR20 and NR30) and not at the upriver site NR2, the change is considered to possibly be mining-induced, thereby warranting further investigation.

3.2.1 TARP Exceedances

The following **Figures 3.2 to 3.6** show each of the water quality parameters relevant to the TARPs for the entire monitoring history at site NR11 (from 2002 up until April 2014, i.e. just following the completion of Longwall 705). These figures also show the baseline parameter means and the relevant Level 1 and 2 Triggers, which are represented by the broken black, orange and red lines respectively.

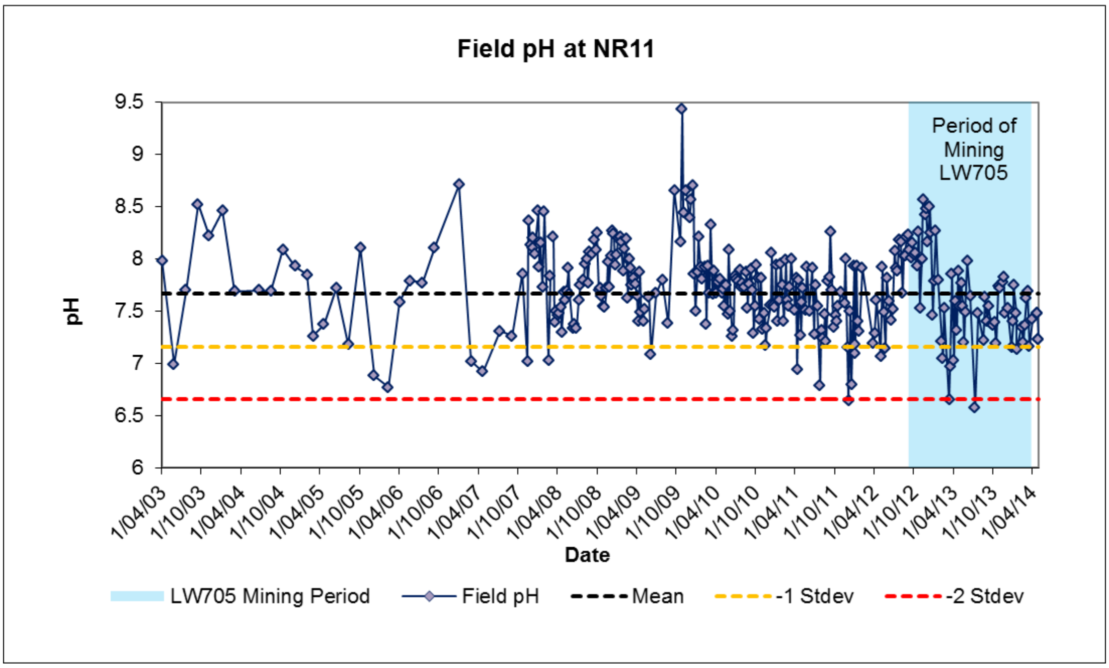

Figure 3.2 Field pH at site NR11 before, during and after mining of Longwall 705.

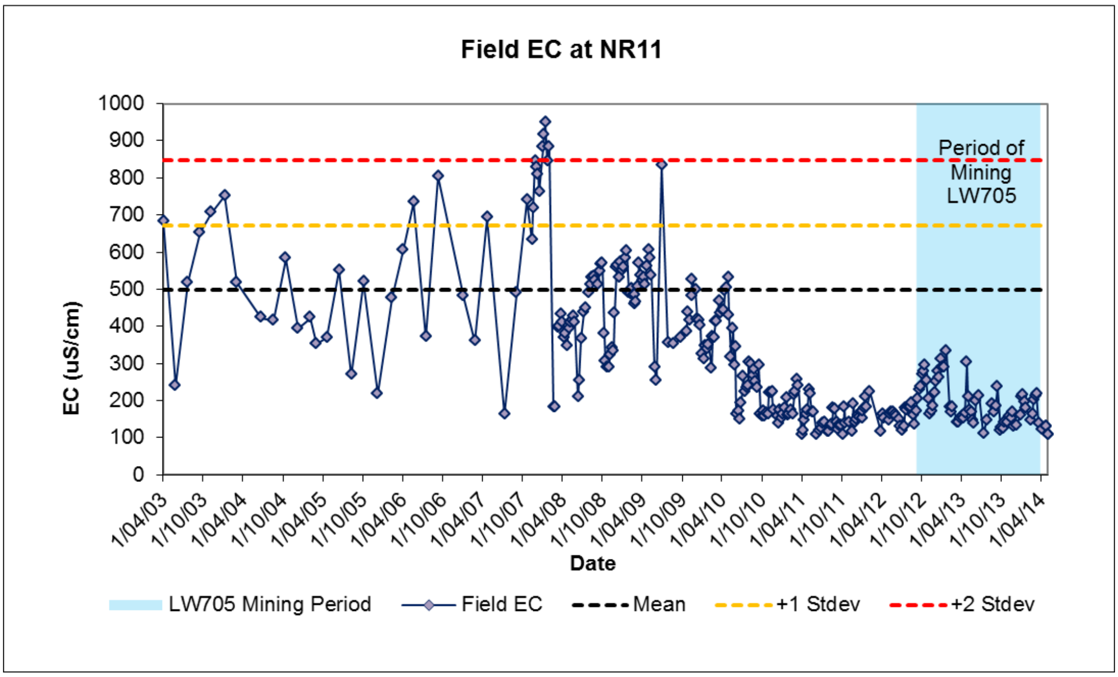

Figure 3.3 Field EC at site NR11 before, during and after mining of Longwall 705.

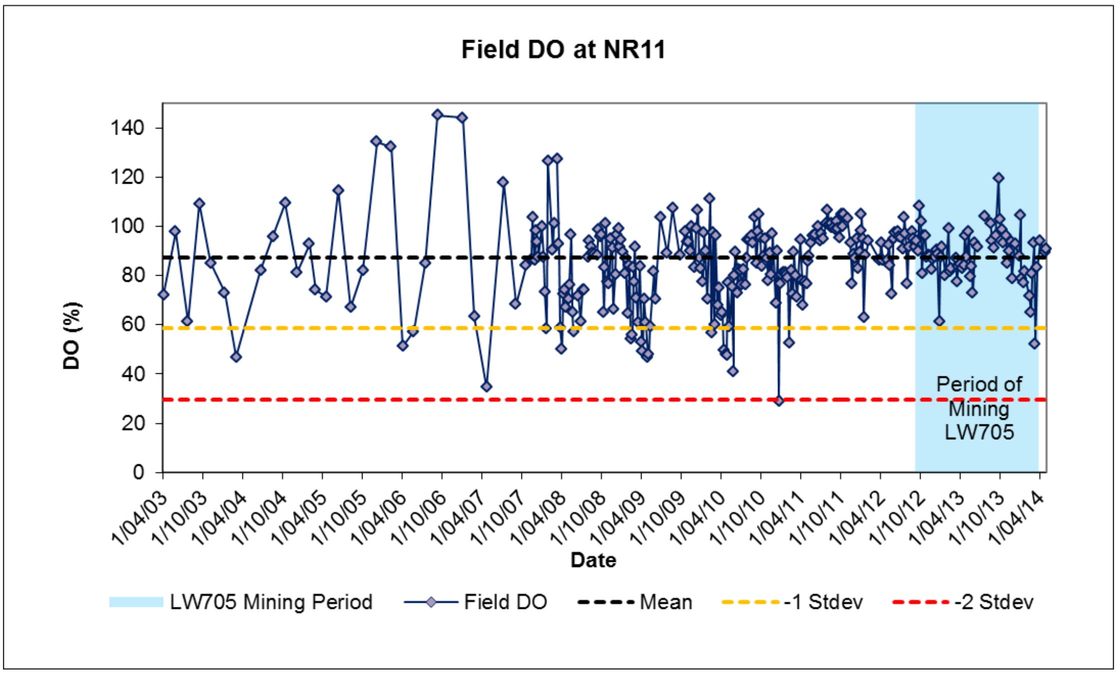

Figure 3.4 Field DO at site NR11 before, during and after mining of Longwall 705.

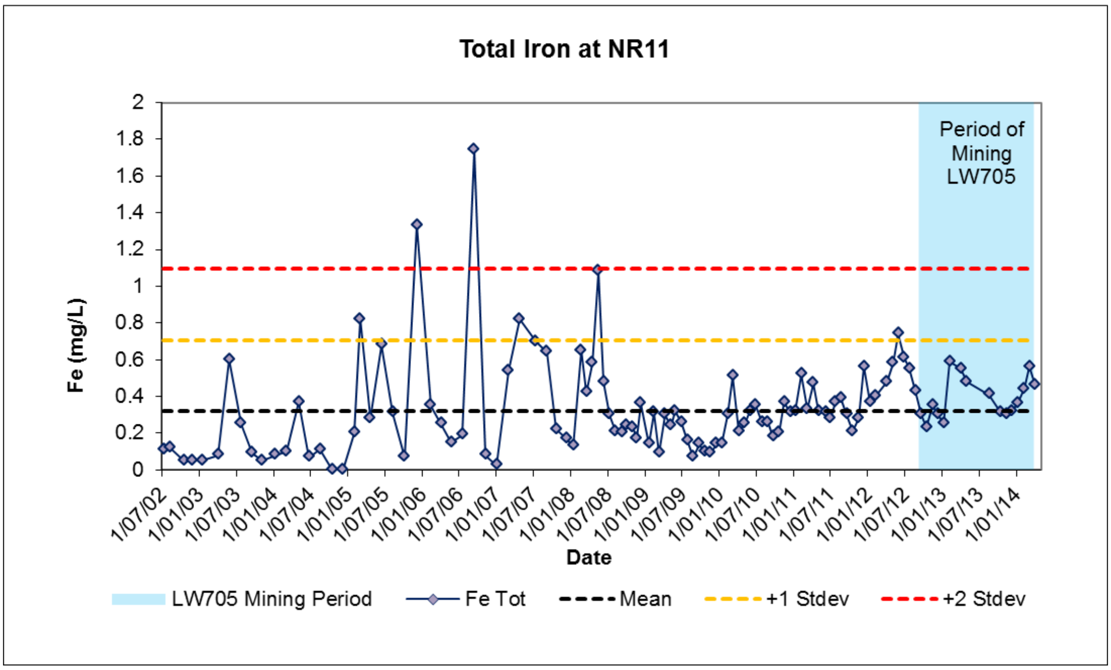

Figure 3.5 Total Iron at site NR11 before, during and after mining of Longwall 705.

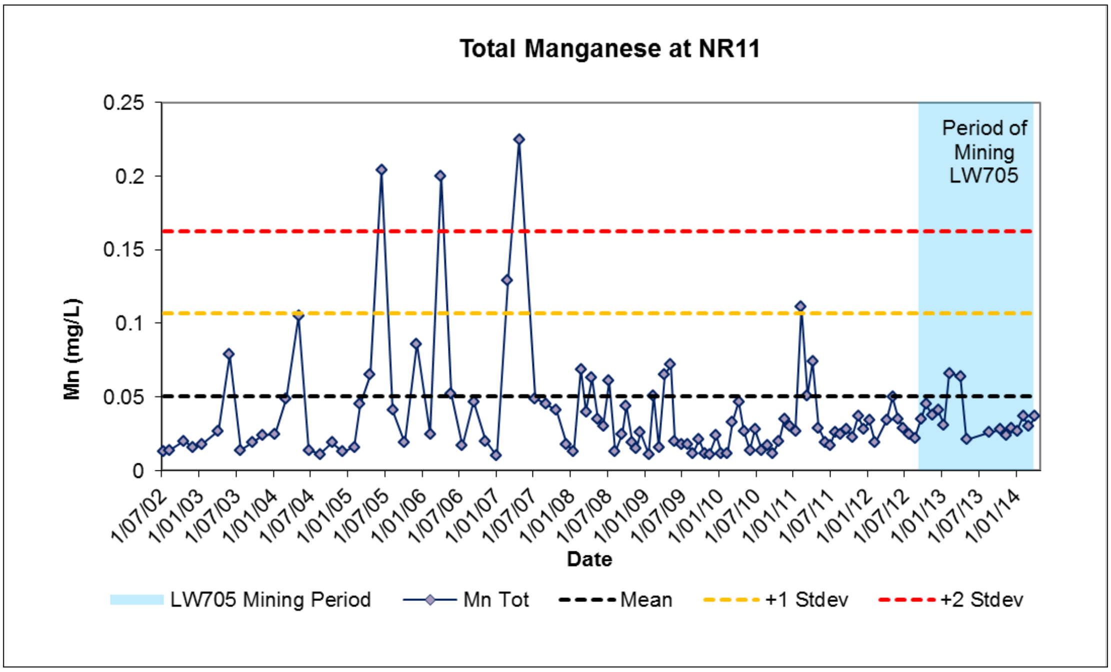

Figure 3.6 Total Manganese at site NR11 before, during and after mining of Longwall 705.

As **Figures 3.2 to 3.6** above show, there have been no TARP exceedences at NR11 as a result of the mining of Longwall 705. As can be seen, there were some pH values and one DO value below the respective TARP trigger levels, however none of these conditions persisted for a period of two consecutive months or greater, and thus no TARP monitoring level was reached.

No water quality TARP monitoring level was reached at the monitoring sites NR12, NR13, NR20 and NR30.

3.2.2 Plateau Streams Effects

The ICEFT identified no stream bed cracking or bank instability in monitored lower order plateau streams during the monitoring program for Longwall 705.

3.3 ASSESSMENT OF GENERAL CHEMICAL EFFECTS IN THE RIVER

Monitoring and inspections have been carried out along the Nepean River between NR110 and NR50 to determine any impacts from Longwall 705 in accordance with the Appin Area 7 Water Management Plan.

The inspections, carried out by the ICEFT, were done on a weekly basis and included water quality, water levels, and gas release monitoring.

3.3.1 Gas Release Zones and Iron Staining

During the extraction of Longwall 701 (between 27 October 2007 and 9 May 2008), four gas release zones and a small zone of iron staining were identified in the Nepean River, whilst a single gas release zone and a small zone of iron staining were identified in Elladale Creek. Three additional minor, intermittent gas release zones were identified in the Nepean River during the extraction of Longwall 702.

During the extraction of Longwall 703, four of the eight pre-existing gas zones in the Nepean River showed minor reactivation. Three new gas release zones were identified in the Nepean River and one in the backwaters of Ousedale Creek.

At the end of mining of Longwall 703 all gas releases had ceased, except Gas Zone 5 (situated in Elladale Creek). No iron staining was observed when regular monitoring was undertaken on 16th March 2011.

During mining of Longwall 704, six previously identified gas zones were re-activated and three new zones formed. The releases were defined by the ICEFT as light and intermittent, except Zones 9 and 15 which were light-moderate and on occasion were constantly releasing. By the end of mining of Longwall 704 all gas releases had ceased.

During mining of Longwall 705, three new gas zones were identified: Gas Zones 16, 17 and 18, the key information for which is shown in **Table 3.2** below.

Table 3.2 Gas Zones Activated in Appin Area 7 during Mining of LW705

Site ID	Date First Observed	Last Observed	Description
AA7LW705 Gas Zone 16	4/10/12	17/01/14	Multiple releases on western side of river with one main constant release. This gas zone is spread variably over approximately 280 m^2
AA7LW705 Gas Zone 17	12/2/13	19/02/14	Up to 7 intermittent releases
AA7LW705 Gas Zone 18	18/3/13	16/04/14	Up to 20 intermittent releases

Figure 3.7 below shows the locations of gas zones identified in the Nepean River during the mining of Longwall 705.

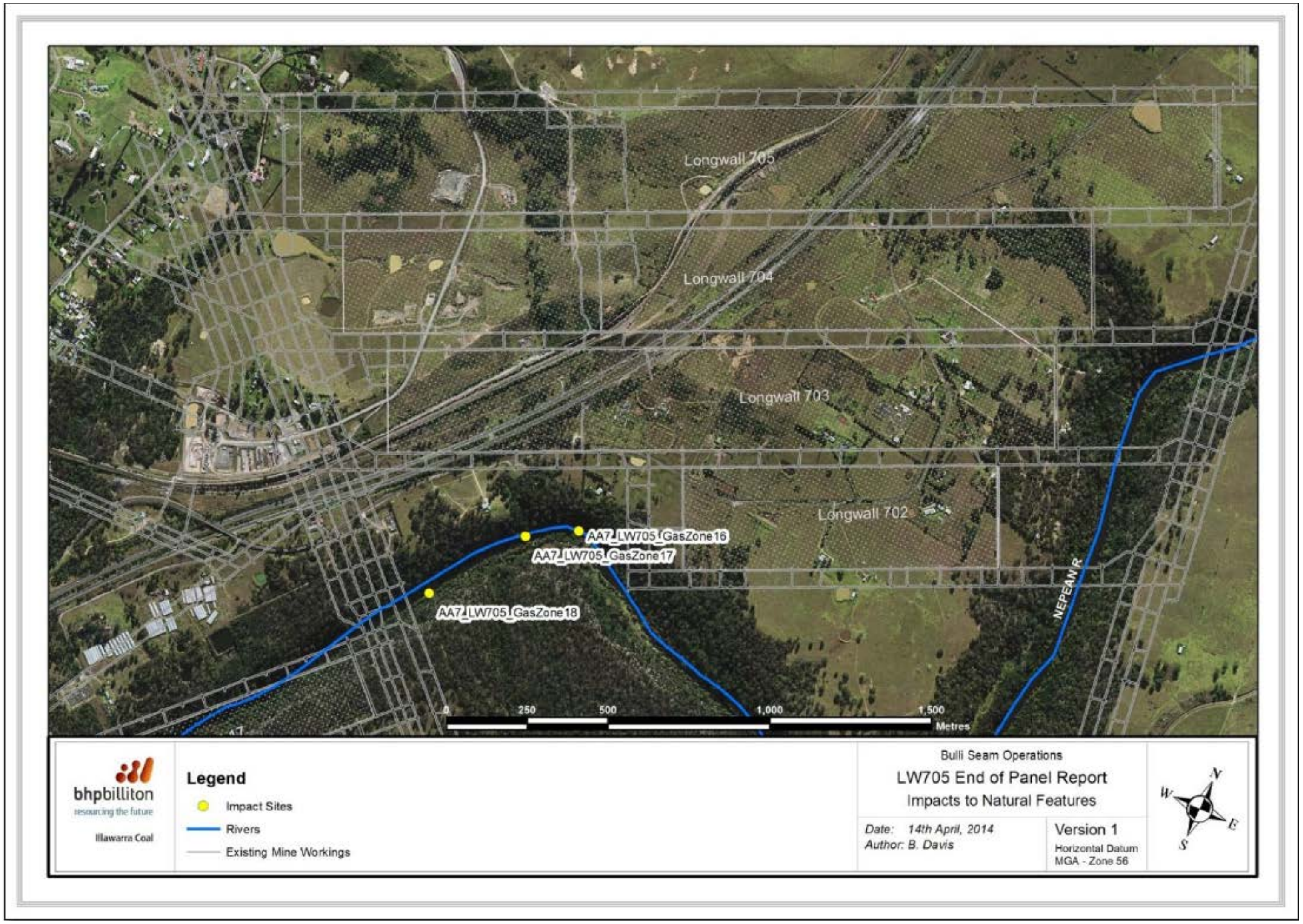

Figure 3.7: Gas Release Zones in the Nepean River Observed During the Mining of Longwall 705.

It is possible that emission of strata gas into the Nepean River could give rise to some reduction in dissolved oxygen (DO) in the River due to microbiological consumption of dissolved methane by natural aerobic bacteria (‘obligate aerobes’, also known as methanotrophs) within the water column. The minor emissions of methane-rich strata gas into the Nepean River discussed above do not appear to have caused any DO sags during the mining of Longwall 705 (see **Section 3.3.2**). The DO concentrations in the River during the period of mining Longwall 705 were within the bounds of DO measured during the pre-mining baseline period for similar flow rates in the river.

The localised effects of Gas Zone 16 were reported on in detail in the letter style report Ecoengineers (2013), which predicted based on dissolved methane concentrations that the gas emission rate of the plume was approximately 200 L/min.

3.3.2 Dissolved Oxygen

Pre-mining baseline monitoring for Longwall 705 showed depleted DO levels in the Nepean River under low flow conditions can be induced by:

1. inflows from Cataract River; and
2. inflows from minor tributaries and general runoff which nutrient analyses have strongly suggested are affected by agricultural and industrial activities.

The Nepean River is a flooded river with no cascades or rapids above Menangle Weir. It therefore has a low Re-aeration Coefficient (USEPA, 1985).

Therefore, plots of DO versus distance down the River are normally presented for days when the flow was less than the 50 percentile (<105.4 ML/day, based on post-millennium drought flows) at Menangle Weir. The plots for days with lowest possible flows are chosen because during such flows the potential effect of gas emissions has the greater ecological significance (Ecoengineers, 2008).

SCA data for Menangle Weir showed that flow was below the 50 percentile on only two monitoring and sampling dates: 13 December 2012, when the flow rate was 73.035 ML/day (43.6 percentile); and 9 January 2013, when the flow rate was 29.795 ML/day (19.2 percentile) (see **Table 2.5**).

Figures 3.8 and 3.9 below plot DO concentrations in the River on these dates. Total Nitrogen (TN) and Total Phosphorus (TP) concentrations are also plotted, as nitrogen and phosphorous control algal and/or bacterial growth (alternatively generating or removing DO respectively) in freshwater ecosystems.

Note that the following sites are not located along the river but within the lower part of tributaries of the river:

- SW2 is within the lower reaches of Allen’s Creek;
- NR3 is within the lower reaches of Harris Creek;
- NR4 is within Nepean River but under low flow conditions (<25 percentile) may be affected by backwater from Cataract inflows;
- NR5 is within the lower reaches of Cataract River;
- NR8 is within the lower reaches of Elladale Creek;

- NR10 is within the lower reaches of Ousedale Creek; and
- NR40 is within the lower reaches of Menangle Creek.

In **Figure 3.8 and 3.9** below the respective concentration parameter values for the sites SW2, NR3, NR5, NR8, NR10 and NR40 are plotted separately from the River transect trend line so that the magnitude of that parameter in the lower end of the tributary in relation to its magnitude upriver and downriver of each respective confluence is clearly indicated. The geographic position of the lower tributary site is simply projected to the nearby confluence.

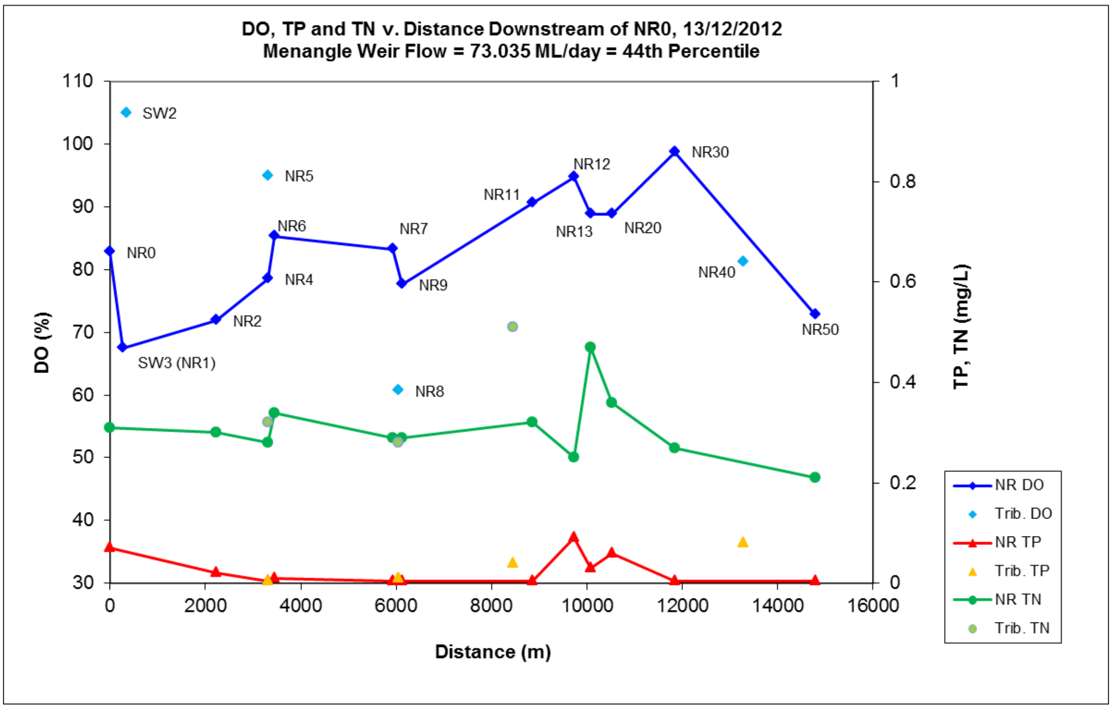

Figure 3.8: Dissolved Oxygen, Total Nitrogen, and Total Phosphorus in Nepean River and Tributaries, 13/12/2013

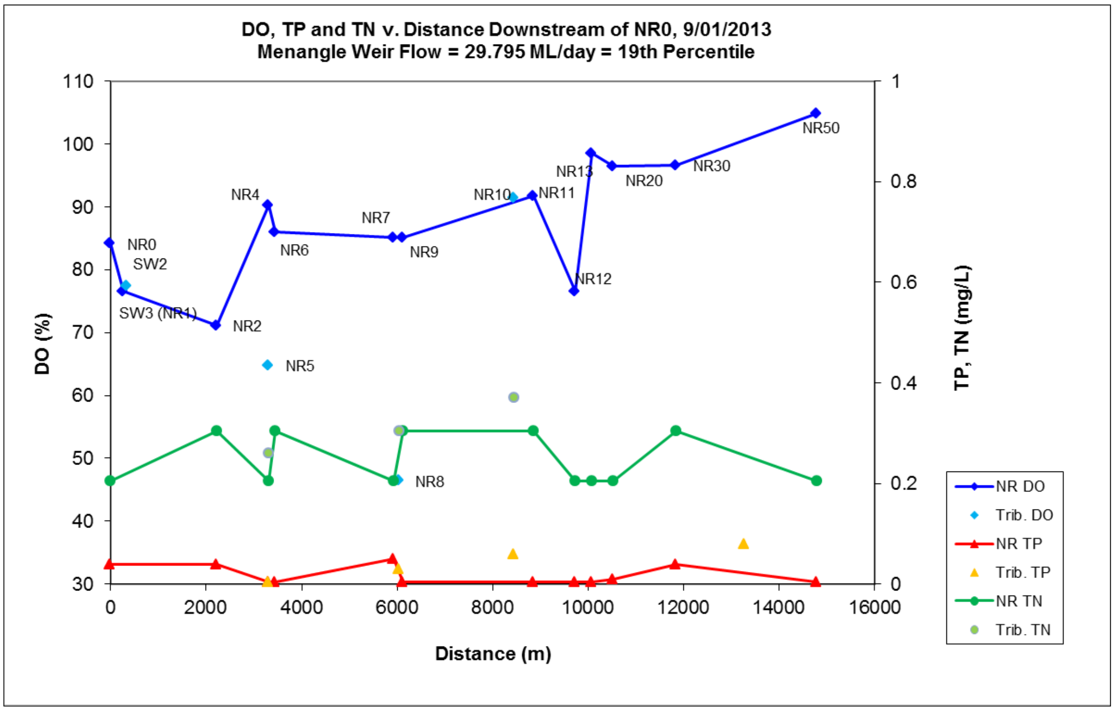

Figure 3.9: Dissolved Oxygen, Total Nitrogen, and Total Phosphorus in Nepean River and Tributaries, 9/01/2013

Examination of **Figures 3.8 and 3.9** above show that Nepean River surface water qualities were dominated by the following processes:

1. The River is well oxygenated, with minima of 67.4 and 71.4 % respectively. Inputs of low DO water from tributaries had little effect on Nepean River oxygen saturation.
2. Total phosphorus was generally at low levels in both the Nepean River and the tributaries and had no observable effect on DO saturation in the River.
3. Total nitrogen was generally at low levels in the Nepean River. Inputs from tributaries of water containing higher TN concentrations, such as that of Menangle Creek had no observable impact on Nepean River TN concentrations or DO saturation.

DO reductions in the Nepean River, attributed in the Longwall 703 EOP report (Ecoengineers 2011) to inputs of water from small tributaries carrying agricultural and industrial pollution, were not observed during mining of Longwall 705.

No DO sags in the vicinity of Gas Zones 16, 17 and 18 (which lie between sites NR6 and NR7) were observed on the low flow dates shown in **Figures 3.8 and 3.9**. Periods of low flow such as these are the potentially most effected by gas releases and the action of methanotrophic bacteria.

As such, the fact that no DO sags were observed on these dates shows that DO reduction through microbial consumption of dissolved methane was not a dominant process in the Nepean River in the vicinity of Longwall 705.

3.4 PREDICTED VERSUS OBSERVED IMPACTS

Table 3.5 below outlines the water related impacts predicted by the Appin Longwalls 705 – 710 Subsidence Management Plan and any impacts observed during and following the extraction of Longwall 705 of relevance to water-related matters reported to Ecoengineers by BHPBIC or resulting from this assessment.

Table 3.5: Predicted Versus Observed Impacts of Longwall 705

Feature	Predicted Impacts	Observed Impacts
Nepean River	Water level to remain essentially unchanged.	No mining-induced water level change has been observed – natural fluctuations with rainfall and SCA dam water releases.
	Potential for surface water flow diversion is very low.	No surface water flow diversion has been observed.
	Methane rich strata gas emissions into the river likely, with some associated reduction in dissolved oxygen possible.	Three new gas zones were observed during the mining of Longwall 705, one of which is still active. No associated reduction in riverine dissolved oxygen has been observed.
	Low likelihood of inducement of ferruginous springs. Significant impacts on Nepean River pH and iron and dissolved oxygen concentrations not predicted.	No new iron staining or iron seeps resulting from the extraction of Longwall 705 were identified.
Harris Creek	Mine subsidence induced ferruginous springs possible, with potential impacts on water quality.	No subsidence induced fracturing or iron staining has been observed in Harris Creek.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 FLOW EFFECTS IN NEPEAN RIVER

Daily flow data records for Maldon, Menangle and Broughtons Pass weirs from 1990 have been reassessed and assessed in order to improve the study of dry weather recessions in the Nepean River adjacent to Appin Area 7. All dry weather recessional flow periods in the Menangle minus Maldon minus Broughtons Pass flow record were identified and plotted to identify log-linear recession curves and provide their R^2 values.

This study showed that there is a very strong correlation, with a strong R^2 of 0.88, between the starting flow rates of recessional periods and subsequent rate of recession. There are hydrodynamic reasons associated with the typical topography of the basal part of the Nepean River gorge why such a correlation might be expected.

This relationship was then used to check the recessions identified from the period of mining of Longwall 705. Analyses showed that rates of recession during the mining period of Longwall 705 were closely similar and only marginally lower (shallower) than the mean rate and range estimated by the study of 55 baseline dry weather recessions between 1990 and 2007, indicating that there has been no observable loss or diversion of water from the Nepean River as a result of the mining of Longwall 705.

4.2 WATER QUALITY EFFECTS ON NEPEAN RIVER

4.2.1 Gas Emissions into the River

Gas Zones 16, 17 and 18 were identified in the Nepean River during the mining of Longwall 705. Of these, only Gas Zone 18 remains active. No gas zone release rate has exceeded 3000 L/min and as such, each of these releases is a Level 1 impact as per the TARPs.

4.2.2 Water Quality in the River

Emissions of methane-rich strata gas into the Nepean River were observed during the extraction of Longwall 705. While it is possible that emission of strata gas into the Nepean River gave rise to some reduction in dissolved oxygen in the River due to microbiological consumption of dissolved methane by natural aerobic bacteria (‘obligate aerobes’) within the water column, the magnitude and riverine extent of any reduction in DO during the period of mining Longwall 705 was well within the bounds of DO measured during the pre-mining baseline period for similar flow rates in the river.

Assessment of data from 2002 to April 2014 for the parameters pH, EC, DO, Total Fe and Total Mn showed that no water quality TARP monitoring level was reached at the monitoring sites NR11, NR12, NR13, NR20 and NR30 as a result of mining of Longwall 705.

4.2.3 Saline Ferruginous Springs

The extraction of Longwall 705 has not led to the creation of any newly identified ferruginous springs in the Nepean River.

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