ASSESSMENT OF SURFACE WATER FLOW AND QUALITY EFFECTS

APPIN COLLIERY LONGWALLS 705 TO 710

for

BHP BILLITON ILLAWARRA COAL

MAY 2008

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EXECUTIVE SUMMARY

Water quality effects associated with the proposed Longwalls 705 - 710 at Appin Colliery Area 7 have been assessed.

Mining-induced strata gas emissions to the Nepean River and mine subsidence-induced ferruginous springs discharging directly to Harris or Foot Onslow Creeks or to Nepean River are inferred to be the principal mechanisms that might give rise to adverse water quality impacts from the proposal.

Gas Emissions into the River

The Nepean River is a flooded river with no cascades or rapids above Menangle Weir to speak of. Such conditions lead to a low re-aeration coefficient meaning that depleted levels of dissolved oxygen are slow to recover down river, particularly under low flow conditions.

Dissolved oxygen ‘sags’ attributable to a variety of natural and anthropogenic causes have been observed during the pre-mining baseline period for Appin Area 7 and shown to persist within the study area since the mining of Longwall 701.

Emission of methane-rich strata gas into the Nepean River is a likely consequence of the proposed Longwalls 705-710. It is therefore likely that emission of strata gas into the Nepean River will give 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.

However, further monitoring and analysis of the possible influence of gas emissions in the river is necessary to better quantify any subsequent dissolved oxygen reduction and its possible aquatic ecology impacts. Additional water quality monitoring has been proposed to investigate this issue.

Minor visible iron precipitates are expected to occur in the Nepean River in association with gas release sites. No detectable change in water quality is predicted to occur from such minor iron staining, however minor aesthetic impacts may occur.

Ferruginous Springs

The inducement of ferruginous springs due to mining has been occasionally observed over Bulli Seam mining areas, especially when they are in proximity to areas of Wianamatta Shale. However, mining to date in Appin Area 7 has not led to the creation of any ferruginous springs, and it might be inferred that the catchments further to the north proposed to be mined under by Longwalls 705 to 710 are at a low probability of this phenomenon occurring.

Such springs generally do not contain sufficient dissolved iron and manganese to cause a significant depression of Nepean River pHs through the oxidation and precipitation of hydrous iron and manganese oxides because the River water contains sufficient buffering bicarbonate/carbonate alkalinity. Due to the low likelihood of ferruginous springs being induced and the inherent alkalinity of the River, any ecological consequence of ferruginous springs is predicted to be minor. However, the consequences of such a spring on aesthetics of the River would be major.

Sub-Bed Flow Diversions

Nepean River bed flow diversions due to river bed fracturing arising from Longwalls 705 -710 are considered unlikely on:

- subsidence prediction grounds due to the offset of the longwalls from the River as described by MSEC (2008);
- on the basis of no detectable change of log-linearity of low flow recessions for the difference between River flows at Maldon and Menangle Weirs pre- and post-mining of the recently mined Area 7 Longwall 701.

It is therefore concluded it is unlikely will be any detectable loss of River flow or diversion of water from the River due to any fracturing of the River bed.

Based on observed past magnitudes of maximum discrete zones of sulfuric acid production in rivers and streams subject to mining-induced bedrock fracturing, the pre-existing total alkalinity in the River water is more than adequate to fully neutralize any sulfuric acid produced from any increase in the dissolution of pyritic minerals in the underlying sandstone caused by mining.

It is therefore predicted that it is highly unlikely there will be any significant effect on River water pH, total iron, manganese, nickel or zinc levels from any sub-bed diversion effects resulting from the extraction of the proposed longwalls, even in the unlikely event of an upsidence- induced fracturing of a rock bar or zone of river bedrock due to the existing levels of alkalinity in River water.

Recommendations

It is recommended that the following additions should be made to the established BHPBIC river water quality monitoring program whenever any significant strata gas emission plumes are detected, particularly when they are coincident with low flow conditions in the River, defined as up to the 50 percentile or 34 ML/day flow rate at Menangle Weir:

1. Gas emission flow rates should be re-measured and then monitored again at 3-monthly intervals.
2. Gas emission chemical composition should be re-measured and then monitored again at 3-monthly intervals. This should include analysis for hydrogen sulfide down to the parts per million (ppm) by volume level. Analysis by the Draeger tube method would be satisfactory.
3. Samples for dissolved methane levels in surface waters should be collected monthly both exactly over major gas plumes and at the regular down river monitoring sites. Analysis should be by a method with a limit of resolution of no more than 10 µg/L.
4. Samples for total dissolved sulfide and total phenols levels in surface waters should be collected monthly both exactly over the major gas plumes and at the regular down river monitoring sites. Analysis should always be by methods which provide the lowest possible limit of resolution.

Once the magnitude and biogeochemical effects of these emissions are better characterized the frequency of these analyses could be reduced.

1. INTRODUCTION

Ecoengineers Pty Ltd ('Ecoengineers') were engaged by BHP Billiton Illawarra Coal ('BHPBIC'), to prepare an assessment of water quality effects that may arise from the proposed extraction of six longwalls numbered 705 through 710 in the existing Appin Colliery Area 7.

The regional location of the 'General SMP Area' for Longwalls 705 - 710 is defined by Mine Subsidence Engineering Consultants (MSEC, 2008) to be that area that is likely to be affected by the proposed longwalls. The extent of the SMP Area has been calculated by combining the areas bounded by the following limits:-

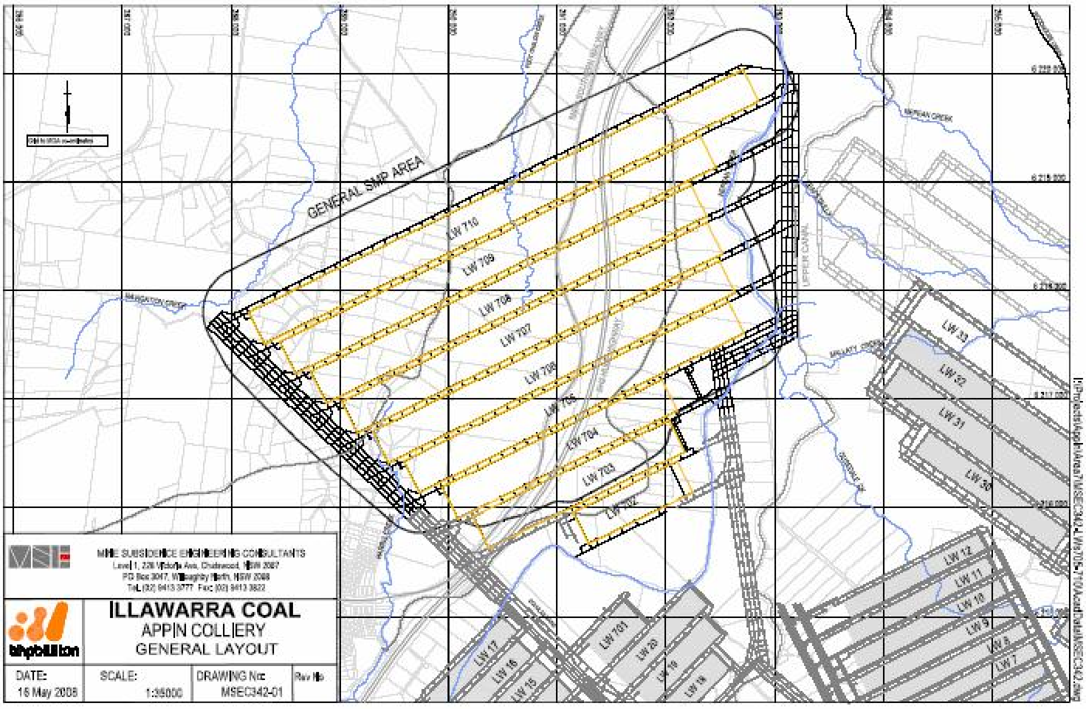
- the 35 degree angle of draw line,
- the predicted vertical limit of subsidence, taken as the 20 mm subsidence contour; and
- features sensitive to far-field movements.

The 35 degree angle of draw line is described as the "surface area defined by the cover depths, angle of draw of 35 degree and the limit of the proposed extraction area in mining leases of the Southern Coalfield", as stated in Section 6.2 of the Department of Primary Industries (DPI) SMP Guideline 2003.

Given that the depth of cover above the proposed longwalls varies between 470 metres and 540 m, the 35 degree angle of draw line has been conservatively determined by drawing a line that is a horizontal distance, varying between 330 and 380 m from the proposed extraction areas of Longwalls 705-710.

Figure 1.1 below shows the general layout of the proposed longwalls, indicating the extents of the MSEC-defined SMP Area and showing the relative positions of the yet-to-be extracted Longwalls 702 – 704 to the immediate south.

Figure 1.1 General Layout of Proposed Longwalls 705 – 710.



It is relevant to note that BHBIC has just mined the first longwall in this series, Longwall 701 south of, but not beneath the Nepean River over the period 27 October 2007 through 9 May 2008 and has previously mined some years ago:

- former Tower Colliery Longwalls 17 and 16 along and adjacent to the Nepean River up-river of Area 7 west of Longwall 701 and beneath the major eastern tributary Cataract River between July 1988 and November 1989; and
- former Tower Colliery Longwalls 20 and 18 adjacent and just south east to Longwall 701 and just up to the Nepean River as well as beneath the minor eastern tributary Elladale Creek between January and December 1990 (noting Longwall 19 was not mined due to a fault).

It is also relevant to note that BHBIC has approval to mine Longwalls 702 through to 704 on the western side of Nepean River. The mining of Longwall 702 will commence shortly. Proposed Longwalls 705 through to 710 lie to the north of Longwall 704.

The depth of cover to the Bulli Seam within the General SMP Area varies between a minimum of 440 m, in the base of the Nepean River valley, and a maximum of 620 m, near the western end of Longwall 708. The depth of cover directly above the proposed longwalls varies between 470 m, at the eastern end of Longwall 707, and 620 m, near the western end of Longwall 708. The seam floor within the General SMP Area generally dips from the south-east to the north-west.

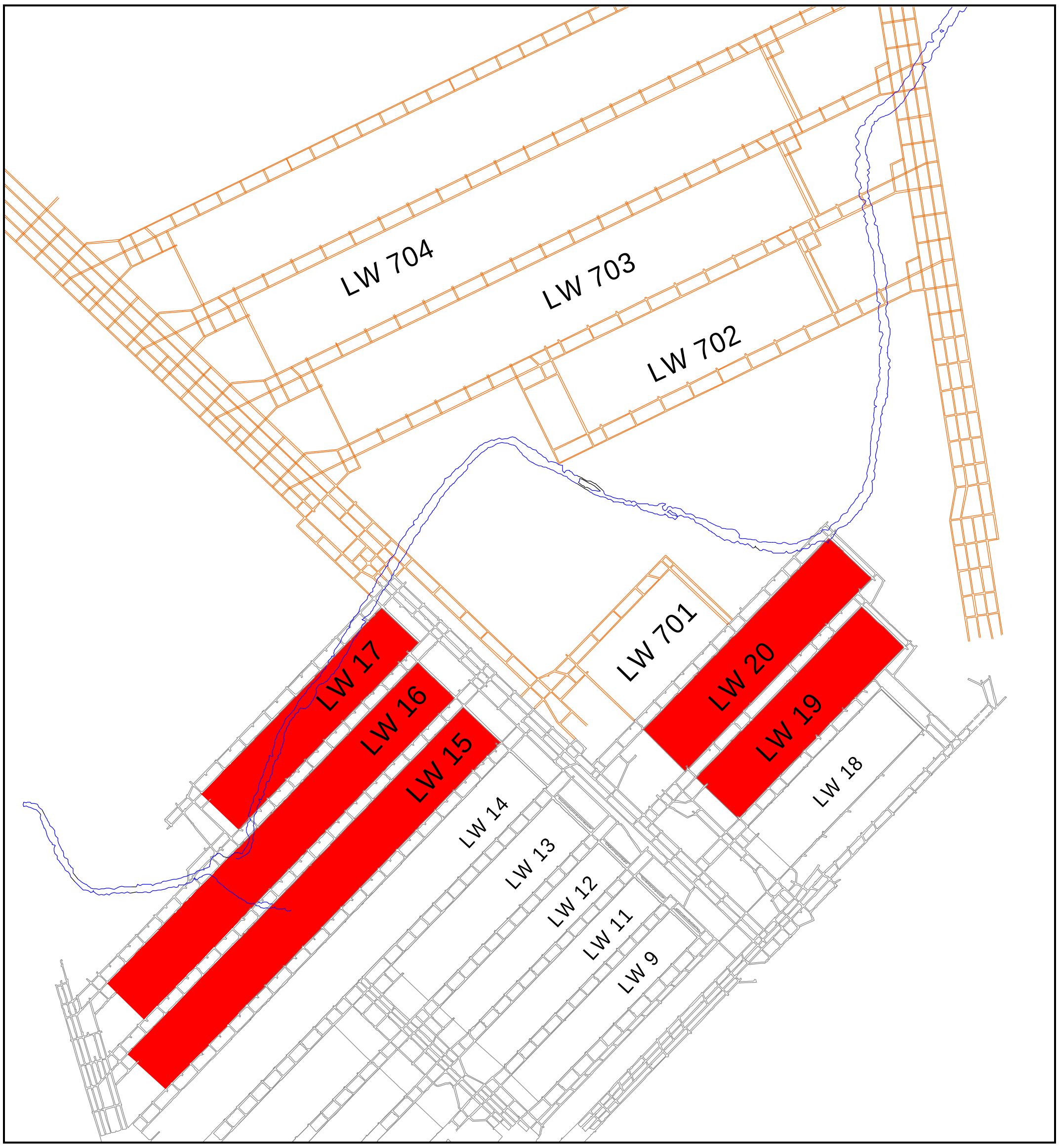
The seam thickness within the proposed longwall goaf areas varies between a minimum of 2.8 m, near the eastern end of Longwall 708, and a maximum of 3.5 m, near the eastern ends of Longwalls 709 and 710. The proposed longwalls will extract the full seam height.

Our investigation of possible mechanisms inducing water quality effects has been principally restricted to the identification, classification and quantification of effects caused within the General SMP Area i.e. in Nepean River, in tributaries on the western side of the River such as Harris Creek, Foot Onslow Creek or Navigation Creek, farm dams west of the River, and tributaries on the western side of the River such as Ousedale Creek, Leafs Gully Creek and Nepean Creek.

The report also considers potential down-river far field effects in Nepean River north of the General SMP Area where appropriate.

Figure 1.2 below shows the locations of the just mined Longwall 701, the approved longwalls 702 – 704 on the western side of the Nepean River and the aforementioned past Appin Longwalls 15, 16 and 17 and 19 and 20 to the west and southeast of Longwall 701.

Figure 1.2 Disposition of Past Mined Appin Longwalls 15, 16 17, 19 and 20, Just Mined Longwall 701 and Approved Longwalls 702 – 704.



1.1 REGULATORY CONTEXT AND BASES OF THIS ASSESSMENT

The local landscape over proposed Longwalls 705 – 710 is largely given over to farming and only relatively narrow zones of native bushland occupy the western and eastern banks of Nepean River and the lower watercourses of Harris Creek, Ousedale Creek and Leafs Gully Creek and Upper Nepean Creek. The catchment area to the west of the River includes numerous rural properties, where surface runoff is retained by numerous farm dams.

There are no drinking water catchment areas or declared special areas within the SMP Area. The nearest drinking water catchment area is the *Upper Nepean Catchment Area*, which is also part of the Metropolitan Special Area, administered by Sydney Catchment Authority ('SCA'). The closest point of this catchment area to the proposed longwalls is at Broughtons Pass Weir, which is located over 6 km south of the proposed longwalls.

The location of the Nepean River is shown in Drawing No. MSEC342-07 in MSEC (2008). It can be seen from this drawing that the proposed longwalls do not directly mine beneath the river. The longwalls have been offset such that they are located at a minimum distance of 180 metres from the edge of the Nepean River.

The total length of the Nepean River within the General SMP Area is approximately 3.6 km. The total length of river within the SMP Area, which is extended to the predicted limits of 20 mm upsidence and 20 mm closure, is approximately 7.8 km, which start approximately 380 m south of the finishing (western) end of Longwall 703 to approximately 590 m north of the commencing (eastern) end of Longwall 710.

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, where it becomes part of the Hawkesbury. The total length of the Nepean River is approximately 145 km.

The section of river that flows within the General SMP Area could be described as a *flooded valley*. The water level within the SMP Area is predominantly regulated by the downstream weir at Menangle, which acts as a dam. Menangle Weir is located approximately 2.5 km north of the proposed longwalls. The water flows upstream of the SMP Area are regulated by the Douglas Park Weir, which is located approximately 2 km south-west of the proposed longwalls. The length of the Nepean River between the two weirs is approximately 14 km. Both weirs lie outside the SMP Area.

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 aquatic ecosystem importance over many years e.g. Independent Expert Panel on Environmental Flows for the Hawkesbury Nepean, Shoalhaven and Woronora Catchment (2002a, b, c) and has therefore, been defined as an *area of environmental sensitivity* for the purposes of this SMP application.

There are no specific Water Quality Objectives established by the Independent Inquiry into the Hawkesbury-Nepean River System by the Healthy Rivers Commission and the Commission recommended using the trigger values in the national water quality guidelines (ANZECC&ARMCANZ, 2000).

This assessment of surface water flow and quality is based upon past experience in the investigation and assessment of water quality effects induced by mining in the Southern Coalfield and specifically from:

- hydrologic and water quality monitoring studies conducted in Nepean River from up-river of Longwall 701 from 10 July 2002 to well down-river of proposed Longwall 710 to the present day by BHPBIC;
- regional aquatic ecological studies conducted in Nepean River, and tributaries of the Nepean River, namely Elladale Creek, Ousedale Creek, Mallaty Creek and Upper Nepean Creek since 2003 by The Ecology Lab (e.g. The Ecology Lab 2004a,b,c,d,e, 2005, 2006a,b and 2007);
- geochemical studies conducted at the former Tower Colliery, now known as Appin West site since 1998 by Ecoengineers Pty Ltd (e.g. Ecoengineers 2005a, b, c, 2006a, b and 2007); and

- groundwater hydrogeological and surface water studies conducted at the former Tower Colliery since 2006 by Geoterra Pty Ltd (e.g. Geoterra, 2006a, b).

Figure 1.3 below shows the BHPBIC water monitoring sites in Nepean River.

Figure 1.3 BHPBIC Nepean River and Lower Tributary Water Quality Monitoring Sites

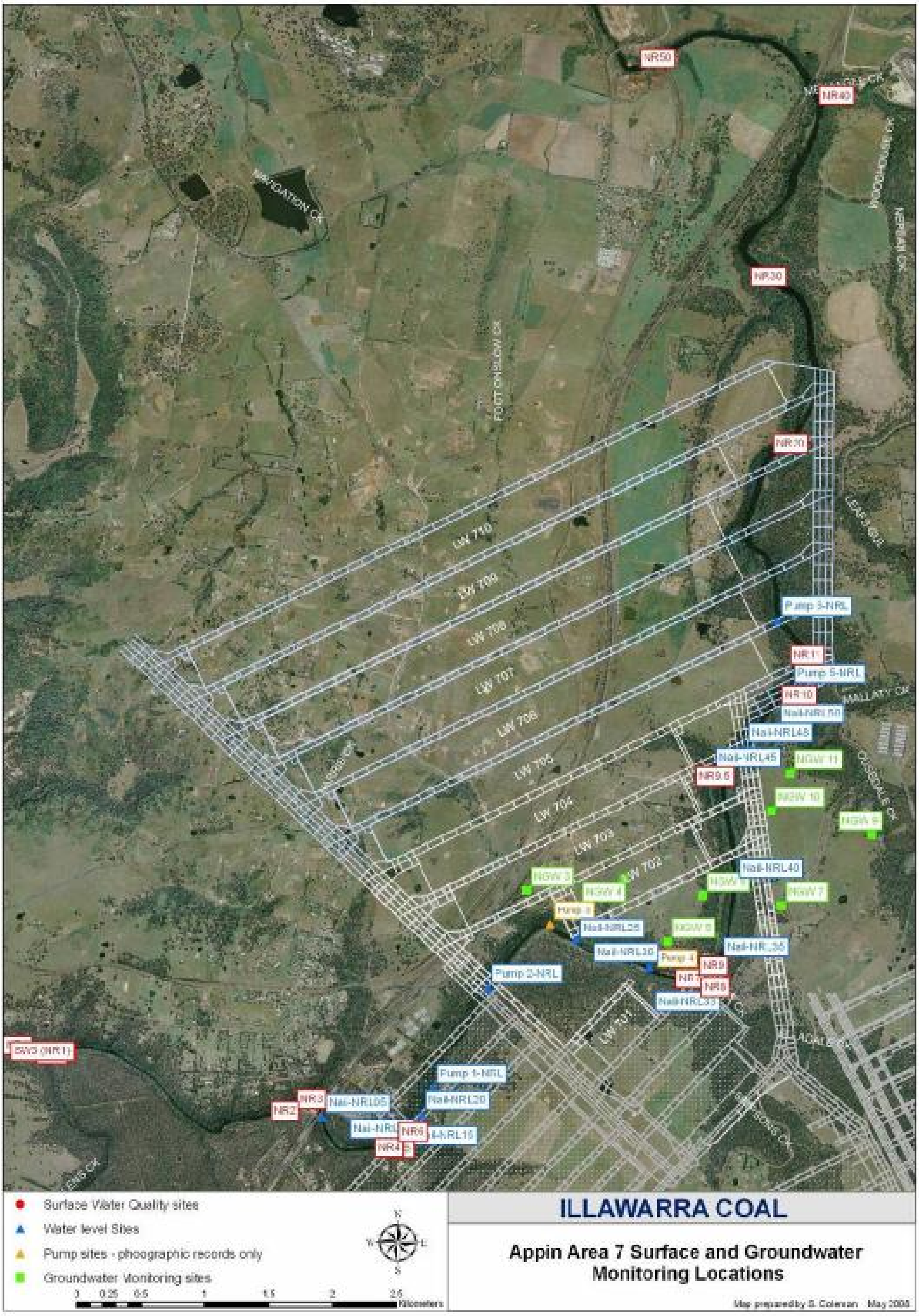
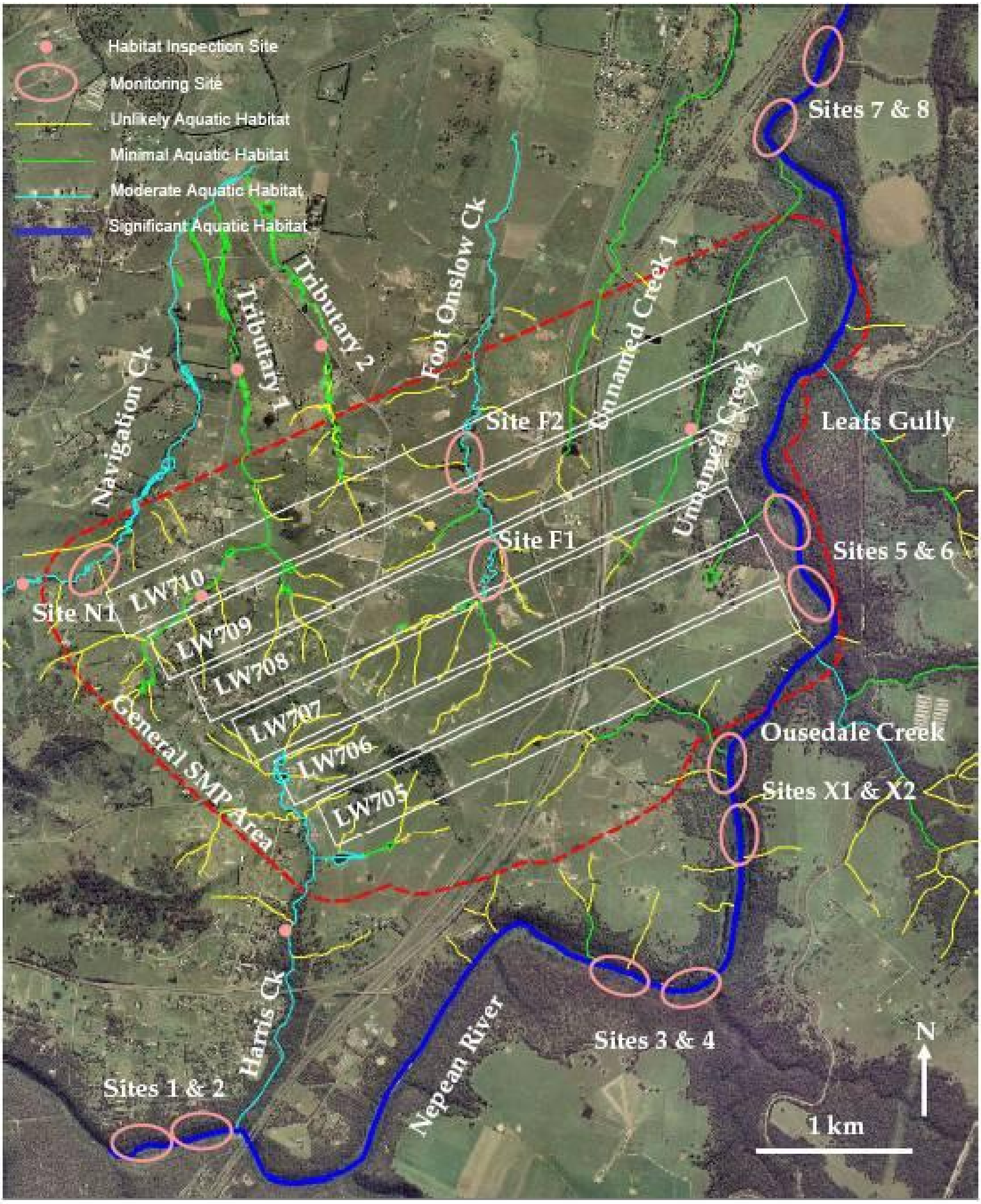


Figure 1.4 shows the locations of aquatic ecology monitoring sites in the Nepean River and in various creeks in the vicinity of proposed longwalls 705 - 710.

Figure 1.4 The Ecology Lab Aquatic Ecology Monitoring Sites in Nepean River

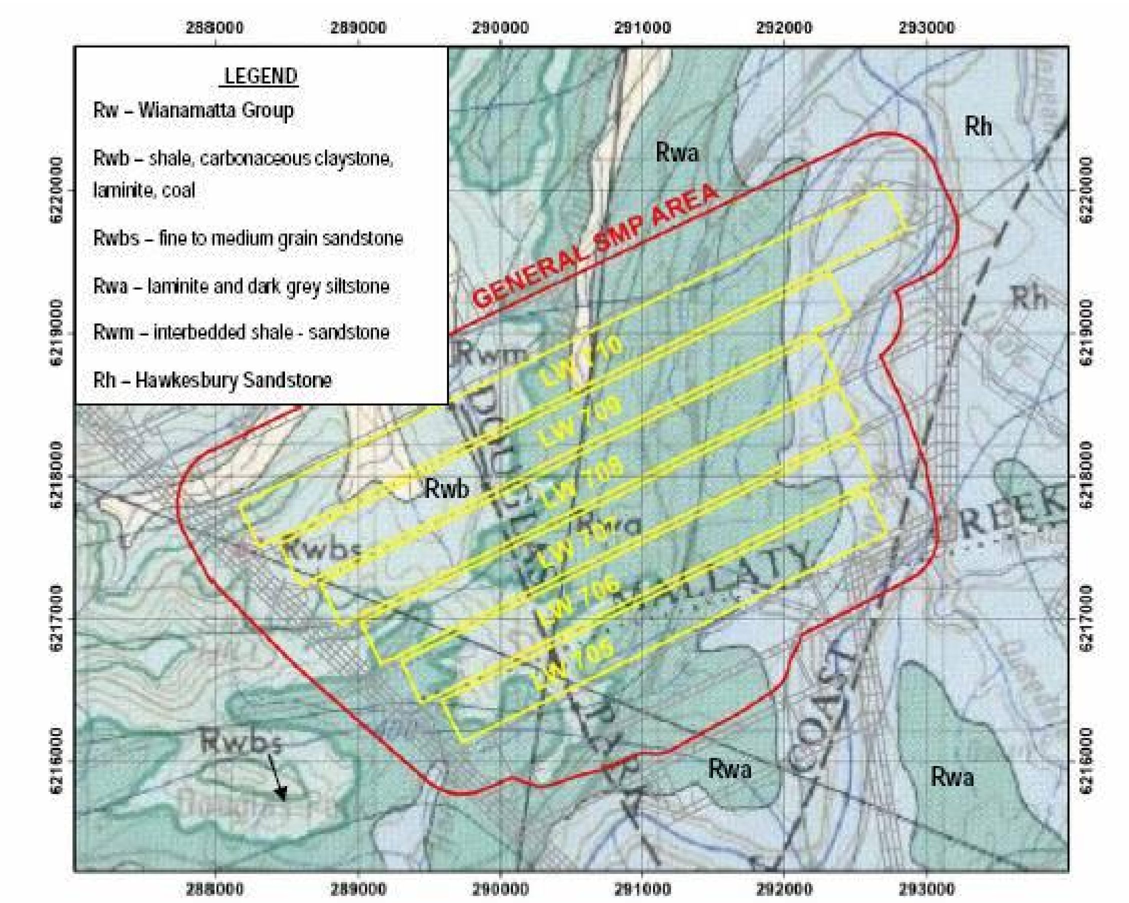


2. BACKGROUND

2.1 NEAR-SURFACE GEOLOGY, GEOMORPHOLOGY AND SOILS

Figure 2.1 below shows the mapped general extents of Hawkesbury Sandstone and Wianamatta Shale surface outcropping respectively in the local area. The Wianamatta Shale has a maximum thickness of about 100 m in the General SMP Area and the lower valley slopes and walls of these creeks are characterised by Hawkesbury Sandstone outcropping, with the lower creek lines being incised into the Sandstone.

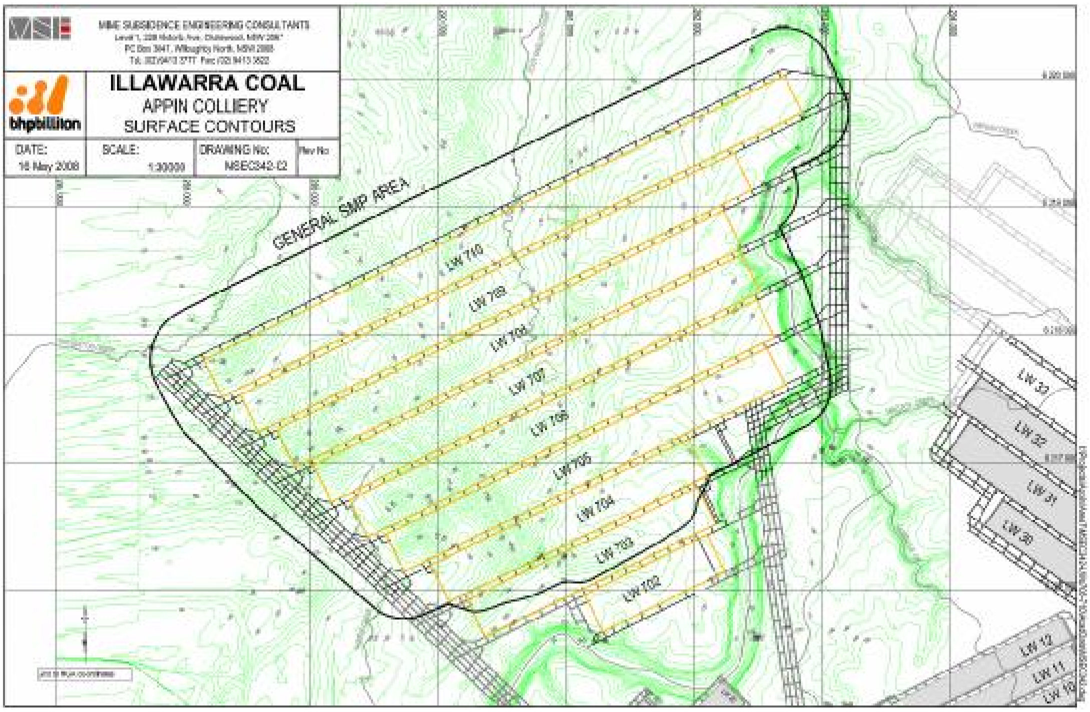
Figure 2.1 Surface Geology Within and Adjacent to the SMP Area.



Landscape types are classified as Cumberland Plains Lowlands and Hawkesbury-Nepean River Valley.

Figure 2.2 below shows the surface contours of the General SMP Area. The Area comprises a plateau dissected north and south by Foot Onslow and Harris Creeks respectively with the western section rising towards Spaniards Hill, an outlier of the Razorback Range.

Figure 2.2 Surface Topography of the General SMP Area



Steepest slopes within the General SMP Area were identified within the valleys of the Nepean River and associated tributaries, which h

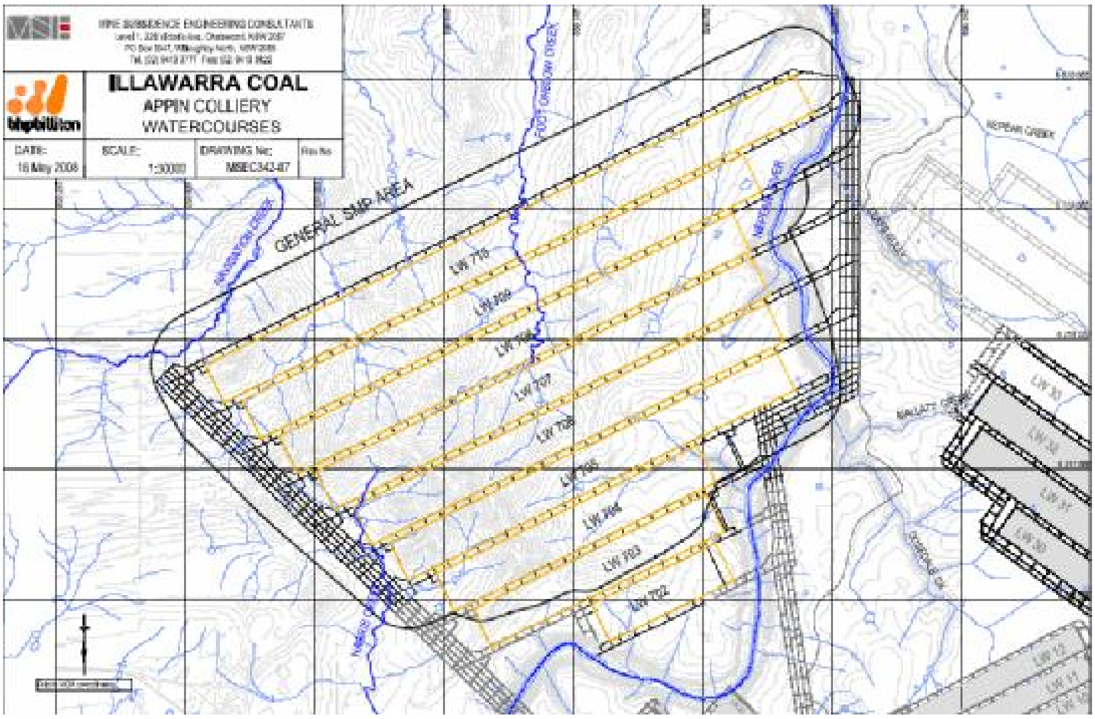
Major tributaries draining to Nepean River within the General SMP Area are as follows:

- **Foot Onslow Creek** is an ephemeral creek which is located directly above the middle of proposed Longwalls 708 to 710. The creek generally flows in a northerly direction until it joins the Nepean River, approximately 3 km north of Longwall 710. The natural grade of the creek within the General SMP Area varies between 10 mm/m and 100 mm/m, with an average grade of approximately 20 mm/m.
- **Harris Creek** is an ephemeral creek which is located directly above the western ends of proposed Longwalls 706 and 707. The Creek generally flows in a southerly direction until it joins the Nepean River approximately 1.9 km south-west of the proposed longwalls. The natural grade of the creek within the General SMP Area varies between a minimum of 5 mm/m and a maximum of 250 mm/m, with an average grade of approximately 25 mm/m.
- **Navigation Creek** is an ephemeral creek which is located in the north-western corner of the General SMP Area and is not located directly above any of the proposed longwalls. The creek generally flows in a north-easterly direction until it joins the Nepean River approximately 8 km north of the proposed longwalls. The natural grade of the creek within the General SMP Area varies between 5 mm/m and 20 mm/m, with an average grade of approximately 10 mm/m.

Figure 2.3 below shows the major watercourses in the SMP Area.

The land on the eastern side of the SMP Area generally drains into the Nepean River via minor un-named 1st and 2nd order streams often intersected by farm dams. A central section drains north into Foot Onslow Creek via minor un-named 1st and 2nd order streams often intersected by farm dams while the land in the western parts of the SMP Area generally drain either south into Harris Creek or north into Navigation Creek via similar streams. Both Foot Onslow Creek and Navigation Creek flow north into Nepean River, entering it well north of Menangle Weir. Farm dams along the 1st and 2nd order un-named creeks can also be seen in **Figure 2.3**

Figure 2.3 Major Watercourses and Farm Dams in the General SMP Area.



Creeks within the SMP Area generally have Wianamatta Shale beds, however, there are sections which have sedimentary deposits of clays derived from the Shale typically along the upper reaches of the creeks. Upper catchments of Ousedale Creek, its major tributary Mallaty Creek, and tributaries of the Nepean River - Leafs Gully and Nepean Creeks on the eastern side of the River are also all characterised by outcropping Wianamatta Shale.

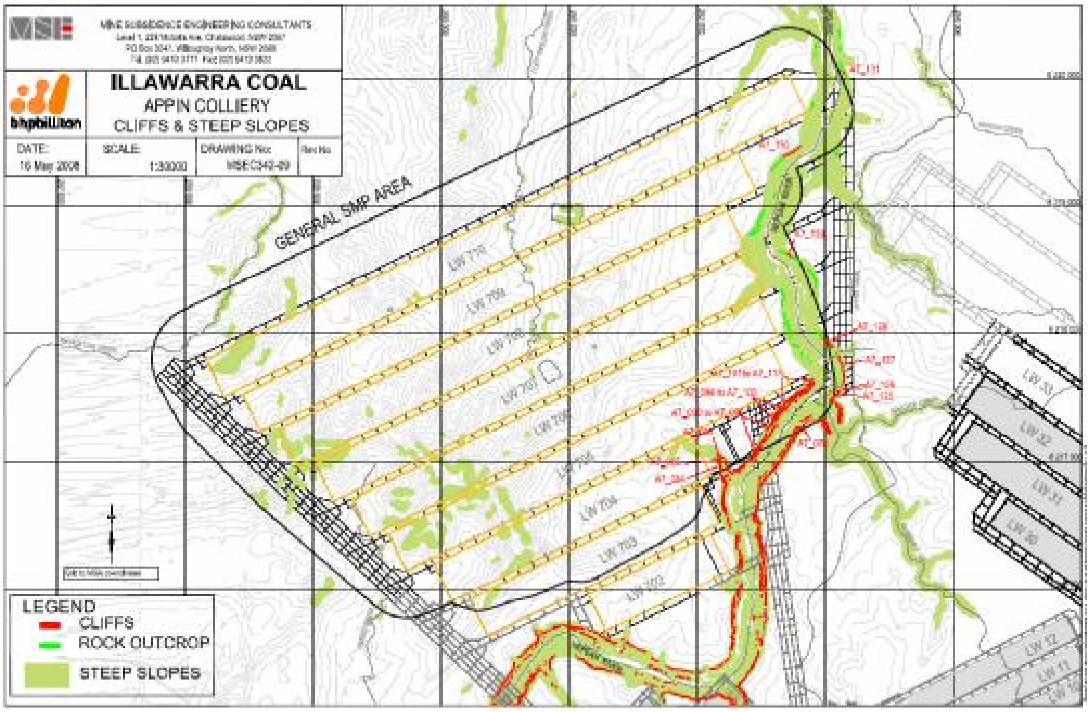
A number of areas containing steep slopes have been identified within the General SMP Area by MSEC (2008). The reason for identifying steep slopes is to highlight areas in which existing ground slopes may be marginally stable and subject to erosive transport of fines into major creeks or into Nepean River.

For the purposes of this report, a steep slope has been defined as an area of land having a natural gradient between 1 in 3 and 2 in 1.

The maximum slope of 2 to 1 represents the threshold adopted for defining a cliff. The minimum slope of 1 to 3 represents a slope that would generally be considered stable for slopes consisting of rocky soils or loose rock fragments. Clearly the stability of natural slopes varies depending on their soil or rock types, and in many cases, natural slopes are stable at much higher gradients than 1 to 3, for example talus slopes in Hawkesbury Sandstone.

The areas of steep slopes were identified from the 1 m surface level contours which were generated from an aerial laser scan of the area, and the locations have been shown in **Figure 2.4**. They have natural gradients varying between 1 in 3 and 1 in 2, with isolated areas having natural gradients of up to 1 in 1.5.

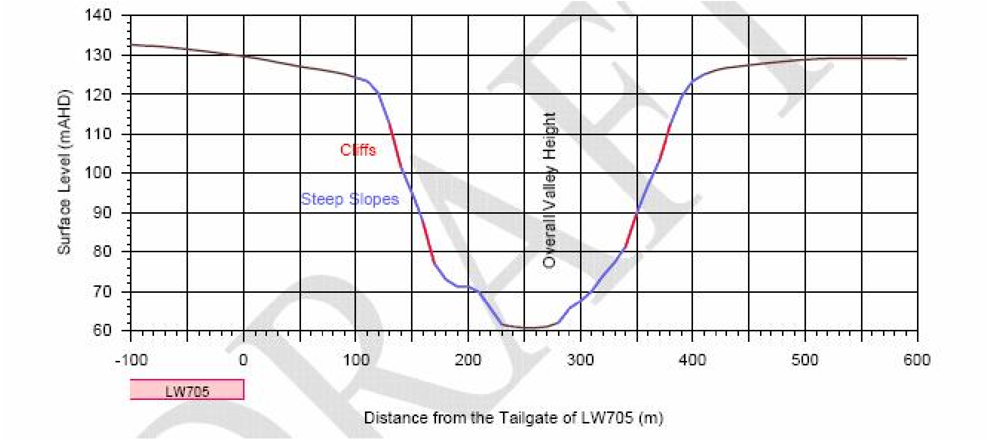
Figure 2.4 – Cliffs and Steep Slopes in General SMP Area



Steeps slopes have also been identified along the hills above the western ends of the proposed longwalls which have natural gradients varying between 1 in 3 and 1 in 2.5, with isolated areas having natural gradients of up to 1 in 2.

The land within the General SMP Area drains freely into the Nepean River and the associated drainage lines, and no areas are considered flood prone. The banks of the Nepean River and the narrow river flats and islands in the bottom of the Nepean River valley, however, are susceptible to inundation during major flood events. **Figure 2.5** below shows a typical cross-section of Nepean River within the General SMP Area and up-river and down-river of it.

Figure 2.5 Typical Cross Section of Nepean River Valley



The surface within the General SMP Area generally consists of soils derived from Hawkesbury Sandstone and Wianamatta Shale, as can be inferred from **Figure 2.1** above. The majority of the slopes are stabilised, to some extent, by natural vegetation.

Soils within the General SMP Area have been mapped by the Soil Conservation Service of NSW and are described by Hazelton and Tille (1990) to be of five soil landscape types:

Hawkesbury type developed on very steep slopes of Hawkesbury Sandstone of greater than 25% within creek main valleys and lower sections of tributaries. Local relief 100 – 200 m with slopes >25%. The soils are shallow (typically <50 cm) discontinuous Lithosols/siliceous sands associated with rock outcrops, Earthy sands, Yellow Earths and locally deep sands on the inside of benches, along joints and fractures and narrow valley flats. There are some localised Yellow and Red Podzolics associated with shale lenses. These soils may be found in close proximity to Nepean River and in the lower section of Harris Creek (as well as the lower sections of Ousedale and Leafs Gully Creek east of the River).

Blacktown type developed on gentle undulating country of Wianamatta Group Shales. Local relief to 30 m, slopes usually <5%. Broad rounded crests and ridges with gently inclined slopes. The soils are shallow to moderately deep (<150 cm) Red and Brown on crests, upper slopes and well-drained areas; deep (150 -300 cm) Yellow Podzolics and Soloths on lower slopes and in drainage depressions and localised areas of poor drainage. These are moderately reactive soils, with highly plastic subsoils but are not particularly susceptible to erosion. These soils may be found in the central plateau overlying the SMP Area in the middle sections of Harris Creek and Foot Onslow Creek as well as all areas draining directly to the River.

Picton type developed on steep to very steep side slopes characterised by mass movement and terracettes on Wianamatta Group and derived colluvial materials, usually having a southerly aspect. Local relief 90 – 300 m, slope gradients >20%. Extensively cleared. Soils are shallow to deep (50 – 200 cm) Red Podzolic and Brown Podzolics and Soloths on lower slopes and benches with Red Earths and Brown Earths on colluvial material. Very deep (>300 cm) Yellow Podzolic soils and Soloths on lower slope and within the drainage lines. These soils occur in upper Harris Creek only on the semicircle of ridges leading up to Spaniards Hill to the northwest. These soils have an extreme erosion hazard and capacity for mass movement (slumping) hazard on steep slopes. Erosion of such soils along 1st and 2nd order streams (drainage lines) is particularly noticeable within the General SMP Area on cleared farmland and has likely been exacerbated by the actions of stock.

Luddenham type developed on undulating to rolling hills again on Wianamatta Group Shales, often associated with Minchinbury Sandstone outcrops. Local relief 50 – 80 m slopes 5 – 20%. Narrow ridges hill crest and shallow valleys. Extensively cleared. Soils are shallow (<100 cm) Brown Podzolics and Massive Earthy Clays on crests, moderately deep Red Podzolics on upper slopes, moderately deep (<150 cm) Yellow Podzolics and Prairie Soils on lower slopes and near drainage lines. These soils occur only in a small area in the centre of the SMP Area. They have a high erosion hazard and erosion of such soils along 1st and 2nd order streams (drainage lines) is particularly noticeable within the SMP Area on cleared farmland and has likely been exacerbated by the actions of stock.

Theresa Park developed on Tertiary and Quaternary floodplain and terraces of the Nepean River. Gently undulating slopes mostly <5% but ranging to 10% on high level terraces. Soils are Red Earths and Red Podzolics and alluvial bedding is sometimes evident with Alluvial soils in the drainage lines. Solodic soils also occur where there is water-logging. These soils are highly variable and include poorly structured orange to red silty loams, brown loams and sandy loams. In the General SMP Area these soils occur only to a very minor extent in the very upper portions of Foot Onslow Creek and Navigation Creek north of Longwall 710 and are completely pastured. These soils exhibit high erosion only under concentrated flows.

There are no swamps or wetlands that have been identified within the SMP Area.

There are, however, water-related ecosystems within the SMP Area, in particular, along the Nepean River and the larger drainage lines, principally in Harris Creek. These have been investigated and are described in reports by Biosis (2008a) and The Ecology Lab (2008).

There are no lands within the General SMP Area that have been declared as critical habitat under the *Threatened Species Conservation Act 1995*. There are, however, threatened and protected species within the SMP Area which are described in reports by Biosis (2008a) and The Ecology Lab (2008).

2.2 LOCAL HYDROLOGY

Water flows in the Nepean River are derived from a number of sources, which include flows from; catchment areas, licensed discharges, including Appin West Colliery and Tahmoor Colliery, and runoff from agricultural and urban areas. Flows from catchment areas contribute the majority of base water flows into the river.

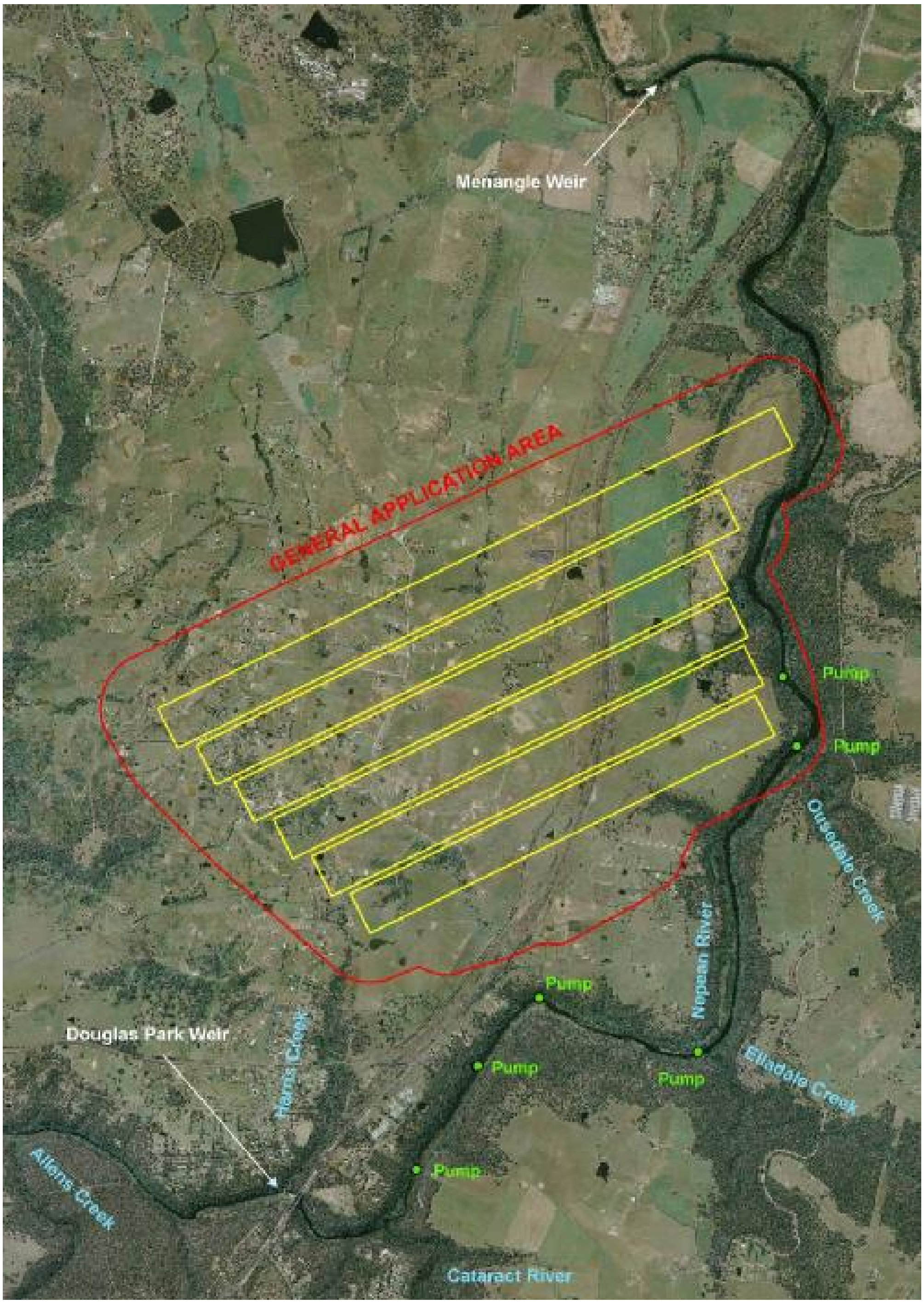
The major tributaries upstream of the General SMP Area are the Cataract, Cordeaux and Bargo Rivers. Some natural catchment flows are retained by large storage dams upstream of the SMP Area for the purposes of Sydney water supply systems. Water is also retained by numerous farm dams within the local catchment.

Water flows vary within Nepean River, and are largely dependent on rainfall events within the catchment. Regular flow monitoring has not been undertaken within the SMP Area as there are no areas of restricted flow and it is very difficult to measure flow across flooded channels.

The closest monitoring station upstream of the SMP Area is at Maldon Weir, which is located approximately 13 km upriver from the proposed longwalls. The closest monitoring station downstream of the SMP Area is at Menangle Weir, which is located approximately 2.5 km north of proposed Longwall 710.

Water is also directly drawn from the Nepean River by licensed extraction pumps between Maldon and Menangle Weirs and some of these pumps are located within the SMP Area, and are shown in **Figure 2.6** below.

Figure 2.6 Licensed Extraction Pumps in Nepean River in the Vicinity of General SMP Area



Measured daily mean water flows at Maldon Weir have been provided by SCA for the period between 9 June 1975 and 9 April 2008. There are extensive gaps in the Maldon record and so the record only covers a total of 8562 days (23.44 years) out of a total period of 11992 days (32.84 years).

Measured daily mean water flows at Menangle Weir have been provided by the SCA for the period between1 July 1990 and 9 April 2008. This is a nearly complete record comprising 6339 days (17.35 years) out of a total of 6493 days (17.78 years).

Much of the data at both weirs has only a poor quality HYDSTRA rating. For this reason measured flow data has been ranked and the results are summarised in **Table 2.1.**

Table 2.1 Percentiles for Entire SCA Flow Frequency Records for Maldon and Menangle Weirs

Percentile	**Maldon Flow (ML/day)**	**Menangle Flow (ML/day)**
90	404.243	231.250
80	68.456	96.567
70	29.345	58.981
60	20.134	43.662
50	15.123	33.950
40	11.739	24.452
30	8.940	16.836
20	6.615	9.714
10	4.035	5.011
Total Days Recorded	8562	6339

The Maldon Weir has a nominal catchment of 865 km^2 but in reality its catchment comprises some 333 km^2 below Pheasants Nest Weir for the approximately 50 percentile (median) and lower flows (at Maldon Weir) when SCA is generally not spilling over Pheasants Nest Weir. This includes the catchments of Bargo River (approx. 181 km^2), Stony Quarry Creek, Picton (approx. 120 km^2) and Allens Creek Catchment itself (approx. 32 km^2).

Due principally to the effects of SCA controlling discharges over Pheasants Nest Weir, flow at Maldon Weir is only poorly fitted by a standard log-linear relationship between Flow (F) and probability of exceedance (P) commonly used to interpolate flows with:

$P = -5.469 + 42.162 \log_{10} F$
Adjusted $R^2 = 0.8461$

Durbin-Watson statistic = 0.798

Below 50 percentile flows (of 15.123 ML/day) during which it is unlikely that SCA is releasing over Pheasants Nest Weir, flow at Maldon Weir is better fitted by a standard log-linear relationship Flow (F) and probability of exceedance (P)

$P = -23.488 + 58.219 \log_{10} F$
Adjusted $R^2 = 0.9256$

Durbin-Watson statistic = 0.719

However, flow at Menangle Weir is well fitted by a standard log-linear relationship between Flow (F) and probability of exceedance (P) over the entire usual 10 – 90 percentile range with:

$P = -30.378 + 53.2210 \log_{10} F$
Adjusted $R^2 = 0.9712$

Durbin-Watson statistic = 1.162

The long term median flow at Maldon Weir is 15.1 ML/day and at Menangle Weir is 34.0 ML/day.

The Maldon Weir catchment comprises some 181 km^2 below Pheasants Nest Weir for the 50 percentile (median) flows when SCA is generally not spilling over the weir. In addition, the catchments of Stone Quarry Creek, Picton (approx. 120 km^2) and Allens Creek (approx. 32 km^2) also flow to Nepean River downstream of the weir. Hence the flows at Maldon Weir underestimate flows in the Nepean River at Douglas Park Weir by at least 85% and even more so when Pheasants Nest Weir is spilling which is generally greater than for the 50-percentile situation.

Relatively consistent discharges to the Nepean River below Maldon Weir come from Stony Quarry Creek, Picton, Allens Creek, Wilton, the Cataract River as an environmental flow (minimum and median 1.7ML/day, mean 27 ML/day), as well as irregular flow inputs from minor and major creeks (unquantified) such as Harris Creek, along with approximately 1 ML/day from Allens Creek via the Appin West Colliery licensed discharge (Geoterra, 2006).

It is not practical to measure flows within the SMP area, however interpolation between Maldon and Menangle Weir long-term flow records on the above basis suggest a median flow past the General SMP area of approximately 30 ML/day.

Some cessation of flow events have been recorded by the SCA, which reflect periods where more water is extracted from Nepean River than is flowing from upstream. Water levels below the weir spill point of 36 mm at Maldon Weir and 295 mm at Menangle Weir have been recorded. Subtraction of daily Maldon Weir flows from Menangle Weir flows can give negative values either because of flow gauging errors or the effect of licensed extractions but such negative values have become rare since cessation of the 2000 – 2006 drought in mid September 2006.

Water flow conditions in the Nepean River:

- vary greatly and are highly responsive to rain events due to the significant areas of catchment involved; with
- maximum flow rates reaching very high levels during sustained storm events; and
- Nepean River has ceased to flow on a small number of occasions and this occurs usually when the rate of pumping out of the river exceeds the rate of inflow; and
- median flow rate in the Nepean River above the General SMP Area is likely to be much more than the median flow rate at Maldon Weir, which is 15 ML/day, by about 85% i.e. approximately 28 ML/day and a little less than the median flow rate at Menangle Weir, which is 34 ML/day, there is about 30 ML/day.

The flow rate at Menangle Weir is considered to be more representative of the flows within the SMP Area than the flow rate at Maldon Weir.

There are fewer additional sources of significant inflows to Nepean River from catchment areas between the SMP Area and Menangle Weir when compared to the catchment areas between the SMP Area and Maldon Weir. Interpolation between Maldon and Menangle Weirs would suggest a median flow past the SMP area of approximately 30 ML/day.

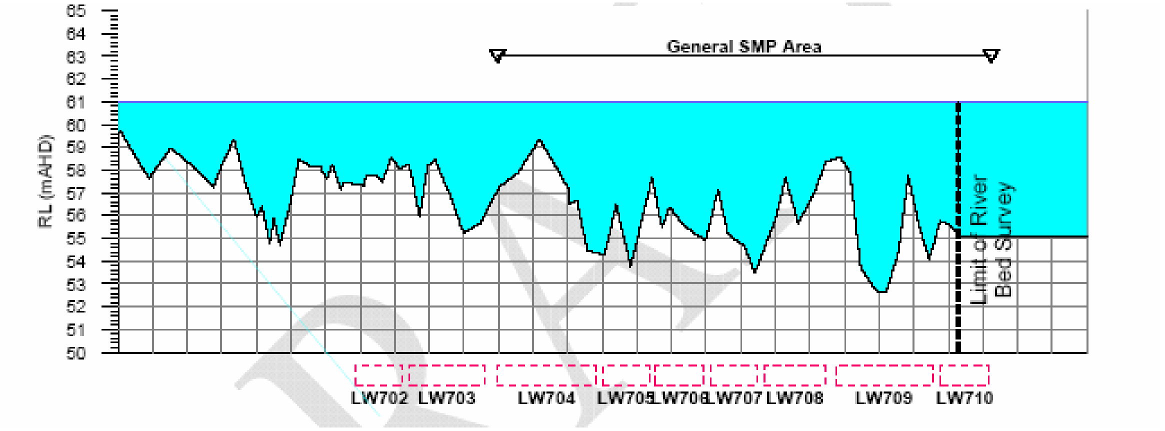
Maximum flow rates can reach very high levels during sustained rainfall events and storms, whilst minimum flow past the SMP area is rarely likely to be less than 1.5 ML/day (5 percentile flow).

As noted above, water level in the section of Nepean River within the SMP Area is predominantly controlled by Menangle Weir. The Weir ensures that Nepean River remains fully charged at all times, even when there is little flow in the river.

The water level along the Nepean River was surveyed by BHPBIC in 2003, well after the completion of Longwall 20. This survey showed that the water level falls 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 km. The slight fall in water level most likely represents friction and head losses occurring along the river.

BHPBIC also conducted a survey of bed levels in 2003, which measured levels at points representing the approximate deepest parts along the river. The longitudinal section of the Nepean River within the SMP Area is shown in **Figure 2.7**, with a constant water level of RL 61.00 shown to illustrate the approximate water surface. It can be seen from this figure that the bed profile changes considerably along its length and the river is typically between 2 and 7 m deep.

Fig. 2.7 Elevation of Nepean River within the SMP Area



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 at the outside of river bends and becomes generally deeper as it travels downstream with a depth range from less than 0.25 m over sand bars to greater than 8 m in deeper rock based pools (Geoterra, 2006a).

Table 2.2 shows the annual rainfalls recorded at Douglas Park (St. Mary's Towers).

TABLE 2.2 ANNUAL RAINFALLS AT DOUGLAS PARK SINCE 1998

Year	Rainfall (mm)
1998	809.6
1999	947.2
2000	582.2
2001	609.4
2002	496.6
2003	532.9
2004	618.0
2005	698.6
2006	402.7
2007	998.6
Average 1998 - 2007	**669.6±194.2**
2008 January – March	**418.0**

Between 2000 and 2006, the area was in drought. It experienced significantly lower than average rainfalls than applied over the previous decade. This is more than 30% lower than the long term median annual rainfall at Cataract Dam which, over the 100 years since recording commenced in 1904 has been about 1000 mm.

The Bureau of Meteorology (BOM) national map for Annual Areal ET for the period 1960 – 1991 indicates that the region should have a mean annual ET in the 500 – 600 mm/year range.

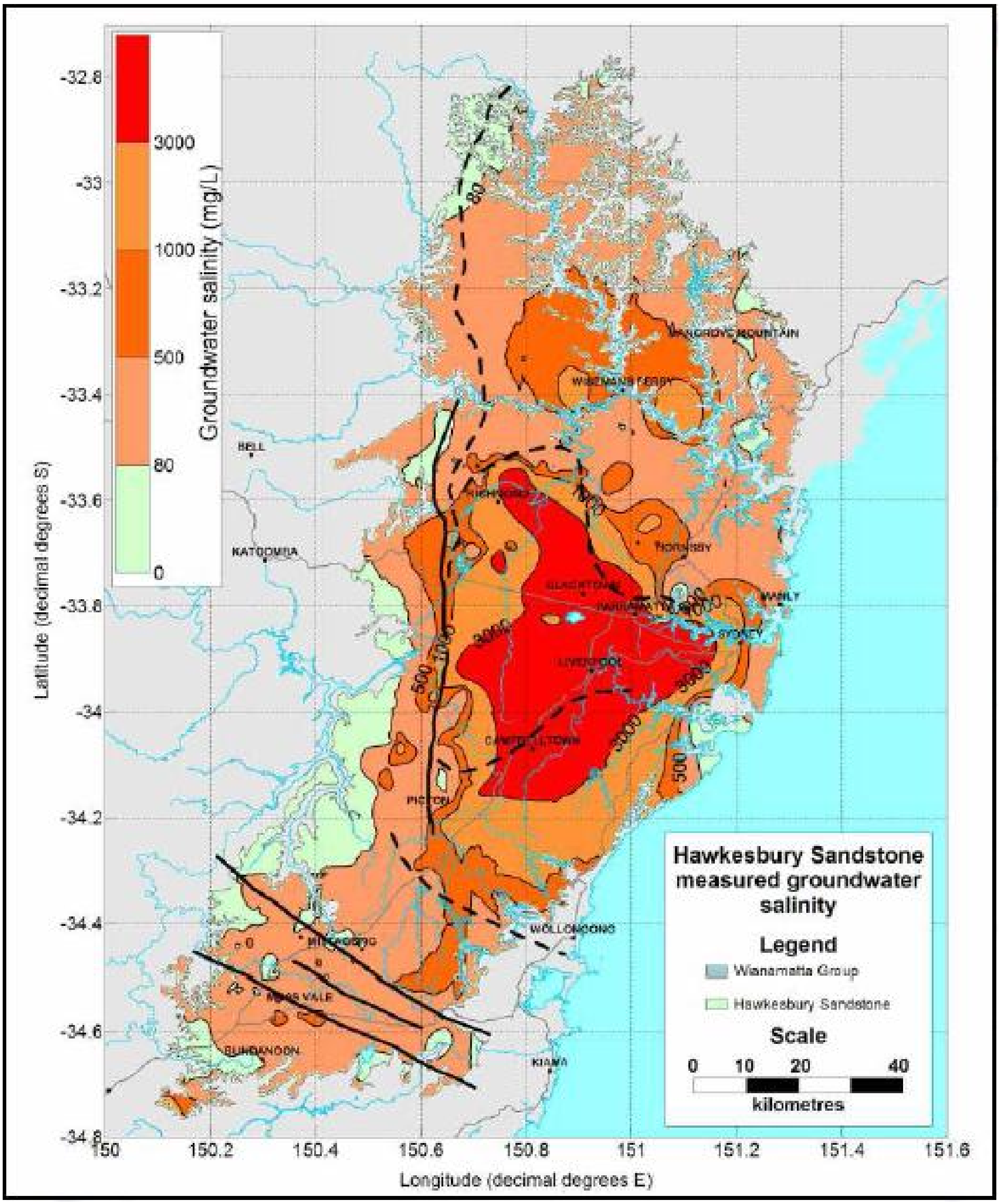
Actual annual ET in the General SMP Area, which is largely cleared for pasture and generally drains Wianamatta Shale-based soil mantled or outcropping terrain, can be estimated using the Zhang et al. 1999, 2001, approach for which, assuming 100% grass cover and an average annual rainfall of 670±194 mm/year is estimated to be approximately 502+84,-106 mm/year (1.4+0.2, -0.3 mm/day). For non-drought years such as exemplified by 1998, 1999 and 2007 (i.e. average rainfall 998±97 mm) upland ET is expected to lie in the range 603±34 mm (1.7±0.1 mm/day) and in the Nepean River gorge to be about 735± 55 mm/year i.e. 2.0±0.2 mm/day.

2.3 NEAR-SURFACE HYDROGEOLOGY

Water in the Nepean Gorge is at the lowest point in the hydrological catchment and therefore has no deeper stream or groundwater system to which it can flow, except for downstream along the gorge towards Menangle Weir.

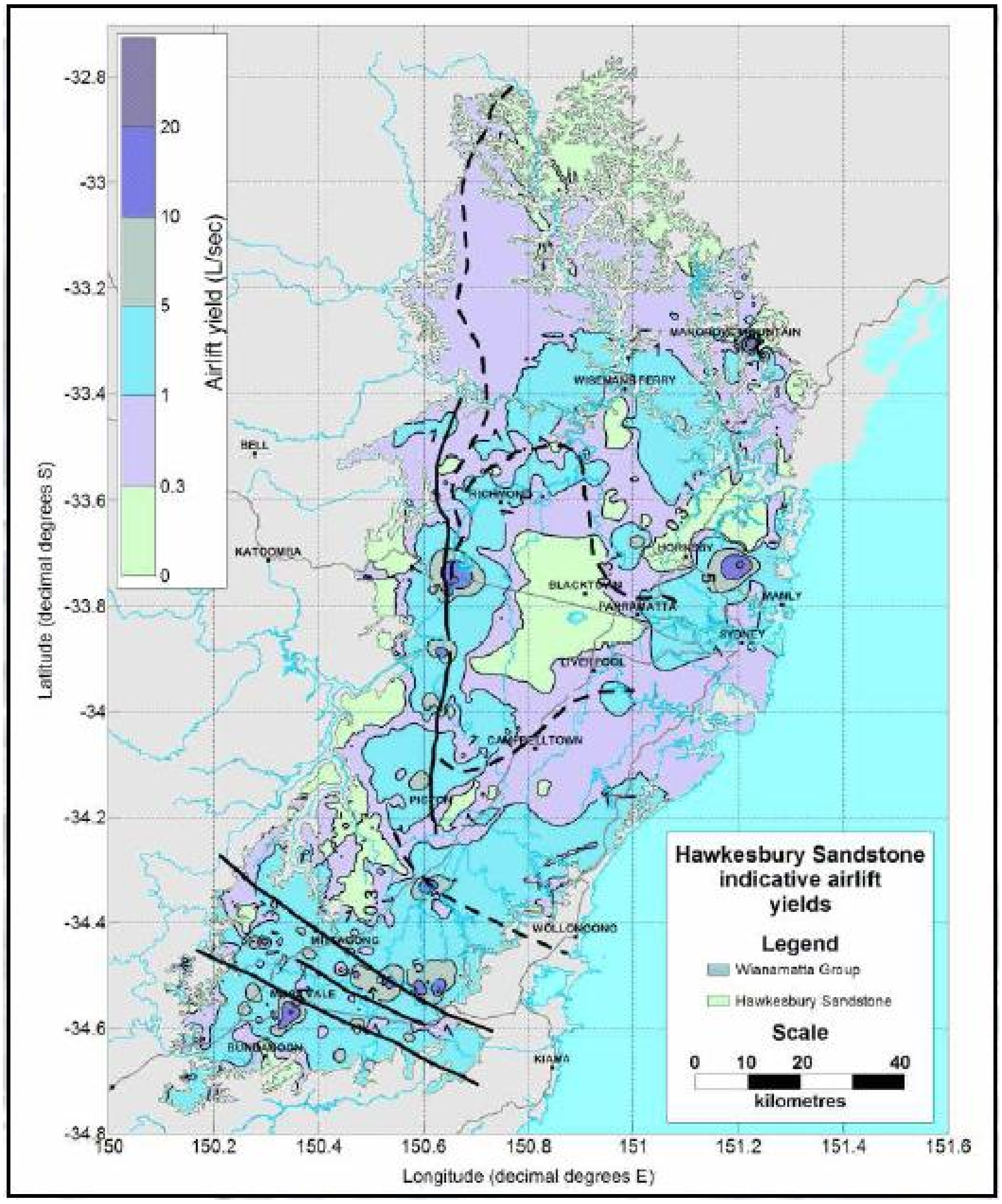
Salinities of regional Hawkesbury Sandstone ground waters presented at a University of Technology Sydney and University of New South Wales sponsored symposium on the hydrogeology of the Sydney Basin in 2007 (proceedings unpublished) suggest that deeper groundwaters in the area meander north along the Nepean River valley as shown in the following **Figure 2.8**.

FIGURE 2.8: HAWKESBURY SANDSTONE MAJOR REGIONAL GROUNDWATER SALINITY ZONATION



Airlift yields are low in the area, typically <1 L/s in the vicinity of Appin Area 7 as shown in **Figure 2.9** below.

Figure 2.9 Typical Hawkesbury Sandstone Airlift Yields in the Sydney Basin and Southern Coalfield.



The local hydrogeology and potential impacts of mining Longwalls 705 – 710 is further discussed in Geoterra (2008).

No consistent water bearing horizons have been identified above the base of the Nepean River during drilling. This was either because they are not present or because the intersection flows were too small to be observed during core drilling.

Potential water migration zones were assessed through interpretation of the drilling, packer testing and cliff inspection data. This data indicates generally low permeability with no discrete continuous permeable zones that can be extrapolated over the study area.

Water injection testing intakes below the pervasive L-MS facies were generally low, with migration along joint planes restricted to strata above the river and in close proximity to the cliffs where lack of horizontal confinement enables seeps to develop.

Bore yields in the general area obtained from the DNR database indicate the sandstone is generally low yielding, with up to 1.8L/s reported.

Miall and Jones (2003) inferred that seeps observed through remnant iron staining on cliffs indicate the presence of a vertical permeability barrier, such as mudstone. Liu et al. (1996) observed that permeability was more variable vertically than horizontally and that permeability in the Hawkesbury Sandstone is extremely variable and primarily relates to sedimentary structures, such as types of cross-bedding, along with variations in grain size and sorting.

Higher permeabilities were found to occur in low-angle cross-stratified to crudely stratified coarse sandstones, and large-scale planar/tabular cross-stratified medium to coarse sandstones. Lower permeability zones occur in small-scale troughs to planar/tabular cross-stratified, fine-medium grained sandstones and lutites (BHPB, undated). Coarser sandstones were found to have higher water inflows during packer testing compared to finer grained facies.

Groundwater flow is primarily controlled by the presence of finer grained aquitards which underlie higher porosity, coarser sandstones, with the finer grained layers appearing as fresh (grey) to moderately weathered and heavily stained (orange to deep red) bands.

2.4 PRIOR LONGWALL MINING-RELATED EFFECTS

The section of the Nepean River within the General SMP Area is different to most other rivers in the Southern Coalfield, in that it is a flooded system, where water levels are predominantly controlled by the Menangle Weir, rather than by natural rockbars. Longwall mining has previously occurred adjacent to or directly beneath the same stretch of river.

Two series of longwalls have mined either directly beneath or close to the Nepean River. The most applicable experiences are those that occurred as a result of the extraction of Tower Longwalls 16 and 17 extracted between 28 October 1999 and 18 April 2000, and Tower Longwalls 18, 19 and 20 extracted between 9 August 2000 and 1 November 2002 as shown in **Figure 1.2**. The closest analogy to the proposed Longwalls 705 – 710 is the most recent Appin Longwall 701, which is adjacent to extracted Longwall 20 as can be seen in Figure 1.2.

The most visually noticeable impacts from previous mining have been the emission of gas bubbles and development of localised iron stains in the Nepean River or its tributaries. The greatest impacts occurred during the extraction of Tower Longwall 17, which mined directly beneath the river.

There has been no reported or observed loss of surface water as a result of the previous mining adjacent to or directly beneath the river. If any surface fracturing did occur during the mining of the Tower Longwalls, they are not visible as they are most likely submerged beneath the surface of the flooded river.

Impacts observed during the mining of these previous longwalls provide a good indication on the likely impacts that might occur as a result of mining the proposed Longwalls 705 to 710.

Elladale Creek field monitoring within the Nepean River suite began at site NR8 (refer Figure 1.4) on 13 June 2002 and sample collection and laboratory analysis was initiated on 10 July 2002. Up to 14 field sampling points within Elladale Creek were monitored between 6 May 2002 and 22 May 2003, after which time the Nepean River monitoring continued to the present.

Routine field inspections by BHPB in Simpsons Creek and Elladale Creek observed an isolated section of creek bed cracking in Simpsons Creek over Longwall 18 around mid June 2001. It was observed that a 10 m length of creek bed cracked which led to minor loss of pool water. No significant fracturing, water loss or water quality deterioration was observed or measured through the remaining length of Simpsons Creek due to subsequent extraction of Longwall 18 (BHPBIC, undated).

Isolated fracturing was observed during extraction of Longwall 19 in Elladale Creek, although no water loss or water quality deterioration was noted. Intermittent gas emissions were noted in pools in lower Elladale Creek over the maingate chain pillars within a 50 m stretch after Longwall 19 was mined (BHPB, undated).

Tower Longwall 20 mined under the junction of the Nepean River and Elladale Creek, where the creek is incised by approximately 35 m into the sandstone plateau. Benchmarks used to monitor pool depths in Elladale Creek were installed on 6 May 2002; three days after Longwall 20 began. Longwall 20 had mined under Elladale Creek by the time further monitoring commenced, however the response to subsidence through bedrock fracturing and lowering of water levels was observed to start around late September to early October 2002, some four months after the creek had begun to subside.

Isolated bedrock compressive fracturing was observed in Elladale Creek, 100 m from the Nepean confluence, on 18 July and 16 September 2002 with no observed water loss or adverse water quality effects, whilst minor gas emissions were observed up till 29 July 2002, with associated water discolouration and increased salinity.

Gas was again observed in the Nepean River, 50 m upstream and 20 m downstream of the Elladale Creek confluence and for 170 m upstream in the Creek bed from 10 September 2002 onwards when Longwall 20 had been extracted 735 m. An ongoing ferruginous discolouration, reduced pH and increased salinity was also observed in Elladale Creek and in deeper water in the Nepean River below 2 m. Water shallower than 2 m depth in the Nepean River was not observed to be discoloured.

Gas emissions had stopped by 19 December 2002 in the Nepean River. The total duration of gas emission of any significance was therefore only a little over three months.

No flow was recorded from Elladale Creek to the River from 21 October 2002 to the end of January 2003, with all but three pools in lower Elladale Creek drying out by 14 November 2002 (BHPBIC, undated). This may have been an effect of the drought.

2.5 PREDICTED WATER-RELATED IMPACTS FOR LONGWALLS 705 -710

Predicted impacts of the mining of Longwalls 705 - 710 on Nepean River and on creeks to the west of the River are presented in **Sections 5.1 and 5.2**, respectively, in the MSEC (2008) report.

2.5.1 Potential Changes to River Water Levels

Menangle Weir is located approximately 2.5 km north of the proposed Longwalls 705 to 710 and, therefore, the predicted systematic subsidence and valley related movements at the weir are negligible. It is possible that the weir could experience very small far-field horizontal movements; however, these movements are expected to be bodily movements with no significant associated ground strains. It is unlikely, therefore, that the extraction of the proposed longwalls would result in any significant impacts on Menangle Weir.

It is expected that the water level along the Nepean River within the SMP Area will remain essentially unchanged after mining, whilst it is expected that the river bed would uplift as a result of the extraction of the proposed longwalls. This is because the upsidence is expected to exceed the subsidence along the river (MSEC, 2008). Based on the conservative predictions of upsidence and relatively small amounts of predicted subsidence, the maximum uplift along the river is expected to be between 255 and 345 mm.

Measurable changes in water level relative to the banks of the river were observed as a result of mining Tower Longwall 17. Based on observations of water levels at Morrison’s Pump and ground monitoring along the TK Line, it is estimated that the banks of the river rose by less than 50 mm following the completion of mining, though the banks had risen by up to 200 mm as the longwall progressed past the monitoring sites (MSEC, 2006). Subsidence and upsidence movements observed during the mining of Tower Longwall 17 were substantially greater than those predicted for Longwalls 705-710 and those observed during the mining of Longwall 701.

Should upsidence exceed subsidence along some sections of the Nepean River, these sections would experience a slight change in the frequency of water inundation that occurs. This may be more noticeable where the banks of the river are shallow. Field investigations of the banks of the Nepean River have been conducted by Geoterra (2008) for the purposes of ascertaining the potential extent of desiccation.

Water levels in the Nepean River fluctuate in response to changes in flow. It is apparent from relative water level surveys that the water level in the river typically rises and falls within a range of 150 mm. It has also been observed that water levels rise by at least 600 mm when flows reach a peak of approximately 730 ML/day at Maldon Weir, which is an event that occurs approximately 8% of the time. These changes in water level associated with increased flow rates in the river are of a similar order of magnitude to the predicted maximum 345 mm (MSEC, 2008) uplift of the banks.

2.5.2 Potential for Surface Fracturing in Nepean River

Longwall mining can result in the development of surface fractures in stream beds. Surface fractures have been observed in almost all incised and rock bedded streams that have been directly mined beneath.

In this case, the proposed Longwalls 705 to 710 do not mine directly beneath the Nepean River. The proposed longwalls are set back at least 180 m from the Nepean River. Observations indicate that only minor fracturing may occur in the bed of the Nepean River as a result of the extraction of the proposed longwalls (Kay et al, 2006). The furthest distance of an observed fracture from a goaf edge is approximately 415 m from Longwall 401 at the base of Broughtons Pass Weir. Any fracturing that does occur at this distance is expected to be minor in nature. Fractures may be visible within the base of the river valley in exposed areas such as river banks and alluvial flats, or be inferred from the emission of gas bubbles in the river.

The likelihood of fracturing is very low for bedrock that is located beyond the predicted limit of subsidence, although some minor fracturing may occur up to approximately 400 m from the proposed longwalls. Mining-induced fracturing at these remote distances is unlikely to result in surface flow diversions or reduction in water quality, as discussed in the following sections.

2.5.3 Potential for Loss or Diversion of River Water

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

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

MSEC (2008) have assessed that the potential for surface water flow diversion to occur as a result of the extraction of the proposed longwalls is very low.

The potential for infiltration of water into the groundwater system is also very low as the Nepean River represents the regional low point in the water table. The potential for loss of surface water into the mine is also unlikely due to the depth of cover, offset of the longwalls in relation to the river, and presence of the Bald Hill Claystone which acts as an aquiclude between the river and the mine. Various studies have been undertaken to determine appropriate depths of cover and mining layouts for mining to safely occur beneath stored waters, including the Inquiry into Coal Mining under Stored Water by Justice Reynolds in 1977. Further detailed discussions on the potential for this form of flow diversion are provided in a report by Geoterra (2008).

2.5.4 Potential for Shallow Ground Water Inflows to River

No natural springs have been identified along the Nepean River within the General SMP Area, although it is possible that some seepage occurs into the river.

Although the proposed longwalls do not mine directly beneath the Nepean River, it is possible that mining-induced springs may develop following the extraction of the proposed longwalls.

Chemical characteristics of mining-induced springs suggest that the source water has passed through upland Wianamatta Shale and/or been in contact with Shale for extended periods. This water then permeates down through natural or mining-induced fractures in the Hawkesbury Sandstone before emerging in the valley wall.

Vertical dilation between Wianamatta Shale and Hawkesbury Sandstone is possible along the tributaries to the Nepean River, particularly if the thickness of the Shale is less than 10 to 15 m. Field studies suggest that vertical dilation in creeks and rivers extend, as a maximum, to a depth of 10 - 15 m. (Mills and Huuskes, 2004).

Saline, ferruginous springs induced by longwall mining has been observed in the Southern Coalfield in sub-catchments of the Cataract and Georges Rivers, most notably:

1. the very large, and long-lived (ongoing) ‘SW2 Spring’ in Cataract River just west of Back Gully Creek induced by Appin Longwall 21 B in 1996; and
2. the moderately large and moderately long-lived ‘Pool 11 Spring’ in Upper Georges River induced by West Cliff Longwall 5A2.

Induction or exacerbation of such springs is believed to result from strata dilation and bed separation leading to increased storage of perched groundwater, especially at, and near to the interface between Wianamatta Shale and underlying Hawkesbury Sandstone. Such springs do not appear to occur in, or remote from, terrain where Wianamatta Shale and Shale-derived soils do not outcrop.

The interface between the Hawkesbury Sandstone and the Wianamatta Shale sequences appears likely to undergo a mine subsidence-induced permeability enhancement along the sub-horizontal interface between these units due to dilation and bed separation induced by subsidence.

The Shale, being marine sediment, continues to contain traces of connate water with an elevated (seawater composition) salt load and a significant load of major cations on cation exchange sites in ratios that are still relatively similar to that of seawater. These may be displaced by protons in weakly acidic infiltrating meteoric water, so increases in salinity are predicted to occur from the subcrop of the basal interface between the Shale and the underlying Hawkesbury Sandstone.

The Shale also contains a high concentration of finely disseminated crystalline iron and manganese oxides (after siderite and rhodocrosite). Hence an elevated dissolved iron (Fe) and manganese (Mn) load, largely due to microbiologically-mediated reductive dissolution of Fe and Mn oxides and oxyhydroxides within the base of the weathered Shale during saturation (Lovley and Phillips, 1986) is expected from waters that become stored in the catchment of the spring. Enhancement of vertical percolation of this more saline, iron-rich water into the upper Hawkesbury Sandstone strata (or at least a surficial Mittagong Formation) due to subsidence-induced dilation and valley closure effects is also conceivable.

It is possible that strata out-gassing (a known effect of mine subsidence) from the Hawkesbury and/or Bulgo Sandstone may lead to accumulations of dissolved methane in perched water at the Hawkesbury Sandston/Wianamatta interface. This effect, if it does occur, is likely to provide a food source for, and increase the activity of iron dissimilatory bacteria driven reduction and dissolution of Fe and Mn oxyhydroxides from the base of the Shale.

We have comprehensively discussed the mine subsidence-related mechanisms driving the induction and maintenance of such ferruginous springs in a number of previous reports (Ecoengineers Pty Ltd., 2005b, 2005c, 2006a, 2006b and 2007).

Tributaries to the Nepean River within the General SMP area are directly mined beneath by the proposed longwalls and can be expected to be subject to dilation. This may enhance perching of shallow groundwaters at the Shale/Sandstone interface and emergence of springs along the drainage line, particularly near where Shale outcropping finishes and Hawkesbury Sandstone outcrop remains (Ecoengineers, 2005a, b, 2006a, b, and 2007b).

2.5.5 Potential for Gas Emissions in the River

Mining can result in fracturing of the strata above the extracted area and/or relative movement of strata along pre-existing joint planes. This may result in the liberation of methane and other gases from the strata to the surface. Gas emissions have typically occurred within deep river valleys, although some gas emissions have also been observed in creeks and water bores.

Substantial studies have been undertaken into the properties of gas within rock strata. Gas is found in most rocks, and can exist in three different states – free gas, dissolved gas in water and absorbed gas. Analyses of gas compositions indicate that the near-surface strata are the direct and major source of the gas rather than the extracted coal resource. The most likely source of strata gas is the Hawkesbury Sandstone (APCRC, 1997). As rocks in the near-surface strata experience compression in response to valley closure movements, free or absorbed gas can be released, typically exiting the stream bed through existing or new fractures and joints (Geoterra, 2008).

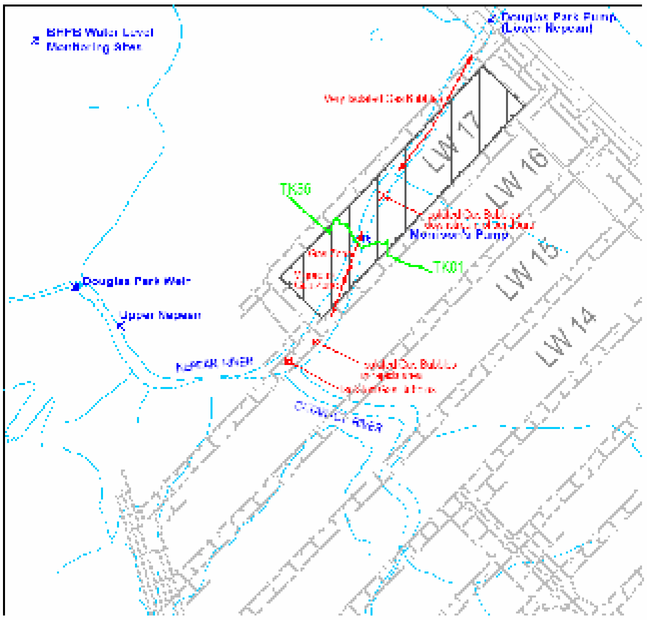
Gas emissions typically occur in isolated locations and the majority of gas emissions occur in areas that are directly mined beneath. These emissions are also typically the most vigorous. However, some gas emissions have occurred in areas that have not been directly mined beneath but influenced by valley related movement.

Gas emissions have previously been observed in the Nepean River during the mining of Tower Longwalls 17, 20 and most recently Appin Longwall 701. In the case of the Nepean River, the bedrock is submerged and covered by alluvial deposits. It is therefore not always possible to visually identify the exact location and extent of fractures through which gas is escaping from underlying strata.

Emissions were observed during the extraction of Longwall 17. Vigorous gas emissions occurred near Morrisons Pump and weekly observations of the site indicated that gas emissions first appeared after the longwall had passed beneath the site. The duration of the emissions in this area was approximately three months.

Observations indicated that there were also some gas emissions in areas that were not directly mined beneath by the Tower longwalls. The furthest gas emissions were located near the northwestern end of Longwall 17, which was approximately 50 metres from Longwall 17. A plan showing the locations of gas emissions is shown in **Figure 2.12** below.

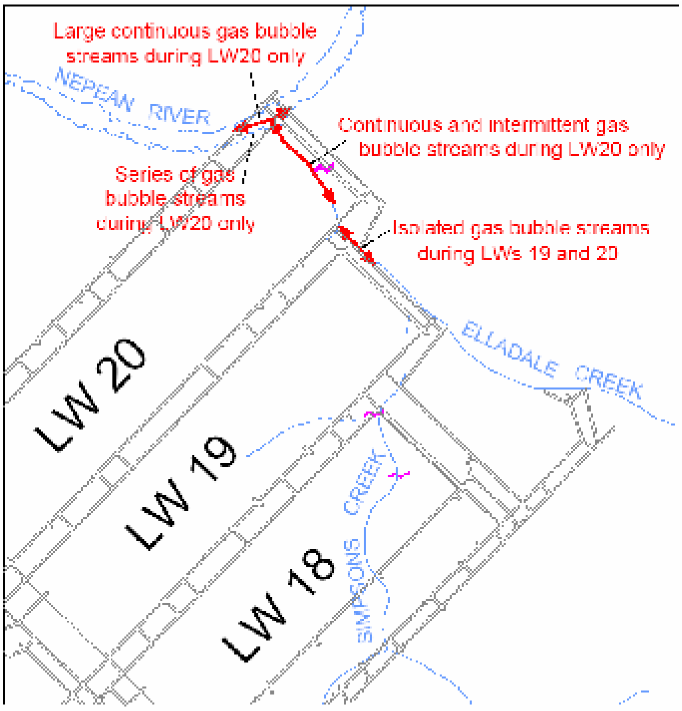
Figure 2.12 Observed Gas Emissions in the Nepean River during the extraction of Tower Longwall 17



It can be seen from the above figure that the majority of gas emissions were observed directly above Longwall 17.

Gas emissions were also observed by BHPBIC in the Nepean River and backwaters of Elladale Creek during extraction of Longwalls 19 and 20. Fractures were also observed in Elladale Creek near the end of Longwall 20 during extraction of Longwall 20. Location and extent of the emissions are shown in **Figure 2.13** below.

Figure 2.13 Locations of Nepean River Gas Emissions in Elladale Creek and Nepean River during Extraction of Longwalls 19 and 20



As noted above gas was observed in the Nepean, 50 m upstream and 20 m downstream of the Elladale Creek confluence on 10 September 2002 and for 170 m upstream in the creek bed when Longwall 20 had extracted 735 m, accompanied by discolouration of the Nepean River water.

Baseline monitoring undertaken by BHPBIC has shown that low DO conditions often apply in the Nepean River upstream of the Menangle Weir particularly during low flow conditions (less than 50 percentile or around 34 ML/day). Careful inspection of all data accumulated by BHPBIC since 2003 shows that dissolved oxygen (DO) concentrations regionally within the Nepean River can be influenced by numerous factors and seems to be principally caused by one or more of the following effects:

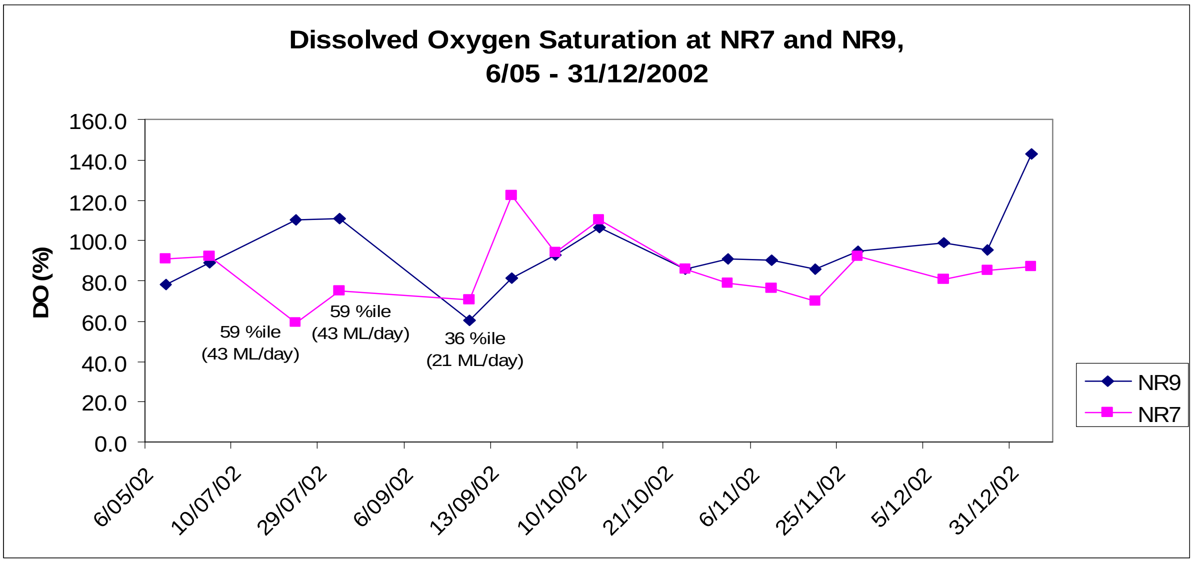
1. low DO water input from tributaries - especially Cataract River;
2. oxidation of reduced dissolved iron input from tributaries - especially from Cataract River and Menangle Creek consuming DO;
3. oxidation of organic matter which may have accumulated in deep pools in the River consuming DO;
4. growth of aerobic bacteria as a consequence of nitrogen- and phosphorus-based nutrients input from tributaries containing agricultural activity and intensive animal feedstock industries (chicken farms and piggeries) consuming DO;
5. growth of cyanobacteria (blue-green algae) during warm summer months again as a consequence of nitrogen- and phosphorus-based nutrients input from tributaries containing agricultural activity and intensive animal feedstock industries (chicken farms and piggeries) generating DO (as algae absorb dissolved CO_2 and bicarbonate and respire oxygen into the water); and
6. aerobic bacterial consumption of hydrocarbons, principally methane derived from mining-induced strata gas emissions.

Tower Longwalls 19 and 20 extracted coal between 13 June 2001 and 1 November 2002. Gas bubbles were observed within the Nepean River and Elladale Creek at locations as shown in **Figure 2.13** above. Emissions were observed for a period of three months then ceased by December 2002.

Figure 2.14 below shows that on 11 September 2002 surface DO levels in the River at sites NR7 and NR9 were 70 and 60% respectively, and DO levels had been depressed at NR7 since July 2002. Flow at Menangle Weir on 11 September 2002 was 21 ML/day – about a 36 percentile flow.

Low surface water DO levels were observed at site NR7 in July, August and September 2002 and also at site NR9 only in September 2002. Gas emissions had stopped by 19 December 2002 and any associated low flow DO sag in the Nepean River then ceased.

Figure 2.14: Dissolved Oxygen Levels at Nepean River Surface Water Sites NR7 and NR9 from May 200 through to December 2002.



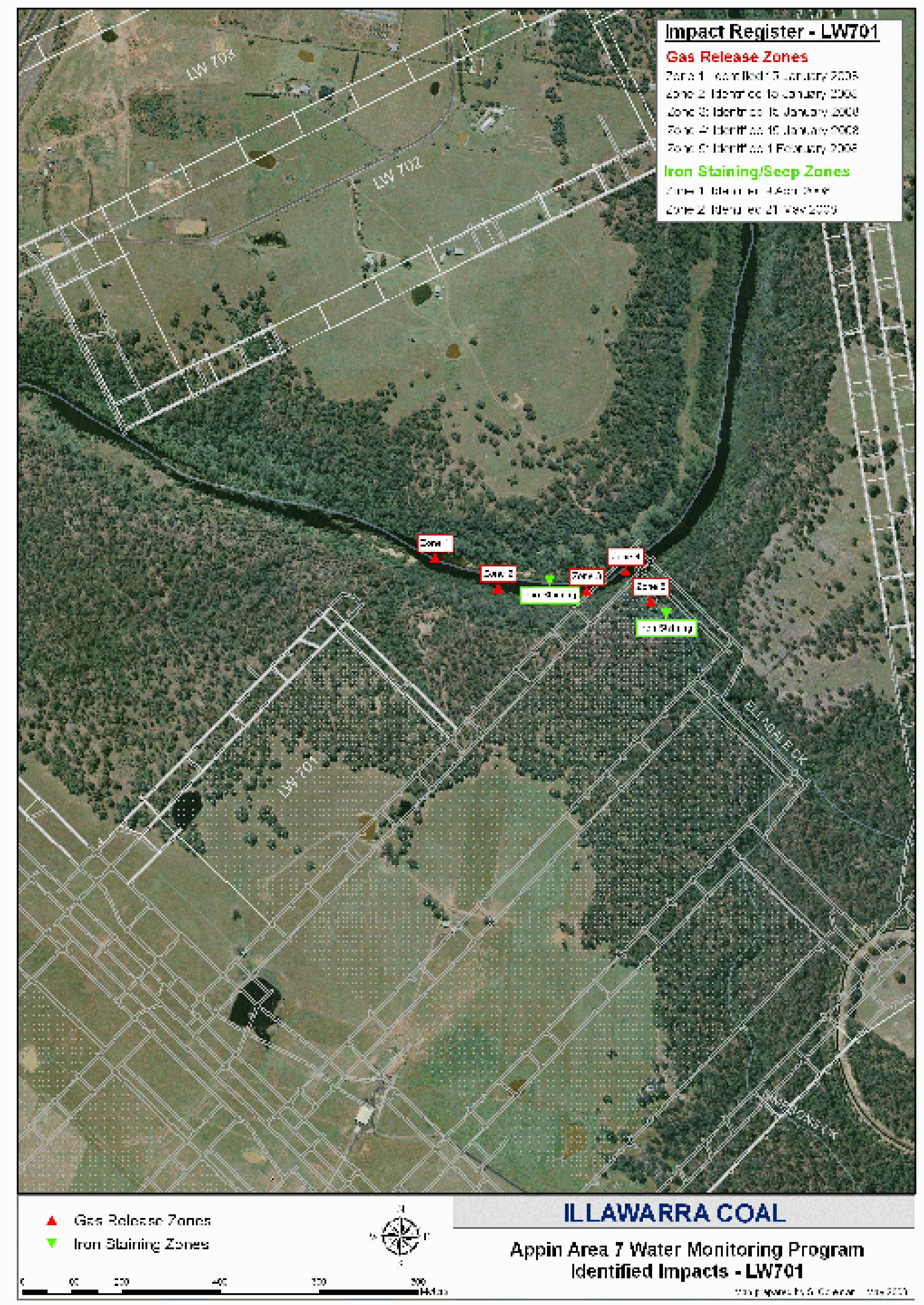
Water quality data obtained by The Ecology Lab (2003) on 22 – 25 September 2003 and 27 – 29 September 2005 at their Sites 3 and 4 in the River (which lie close to the current BHPBIC sites NR7 and NR9) as shown in their **Figure 1.5** in their report showed surface water DO concentrations in the range 70 – 85% of saturation. No observed gas emissions were occurring during this period, demonstrating that other natural and anthropogenic factors can also influence the DO level in the River. It is noted that late 2003 was in the drought period and very low flows applied in the River.

Most recently, monitoring and inspections have been carried out along the Nepean River between Cataract River and Ousedale Creek to determine impacts from Longwall 701 in accordance with the Appin Area 7 Water Management Plan. Extraction began in Longwall 701 in October 2007 and was completed in May 2008. The monitoring included water quality, water levels, and gas release monitoring. A comprehensive review of all data collected in accordance with the Appin Area 7 Water Management Plan will be provided in the End of Panel Report.

Five gas release zones were identified in the Nepean River during the extraction of Longwall 701 whilst a small zone of iron staining was identified in Elladale Creek. Four of the gas zones were identified on 15 January 2008 whilst the fifth zone was identified on 1 February 2008.

Each of the gas zones occurred upstream of the Elladale Creek confluence with the River with the two largest zones identified approximately within 300 m of Longwall 701. **Figure 2.15** below show the locations of these zones and of some associated iron staining in the Creek and the River.

Figure 2.15 Gas Emissions and Iron Staining Zones in Nepean River Near Longwall 701



Since the identification of these zones, various actions have been undertaken, which include gas zone mapping to establish the surface area of each of the zones.

Indicative gas flow rate monitoring was also conducted in early March 2008 to determine the approximate intensity of each of the gas zones. Weekly observations were made detailing the approximate size and intensity of the gas zones and a photo catalogue accumulated for each of the emission sites.

As shown in **Table 2.3**, Zone 1 and 2 had the highest estimated flow rates (i.e. intensity) whilst the flow rates for Zones 3 and 4 were estimated to be below 3 L/min. Since these measurements, the intensities at each of the zones have remained relatively stable. However, the gas zone mapping work has shown the surface area of Zone 4 has reduced significantly and hence the total flow rate at this zone is expected to be much lower.

Table 2.3 Gas Flow Rates from Zones 1 to 4 Near Appin Longwall 701 Measured on 5 March 2008

Gas Zones	Estimated Minimum flow rate (L/min)	Estimated Maximum flow rate (L/min)
Zone 1	90	106.8
Zone 2	56.43	113.1
Zone 3	0.116	0.232
Zone 4	1.26	2.52
Total	147.6	222.7

Table 2.4 below shows the levels of dissolved methane at monitoring sites at Zones 1 and 2 since collection of samples for dissolved methane was commenced. NA = Not Analysed.

Table 2.4 Dissolved Methane Concentrations in Nepean River Near Appin Longwall 701 (µg/L)

	Date	Date	Date
Location	15 April 2008	14 May 2008	12 June 2008
Zone 1	NA	NA	97
Zone 2	NA	NA	398
NR7	45	89	NA
NR9	33	63	NA
NR11	<10	<10	Na

Analyses of dissolved methane at sites NR7 and NR9 on 15 April 2008, and 14 May 2008 were 45 and 33, and 89 and 63 µg/L respectively, indicating that it is unlikely the flux of gas into the River has decreased since the above flow rate measurements.

On 21 May 2007, a routine weekly inspection of the Nepean River was undertaken by BHPBIC. The inspection identified one narrow zone (<1m wide) of iron staining along the northern edge of the river bank which extended approximately 150 m in length and ceased just upstream of the water quality monitoring site NR7. This zone of iron staining is in close proximity to the zone of gas emissions in the river and possibly the iron staining is due to local microbiological iron cycling driven by dissolved methane levels in the water which were around 89 µg/L at site NR7 and 63 µg/L further down river at site NR9.

A minor iron seep was also identified slightly downstream of NR11, however it is unlikely that the iron seep is as a result of extraction of Longwall 701 due to the considerable distance between the location of the seep and mining (approx. 3 km).

Figure 2.16 outlines the locations of both the iron staining zone, which coincides more or less with the current gas emission zone and the minor iron seep near NR11 down river.

Figure 2.16 Ferruginous Staining Associated with Riverine Gas Emission Zone near Longwall 701 and further Down River in May 2008.

Gas emissions into Nepean River arising from the extraction of Longwall 701 have now been occurring for almost six months, approximately twice as long as those induced by Longwall 20 in late 2002. This may be related to the relatively low retreat rate of Longwall 701 and continued subsidence movements during the period October 2007 to May 2008.

2.5.6 Potential Occurrence of Saline Ferruginous Springs

There have been no natural springs identified along the Nepean River within the General SMP Area. However, as noted in the previous section, ferruginous springs have been initiated or existing ones possibly enhanced due to longwalls at other nearby mining areas. There are several previous possible instances of induction or enhancement of saline springs in the local area.

Ferruginous staining has been observed in the river banks around site NR11 just down river from the Ousedale Creek confluence (BHPBIC, 2008d), although this is unlikely to be associated with mining.

West Cliff Longwall 30 mined under the upper catchment of the Ingham's Tributary of Ousedale Creek as shown in **Figure 2.10** below. It is expected that the upper part of the catchment of Ingham's Tributary is mantled by Wianamatta Shale or soils derived from the Shale.

A ferruginous, moderately saline spring was detected in November 2005 at site IT30 in Ingham's Tributary, only 5 months after completion of Longwall 30, as shown in **Figure 2.10** below.

Figure 2.10 Locations of Existing Water Quality Monitoring Sites in Ingham's Tributary (of Ousedale Creek) Including Location of Ferruginous Spring (between IT20 and IT30) First Detected in November 2005.

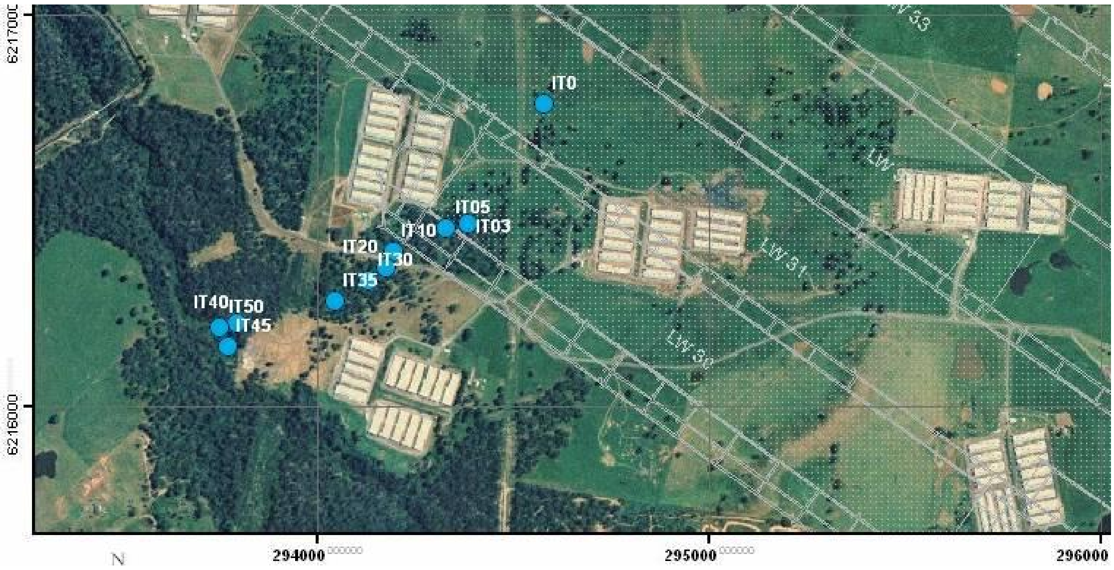


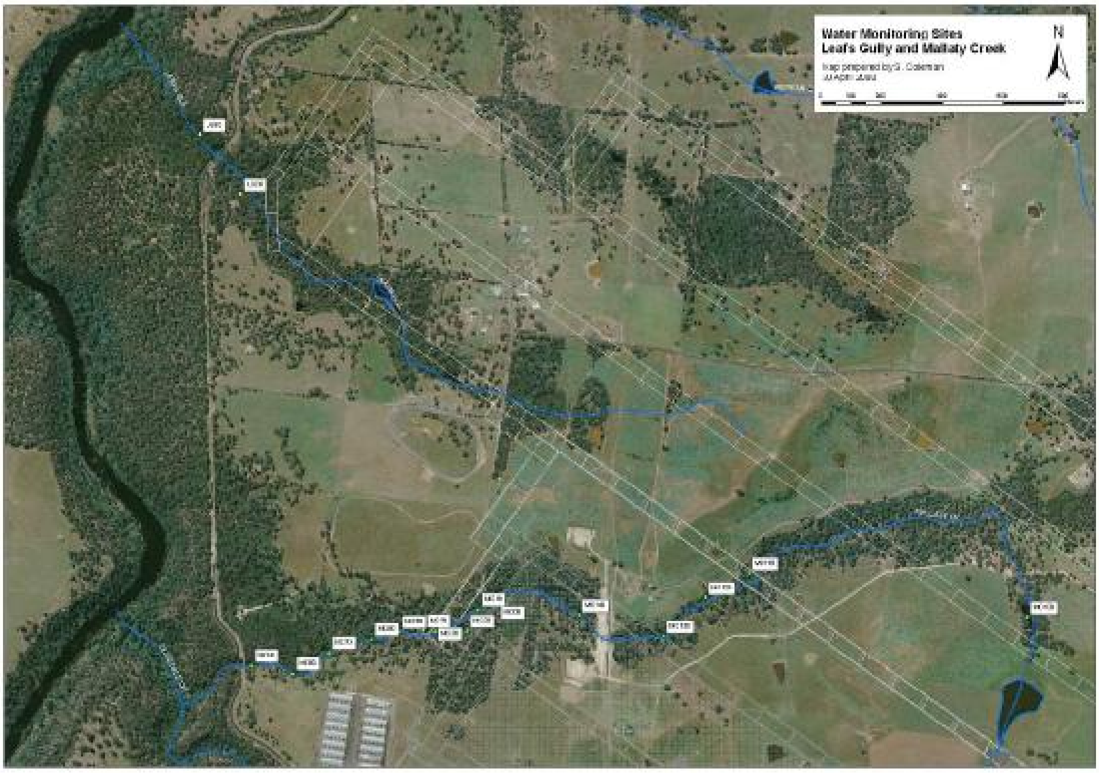
Table 2.5 shows the long term average water qualities upstream and downstream of the spring on Ingham's Tributary over the (monthly) monitoring period November 2005 to April 2008. Variation is expressed at the one standard deviation level. The high magnesium/calcium mole ratio (Mg/Ca) is used as an indicator of water which has percolated through the (marine sedimentary) Wianamatta Shale to produce the spring between these monitoring locations (Ecoengineers, 2007b).

Table 2.5 Water Quality Upstream and Downstream of Ingham's Tributary Spring

Parameter	Upstream Site (IT20)	Downstream Site (IT30)
pH	7.53±0.56	6.64±0.26
EC (µS/cm)	1983±2135	8329±2230
DO (% saturation)	68±43	40±22
ORP (mV)	314±89	258±111
Chloride (mg/L)	407±590	2228±1190
Filt. Fe (mg/L)	0.96±1.17	1.74±1.96
Tot. Fe (mg/L)	2.62±3.25	3.18±2.14
Filt Mn (mg/L)	0.32±10.41	1.08±1.07
Tot. Mn (mg/L)	0.43±0.41	1.14±1.08
Mg/Ca mole ratio	2.50±0.52	4.17±0.89

A similar spring was detected in Mallaty Creek over the western end of the recent West Cliff Longwall 32 between monitoring sites MC140 and MC05 as shown in **Figure 2.11** below.

Figure 2.11 Water Quality Monitoring Sites in Mallaty Creek.



There is downstream data to suggest the spring appeared no later than late December 2005 and hence long predates Longwall 32 which commenced in February 2007. However, it also lies within the angle of draw of Longwall 31 which was mined between July 2005 and December 2006. Total and filterable iron and manganese in the waters downstream of the spring increased markedly in July/August 2006.

The following **Table 2.6** shows the long term average water qualities upstream and downstream of the spring on Mallaty Creek over the (monthly) monitoring period December 2005 to April 2008 – although it is noted the upstream site is new and has only been sampled monthly since January 2008.

Table 2.6 Water Quality Upstream and Downstream of Mallaty Creek Spring

Parameter	**Upstream Site (MC140)**	**Downstream Site (MC05)**
pH	7.46±0.22	6.78±0.34
EC (µS/cm)	410±60	4335±2337
DO (% saturation)	47±28	37±23
ORP (mV)	312±54	332±65
Chloride (mg/L)	75±15	1324±733
Filt. Fe (mg/L)	1.10±0.53	0.76±0.73
Tot. Fe (mg/L)	5.57±4.99	4.14±2.34
Filt Mn (mg/L)	0.38±0.55	0.35±0.19
Tot. Mn (mg/L)	0.43±0.55	0.39±0.23
Mg/Ca mole ratio	2.01±0.33	4.42±1.10

It can be seen that in this particular case the spring is not significantly ferruginous (by comparison with the more recently sampled upstream site).

Although the proposed longwalls do not mine directly beneath Nepean River, it is possible that mining-induced, or enhanced, springs could develop following the extraction of the proposed longwalls.

It has previously been observed that perched water storage occurs in the base of the Wianamatta Shale (Hazelton and Tille, 1990). The chemical characteristics of local springs suggest that the water passes through, and accumulates immediately beneath upland Wianamatta Shale to then permeate through natural or mining-induced fractures in the Hawkesbury Sandstone before emerging in draining streams or the River.

Although the proposed longwalls do not mine directly beneath the Nepean River, it is possible that mining-induced springs may develop following the extraction of the proposed longwalls.

The confluences of the tributaries which flow into the Nepean River are not directly mined beneath and, in these locations; the vertical dilation is expected to be small. The upper reaches of these tributaries, however, are directly mined beneath by the proposed longwalls.

There are no natural springs which have been unambiguously detected along the Nepean River within the General SMP Area, although it is possible that some seepage already occurs into the river. This is discussed in further detail by Geoterra (2008).

A summary of the maximum predicted values of cumulative subsidence, upsidence, net vertical movement and closure anywhere along the creeks within the General SMP Area, after the extraction of each proposed longwall, is provided in Section 5.3.1 of MSEC (2008). A summary of the maximum predicted travelling tilts and strains at the creek, during the extraction of each proposed longwall, is provided in Section 5.3.1 of MSEC (2008).

Maximum predicted systematic tilt, tensile strain and compressive strain within the SMP Area, resulting from the extraction of the proposed longwalls, are 8.0 mm/m, 1.3 mm/m and 2.3 mm/m, respectively (MSEC, 2008).

Predicted impacts on Harris, Foot Onslow and Navigation Creeks are presented in Section 5.3 of MSEC (2008).

The predicted profiles of incremental and cumulative subsidence, upsidence and closure along Foot Onslow Creek, after the extraction of each proposed longwall, are shown in Fig. F.03 in Appendix F of MSEC (2008). Predicted changes in surface level along the alignment of the creek are also illustrated by the predicted net vertical movement profile shown in this figure, which has been determined by the addition of the predicted subsidence and upsidence movements.

It is apparent Foot Onslow Creek will be subjected to travelling tilts and strains across its alignment as the extraction faces of the proposed longwalls pass beneath it.

The predicted profiles of incremental and cumulative subsidence, upsidence and closure along Harris Creek, after the extraction of each proposed longwall, are shown in Fig. F.04 in Appendix F of MSEC (2008). The predicted changes in surface level along the alignment of the creek are also illustrated by the predicted net vertical movement profile shown in this figure, which has been determined by the addition of the predicted subsidence and upsidence movements.

A summary of the maximum predicted values of cumulative subsidence, upsidence, net vertical movement and closure anywhere along the creek within the General SMP Area, after the extraction of each proposed longwall, is provided in Section 5.3.2 of MSEC (2008).

A summary of the maximum predicted changes in gradient, due to the predicted systematic tilts, and the maximum predicted systematic strains along the alignment of Harris Creek is also provided in Section 5.3.2 of MSEC (2008).

It is also apparent the upper reaches of Harris Creek will be subjected to travelling tilts and strains across its alignment as the extraction face of proposed Longwall 707 passes beneath it.

The maximum predicted systematic tilts along the alignments of Foot Onslow and Harris Creeks are 6.5 mm/m (i.e.: 0.7 %) and 3.7 mm/m (i.e.: 0.4%), respectively, or a changes in grade of 1 in 155 and 1 in 270, respectively. The maximum predicted systematic tilt along the alignments of the other creeks and tributaries within the General SMP Area is 8.0 mm/m (i.e.: 0.8%), or a change in grade of 1 in 125.

The maximum predicted systematic tensile and compressive strains at Foot Onslow Creek are both 1.3 mm/m and the associated minimum radius of curvature is 11 km.

The maximum predicted systematic tensile and compressive strains at Harris Creek are 0.8 mm/m and 0.5 mm/m, respectively, and the associated minimum radii of curvatures are 19 km and 30 km, respectively.

There are a number of other creeks and tributaries located across the SMP Area which are also likely to experience the full range of predicted systematic subsidence movements. These creeks and tributaries are also likely to experience valley-related movements resulting from the extraction of the proposed longwalls. The predicted upsidence and closure movements will vary along these drainage lines, depending on their locations relative to the proposed longwalls and depending on their effective valley heights. The maximum predicted valley related movements along these creeks and tributaries are expected to be similar to, or less than those predicted for Foot Onslow Creek.

The maximum predicted systematic tensile and compressive strains at the other creeks and tributaries within the General SMP Area are 1.3 mm/m and 2.3 mm/m, respectively, and the associated minimum radii of curvatures are 12 km and 6.5 km, respectively.

Fracturing of the uppermost bedrock has been observed in the past where the systematic tensile strains have been greater than 0.5 mm/m or where the systematic compressive strains have been greater than 2 mm/m. It is likely, therefore, that some minor fracturing would occur in the uppermost bedrock based on the predicted maximum systematic strains.

Elevated compressive strains across the alignments of the drainage lines are likely to result from the valley-related movements. The maximum predicted closure movement across the alignment of Foot Onslow Creek is 270 mm. The maximum predicted closure movements at the other creeks and tributaries within the General SMP Area are expected to be similar or less than that at Foot Onslow Creek.

Compressive strains resulting from valley-related movements are more difficult to predict than systematic strains. It is expected that the compressive strains due to closure movements at the drainage lines which are directly mined beneath by the proposed longwalls would be much greater than 2 mm/m.

Vertical dilation between Wianamatta Shale and Hawkesbury Sandstone is therefore possible, especially along the tributaries to the Nepean River, such as Foot Onslow Creek, Harris Creek and drainage lines feeding into these creeks or Navigation Creek.

This could particularly occur particularly if the thickness of the Shale is less than 10 m, as field studies suggest that vertical dilation in creeks and rivers extend, as a maximum, to these depths (Mills and Huuskes, 2004). Where these tributaries flow into the Nepean River, however, the vertical dilation is expected to be small as they are located at the ends of the proposed longwalls.

2.6 BASELINE WATER QUALITY AND LOCAL WATER QUALITY ISSUES

We have assessed BHPBIC surface water monitoring data (refer **Figure 1.3** above for their sampling sites) for the Area 7 baseline period from commencement of monitoring in July 2002 up to the commencement of the first Area 7 longwall (Longwall 701) in mid October 2007 and the salient points of these are summarized in **Figures 2.20 to 2.29** below which show the magnitudes of major water quality parameters within the River and in the lower ends of tributaries for distance down the River from maximum upriver site NR0.

Note that in **Figures 2.20 to 2.29** the following (labelled) sites not located along the River proper but within the lower part of tributaries of the River as follows:

- SW2 is within the lower reaches of Allens Creek;
- NR3 is within the lower reaches of Harris Creek;
- NR4 is within Nepean River but probably not adequately up-river of the Cataract River confluence under low flow conditions <25 percentile to not 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 with the lower reaches of Menangle Creek.

In the subsequent figures the respective concentration parameter values for the sites SR2, NR3, NR4, NR5, NR8, NR10 and NR40 in the lower parts of the above tributaries are shown not plotted on 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.

The following five **Figures 2.20 to 2.24** show, respectively, the average pHs, salinity (EC), DO, Total Iron (Fe), and Total Manganese (Mn) in the River and in the lower ends of major tributaries for the baseline period July 2002 to October 2007 prior to the mining of Longwall 701.

Figure 2.20 Average pH versus Distance Down River for the Longwall 701 Baseline Period July 2002 – October 2007

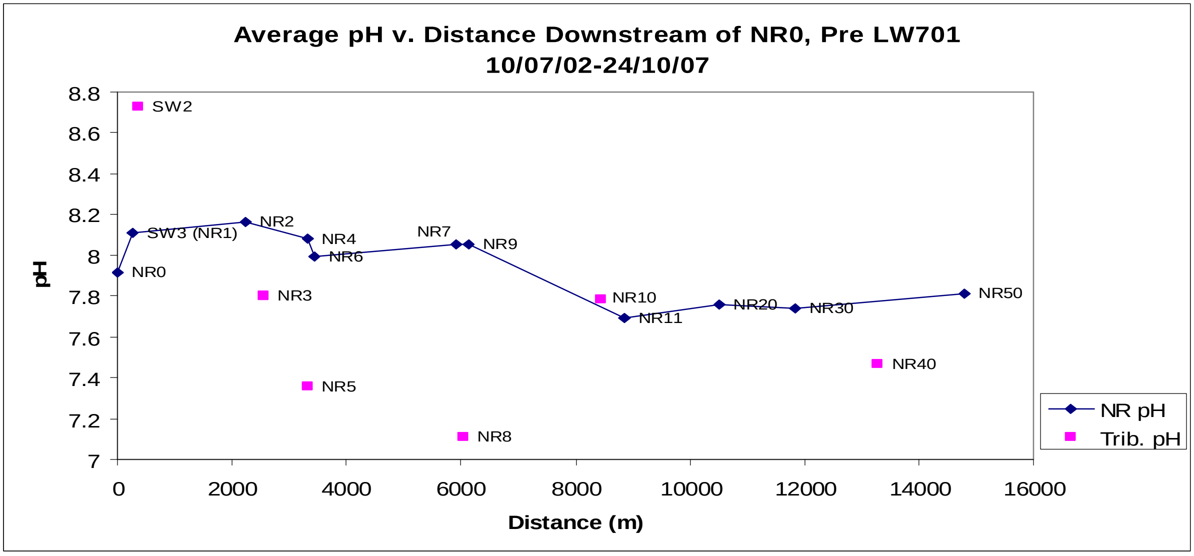


Figure 2.21 Average Salinity (EC) versus Distance Down River for the Baseline Period July 2002 – October 2007

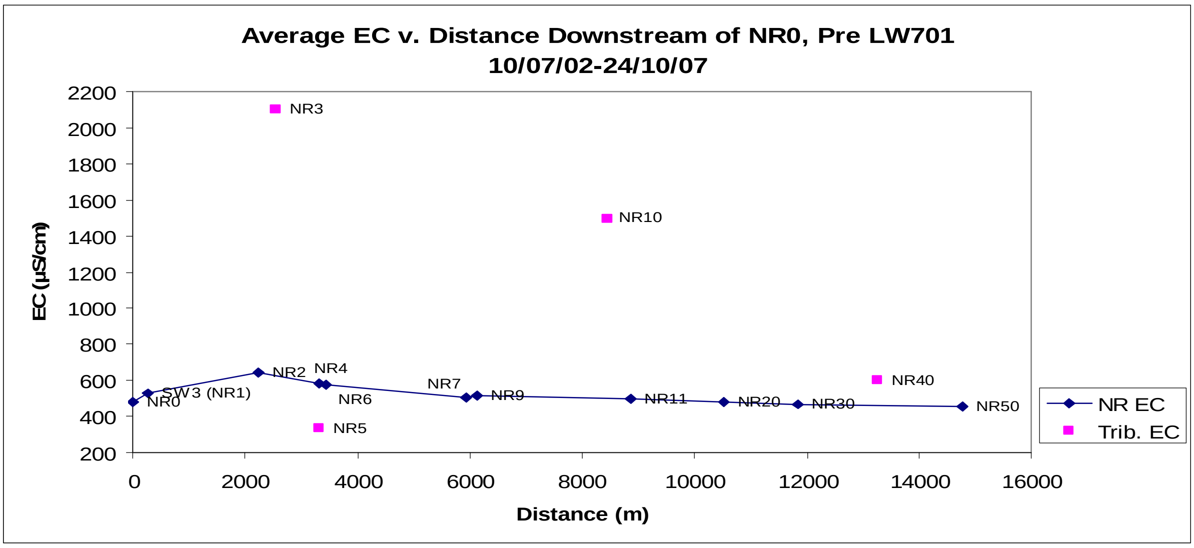


Figure 2.22 Average Dissolved Oxygen (DO) versus Distance Down River for the Baseline Period July 2002 – October 2007

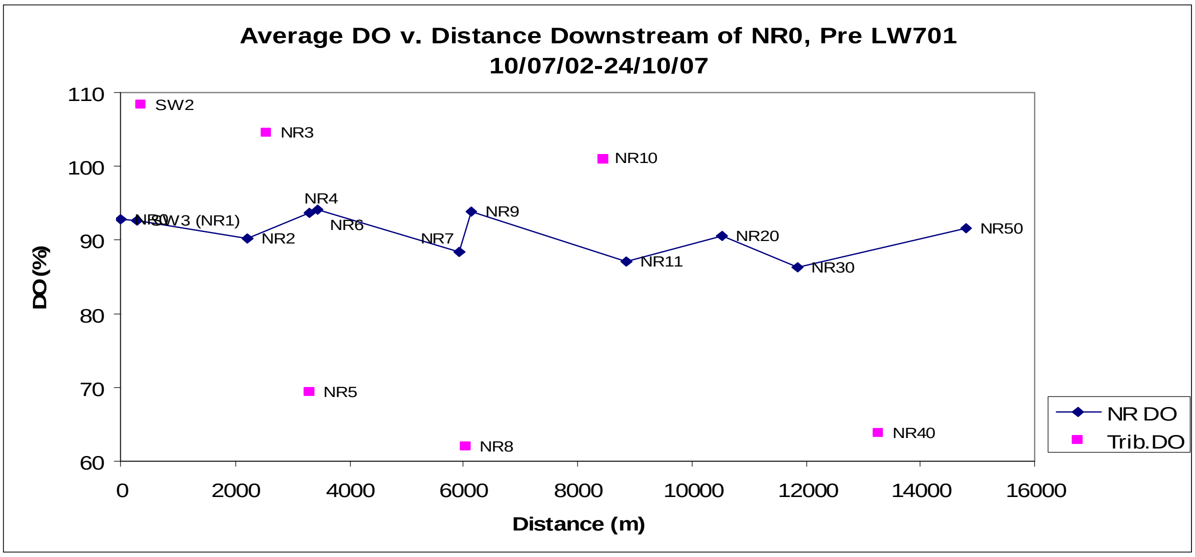


Figure 2.23 Average Total Iron (Tot. Fe) versus Distance Down River for the Baseline Period July 2002 – October 2007

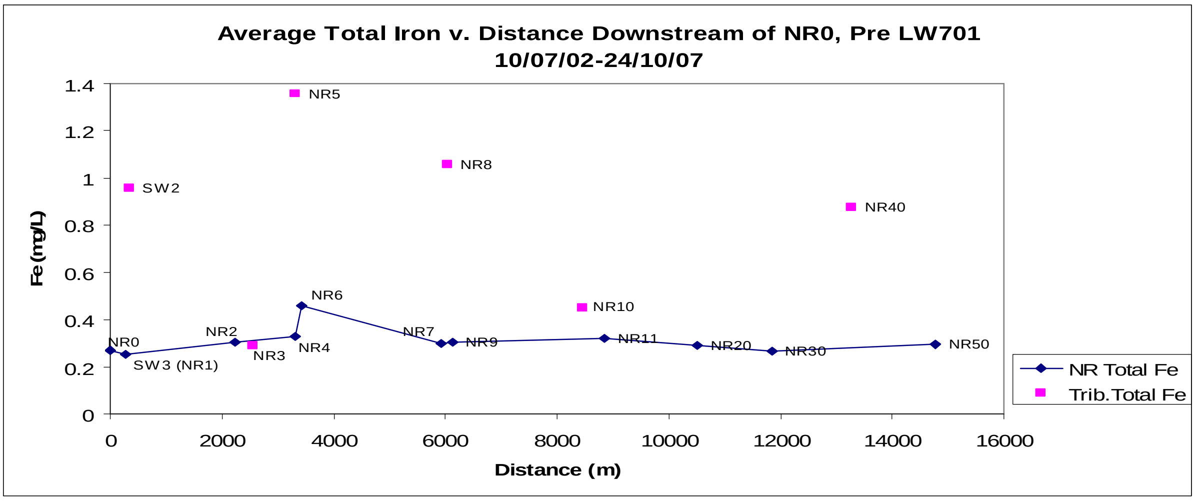
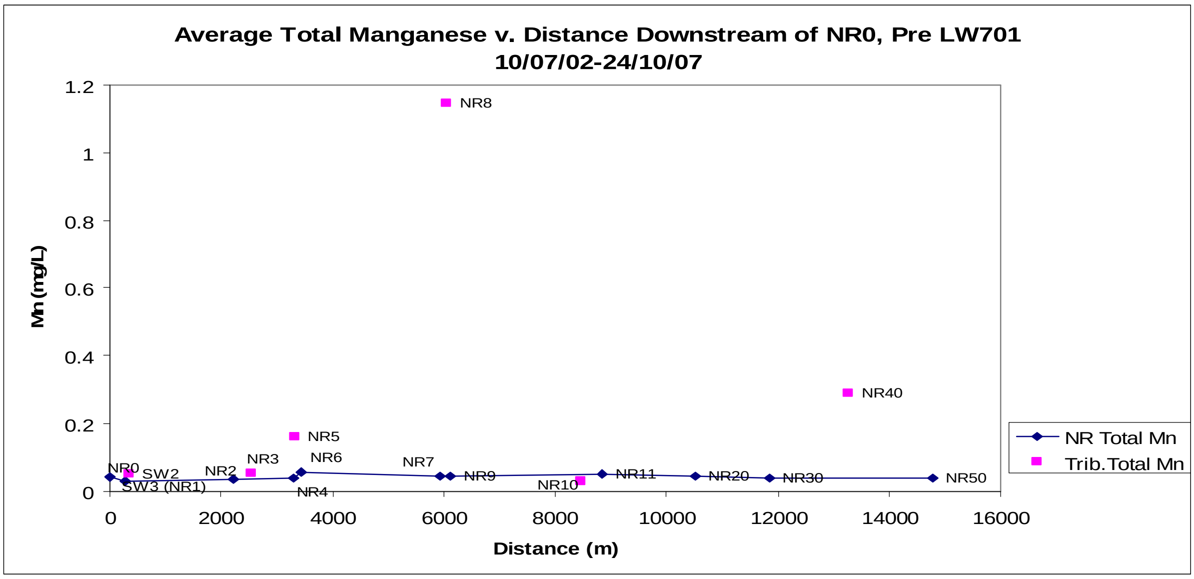


Figure 2.24 Average Total Manganese (Tot. Mn) versus Distance Down River for the Baseline Period July 2002 – October 2007



The following five **Figures 2.25 to 2.29** show, respectively, the pHs, salinity (EC), DO, Total Iron (Fe), and Total Manganese (Mn) in the River and in the lower ends of major tributaries for a typical low flow situation during the baseline period July 2002 to October 2007 prior to the mining of Longwall 701. The chosen low flow situation was the period 9 – 11 August 2005 when flow in the River was about 17 ML/day at Menangle Weir – a 31 percentile flow.

Figure 2.25 pH versus Distance Down River for the a Typical Low Flow Situation during the Baseline Period July 2002 – October 2007

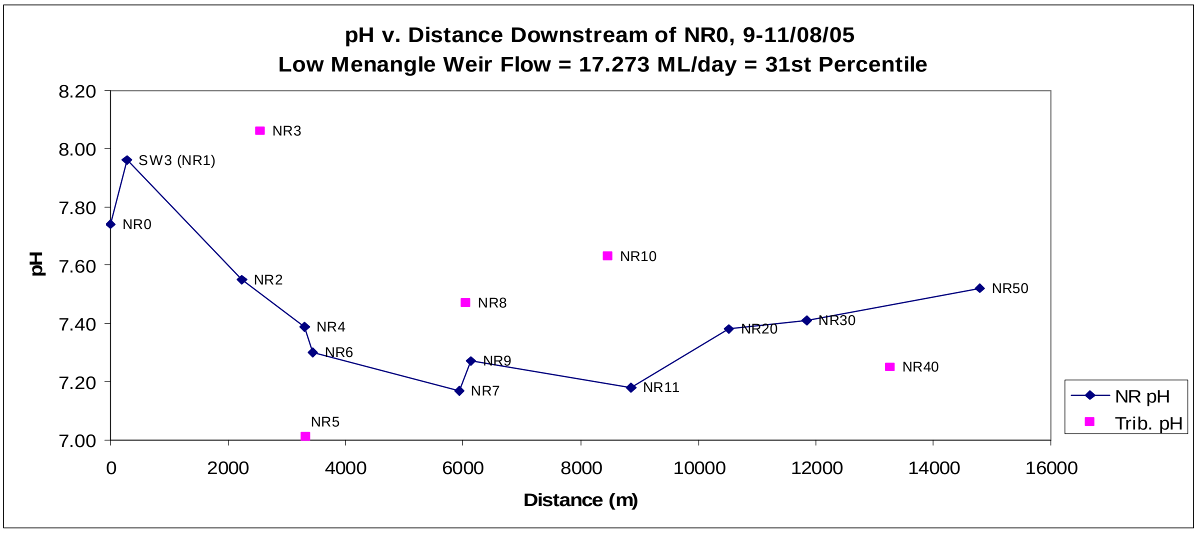


Figure 2.26 Salinity (EC) versus Distance Down River for a Typical Low Flow Situation during the Baseline Period July 2002 – October 2007

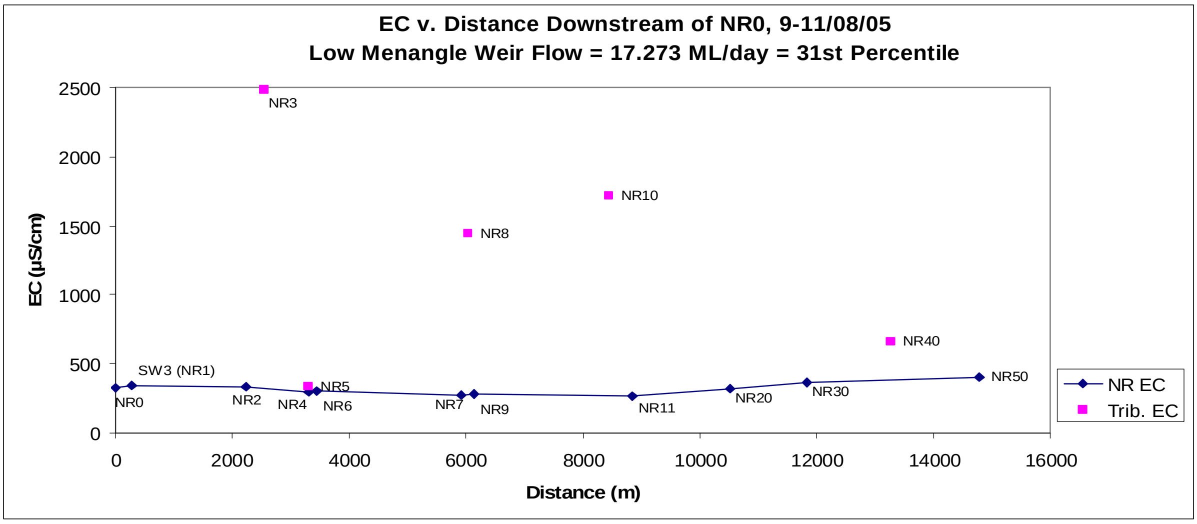


Figure 2.27 Dissolved Oxygen (DO) versus Distance Down River for a Typical Low Flow Situation during the Baseline Period July 2002 – October 2007

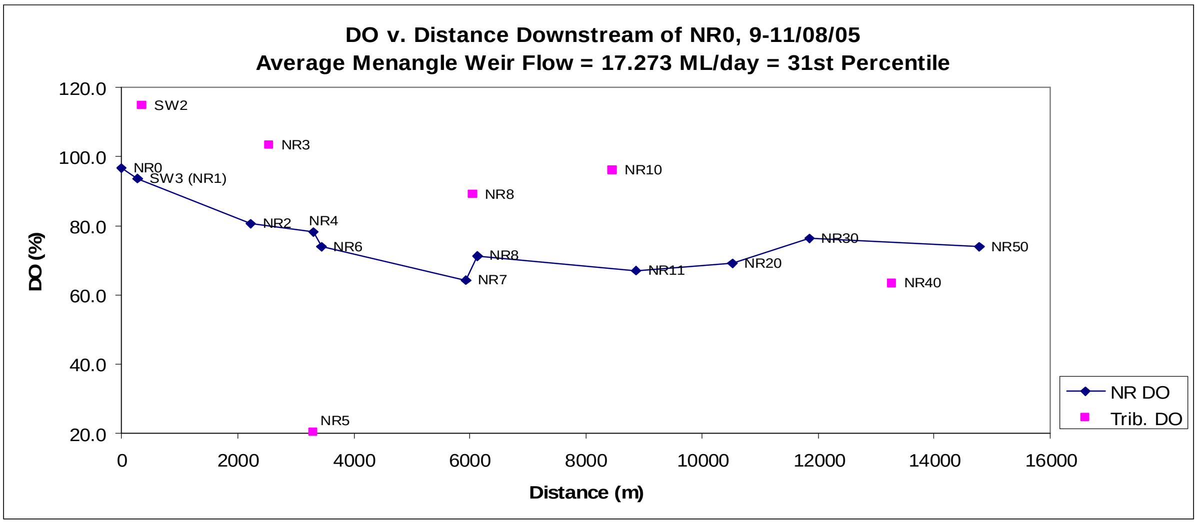


Figure 2.28 Total Fe versus Distance Down River for a Typical Low Flow Situation during the Baseline Period July 2002 – October 2007

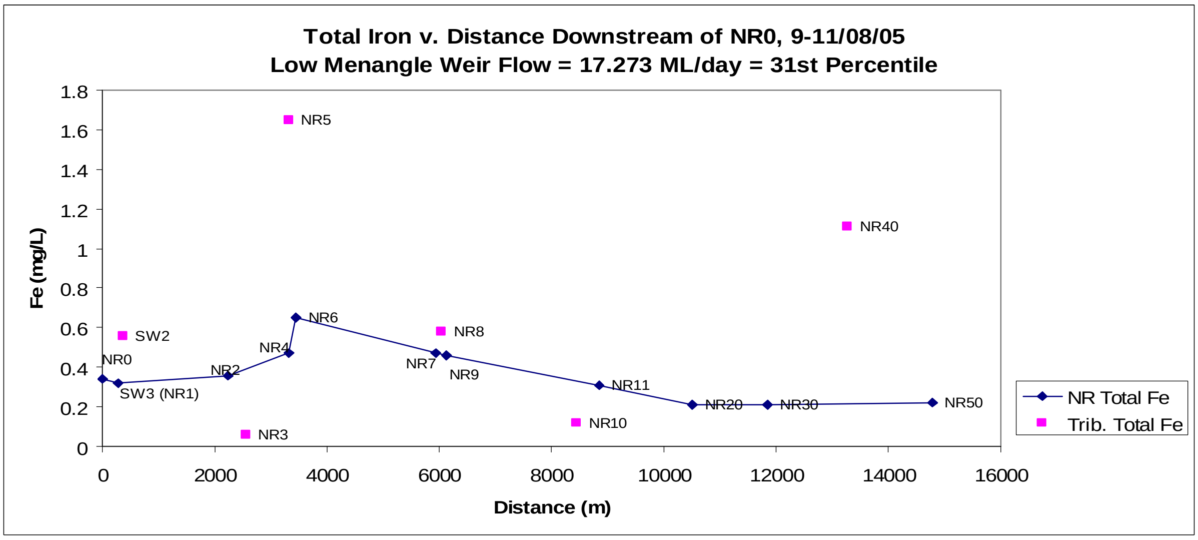
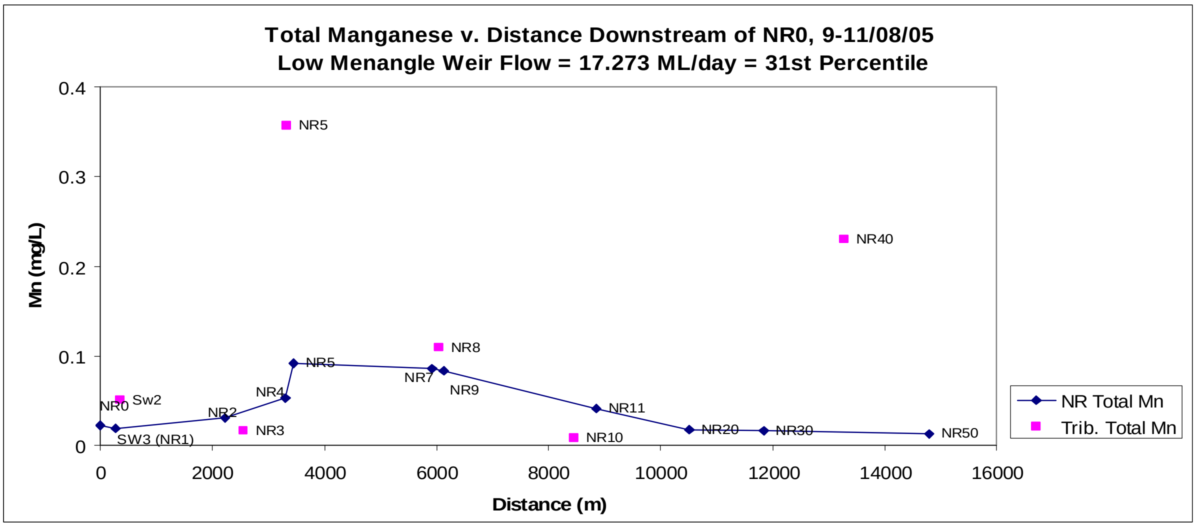


Figure 2.29 Total Mn versus Distance Down River for a Typical Low Flow Situation during the Baseline Period July 2002 – October 2007



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

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

Inspection also shows that when flows in the Nepean River remain relatively constant due to controlled or no release from Maldon Weir and dry weather, and conditions are warm and sunny then pH values in the river may occasionally be found in the naturally occurring 8.25 – 9.5 high pH unit range.

This especially applies where Nepean River passes through an area dominated by farmland in the General SMP Area, and hence there is pre-existing nutrient total phosphorus (TP) and total nitrogen (TN) inputs from the effects of fertilization and live stock waste pollution of small catchments draining into the river.

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

It is clear that algal primary productivity in river pools maximizes 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 pHs in the River rising to maximal levels as high as 9.5 during warm, sunny conditions.

This suggests that to expect 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 is acclimatized to pHs at least as high as 9.5.

As can be seen, there is very little difference in mean river baseline water quality immediately upriver, adjacent to and immediately downriver of the General SMP

Area. Baseline water qualities, especially under the ecologically more critical low flow conditions <50 percentile, are clearly dominated by the following processes:

1. There are inputs of more acidic water from Cataract River and Menangle Creek and inputs of more alkaline water from Harris, Elladale and Ousedale Creeks.
2. There are inputs of more saline water from Harris, Elladale and Ousedale Creeks but these have negligible bulk effect on overall river salinity.
3. There is a consistent input of low DO water from Cataract River and this is the primary driver of DO in the River immediately downstream of the Cataract River confluence. The river appears to have a relatively low degree of re-aeration downriver of this point i.e. the (flooded) geomorphology of the river is such that it has a low Re-aeration Coefficient (RAC) adjacent to the General SMP Area.
4. There are consistent inputs of Fe and Mn to the river from Cataract River, Elladale Creek and Menangle Creek.

The issue of salinity is relevant to the assessment of potential impact(s) on aquatic ecology for Longwalls 705 – 710 because mine subsidence-related effects can potentially affect two chemically very different classes of aquatic ecosystem namely the following:

1. The low salinity (lowland river) context of Nepean River where runoff into the river is dominated by a Cumberland Plain (Lowlands) landscape dominated by Hawkesbury Sandstone outcrop and sandstone derived soils, salinity of the river water (expressed in Electrical Conductivity (EC) units) even taking into account the Appin West Colliery discharge to Allens Creek is unlikely to ever exceed 1000 µS/cm and chloride and sulfate ion concentrations are unlikely to frequently exceed about 20 and 100 mg/L, respectively.
2. The water quality context of Harris, Elladale and Ousedale Creeks and Leafs Gully which arise almost exclusively in Cumberland Plain (Lowlands) landscape dominated by Wianamatta Shale outcrop and Shale-derived soils are such that salinities in the middle and lower sections of these creeks frequently exceed 10,000 µS/cm, and chloride and sulfate ion concentrations are likely to frequently exceed 1500 mg/L and 50 mg/L respectively.

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

1. the anion bicarbonate is the principal and most variable driver of salinity-based ecotoxicity in such waters (e.g. Cowgill and Milazzo,1991; Hart, 1992; Hoke et al., 1992; Williams et al. 1993; Mount et al., 1997; USEPA, 1994); and this means that
2. as pH is lowered the proportion of total alkalinity in the water comprised of bicarbonate ion increases and the proportion comprised of carbonate and hydroxide decreases (e.g. Stumm and Morgan, 1996), hence the ecotoxicity due to salinity alone by definition increase (per unit of salinity).

It is important to note that as the pH is of the river water is lowered (e.g. here due principally to input of Fe and Mn and their oxidation and precipitation as hydrous oxides, and/or the addition of dissolved CO_2 from exogenous sources e.g. CO_2 in decomposition of natural organic matter) the ratio of bicarbonate to carbonate ion concentrations (i.e. $[HCO_3^-] / [CO_3^{2-}]$) rises (e.g. Toran and Saunders, 1995).

As noted in **Section 1.2**, there are no Water Quality Objectives regarding salinity arising from the Independent Inquiry into the Hawkesbury Nepean River System by the Healthy Rivers Commission and the Commission recommended using the trigger values in the national water quality guidelines (ANZECC&ARMCANZ, 2000).

We are of the view that Nepean River should be regarded a lowland river where the default EC trigger value in the national water quality guidelines is 2200 uS/cm (ANZECC/ARMCANZ, 2000). 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 throughout by Wianamatta Shale-derived soils, the Shale being marine sediment (Hazelton and Tille, 1990). These marine sediments continue to provide salinity to runoff and groundwater seepages (interflow, throughflow etc) to the present day.

A number of tributaries of the Upper Nepean River naturally contribute relatively saline water to the river.

We have previously shown (Ecoengineers, 2006b) that the long term mean salinity of lower Elladale Creek west of Appin at site NR8, a catchment which is largely mantled by Wianamatta Shale-derived soils (and drains to Nepean River), is 2899±1775 µS/cm at the one standard deviation level, a value which is not only highly variable with respect to salinity but most of the time significantly exceeds the default trigger value (2200 µS/cm) even for lowland rivers for southeastern Australia in the national water quality guidelines (ANZECC/ARMCANZ, 2000).

Three recent ecological studies have been conducted by The Ecology Lab 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, Georges River) most macroinvertebrate taxa (families) are well acclimatized to TDS up to at least 2000 mg/L (i.e. EC up to approx 3200 uS/cm).

We infer that this is simply because over the long term, such (moderate salinity) conditions arise sufficiently frequently in local rivers due to either:

1. the long term frequency of drought conditions during which time these rivers variably became a series of poorly connected or unconnected pools subject to evaporative concentration; and/or
2. anthropogenic discharges e.g. from farming activities, and towns due to the length of time that Europeans have been in the area; and/or
3. effects of the relatively ubiquitous occurrence in at least parts of the catchments of the major rivers of soil profiles derived from the marine Wianamatta Shale sediment which can naturally result in moderate salinities (i.e. well in excess of 2200 uS/cm) in tributary streams.

2.7 BASELINE AQUATIC ECOLOGY

The Ecology Lab (TEL) (2008) have comprehensively reported on the aquatic ecology of the General SMP area and any impacts associated with this proposal.

2.8 MINING-RELATED POTENTIAL AQUATIC EFFECTS

2.8.1 Geochemical Effects of Riverbed and Rockbar Fracturing

Strains due to differential subsidence, leading to ‘upsidence’ and ‘valley closure’ beneath incised creeks and riverbeds can produce a complex suite of physico-chemical effects. Hydrological measurements, visual observations and water quality monitoring over recent years in the Southern Coalfield indicate these effects are:

1. Compressive or tensile (strain) failure fracturing of the Hawkesbury Sandstone bedrock leading to increased permeability and storage, possibly reduced surface flows, especially at the low end of the flow rate regime and more rapid draining of defined rock bar controlled pools in no and low flow situations.
2. Diversion of stream flows through the fractured bedrock leading to loss of surface flows and potential loss of catchment yield to deep aquifer storage. This effect has been described in our previous reports as ‘sub-bed diversion’ (Ecoengineers Pty Ltd., 2005b, c; 2006b).
3. Dispersion of small quantities of kaolinite from freshly fractured unweathered sandstone in the bedrock and its re-emergence from the bedrock immediately downstream of upsidence-affected areas. This effect has only been detected visually, occurs very early in the fracturing sequence, does not significantly affect downstream turbidities at anywhere near the levels that natural rainfall/runoff events cause and decays very rapidly.
4. Dissolution and oxidation of accessory siderite/rhodocrosite (ferrous/manganous carbonate; Fe/MnCO_3) and marcasite (a form of pyrite, FeS_2) within freshly fractured or dilated groundwater pathways in the Sandstone, leading to release of sulfuric acid (H_2SO_4), dissolved iron (Fe), manganese (Mn), nickel (Ni) and zinc (Zn) and re-emergence of more acidic waters of lower pH, lower redox potential (Eh) and dissolved oxygen (DO) concentrations and higher concentrations of the above metals from bedrock immediately downstream of upsidence-affected areas.
5. Increased concentrations of dissolved aluminium (Al) in water emerging immediately downstream of fracturing-affected areas due to the dissolution of aluminium from kaolinite in the walls of flow paths conducting acidic water through the fractured bedrock.

Numerous studies and water quality monitoring undertaken in the Southern Coalfield have concluded that the estimated maximum daily rate of acid generation in any discrete sub-bed flow diversion/marcasite oxidation zone is currently believed to be of the order of 100 mole H_2SO_4/day which is equivalent to 100 mole $CaCO_3$/day to completely neutralize it, and that this maximum possible peak rate is not sustained for any more than a few months.

A critical characteristic of Hawkesbury Sandstone in the context of upsidence induced acid generation is that the Sandstone has almost no neutralizing capacity and in most cases there is generally also very little neutralizing capacity in the chemistry of local natural stream and river waters. However, naturally occurring carbonate inputs from Wianamatta Shale derived soil areas provide increased acid buffering potential in the Nepean River.

Any acid released by oxidation of the marcasite in the Sandstone is generally largely attenuated naturally downstream principally by dilution, and by reaction with the low concentration of carbonate alkalinity in the passing creek or river water in which the acid dissolves. Given the flow and carbonate concentrations that occur in the Nepean River, it is unlikely that low pH conditions in the Nepean River will eventuate from the oxidation of pyrite type minerals in the Sandstone caused by valley related subsidence movements.

2.8.3 Strata Gas Emissions into the River

Southern Coalfield strata gases are known to be high in methane – typically >90% by volume. They invariably also contain some carbon dioxide, nitrogen and small amounts of ethane – typically no more than 1% of the proportion of methane. Strata gases may also contain a low level of hydrogen sulfide and their emissions may or may not be accompanied by a small proportion of produced water also containing dissolved sulfide (e.g. Ecoengineers, 1998).

Possible ecological risks arising from emissions of strata gases are:

- The capacity of the gas to induce production of aerobic bacterial biomass ‘feeding’ on the methane as a feedstock,
- the consumption of DO within a water body into which the gas may be emitted,
- the production of low trace levels of potentially ecotoxic dissolved hydrogen sulfide and the production of potentially ecotoxic phenols – principally 4–methylphenol (para-cresol) as a known metabolic byproduct of the aerobic bacterial biomass (e.g. Ecoengineers, 1998).

If substantial gas emissions occur at the surface than these could cause localized aquatic and terrestrial vegetation dieback. Such vegetation dieback is rare and has only been recorded in one location in the Southern Coalfield. Vegetation dieback has not been observed in areas that have not been directly mined beneath. Further assessment of the potential impact of strata gas emissions of flora and fauna are provided in the report by Biosis (2008).

2.8.4 Strata Dilation Effects of Subsidence

The effect of induction of ferruginous springs as a consequence of mine subsidence has been observed before in the Southern Coalfield in sub-catchments of the Nepean, Cataract and Upper Georges River, most notably by producing:

- the very large, and long-lived ‘SW2 Spring’ in Cataract River just west of Back Gully Creek; and
- the moderately large and moderately long lived ‘Pool 11 Spring’ in Upper Georges River.

Other considerably smaller and shorter lived springs have been observed and monitored in association with mining operations within the Southern Coalfield.

On the basis of experience in the Southern Coalfield, it is inferred that such springs, if they do arise:

- may be generated by a catchment of as little as approximately 0.2 km^2;
- are likely to have a lifetime of at least 4 years with or without significant diminution in intensity; and in the worst case
- may be relatively permanent once instigated, depending upon the size of the dilated catchment area providing their water supply.

The experience of the Cataract Gorge SW2 Springs suggests that a catchment size of the order of only 1 km^2 appears to be sufficient to confer a lifetime in excess of 10 years.

It is known that mining subsidence can have the effect of delaminating and dilating erosion surfaces and bedding planes within and between strata. These effects are predicted to occur preferentially along the interfaces between materials with different elastic properties.

In terms of the likely mechanism giving rise to such springs, it is now known that where broad scale upland subsidence occurs as a consequence of mining, delamination, dilation and hence permeability enhancement is likely along the sub-horizontal interface between the sub-cropping Hawkesbury Sandstone, perhaps an interfacial Mittagong Formation (thin intercalated lenses of sandstone and shale) and outcropping Wianamatta Shale and Shale-derived soils (Hazelton and Tille, 1990).

This in turn apparently facilitates the increased detention and storage of infiltrating meteoric waters within the Shale and close to the Shale/Sandstone interface. The water stored at the shale/sandstone interface subsequently drains downgradient in the direction of the local creek or river. In some cases it can then travel down natural or induced vertical cracks and along widened bedding planes in the sandstone and subsequently appear as well-defined springs. That significant water storage at the Wianamatta/Hawkesbury interface occurs and is pronounced has now been indicated by:

1. water yields recovered from various shallow boreholes drilled over the last 15 years in the Southern Coalfield on plateaux mantled with Shale (i.e. those drilled just into the upper layers of the Hawkesbury);
2. periodic longwall mining-induced seepages into the Cataract Tunnel; and by
3. the emergence of highly visible ferruginous springs in the Upper Georges and Cataract Rivers.

It has been estimated that longwall mining-induced subsidence effects on Shale-mantled upland catchments in the Southern Coalfield might generate ferruginous springs from upland catchments at a maximum recharge/discharge rate of about 0.8 mm/day and a mean recharge/discharge rate of about 0.2 mm/day.

This would generate average flows of the order of 0.2 ML/day and maximum flows of the order of 0.4 ML/day per km^2 of catchment (Ecoengineers, 2005a).

Detailed geochemical investigation has shown such waters have the following pronounced geochemical characteristics:

1. A very distinctive geochemical signature characteristic of leaching of salts stored in (marine- derived) Wianamatta Shale clay soils. Specifically, the

following is observed: a very high magnesium/calcium (Mg/Ca) <u>mole</u> ratio of +3.6 – +5.0 (noting it is +5.2 in seawater), a very low strontium/calcium mole ratio (Sr/Ca) of 0.004 – 0.009 (noting it is 0.009 in seawater), a narrow log bromide/chloride (log(Br/Cl)) mole ratio of -2.85 – -2.95 (noting it is -2.81 in seawater), a narrow log boron/chloride (log(B/Cl)) mole ratio of -11 - -18 (noting it is -12 in seawater), and a narrow log sulfate/chloride (log(SO_4/Cl)) mole ratio of typically -1.3 – 2.0 (noting it is -1.3 in seawater). In other words, these waters have the signature of a marine shale soil profile subsequently modified only by cation exchange processes on clays (for sodium, Na, potassium, K, Ca, Mg and Sr), clay adsorption (for B), and Fe and Mn oxide dissolution effects during percolation (e.g. Appelo and Postma, 1993).

2. Depending upon the depth of shale infiltrated such waters often exhibit characteristically elevated levels of dissolved iron (Fe) and manganese (Mn) typically ranging from 0.2 – 40 mg/L and 0.1 – 2 mg/L respectively. Due to the well known high concentrations of disseminated Fe and Mn oxides (after siderite and rhodocrosite) in weathered Wianamatta Shales (which gives them their distinctive brick red through dark maroon colours), reductive dissolution of those oxides (‘bleaching’) has occurred in the subsoil storage under the influence of so-called Fe and Mn dissimilatory bacteria (typically Geobacter species) that are well known to oxidize percolating dissolved organic matter (DOM) and, in that same biogeochemical process, use such oxides as their terminal electron acceptors (TEAs; Lovley and Phillips, 1986).
3. As distinct from the oxidative dissolution of marcasite that can occur in freshly fractured Hawkesbury Sandstone, the reductive dissolution (bleaching) of disseminated Fe and Mn oxides in the Wianamatta Shales does <u>not</u> increase SO_4 concentrations and does <u>not</u> produce acidity and hence lowering of pH *in situ* (although this will be created at emergence into the open air of such waters - see below). Hence these waters generally maintain constant SO_4 concentrations (albeit higher the greater the depth of Shale and extent of salts leaching involved) and generally have near neutral to only weakly acidic pHs when properly sampled *in situ* or immediately upon emergence and if not subsequently passed through bulk fractured sandstone.

When a spring of this ‘Wianamatta Shale-type water’ emerges into the open air it tends to immediately react with the oxygen in the air or dissolved in the water of the creek or river it may flow into. This results in the precipitation of Fe and Mn hydrous oxides, generating acidity <u>and</u> consuming oxygen.

Fe and Mn oxidation and precipitation of hydrous oxides creates acidity principally through the following reactions:

$$2Fe^{2+} + 0.5O_2 + 5H_2O \Rightarrow 2Fe(OH)_3 + 4H^+$$

$$Mn^{2+} + 0.5O_2 + H_2O \Rightarrow MnOOH + 2H^+$$

Where such springs flow directly into ephemeral or low flow creeks, the bicarbonate/carbonate alkalinity of the water should generally be sufficient to ensure that the generation of acidity through the oxidation of the dissolved Fe and Mn is insufficient to produce pHs low enough to cause any ecotoxic effects. The only situation where this could potentially not apply is where such a spring flowed into a large stream or river where the existing water was very fresh i.e. of very low salinity and hence of low alkalinity (Appelo and Postma, 1996).

However, ecological stresses obviously may also be caused by the low DO levels induced where such springs enter a watercourse.

In summary:

1. Saline ferruginous springs referred-to are very unsightly and highly visible due to the voluminous precipitation of oxidised ferruginous material and unless they arise in well wooded country are readily detected by the public.
2. Increased inflows of saline waters into local creeks as a consequence of increasing infiltration into, and interflow through local Wianamatta Shale soils and outcrops due to mine subsidence-related effects (e.g. shearing) are a <u>potential</u> aquatic ecological stressor on local aquatic ecosystems (ANZECC/ARMCANZ, 2000), <u>unless</u> the waters in these creeks can be demonstrated to already receive Wianamatta Shale-derived waters of a similar salinity level and Fe and Mn concentrations.
3. As the reduced Fe and Mn load in the spring water is oxidised, <u>and</u> if it discharges to a creek, it consumes all dissolved oxygen (DO) in the creek water at and immediately downstream of the point of entry to the creek. This could have significant ecotoxic effects both due to the reduction in DO and a smothering effect in the creek bed (ANZECC/ARMCANZ, 2000).
4. If the magnitude of such a spring was sufficiently large and it were detected, detained and treated in some way within the catchment, then creek waters containing significant concentrations of dissolved Fe and Mn could also pass either indirectly or directly into Nepean River or Georges River. This in turn again creates a significant consumption of dissolved oxygen at the point of entry which has the potential to discharge DO from the water, and cause bed smothering of the immediately downstream major pools.

3. RISKS OF POTENTIAL WATER-RELATED EFFECTS

3.1 EFFECTS OF FERRUGINOUS SPRINGS

On the basis of field observation, it is considered that ferruginous springs would be more prone to arise or be enhanced in tributary streams i.e. Harris Creek, Upper Foot Onslow Creek and Upper Navigation Creek rather than in Nepean River. This increased probability is suggested by the following:

1. the drilling of Tower Colliery borehole 22 in August 2001 in which a considerable flow of a classic Wianamatta Shale water with high dissolved Fe and Mn concentrations was encountered in the low part of a westward draining catchment flowing towards Nepean River;
2. visual detection of a spring in Ingham's Tributary of Ousedale Creek at site IT30 which was detected after completion of West Cliff Longwall 30 and possibly induced or enhanced by mining of that longwall; and
3. the more recent geochemical detection of a pre-existing spring in Mallaty Creek between existing BHPBIC water quality sites MC05 and MC130.

Should the following occur:

1. discharge of ferruginous springs into tributary creeks such as Harris, Upper Foot Onslow or Upper Navigation Creek which typically have very low flows; or
2. discharge of ferruginous springs into farms dams sited along drainage lines,

within the General SMP Area, they possess the potential capacity to drive down pH, consume DO and deposit ferruginous precipitates.

Given that such waterways and water storages are already highly impacted by current land uses and, being located in a Wianamatta Shale-derived region may already be receptors for such springs which have arisen naturally, these mining effects may not be so significant that they can be identified.

The upland valleys on the western side of the Nepean River are shallow but substantial in area. Consequently the area of potential subsidence and dilation of near surface strata is expected to be comparable with the ~1.00 km^2 (100 ha) that was mined under by Appin longwalls to create the Cataract River SW2 spring.

Based on studies of previous springs we conclude that longwall mining induced subsidence effects on upland catchments in the SMP Area might generate individual ferruginous springs from upland catchments discharging to the river up to a maximum recharge/discharge rate of about 0.2 ML/day and a mean recharge/discharge rate of about 0.1 ML/day.

We modelled the effects of the mixing of 0.2, 0.1 and 0.05 ML/day of spring waters emanating from catchments over Longwalls 705 - 710 with 0.4 and 4.0 ML/day of river water i.e. river base flows equivalent to the 3.5 and 10 percentile flows using PHREEQC (Parkhurst and Appelo, 1999). This was done in order to obtain probabilistic information regarding the impact of such a spring discharging directly to Nepean River.

We assumed, by_analogy with the IT30 spring sampled in Ingham's Tributary of Ousedale Creek as given in **Table 2.4** above, that any upland subsidence induced springs over Longwalls 705 to 710 would have a maximum Total Fe concentration of the order of 3.2 mg/L, and a maximum Total Mn concentration of 1.2 mg/L (being the long term mean plus one standard deviation as established by BHPBICs monitoring program). We have also assumed that for river flows up to 4.0 ML/day the river water would have a composition closely similar to the average for BHPBIC water quality monitoring site NR11.

Table 3.1 shows the outcomes of that modelling, giving the estimated DO levels in the River at the point of mixing of spring and river waters.

TABLE 3.1: MODELLED DISSOLVED OXYGEN SATURATION AT POINTS OF MIXING OF A FERRUGINOUS SPRING DISCHARGING DIRECTLY TO THE RIVER UNDER 3.5 AND 10 PERCENTILE RIVER FLOW CONDITIONS

Spring Flow Rate (ML/day)	**Estimated DO (% saturation) in River at Point of Mixing for 3.5 percentile River flow (0.4 ML/day)**	**Estimated pH in River at Point of Mixing for 3.5 percentile River flow (0.4 ML/day)**	**Estimated DO (% saturation) in River at Point of Mixing for 10 percentile River flow (4.0 ML)**	**Estimated pH saturation) in River at Point of Mixing for 10 percentile River flow (4.0 ML/**
0.20	53	6.83	83	7.36
0.1	67	6.96		
0.05	75	7.12		
0.00	87	7.69		
National Water Quality Guidelines (NSW lowland rivers)	>85	6.5	>85	6.5

From the above **Table 3.5** the following may be inferred:

1. for all discrete spring flows into Nepean River above 0.05 ML/day and river flows below about 0.4 ML/day i.e. below 3.5 percentile flows the default guideline for DO in the national water quality guidelines would not be met at the spring emergence point.
2. for all discrete spring flows into Nepean River below ~0.2 ML/day and river flows above ~4.0 ML/day i.e. above 50 percentile flows, the default guideline for DO in the national water quality guidelines would be met.

3.2 EFFECTS OF STRATA GAS EMISSIONS IN NEPEAN RIVER

Emission of strata gas into the Nepean River near Longwall 701 was observed during January 2008.

Dissolved oxygen (DO) versus distance down the River plots are summarized in **Figures 3.1 to 3.10** below for the mining and post-mining period from November 2007 to mid-May 2008. River flow rates at Menangle Weir and their frequency percentiles are also shown. Where possible, Total Phosphorus (TP) is also plotted as TP is invariably the limiting nutrient on algal and/or bacterial growth (alternatively generating or removing DO) in freshwater ecosystems.

Figure 3.1 Dissolved Oxygen in Surface Waters of Nepean River November 2007 in November 2007 just after Commencement of Longwall 701

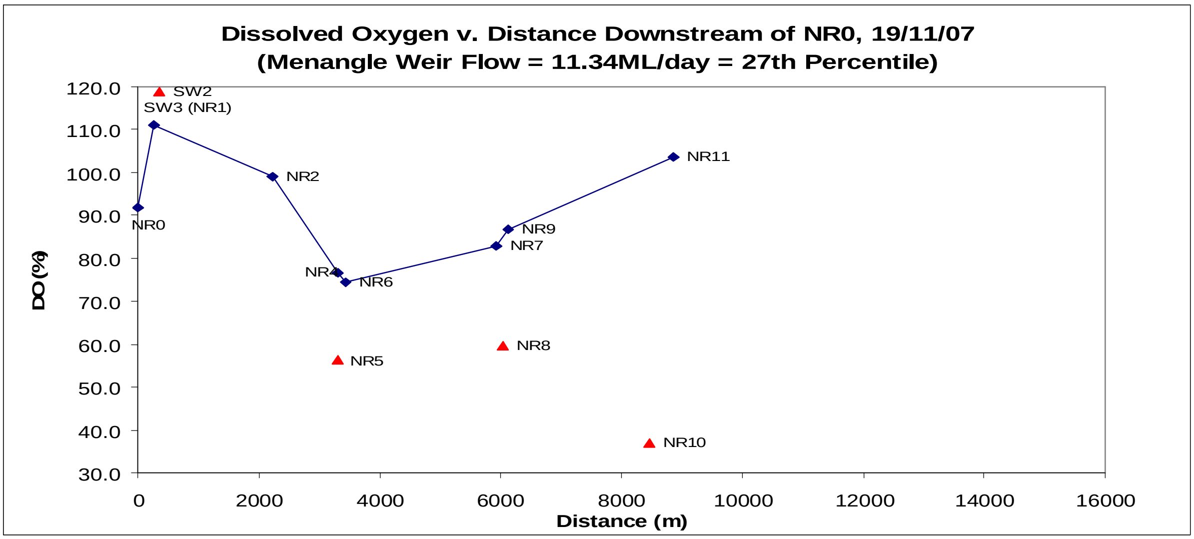


Figure 3.2 Dissolved Oxygen and Total Phosphorus in Surface Waters of Nepean River in December 2007 during Extraction of Longwall 701

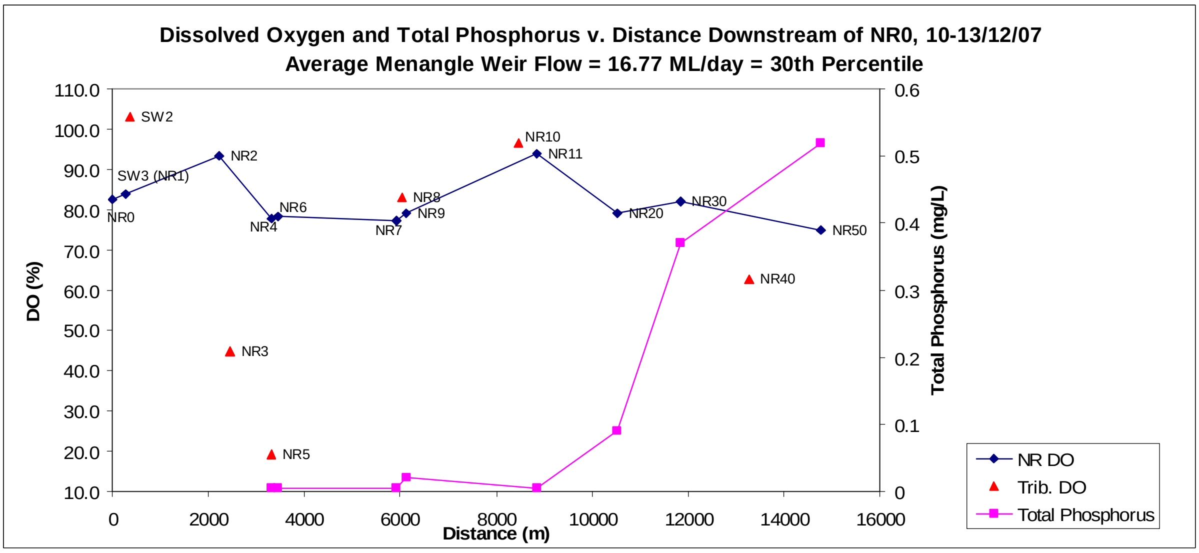


Figure 3.3 Dissolved Oxygen and total Phosphorus in Surface Waters of Nepean River in January 2008 during Extraction of Longwall 701

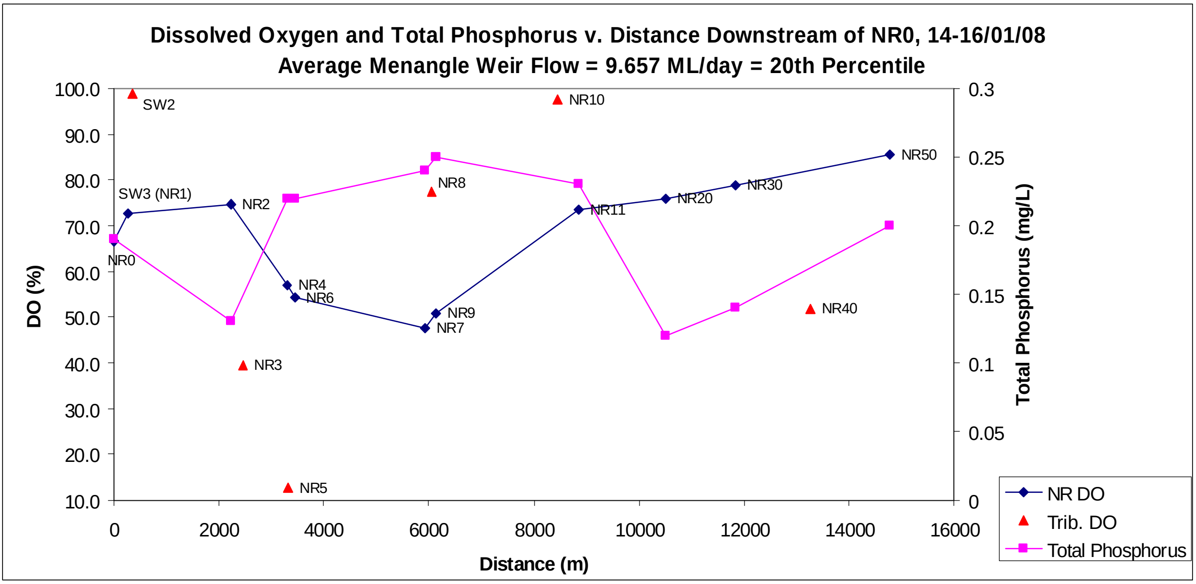


Figure 3.4 Dissolved Oxygen and Total Phosphorus in Surface Waters of Nepean River in February 2008 during Extraction of Longwall 701

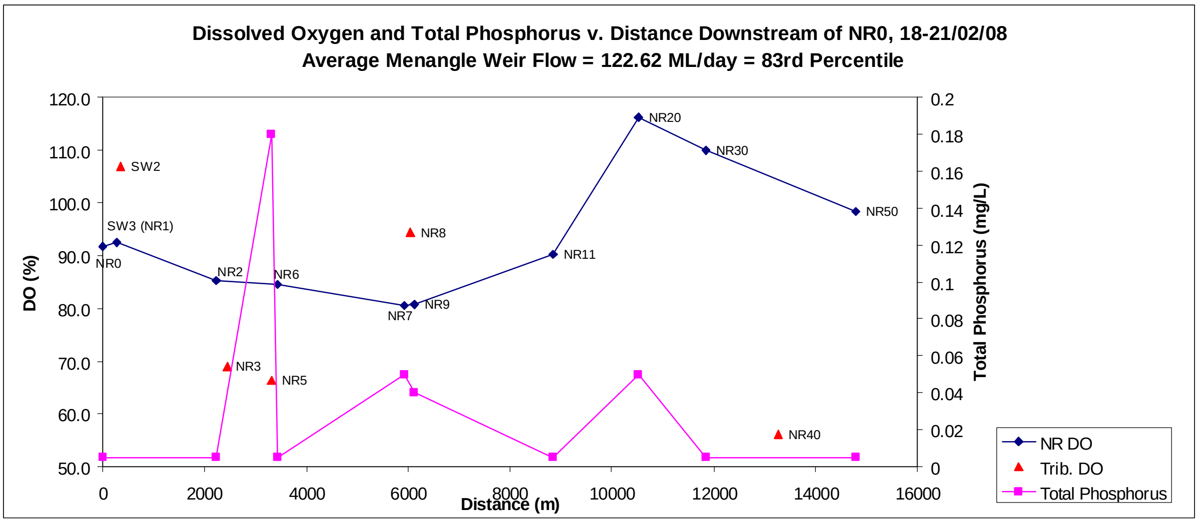


Figure 3.5 Dissolved Oxygen and Total Phosphorus in Surface Waters of Nepean River in March 2008 during Extraction of Longwall 701

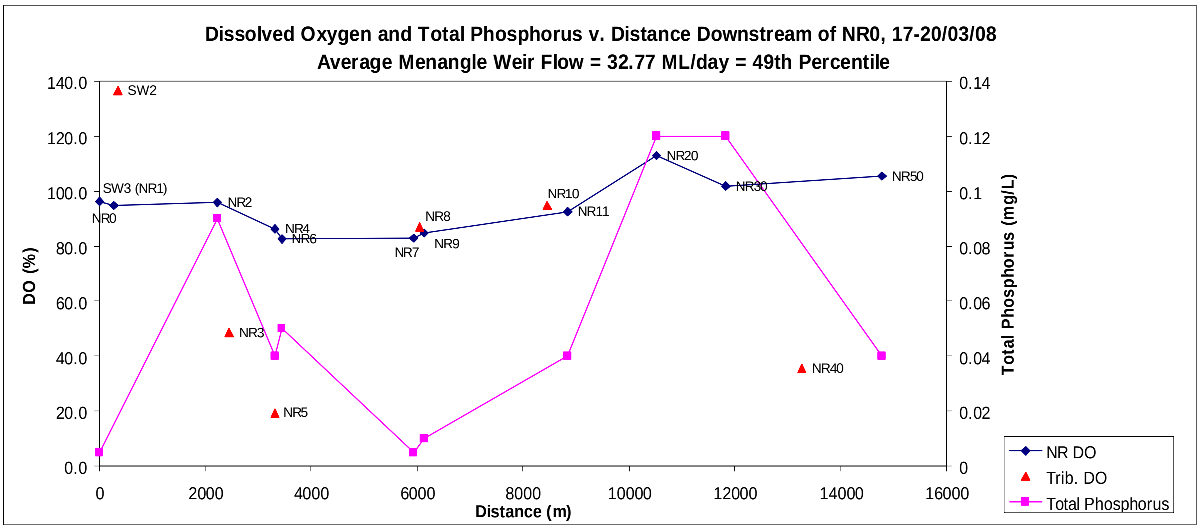


Figure 3.6 Dissolved Oxygen and Total Phosphorus in Surface Waters of Nepean River in April 2008 during Extraction of Longwall 701

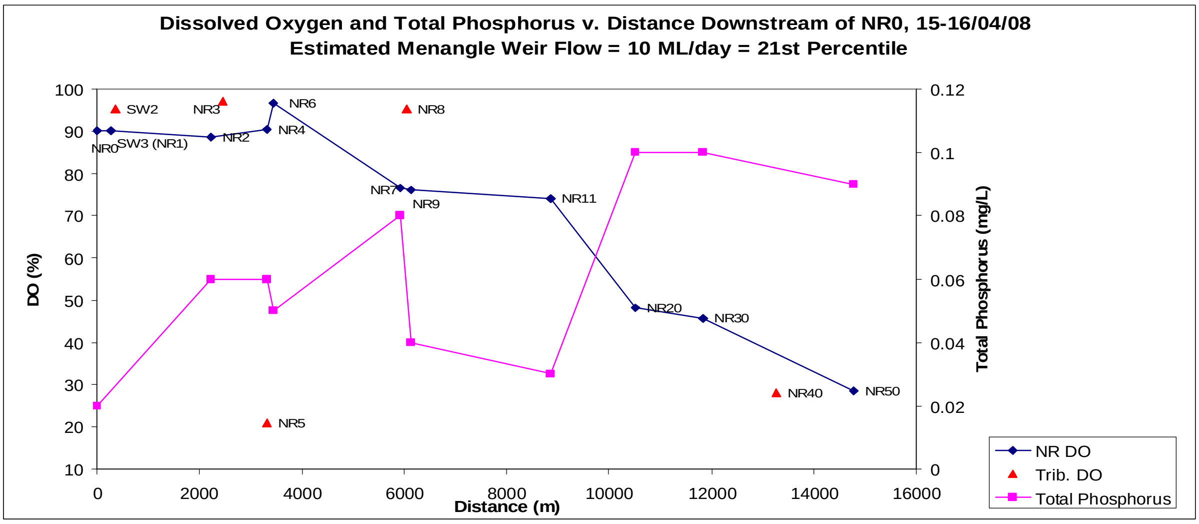


Figure 3.7 Dissolved Oxygen and Total Nitrogen in Surface Waters of Nepean River in April 2008 during Extraction of Longwall 701

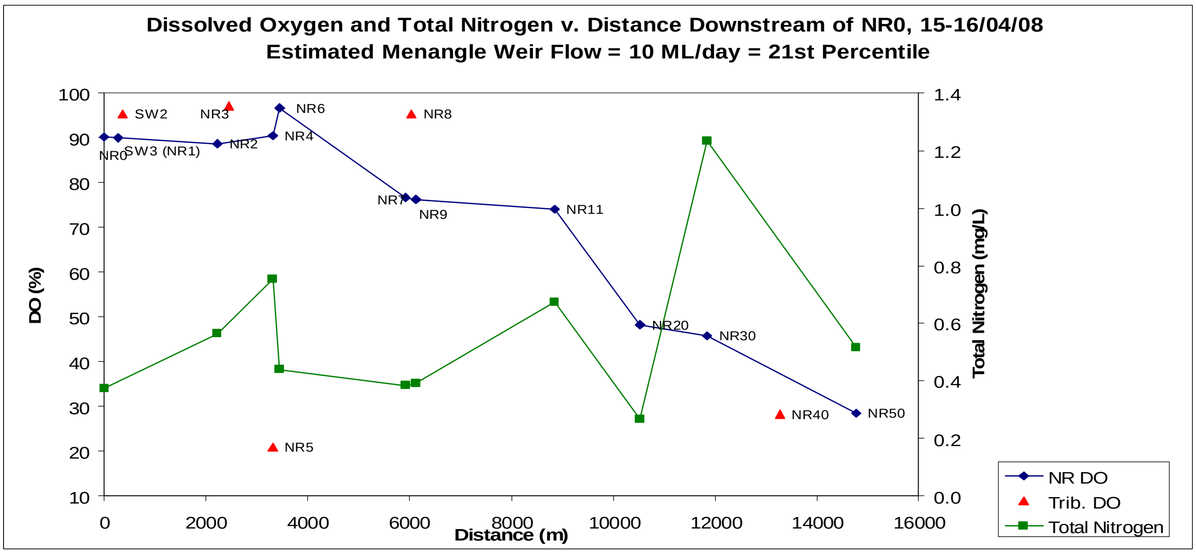


Figure 3.8 Dissolved Oxygen and Total Phosphorus in Surface Waters of Nepean River in May 2008 during Extraction of Longwall 701

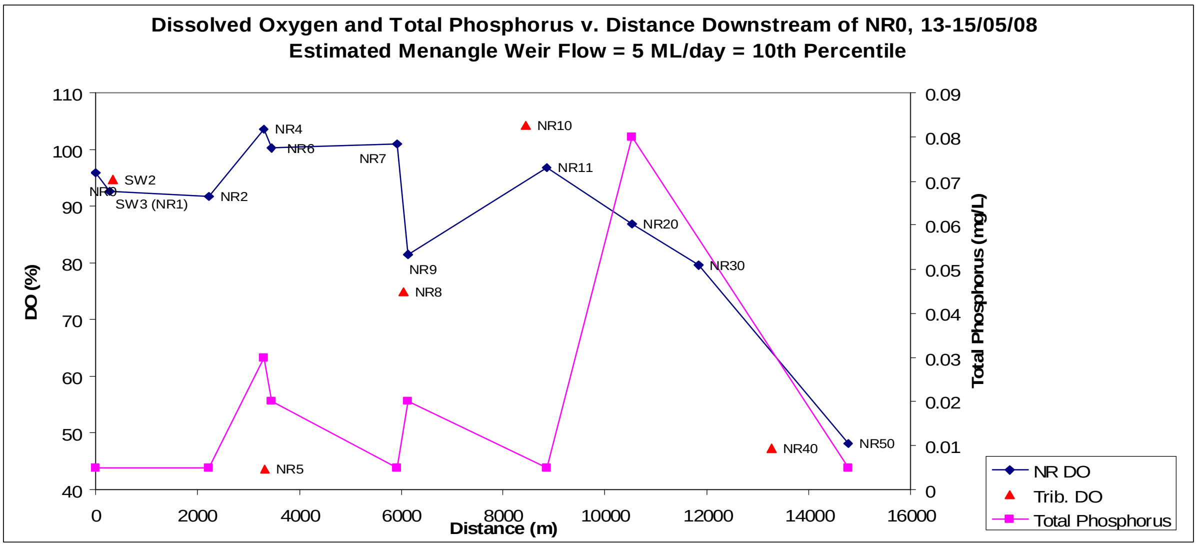
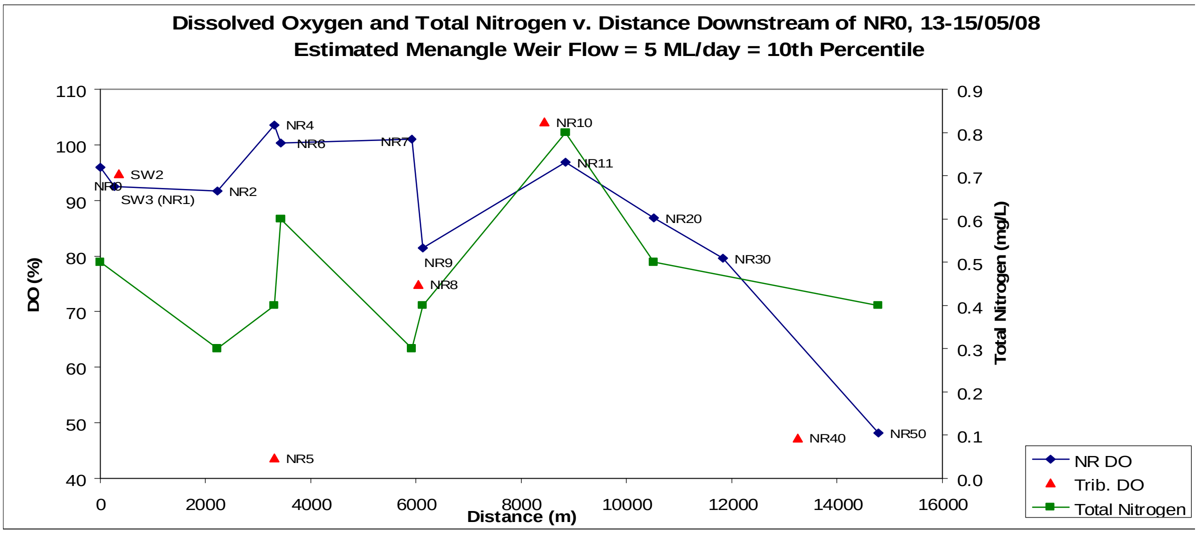


Figure 3.10 Dissolved Oxygen and Total Nitrogen in Surface Waters of Nepean River May 2008 during Extraction of Longwall 701

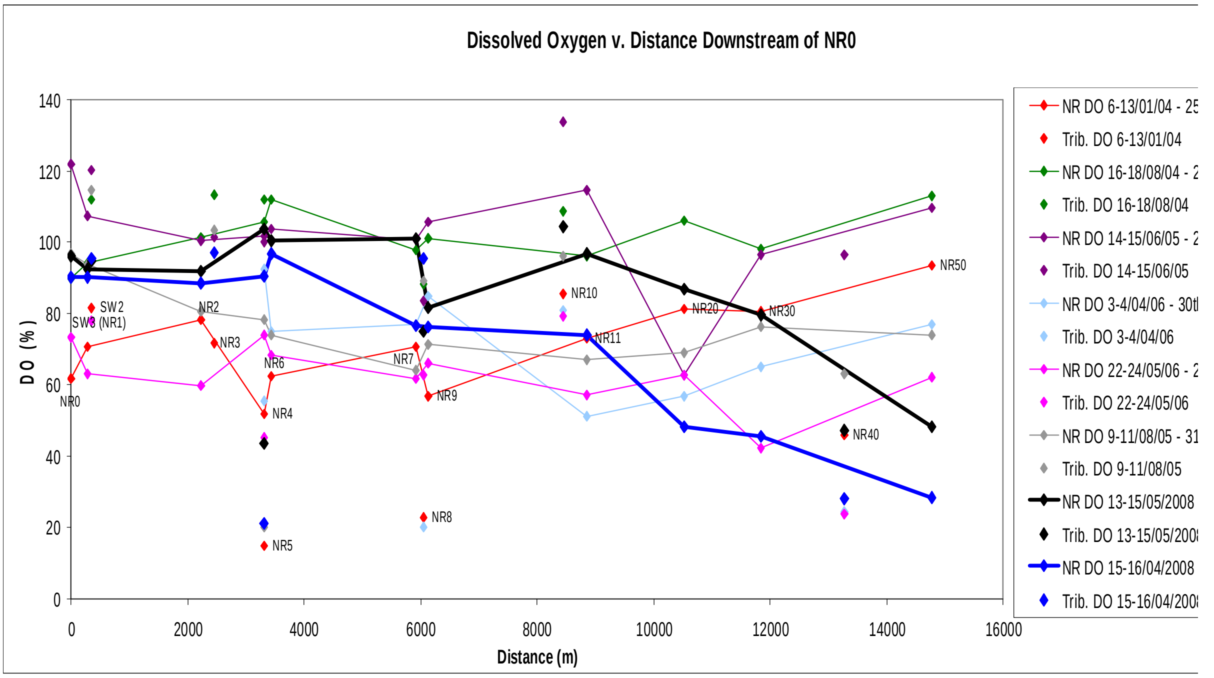


Examination of the above **Figures 3.1 to 3.10** covering the period following commencement of mining Longwall 701 on 27 October 2007 shows that Nepean River surface water qualities, especially under the ecologically more critical low flow conditions <50 percentile, were dominated by the following processes:

1. There is a consistent input of low DO water from Cataract River and Menangle Creek under all flow conditions and the Cataract River input is the primary driver of DO immediately downstream of the Cataract River confluence.
2. In January, April and May 2000 under relatively low flow conditions (20, 21 and 21 percentile at Menangle Weir) there were DO sags of 7, 20 and 20% at the NR7 and/or NR9 sites adjacent to, and immediately downstream of the gas emission zones which are coincident with and may be attributable to strata gas emissions in the river.
3. The River appears to have a relatively low degree of re-aeration down river of this point i.e. the (flooded) geomorphology of the river is such that it has a low Re-aeration Coefficient (RAC) adjacent to the General SMP Area.
4. Beyond site NR11 or NR20, under low flow conditions DO reductions are most likely attributed to inputs of water from small tributaries carrying agricultural and industrial pollution as indicated by TP (and TN) levels.

Figure 3.11 below compares surface water levels of DO within the Nepean River at low flow conditions for six example baseline campaigns with the April and May sampling campaigns made during extraction of Longwall 701.

Figure 3.11: Comparison of Surface Dissolved Oxygen Levels for Six Baseline Campaigns and for the April and May Campaigns during Longwall 701 Extraction



As shown in **Figure 3.11** above, DO conditions can sometimes fall below 60% during low river flow conditions independent of any impact associated with gas release attributed to mining. Other influences such as inputs from Cataract River and (further down river) agricultural and industrial nutrient runoff and input of low DO sources from tributaries are also likely contributors to low DO.

The only previous low flow case where a small but significant DO sag (i.e. 13.7%; 1.12 mg/L; water temperature 26 deg. C) was observed between sites NR7 and NR9 i.e. around the Elladale Creek confluence was the 6 – 13 January 2004 field study. Flow in the River at Menangle Weir on those days was very low and approximately 13 ML/day or

However DO reductions of 20.5% and 19.5% were recorded between sites NR6 and NR9 in April and May respectively when flows in the River at Menangle Weir were estimated to be 53 ML/day (67 percentile) and 22 ML/day (37 percentile) in April and May respectively.

These may be considered examples of what has long been known as ‘DO sags’ i.e. pronounced declines in DO over a discrete stretch of the watercourse.

DO sagging due to aerobic consumption of methane in the strata gas emissions into the River since January 2008 (i.e. associated with Longwall 701) therefore appear to be having an influence on surface water DO levels between the site just downstream of Cataract River confluence (NR6) and the site just downstream of Elladale Creek confluence in the River in April and May 2008.

We therefore conducted a due diligence study to determine whether there are any other ‘natural’ factors which might apply in the stretch of the River between sites

NR7 and NR9 which could explain the observed DO sags since January 2008 and in particular those observed in April and May 2008.

We first looked at the above mentioned ‘worst case’ from the pre-mining baseline period where there was a minor reduction in DO observed between sites NR7 and NR9. The following plots show this January 2004 baseline low flow DO sag in relation to other relevant parameters which may be involved in mechanism producing a natural DO reduction between sites NR6 and NR9 of i.e. Total Fe, Total P, Total N and DOC.

Figure 3.12 Dissolved Oxygen and Total Iron in Nepean River Baseline Case 6 – 13 January 2004

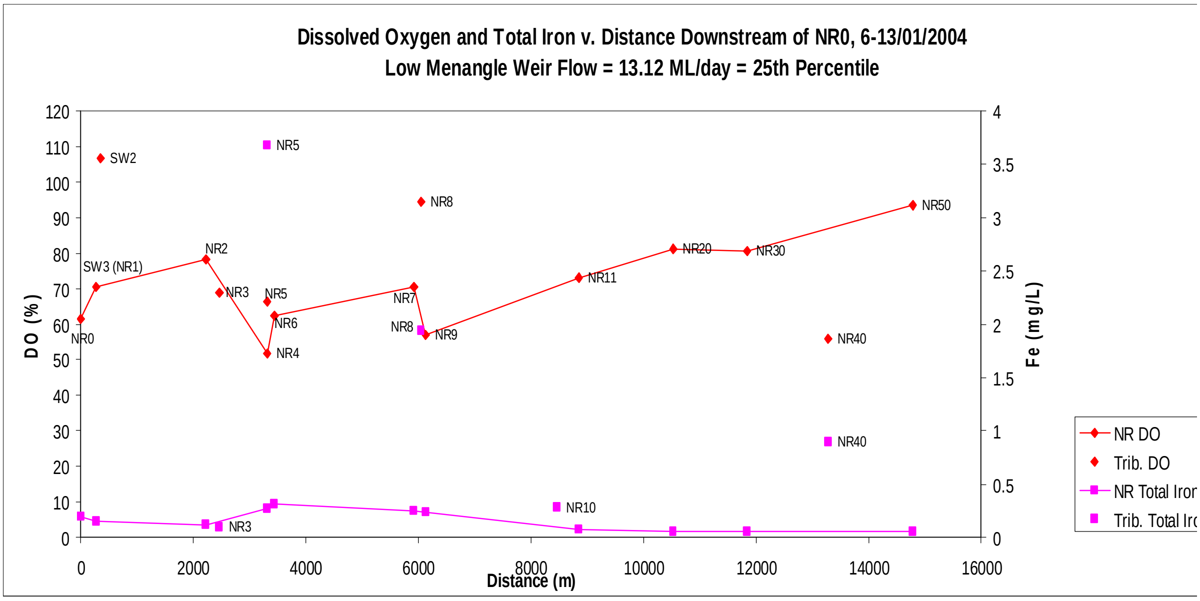


Figure 3.13 Dissolved Oxygen and Total Phosphorus in Nepean River 6 – Baseline Case 13 January 2004

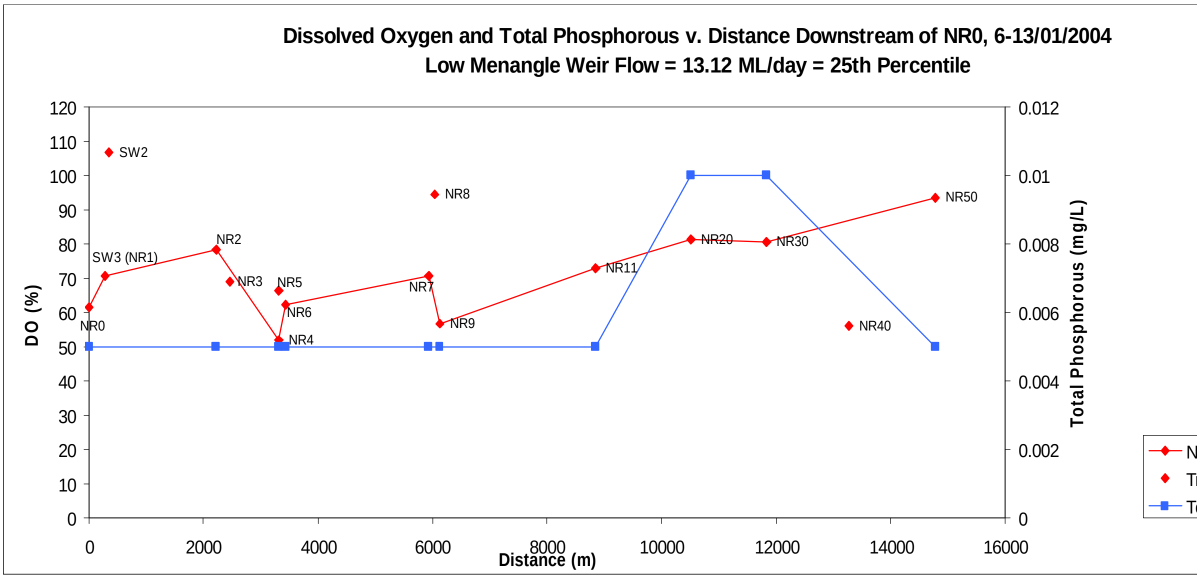


Figure 3.14 Dissolved Oxygen and Total Nitrogen in Nepean River Baseline Case 6 – 13 January 2004

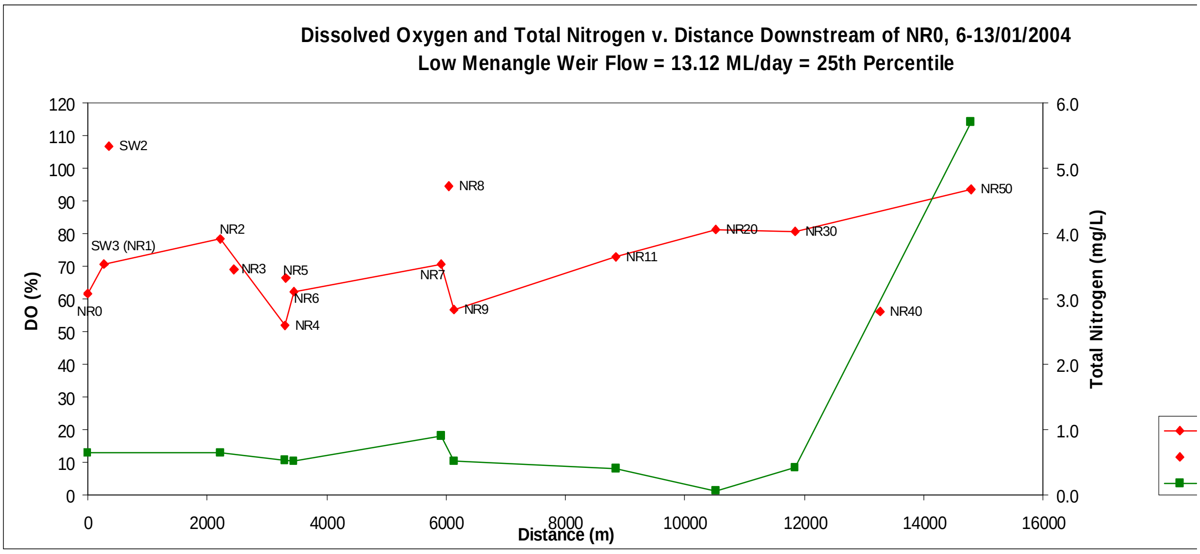
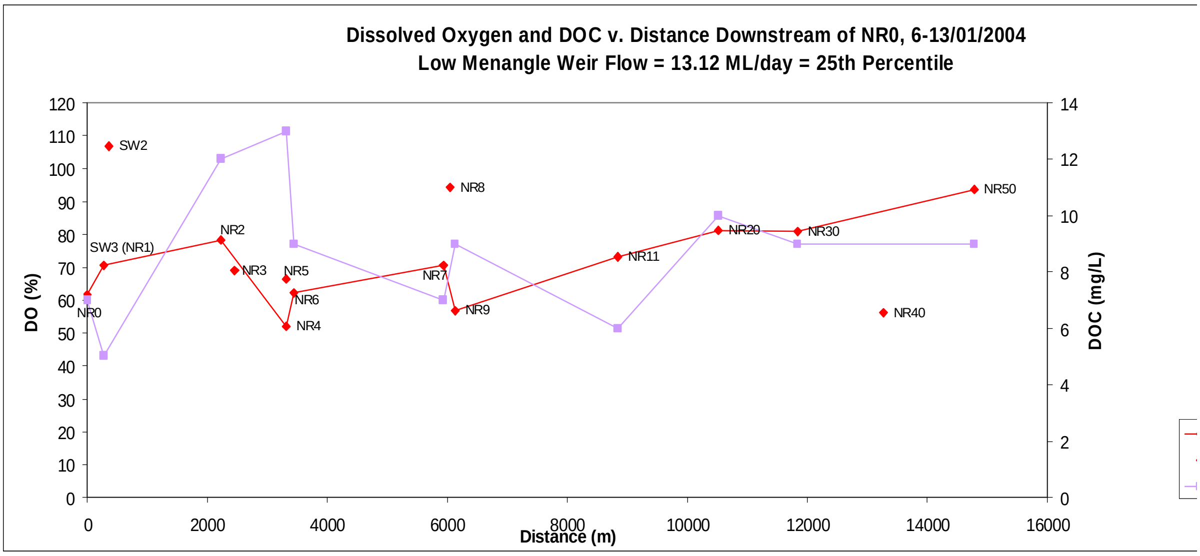


Figure 3.15 Dissolved Oxygen and Dissolved Organic Carbon in Nepean River Baseline Case 6 – 13 January 2004



For this January 2004 baseline low flow test case, <u>chloride-based mixing calculations</u> show the upriver flow in the River constituted 99.29% of the downriver flow i.e. for a flow at Menangle Weir of 13.12 ML/day (a 25 percentile) only 0.71% or 0.093 ML/day was contributed by Elladale Creek.

Mixing calculations show the input of low DO water from Elladale Creek (22.7%; 1.86 mg/L) would have contributed to a DO drop in the River of 0.01 mg/L in the River i.e. 0.1% <u>and may therefore be considered negligible</u>.

Upriver Total Fe was 0.250 mg/L and downriver Total Fe was 0.265 mg/L, the increased Fe being due to the Elladale Creek input (at 1.94 mg/L). The River Total Fe increment (0.015 mg/L) or 0.00027 mmoles/L would there account for a contribution to the observed 13.7% DO sag of 0.00014 mmoles/L or 0.014 mg/L i.e. a sag of 0.17% <u>and may therefore be considered negligible.</u>

Upriver DOC was 7 mg/L, DOC in Elladale Creek was 15 mg/L and downriver DOC was 9 mg/L i.e. an increase. Mixing calculations show the input of higher DOC water from Elladale Creek would have contributed to an increase of DOC in the River to 7.06 mg/L i.e. negligible.

However, the slight increase in DOC downriver to 9 mg/L does suggests that there was perhaps a deposit of logs and other organic debris on the deep eastern side of the bend in the River between sites NR7 and NR9.

Organic matter leaching from that at a rate of say 0.5 mg/L DOC (0.042 mmole/L) could have consumed 1.33 mg/L DO i.e. a similar value to the observed DO sag of 1.33 mg/L.

It is noted that the January 2004 baseline test case was in mid-summer with a very high water temperature (26 deg. C) and in the middle of drought conditions with antecedent zero releases over Pheasants Nest Weir i.e. low flows at Maldon Weir. Under such circumstances decomposition of natural organic matter collected at the bend in the <u>River would be expected</u> and provide a reasonable explanation for the observed DO sag of 13.7% between sites NR6 and NR9.

Next we examined, in the same manner as for the January 2004 baseline case, the May 2008 case. Analogously, the following plots show this May 2008 post-mining low flow DO sag in relation to other relevant parameters which may be involved in mechanism producing a natural DO reduction between sites NR6 and NR9 of i.e. Total Fe, Total P, Total N and DOC.

Figure 3.16 Dissolved Oxygen and Total Iron in Nepean River Post-Mining Case 13 – 15 May 2008

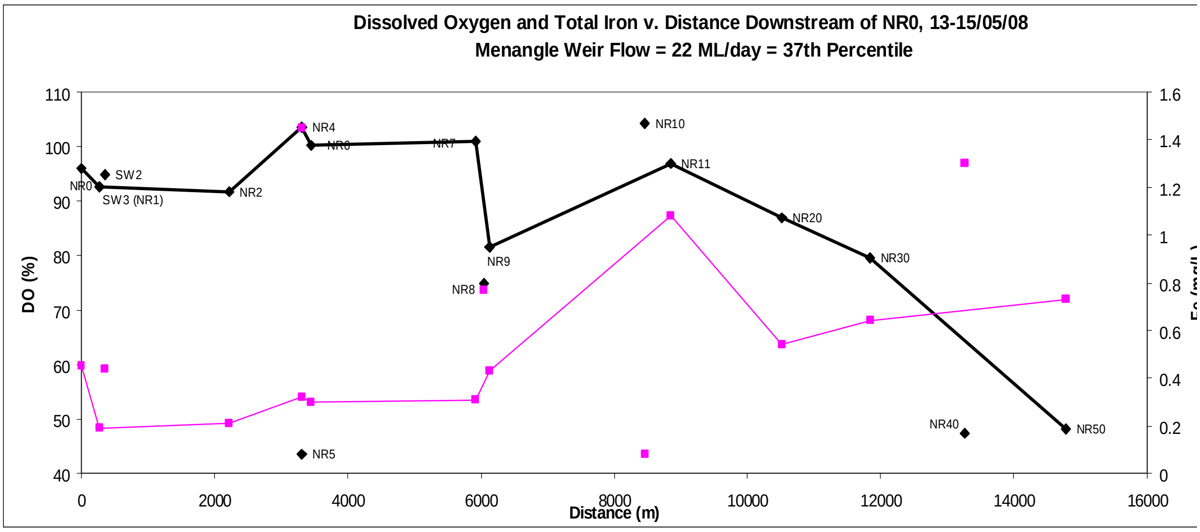


Figure 3.17 Dissolved Oxygen and Total Phosphorus in Nepean River Pots Mining Case 13 – 15 May 2008

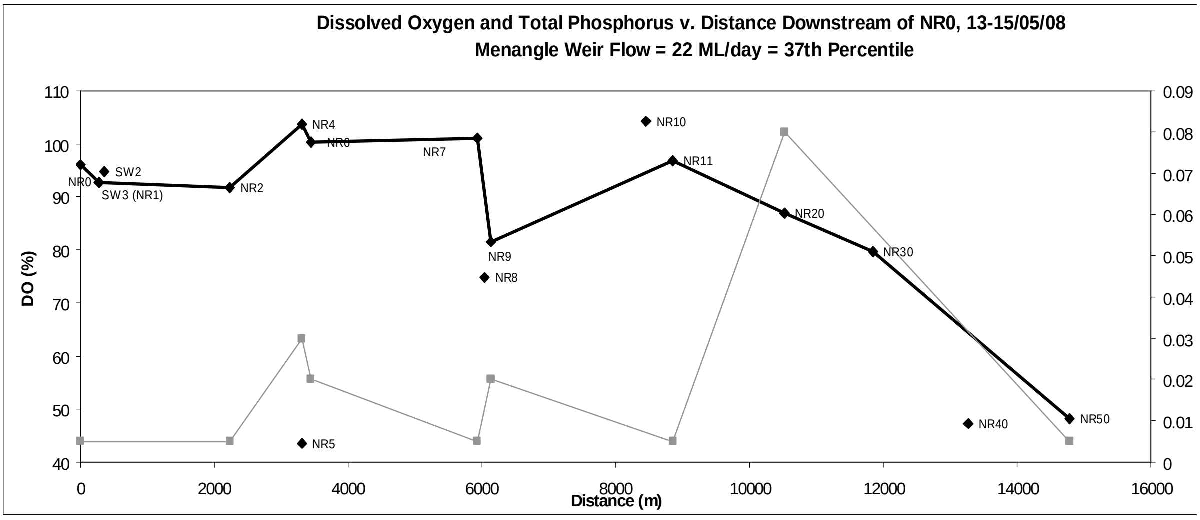


Figure 3.18 Dissolved Oxygen and Total Nitrogen in Nepean River Post Mining Case 13 – 15 May 2008

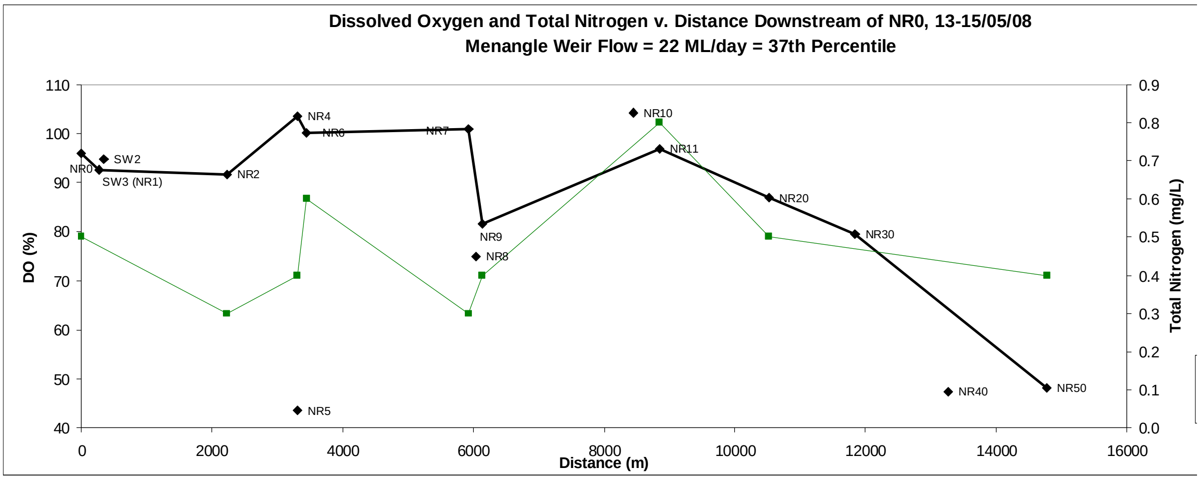
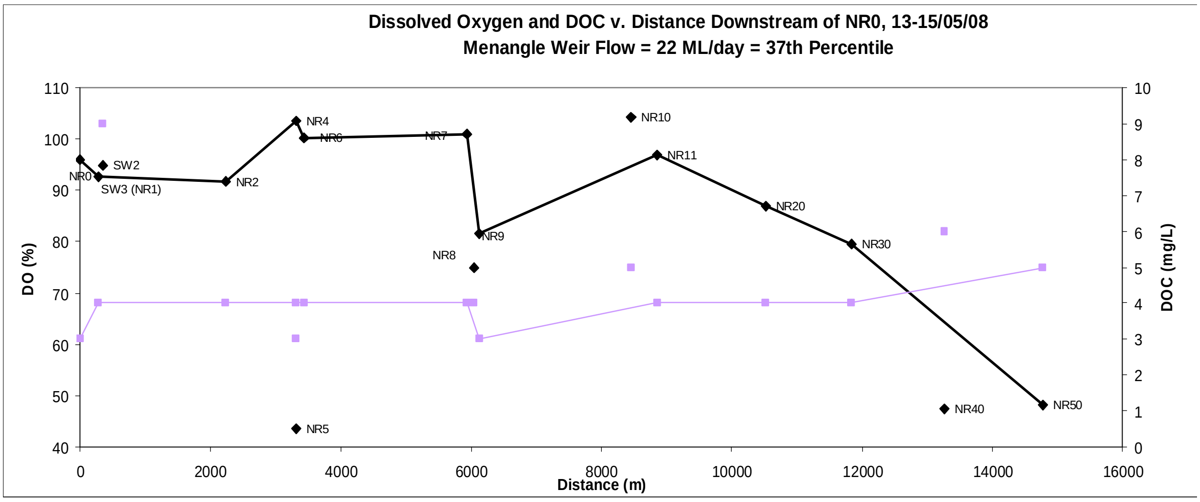


Figure 3.18 Dissolved Oxygen and Dissolved Organic Carbon in Nepean River Post Mining Case 13 – 15 May 2008



For this May 2008 post-mining test case, chloride-based mixing calculations show the upriver flow in the River constituted 98.47% of the downriver flow i.e. for a flow at Menangle Weir of 22 ML/day (a 37 percentile) only 1.53% or 0.34 ML/day was contributed by Elladale Creek.

Mixing calculations show the input of low DO water from Elladale Creek (74.9%; 7.64 mg/L) would therefore have contributed to a DO drop in the River of 0.04 mg/L in the River i.e. 0.4% and may therefore be considered negligible.

Upriver Total Fe was 0.310 mg/L and downriver Total Fe was 0.430 mg/L, the increased Fe being due to the Elladale Creek input (at 0.77 mg/L). The River Total Fe increment (0.12 mg/L) or 0.0021 millimoles/L would account for a contribution to the observed DO sag of 0.00105 mmoles/L or 0.033 mg/L i.e. 0.33% and may therefore be considered negligible.

Upriver DOC at site NR6 was only 4 mg/L, DOC in Elladale Creek was also 4 mg/L and downriver DOC was only 3 mg/L i.e. an apparent decrease in the River of 1 mg/L. It is noted the laboratory measurement error at this level is ±1 mg/L.

Regardless, this apparent drop of 1 mg/L DOC would be equivalent to 0.083 millimoles/L DOC. If the DOC were natural organic matter i.e. not methane it would have an approximate formula of CH_2O. Thus the theoretical maximum biological consumption reaction is:

$CH_2O + O_2 = CO_2 + H_2O$ i.e. one molecule of DOC consumes two molecules of oxygen.

Consumption of 1 mg/L or 0.083 mg/L DOC would therefore consume about 0.083 mmoles/L DO (O_2) i.e. 2.66 mg/L = 25.8%.

This is certainly a value which is commensurate with the observed DOP sag of 19.5%.

Conversely methane is also consumed preferentially by ‘obligate aerobes’ i.e. natural aerobic bacteria according to the reaction:

$CH_4 + 2O_2 = CO_2 + 2H_2O$ i.e. one molecule of methane consumes two molecules of oxygen.

The January 2005 baseline test case occurred during summer and during drought with a water temperature of 26 deg. C.

In contrast to the January 2004 baseline test case discussed above, the May 2005 post-mining test case was in early winter with a much lower water temperature (15 deg. C), and at almost twice the flow rate (22 ML/day versus 13 ML/day at Menangle Weir). May 2005 post-mining test case has also followed a lot of high flow rate flushing of the River over 2007 and early 2008 with antecedent significant releases over Pheasants Nest Weir i.e. high flows at Maldon Weir.

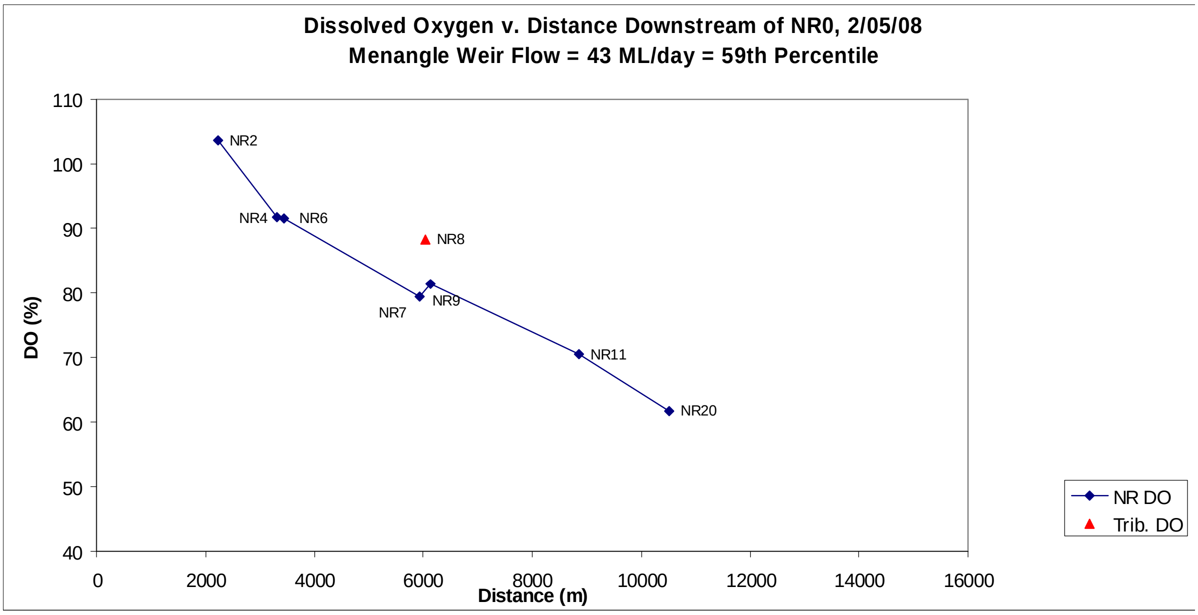
Hence it is both:

1. unlikely that there is an available pool of natural organic matter in the bend in the River; and/or
2. that water temperatures were high enough for its aerobic decomposition.

It is noted that the DOC in the River is very flat at ~4 mg/L upriver past the Cataract River confluence. An apparent drop in DOC across the Elladale Creek confluence bend of only 1 mg/L is therefore more likely to be simply due to measurement error.

We also note that a field monitoring campaign was also conducted on 2 May 2008 when flow in the River was 43 ML/day at Menangle Weir i.e. a 59 percentile flow. The following figure shows the pattern of surface DO down the River on that occasion.

Figure 3.19 Dissolved Oxygen in Nepean River Post-Mining Case 2 May 2008



Again it can be clearly seen that although DO sagging was also observed in the River to the south, presumably as a consequence of the input from Cataract River between sites NR4 and NR6 and to the north of site NR9, presumably as a consequence of agriculturally derived nutrients entering the River again there was still a 10.2% DO sag observed between sites NR6 and NR9.

Finally we <u>approximately</u> assessed the possible mechanistic link between the observed DO sagging in the River between sites NR6 and NR9 and hydrocarbon gas emissions within the Nepean River has also been as follows:

1. At 20 ^{o}C, the full saturation of pure methane in water is 24.37 mg/L. For a gas of 95% methane concentration solubility would be about 23.15 mg/L. Levels of dissolved methane have only recently been monitored in the River and the available data to date is listed in **Table 2.4** in **Section 2.5.5** above.
2. If there was <u>full equilibration and no biological consumption</u> of dissolved methane in the water the BHPBIC field team should have obtained values of 10 – 20 mg/L dissolved methane in the water near the bubbling. However, the highest value for dissolved methane seen so far (Zone 1) immediately downstream of the bubbling is only 398 ug/L. (0.398 mg/L) on 12 June 2008. Incidentally, this equates to approximately 1.72% methane saturation in the Nepean River at the (major) Zone 2 plume.
3. The rate of methane bubbling in early March 2009 was estimated at about 148 - 223 L/min averaging (say) about 185 L/min (refer **Table 2.3**) and this was largely distributed between Zones 1 and 2.
4. As previously noted, the rate of flow (37% percentile) in the River which applied in the 13 – 15 May 2008 sampling campaign was about 22 ML/day at Menangle Weir or say about 19 ML/day (noting BHPBIC field team estimated a flow of about 18 – 20 ML/day) at the gas emission zone of some 13,200 L/min.

5. It can be shown from other gas emission sites around the world that over short timescales, gases passing up through short water columns approximately 2 m deep equilibrate in about a 1:1 liquid: gas volume ratio. This ratio typically only slowly increases with increasing depth and size of the gas plume, approximately doubling for every 10 times increase in water depth (e.g. Liefer et al. 2000; Clark et al., 2003).
6. This suggests that to a first approximation the gas bubbling into the River would likely only equilibrate with about 185 L/min i.e. only about 1.40% of the 13,200 L/min water passing by on 13 – 15 May and thus the maximum overall solubility of methane in the River at this point should be about 0.014 x 23.15 = 0.324 mg/L (= 324 µg/L) or 0.020 millimoles/L dissolved methane (CH_4). This agrees reasonably well with the surface level of 398 µg/L (= 0.025 millimoles/L) dissolved CH_4 measured at Zone 2 on 12 June 2008.
7. As previously noted the chemical reaction which describes the aerobic consumption of methane is essentially $CH_4 + 2O_2 = CO_2 + 2H_2O$ i.e. one mole of methane consumes 2 moles of oxygen. This means that over the entire water cross section well mixed River water passing by Zone 2 should theoretically have about 0.05 millimoles/L of DO eventually consumed downriver of this location i.e. 1.92 mg/L.
8. This is about 18.6% of the saturation DO in the River water at a temperature 14 ^oC (where 100% DO saturation = 10.31 mg/L). This agrees reasonably well with the observed 19.5% DO sag observed between sites NR6 and NR9. It is therefore assumed that by the time the River water reaches site NR9 where dissolved CH_4 has dropped to levels of the order of 33 – 63 µg/L it invariably has been subject to significant aerobic consumption by aerobic bacteria in the water column, consuming DO.

We therefore conclude that the approximately 20% DO sags observed between site NR8 and site NR9 on April and May 2008 were most likely due to aerobic consumption of dissolved methane from strata gas emissions into the River.

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

This means that reductions in DO levels (’DO sags’), irrespective of how they arise, are likely to persist down river under low flow conditions.

Of particular significance in the current context is that strata gas emission-induced reduction DO sagging may well become contiguous with the observed, pre-existing agricultural land use-induced DO sagging which the BHPBIC water quality monitoring data indicates is pronounced under most seasonal conditions except during a few warm summer months when algae are clearly blooming in the River (and inject DO in the water).

Strata gas emissions into Nepean River and their potential biogeochemical impact at low river flow rates may constitute a risk to the aquatic ecology of the River from the proposed mining of Longwalls 705 – 710.

3.3 FLOW AND GEOCHEMICAL EFFECTS OF RIVER FLOW DIVERSIONS

The likelihood of sub-bed flow diversions is considered extremely low due to the offset of the Area 7 longwalls from the river as described by MSEC (2006, 2008).

Nevertheless, we have also quantitatively examined a series of low flow (i.e. <50 percentile flows at Menangle Weir = 34 ML/day) recession examples where we have subtracted the flows at Maldon Weir from the concurrent flows at Menangle Weir to get a measure of the flow through the River in the vicinity of Area 7 Longwall 701 for the baseline pre-mining and posting periods.

Two examples only are given below of the derived standard log-linear low flow recession curves for the difference in flow rates between these two weirs, one from the just pre-mining baseline period and one (of three identified cases) from the post-mining period for Longwall 701.

Figure 3.20 Example Recession Curve for Locally Derived Flows in River for Pre-mining (Longwall 701) Baseline Period 16 September – 7 October 2007

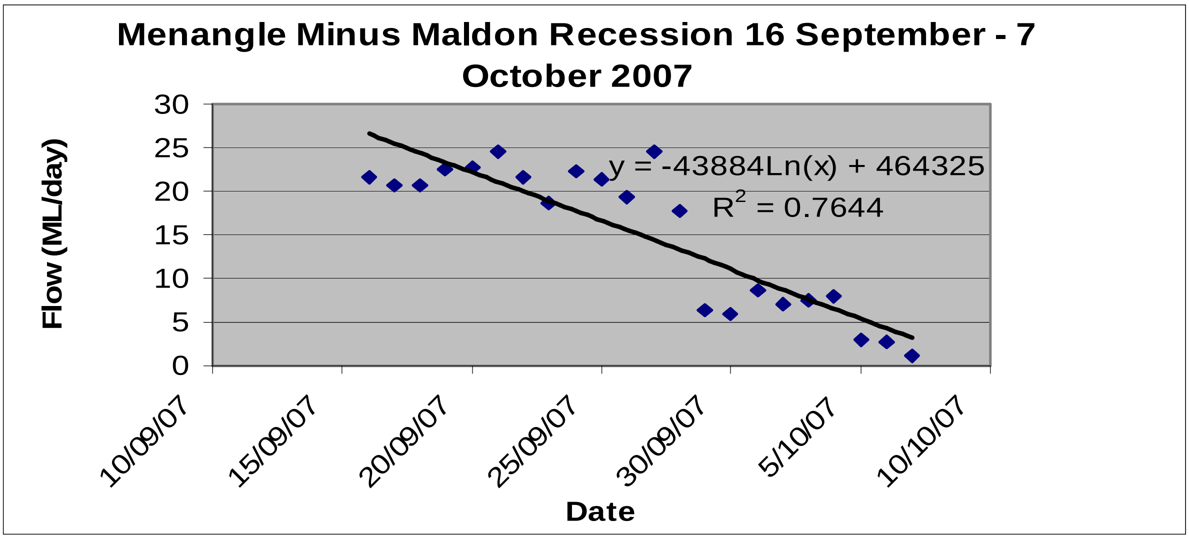
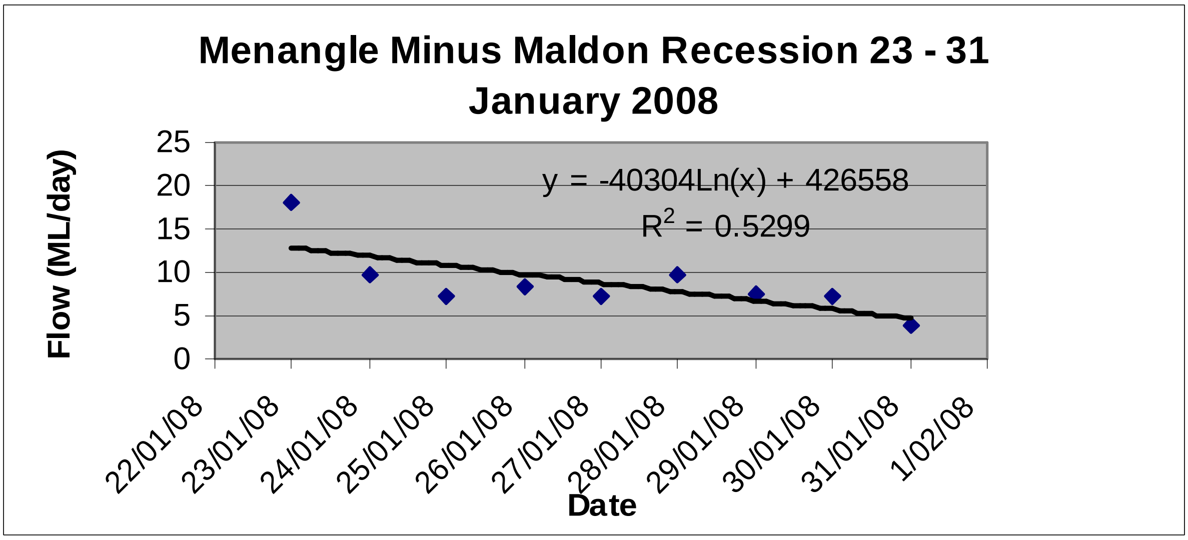


Figure 3.21 Example Low Flow Recession Curve for Locally Derived Flows in River for Longwall 701 Post-mining Period 23 – 31 January 2008



We have found that for 7 cases of low flow recession curves identified from the pre-mining period for Area 7 Longwall 701, the average slope of the log-linear recession curve is -46951±12921 at the one standard deviation level and the average intercept for these curves is 493587±134863 at the one standard deviation level.

We have found that for 3 cases of low flow recession curves identified from the post-mining period for Area 7 Longwall 701, the average slope of the log-linear recession curve is -40294±22112 at the one standard deviation level and the average intercept for these curves is 426419±233968 at the one standard deviation level.

Regardless of the known presence of licensed extractions None of the 7 pre-mining baseline recession curves 3 Longwall 701 post-mining recession curves show any non-linear steepening of their slopes as the difference in flows between Maldon and Menangle Weirs declined to zero such as would be created by an increasing non-recoverable loss water into the river bed.

Furthermore, well within an estimation error of one standard deviation on the mean, both the slopes and intercepts of the low flow recession curves for the Longwall 701 post-mining period (n=3) were the same as for the pre-mining period (n=7) indicating that at least at the coarse level of examining River water flows generated by rainfall/runoff over the total catchments lying between both weirs there is no significant loss of water from the River since extraction of Longwall 701 commenced.

The Nepean River contains significant bicarbonate alkalinity – typically in the range 138±59 mg/L expressed as calcium carbonate ($CaCO_3$) concentration, which equals 1.38 millimoles/L at site NR11.

This alkalinity is available to neutralize any H_2SO_4 acidity released by weathering of marcasite in the fractures of sandstone exposed through the cracking of river bed and/or rock bars.

For the 10 percentile baseflow in the River adjacent to the General SMP Area of around 4 ML/day (i.e. 85% of the 10 percentile flow at Menangle Weir which is 5 ML/day), this means that, each day the total alkalinity passing down the river is equivalent to approximately 5520±2360 moles of calcium carbonate per day.

Thus, even allowing for the unlikely event of an unusually low total alkalinity in the water of 5520 – 2 x 2360 = 800 moles of calcium carbonate, there is still adequate alkalinity in the water to completely neutralize any water quality effect arising from a significant number of discrete zones of sub-bed fracturing.

In this sense, the situation in Nepean River differs fundamentally from that in other rivers such as Cataract and Bargo Rivers (which contain water of much lower total alkalinity) where mining-induced sub-bed diversions and consequently episodes of marcasite dissolution have occurred. For Nepean River:

1. it is unlikely that low pHs could be induced in Nepean River;
2. any dissolved iron would be oxidized and precipitated;
3. Al will not be released from kaolinite in the sandstone as both the mineral and Al itself is very insoluble within the pH 6.5 – 8.5 range.

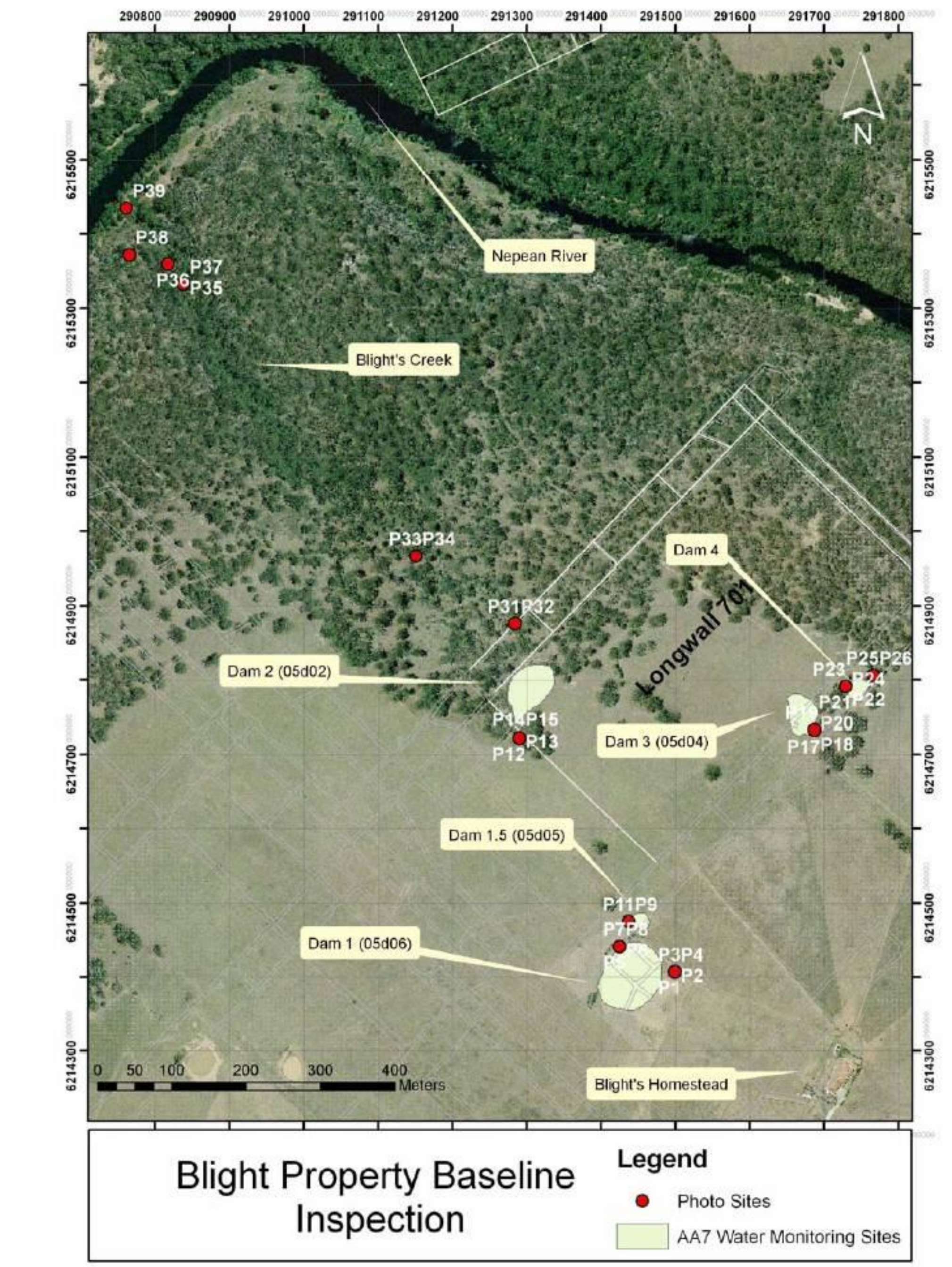
Consequently, manifestation of this effect on river water quality is considered highly unlikely.

3.4 EFFECTS OF SUBSIDENCE ON FARM DAMS

Inspections of the surface above the mining area are required by the Appin Area 7Subsidence Management Plan (SMP). The SMP was approved by the Department of Primary Industries 1 November 2006. Pre-mining and post mining inspection with the approval of the landholder is undertaken as required in the Area 7 Property Subsidence Management Plan and the Area 7 Water Management Plan.

There are a significant number of farm dams over Area 7 Longwall 701 as **Figure 3.22** below shows.

Figure 3.22 Disposition of Farms Dams Over and in the Vicinity of Area 7 Longwall 701.



A pre-mining inspection of the Blight property was conducted on the 18th & 22nd October 2007. Five dams were identified on the property with the main dam (Dam 1-05d06) having an operational pump. No groundwater-bores are present on the property. Dams were inspected and a baseline photographic record established. Field water quality parameters were collected and water samples were taken at each site for laboratory analysis. Surface features on the property were discussed with the landholder. Mr Blight emphasised the importance of Dam 1 (05d06) to the property function.

A post-mining inspection of the Blight property was conducted on the 22 January 2008. Dams were again inspected and photographs taken. Field water quality parameters were again collected and water samples were again taken at each site for laboratory analysis.

We have carefully assessed all the water quality data associated with these exercises and can find strictly no geochemical evidence of:

1. induction of saline ferruginous springs within or immediately downgradient of Dam 1 or within the other dams; or
2. structural changes to the immediately underlying Wianamatta Shale arising from near surface mine subsidence effects.

This suggests that it is unlikely that farm dams situated in the catchments of Harris Creek, Foot Onslow Creek or Navigation Creek will be subject to damaging effects arising from the mining of Longwalls 705 – 710.

We understand that periodic ongoing monitoring of the dams on the Blight property over Longwall 701 will continue to occur.

4. ASSESSMENT AND RECOMMENDATIONS

4.1 ASSESSMENT OF LIKELY EFFECTS ON NEPEAN RIVER

Gas Emissions into the River

The Nepean River is a flooded river with no cascades or rapids above Menangle Weir. It has a low Re-aeration Coefficient and any reduced DO levels observed that are attributable to the emission of gas into the River would have a potential to persist for some distance down river under low flow conditions up to at least the 20 percentile flow.

Pre-mining baseline monitoring has shown depleted DO levels in the Nepean River under low flow conditions induced by:

1. inflows from Cataract River; and
2. inflows from minor tributaries and general runoff adjacent-to and north-of the General SMP area which nutrient analyses strong suggest arise from agricultural and industrial activities.

The issue of strata gas emissions into Nepean River and the potential biogeochemical impact presently constitutes an element of risk to the aquatic ecological integrity of the River from the proposed mining of Longwalls 705 – 710.

Such a low DO condition may become contiguous with the commonly observed agricultural- and industrial-induced DO sag which the BHPBIC water quality monitoring data indicates applies under all but warm weather conditions under flows up to at least the 50 percentile condition.

Further data is required to assess the risk of significant strata gas induced sagging of DO in the Nepean River, and recommendations are made below to refine the existing water quality monitoring program have been made to better assess this process.

On the basis of the information presented in previous sections of this report and above we conclude that:

1. the **Likelihood** of one or more zones of gas emission arising within Nepean River as a consequence of the mining of proposed Longwalls 705 - 710 is **High**;
2. the **Consequences** of such emissions to the **Ecological Health** of a significant stretch of the River would be **Negligible** under high conditions (>34 ML/day) which occur up to 50% the time; but
3. the **Consequences** of such emissions to the **Ecological Health** of a significant stretch of the River may be **Significant** under low flow conditions (<13 ML/day) which occur up 25% of the time, although further monitoring of gas emissions and water quality in close proximity to gas emission sites is required to validate this prediction; and
4. the **Consequences** of such emissions on **Aesthetics** of the River from associated iron floc would be **Minor**

Ferruginous Springs

Extraction of Longwall 701, which has not mined under the river or any tributary has not led to the creation of any new ferruginous springs in Elladale Creek or locally elsewhere. It might be inferred that the catchments further to the north proposed to be mined under by Longwalls 705 to 710 are at a similar low probability of risk from this phenomenon.

While the induction of ferruginous springs is considered unlikely for the reason given above, if it should occur, then only for all discrete spring flows into the River above 0.1 ML/day and only for river flows below about 0.3 ML/day i.e. below 3.5 percentile flows would the default lower limit for DO in the national water quality guidelines not be met only at the spring emergence point.

The principal reason why concentrations of ecotoxic Ni and Zn species in the Nepean River derived from any such springs would not exceed their default national water quality guidelines limits (set at 0.011 and 0.008 mg/L respectively for nickel and zinc) for river flows of 1.0 ML/day and above is due to the considerable total alkalinity in the river water.

Such springs do not contain sufficient dissolved Fe and Mn to cause a significant depression of river pHs through the oxidation and precipitation of hydrous Fe and Mn oxides because the river water contains significant bicarbonate/carbonate alkalinity.

On the basis of the information summarised above

1. the **Likelihood** of one or more springs arising adjacent to Nepean River as a consequence of the mining of proposed Longwalls 705 - 710 is **Minor;** and
2. the **Consequences** of such a spring on **Aesthetics** of the River would be **Minor.**

River Sub-Bed Flow Diversions

It is predicted that it is highly unlikely there could be any significant effect on River water level or pH, total Fe, Mn, Ni or Zn concentrations from any sub-bed diversion effects resulting from the extraction of the proposed longwalls, even in the unlikely event of an upsidence induced fracturing of a rock bar or zone of river bedrock.

The likelihood of such an event has already been rendered extremely low due to the offset of the longwalls from the River as described by MSEC (2008) and the capacity for neutralization provided the natural Total Alkalinity of the River waters.

On the basis of the information presented in previous sections of this report and above we conclude that:

5. the **Likelihood** of one or more sub-bed diversions arising within Nepean River as a consequence of the mining of proposed Longwalls 705 - 710 is **Rare**; but
6. the **Consequences** of such a diversion on **Aesthetics** of the River from iron floc would be **Major**; however
7. the **Consequences** of such a diversion to the **Ecological Health** of immediate downstream pool(s) in the River would be **Negligible** under all but the rarest of low flow conditions (<0.4 ML/day) which have occurred no more than 3.5% of the time at Menangle Weir; and
8. the **Consequences** of such a diversion to the **Ecological Health** of immediate downstream pool(s) would be **Insignificant** as a consequence the River exhibiting adequate Total Alkalinity to fully neutralise any sulfuric acid produced.

4.2 ASSESSMENT OF LIKELY EFFECTS ON WESTERN CATCHMENTS

It is possible that ferruginous saline springs may be induced or enhanced in the catchments directly overlying Longwalls 705 to 710. These catchments ultimately flow to the Nepean River via Harris Creek, Foot Onslow Creek and Navigation Creek.

This possibility is demonstrated by:

1. the drilling of Tower Colliery borehole 22 east of Nepean River in August 2001 during which a considerable flow of a classic Wianamatta Shale water with high dissolved Fe and Mn concentrations was encountered in the low part of a westward draining catchment;
2. ongoing export of elevated salinity (approx. 1500 µS/cm), high Fe and Mn waters out of Elladale Creek just east of Longwall 701;
3. detection of a high salinity ferruginous spring in Ingham's Tributary of Ousedale Creek at site IT30 which was detected after completion of West Cliff Longwall 30 and possibly induced or enhanced by mining of that longwall; and
4. detection of a pre-existing high salinity ferruginous spring in Mallaty Creek between sites MC05 and new site MC130.

Given that the gradients in Harris Creek are similar to those in Elladale, Ingham's Tributary and Mallaty Creek there would appear to be a low probability of induction of one or more ferruginous springs in Harris Creek as a consequence of the mining of Longwalls 705 – 710.

The westward draining streams are clearly strongly ephemeral in nature with ongoing broad acre agricultural land use and it is unlikely there would be any significant impact to water quality resulting from the formation of springs in these streams over and above current anthropological effects (The Ecology Lab, 2008).

On the basis of the information summarised above we conclude that for Harris Creek:

1. the **Likelihood** of one or more ferruginous springs arising from subsidence-related effects is **Minor;** and
2. the **Consequences** of such a spring or springs to **Property** would be **Minor** and we base this assessment on a minor risk of potential contamination to a farm or water storage dam**;** and
3. the **Consequences** of such a spring or springs to the **Ecological Health** of immediate downstream pool(s) in the Creek would be **Insignificant** under high flow conditions but **Minor** under low flow conditions and we principally base this conclusion on the reduced habitat due to the existing effects of local agricultural land uses on stream water quality; and
4. the **Consequences** of such a spring or springs on **Aesthetics** in Nepean River would be **Minor** given that Harris Creek flows do not constitute a significant water input to the river.

On the basis of the information summarised above we conclude that for Foot Onslow and Navigation Creek:

1. the **Likelihood** of one or more ferruginous springs arising from subsidence-related effects is **Minor;**
2. the **Consequences** of such a spring or springs to the **Ecological Health** of immediate downstream pool(s) in the Creeks would be **Insignificant** and we principally base this conclusion on the reduced habitat due to the existing effects of local agricultural land uses on stream water quality;
3. the **Consequences** of such a spring or springs on **Aesthetics** in Nepean River would be **Nil** due to the very long distance waters from any such springs would need to flow to reach the River.

4.3 RECOMMENDATIONS

4.3.1 Hydrogeological and Geological Monitoring

The environmental monitoring proposed for the Longwalls 705 to 710 SMP Area should be based on knowledge gained from previous water quality, hydrologic and hydrogeological investigations associated with the extraction of Appin Longwall 701 and West Cliff Longwalls 30, 31, and 32 .

In particular, further refinements should flow from the ongoing assessment of any water-related impact of extraction of Area 7 Longwalls 701 – 704.

Nepean River is invariably a ‘gaining river’ in terms of surface water - groundwater interaction.

The baseline 2007 year experienced a very high rainfall of at least 80 percentile magnitude. In addition, 2008 seems likely to be a year of at least average rainfall and relatively high natural flows. It is likely that on balance the River became even more of a gaining river since cessation of the drought in later 2006 and, if rainfall over 2008/9 is near average that condition should remain.

In our view, the mining-related phenomenon which poses the potentially highest surface water-related environmental risk to the Nepean River is that from subsidence-induced strata gas emissions.

However, there is a very good case to better characterise this phenomenon and in the following section we make specific recommendations regarding further monitoring efforts in this regard. We also suggest that mine subsidence modelling and hydrogeological monitoring should be developed further to improve prediction and characterization of this effect.

In our view, induction or exacerbation of ferruginous springs is considered the element of highest groundwater-related environmental risk from the perspective of upland mine subsidence (leading to strata dilation in and around the Wianamatta Shale/Hawkesbury Sandstone interface near drainage lines).

The effect of increased perching at this interface will obviously be enhanced in years of average to above average rainfall. To what extent this will occur is presently unable to be accurately predicted.

There is a good case for better characterisation of the incremental vertical dilation profile after undermining in the interfacial zone between the Wianamatta Shale and Hawkesbury Sandstone along drainage lines, to study the effects of enhanced water perching and possible strata gas accumulations and thus better understand effects of mine subsidence on shallow groundwater storage and induction or enhancement of springs.

As well as routine monitoring of water levels (only) in deep farm bores accessing groundwater in the lower Hawkesbury in the General SMP Area, it is recommended to install several open boreholes/piezometers through the Shale, any Mittagong formation material between the Shale and well into the upper Hawkesbury Sandstone in the vicinity of any identified pre-existing springs or seeps.

We recommend that a visual survey and spot pH and EC measurements be conducted to look for pre-existing springs or seeps in the General SMP Area along the western banks of Nepean River and in the headwaters of Harris, Foot Onslow and Navigation Creeks well prior to mining.

Strata dilation within such piezometers may be rapidly assessed by periodic gamma logging. Dissolved Fe and Mn and strata gas accumulation within such piezometers may be rapidly assessed by laboratory analyses. Water samples may be rapidly recovered by use of manual Waterra hand pumps.

4.3.2 Baseline and Ongoing Water Quality Effects Monitoring

Baseline surface flow and water quality monitoring occurring in Nepean River upriver and adjacent to proposed Longwalls 705 – 710 and in Lower Harris, Elladale, Ousedale and Menangle Creeks should continue.

Subject to the resolution of land access issues, establishment of further surface flow and water quality monitoring sites should occur in Upper Harris, Foot Onslow and Navigation Creeks prior to the mining of Longwalls 705 - 710.

It is recommended that the following additions should be made to the established BHPBIC River water quality monitoring program whenever any significant strata gas emission plumes are detected in Nepean River:

1. gas emission flow rates be measured and then monitored again at 3-monthly intervals.
2. chemical composition of river water measured and then monitored again at 3-monthly intervals. This should include analysis for hydrogen sulfide down to the parts per million by volume (ppmv) level. Analysis by the Draeger tube method would be satisfactory.
3. Samples for dissolved methane levels in surface waters should be collected monthly both exactly over the major gas plumes and at the regular down river monitoring sites. Analysis should always be by the method which provides the lowest possible Limits of Resolution ('LOR') i.e. 10 µg/L.
4. Samples for dissolved sulfide and total phenols levels in surface waters should be collected monthly both exactly over the major gas plumes and at the regular down river monitoring sites. Analysis should always be by methods which provide the lowest possible Limits of Resolution ('LOR').

A review of the gas emission and water chemistry data should be undertaken as part of the End of Panel reporting process, and/or in response to low flow conditions (<25 ML/day at Menangle Weir) which occur up to 40% of the time to determine if gas emissions are giving rise to prolonged low DO conditions. If prolonged low DO conditions are observed which can be directly attributable to gas emissions, BHPB

Illawarra Coal should prepare a response plan to mitigate this effect, in consultation with relevant stakeholders.

4.3.3 Best Practice Effects Management

In the event that future water monitoring shows that there have been significant hydrologic or aquatic ecotoxic effects within the General SMP Area or immediately downstream in Nepean River then it is possible that management and mitigation measures may be required.

In our view, based on the above discussions the estimated ‘cut off’ river flow rate above which any ‘worst case’ effects possibly induced by mining Longwalls 705 to 710 are considered to be comparable with effects deriving from natural variations in flow rate, water temperature, water quality etc in the River lies in the range of about 0 - 10 ML/day.

We recommend that consideration be given to developing a Plan establishing:

1. Upper limit Level 1 and Level 2 TARPs for estimated total strata gas flow rates into the River from all significant, identified strata gas plumes between a point just upriver of Longwall 701 and near the northern end of any Area 7 longwall currently undergoing extraction of the order of 1000 and 3000 L/min, these values to be refined by further field data and gas solubility modelling.
2. Lower limit DO TARPs for any surface water monitoring station based on one and two standard deviations below the long term baseline mean DOs established for the July 2002 – October 2007 pre-Longwall 701 baseline field monitoring period. For example, the long term pre-Longwall 701 baseline average DO for surface site NR7 is 88.3±28.7%. Thus the Level 1 TARP for this site would be set at 59.6% and the Level 2 TARP would be set at 30.9%. Similarly for surface site NR9 the long term pre-Longwall 701 baseline average DO for surface site NR7 is 93.9±23.4%. Thus the Level 1 TARP for this site would be set at 70.5% and the Level 2 TARP at 47.1%. These levels may be compared with the observed mean levels since extraction of Longwall 701 of 79.9±12.4% and 80.5±13.0% at these two sites respectively.

Where low DO concentration in the Nepean River can be attributable to mining induced gas emissions by this means, it is proposed that exceedance (in the case of DO this means falling below the level) of the Level 1 TARPs would trigger a higher degree and frequency of monitoring and input from relevant stakeholders.

It is envisaged that exceedance of Level 2 TARPs would trigger consultations regarding development and implementation of remedial action(s) in consultation with relevant stakeholders.

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