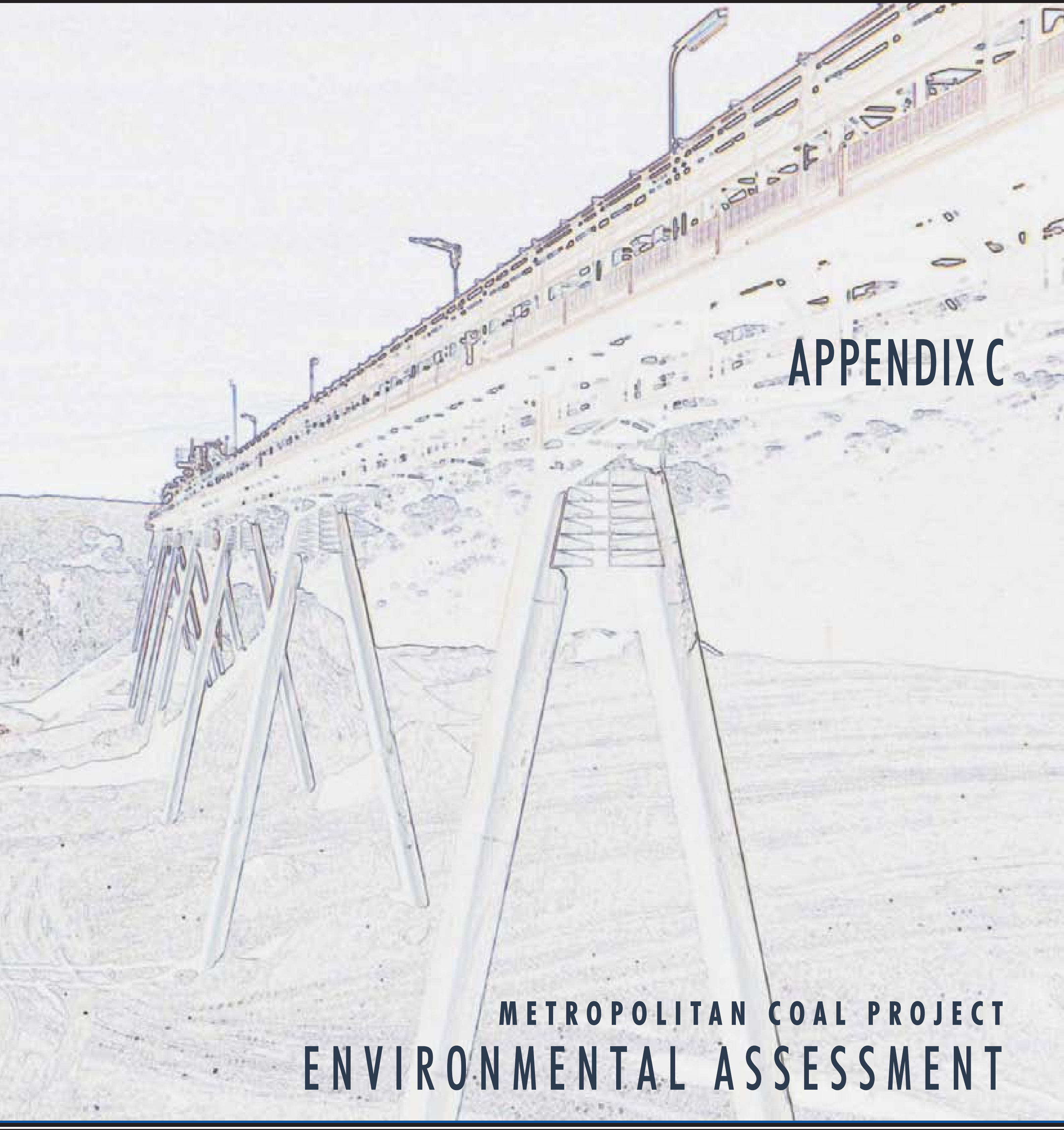

APPENDIX C

METROPOLITAN COAL PROJECT

ENVIRONMENTAL ASSESSMENT

Gilbert & Associates Pty Ltd

HYDROLOGY AND WATER MANAGEMENT CONSULTANTS

METROPOLITAN COAL PROJECT

Surface Water Assessment

Prepared for: **Helensburgh Coal Pty Ltd**

Aug-08
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1.0 INTRODUCTION

Helensburgh Coal Pty Ltd (HCPL), a subsidiary of Peabody (Pacific) Pty Ltd, own and operate the Metropolitan Colliery near the township of Helensburgh in the Illawarra Region of New South Wales (NSW). HCPL is seeking approval for continuation of underground mining operations at the Metropolitan Colliery. Gilbert & Associates Pty Ltd was commissioned to undertake an assessment of the surface water aspects of the Metropolitan Coal Project (the Project) as part of the environmental assessment required for regulatory approval.

Mining at the Metropolitan Colliery commenced in the 1880s. Modern longwall mining of the Bulli Seam commenced in 1995 with some 15 longwall panels having been completed to date. Coal extracted from the underground mining operations is conveyed to the coal processing and rail loading facilities at the pit top in Helensburgh. Reject from the coal processing operations is transported by truck to the Glenlee Washery for emplacement.

The Project, which would extend the life of the operation by some 23 years, would involve the continuation of underground mining operations over an additional 25 longwall panels to the north of the currently approved longwall mining area. The existing processing and coal transport infrastructure would be retained and upgraded as necessary to service the Project.

Surface water catchments relevant to the Project operations comprise the local catchment area which drains and receives drainage from the pit top facilities in Helensburgh and the catchments which overlie and are downstream of the proposed underground mining areas. The approximate location and extent of these catchments are shown on Figure 1 (Pit Top Catchments) and Figure 2 (Longwall Mine Area Catchments).

A description of the Project is provided in Section 2 of the Main Report of the Environmental Assessment (EA).

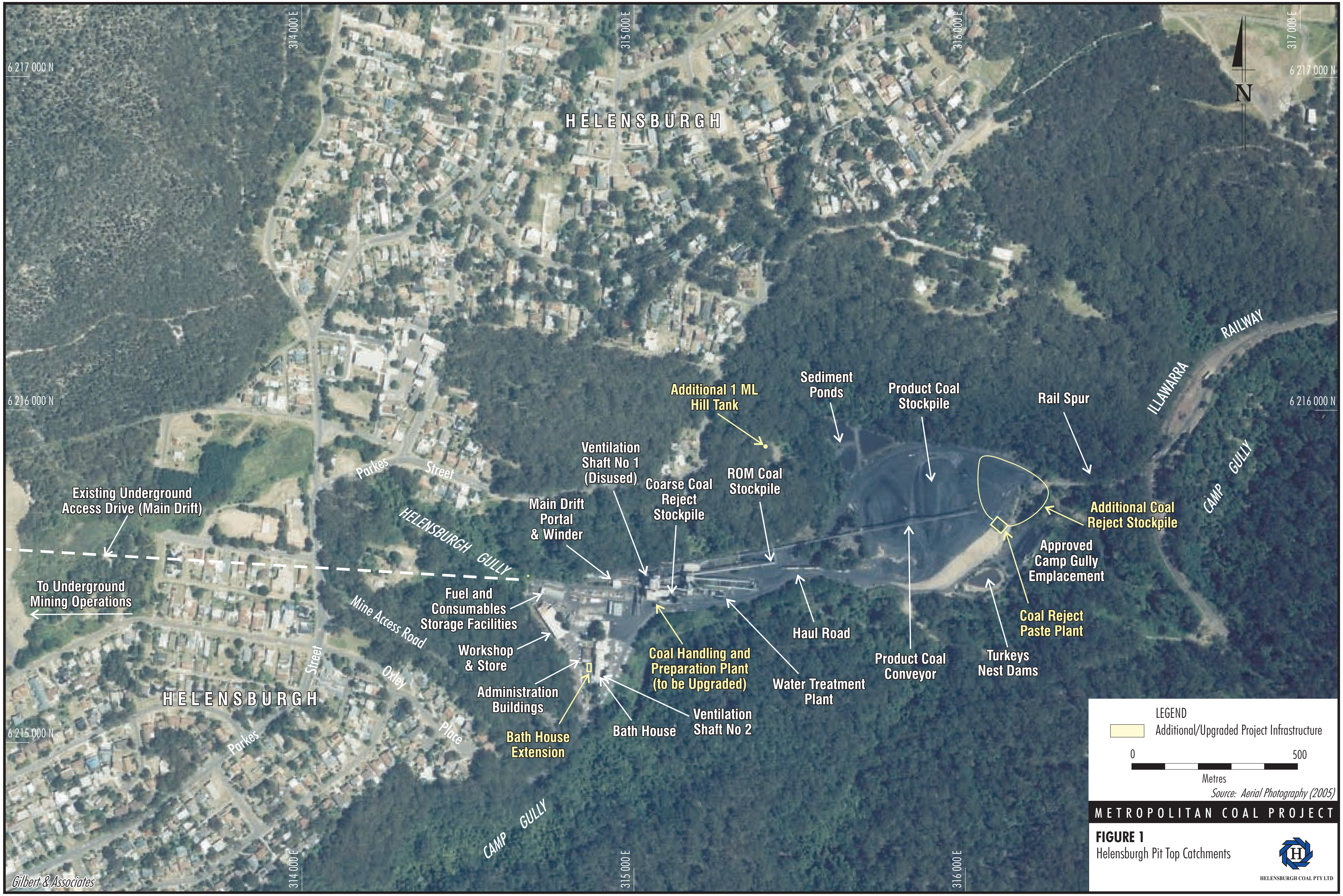
1.1 Study Requirements and Scope

This assessment has been prepared in accordance with the Director-General's Environmental Assessment Requirements (EARs) for the Metropolitan Coal Project environmental assessment (NSW Department of Planning, 30 July 2008). In relation to surface water the EARs require:

*"**Soil & Water** – including:*

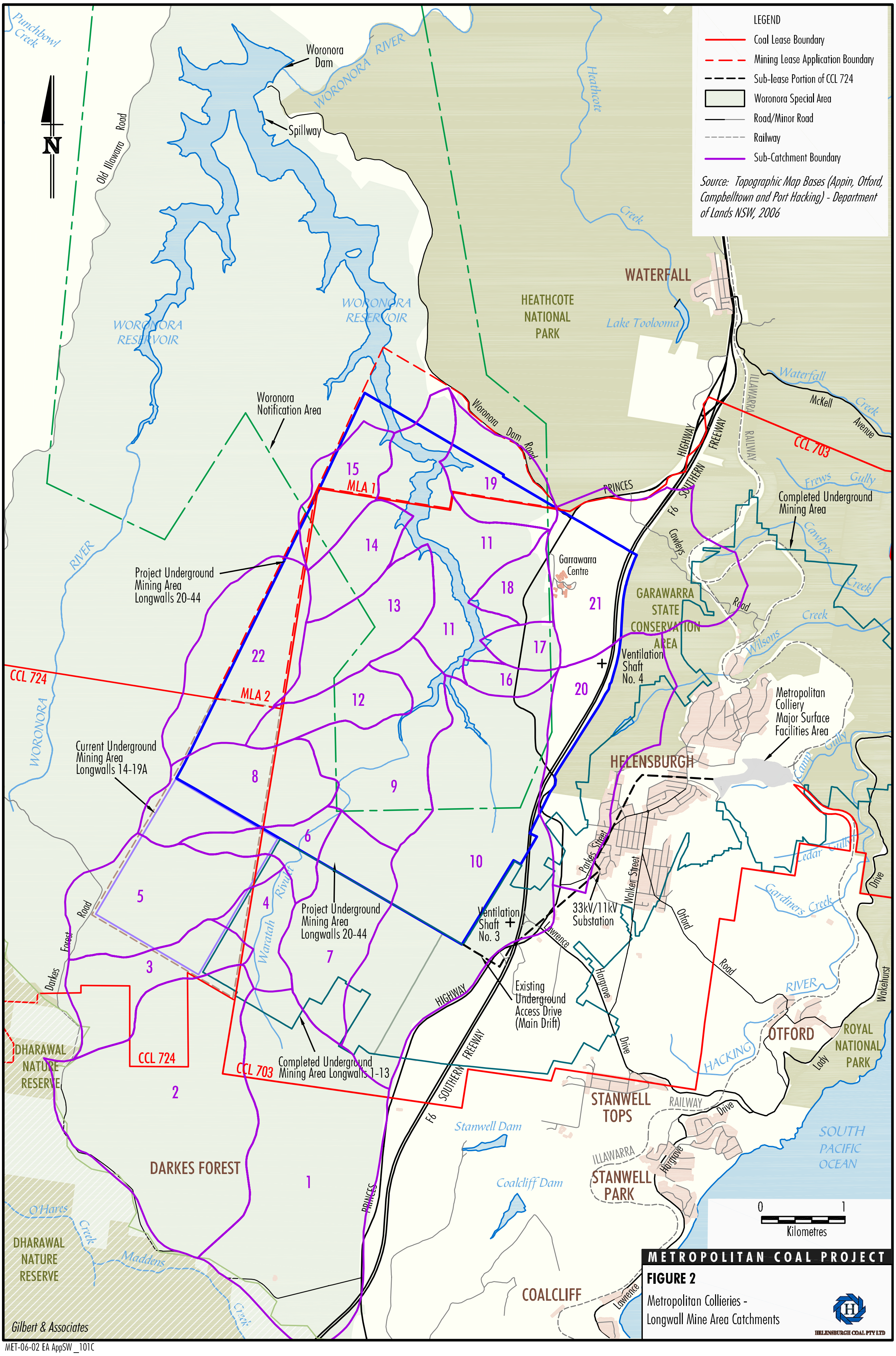
- *…- a detailed assessment of the potential impacts of the project on the quantity, quality and long-term integrity of the surface and ground water resources in the project area, paying particular attention to the Waratah Rivulet and Lake Woronora; and*
- *…development of a site water balance, a detailed description of the measures that would be implemented on site to minimise the water use of the project."*

This assessment has also considered a number of policies, guidelines and plans that were referenced by the EARs for consideration in the surface water assessment, where relevant.



METROPOLITAN COAL PROJECT

FIGURE 1
Helensburgh Pit Top Catchments



METROPOLITAN COAL PROJECT

FIGURE 2

Metropolitan Collieries - Longwall Mine Area Catchments

This assessment also addresses specific assessment issues raised by government agencies during the consultation process for the Metropolitan Coal Project, including:

- potential impacts on the quantity and quality of water in water courses and water storages;
- existing surface and groundwater interactions and the impact of the project on these interactions;
- an assessment of whether the project would have a neutral or beneficial effect on water quality (consistent with the requirements of the Drinking Water Catchments Regional Environmental Plan);
- an assessment of the effect of the project on local streams and surface water yield to the Woronora Reservoir;
- an assessment of the Project's potential impact on local water quality and the persistence of any impacts along the length of Waratah Rivulet and in the Reservoir;
- details of the validation and accuracy of models used in the impact assessment; and
- management of waste water and measures to minimise water use.

As part of the assessment process an environmental risk analysis (Appendix O of the Environmental Assessment) was undertaken. This included a facilitated, risk based workshop involving experts across a range of disciplines and experienced mine managers/operators. The objective of the assessment was to identify key potential environmental issues for inclusion in the Environmental Assessment. The following key potential surface water related issues were identified:

- Cracking of upland swamps leading to deterioration (vegetation composition and health, hydrology, fire susceptibility and erosion).
- Surface water quality - local and Reservoir.
- Water loss from reservoir.
- Loss of stream connectivity.
- Site water discharges.
- Increased demand on water usage.

The surface water assessment has drawn on subsidence predictions produced by Mine Subsidence Engineering Consultants (MSEC, 2008)[1]; a hydrogeological assessment undertaken by Heritage Computing (2008)[2]; results of surface water monitoring of overlying and downstream water courses and ground reconnaissance of the catchment areas and drainages overlying both previously mined areas and the proposed mine development area.

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[1] MSEC (2008), "The Prediction of Subsidence and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Proposed Extraction of Longwall 20 to 44 at Metropolitan Colliery in Support of a Part 3A Application", Prepared for Helensburgh Coal Pty Ltd.

[2] Heritage Computing (2008), "Hydrogeological Assessment In Support Of Metropolitan Colliery Longwalls 20 to 44 Environmental Assessment". Prepared for Helensburgh Coal Pty Ltd.

The surface water assessment has been compiled to address the EARs; issues raised by government agencies during the consultation process; and the surface water related issues identified in the environmental risk analysis. A number of key guidelines have also been used as a basis for assessing impact including:

- National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ).
- National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ).
- Using the ANZECC Guideline and Water Quality Objectives in NSW (DEC).
- State Water Management Outcomes Plan.
- NSW Government Water Quality and River Flow Environmental Objectives (DECC).

The aims and objectives of the Greater Metropolitan Regional Environmental Plan No.2 – Georges River Catchment and the Drinking Water Catchments Regional Environmental Plan No.1 have also been considered. Further discussion is provided in Section 3 of the Main Report of the EA.

The objects of the Water Management Act (NSW) 2000, which is the principal statute governing management of water resources in NSW, were also considered during the assessment. The objects of the Water Management Act, 2000 include:

> *" to provide for the sustainable and integrated management of the water sources of the State for the benefit of both present and future generations and, in particular:*
>
> *(a) to apply the principles of ecologically sustainable development, and*
>
> *(b) to protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity and their water quality, and*
>
> *(c) to recognise and foster the significant social and economic benefits to the State that result from the sustainable and efficient use of water, including:*
>
> > *(i) benefits to the environment, and*
> >
> > *(ii) benefits to urban communities, agriculture, fisheries, industry and recreation, and*
> >
> > *(iii) benefits to culture and heritage, and*
> >
> > *(iv) benefits to the Aboriginal people in relation to their spiritual, social, customary and economic use of land and water,*
>
> *(d) to recognise the role of the community, as a partner with government, in resolving issues relating to the management of water sources,*
>
> *(e) to provide for the orderly, efficient and equitable sharing of water from water sources,*
>
> *(f) to integrate the management of water sources with the management of other aspects of the environment, including the land, its soil, its native vegetation and its native fauna,*
>
> *(g) to encourage the sharing of responsibility for the sustainable and efficient use of water between the Government and water users,*
>
> *(h) to encourage best practice in the management and use of water.*

2.0 REGIONAL HYDROMETEOROLOGY

2.1 General

The Metropolitan longwall mine is situated within the Woronora Reservoir catchment. The Woronora Reservoir supplies water to consumers within the Sutherland Shire Council area. The Woronora Reservoir catchment is part of the SCA's Special Water Supply Catchment Area. The area is relatively undisturbed and closed to public access.

The geology of the Woronora catchment is dominated by the Hawkesbury Sandstones which outcrop in plateau areas and along sections of the valley sides. There are also extensive areas of Hawkesbury Sandstone outcropping along tributaries within the mine development area.

There is significant topographic relief in the catchment and a relatively high drainage density. Surface elevations vary from 170 metres (m) to 390m AHD[3] with ridgelines typically rising between 50 and 100 m above the valley floor. Vegetation comprises predominantly undisturbed eucalypt woodland, heath, mallee and upland swamp vegetation.

2.2 Climate

The area experiences a wet temperate climate. Temperatures vary from average monthly maxima of 26^{0}C in January to 17^{0}C in July. Minimum monthly average temperatures vary from 7.9^{0}C in July to 17.1^{0}C in February. The rain gauge at Darkes Forest immediately south of the mine development area is the closest Bureau of Meteorology rainfall gauge with reliable long term record (1894 to date). The average annual rainfall over this period is about 1,420 mm.

Potential (pan) evaporation (based on the discontinued SCA station at the Woronora Dam) is some 1,150 mm per year. The average monthly rainfall and potential evaporation statistics from these stations are summarised in Table 1 below.

Table 1
Monthly Average Rainfall and Evaporation (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Rainfall*	135	157	154	125	135	140	99	93	75	94	104	107
Average Evaporation**	158	126	106	72	64	43	46	66	90	124	135	168

* Darkes Forest Record 1894 – 2007.
** Woronora Reservoir 1976 – 2002.

Rainfall is typically spread throughout the year but tends to be higher in the summer months. Rainfall intensity and the regularity of rainfall are particular features of the area that have a significant bearing on surface water hydrology including runoff frequency, propensity of floods and on the moisture levels in catchment soils.

[3] Australian Height Datum

Figure 3, which has been reproduced from a map published by IEAust (1987), shows that rainfall intensity in southern NSW is highest near the coast and decreases inland. It also shows that rainfall intensity is affected by local topography and compared to other areas is relatively high near the south coast escarpment.

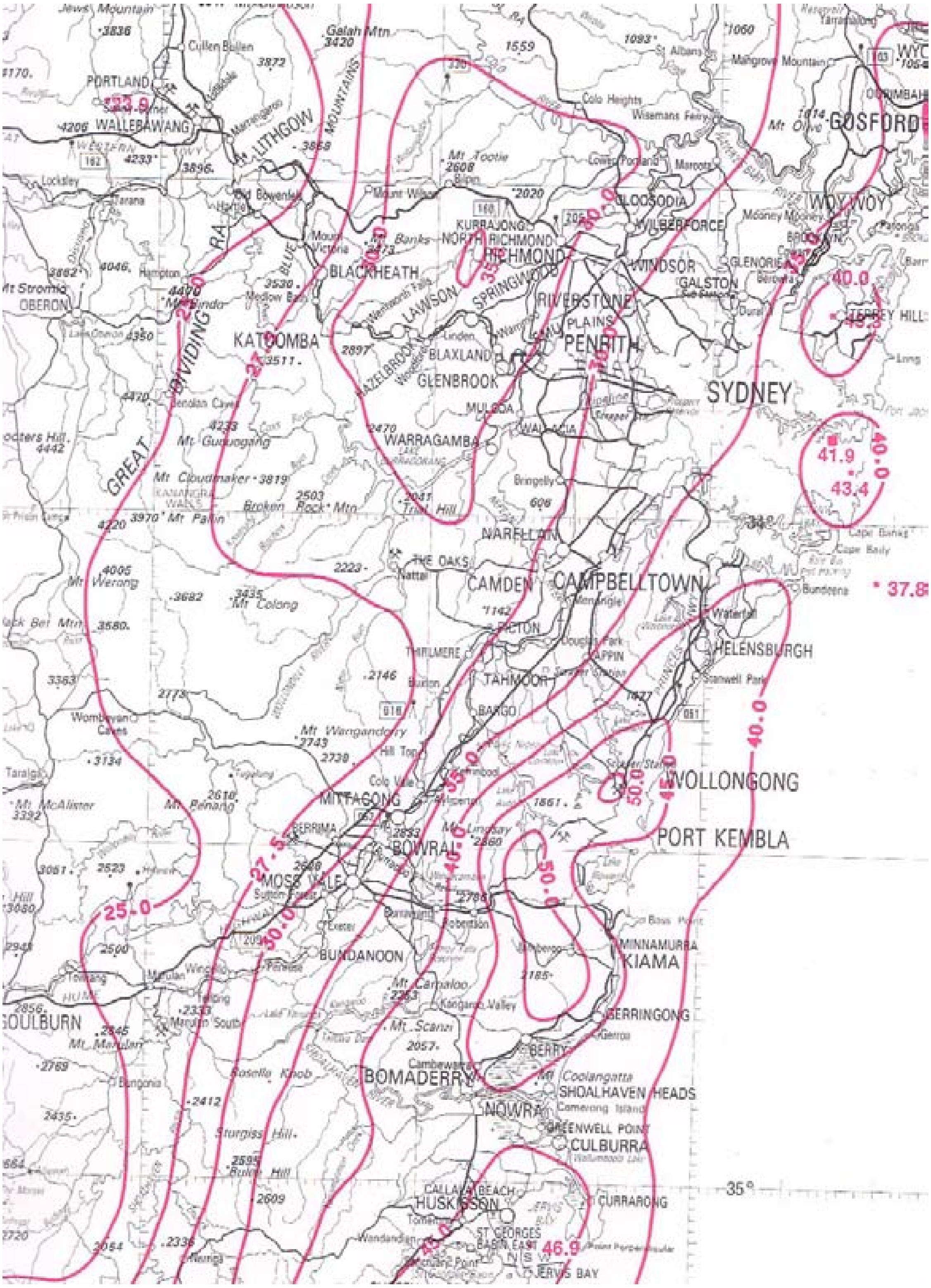


Figure 3 Rainfall Intensity Isopleths for 1 in 2 year ARI, 1 hour Duration - South Coast of NSW

Analysis of the rainfall records from the Darkes Forest rain gauge indicate that extended dry periods are relatively rare - refer Figure 4 below.

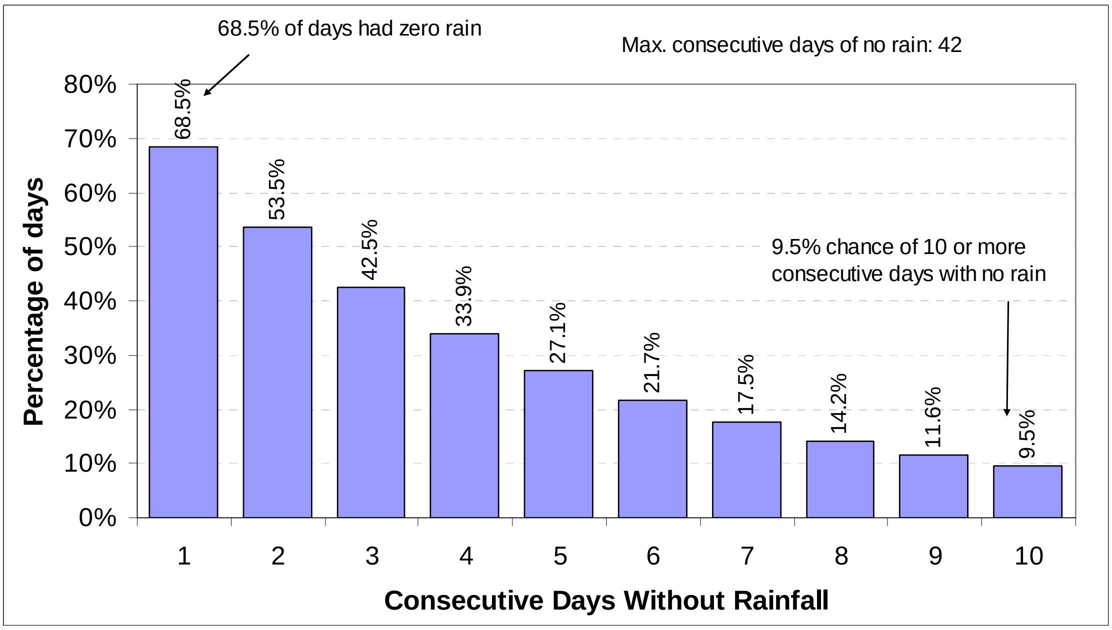


Figure 4 Dry Period Duration Exceedence Characteristics – Darkes Forest

The plot illustrates that rainfall has occurred on some 31% of days over the period of record whilst non rainfall periods lasting 10 consecutive days or longer have occurred for about 10% of the time. The longest continuous dry period on record is 42 days which has occurred twice, once in 1918 and once in 1946. The regularity of rainfall maintains high moisture levels in the catchment which typically has relatively thin sandy soils with low moisture retention capacity.

The surface water assessments reported later in this document have utilised monitoring data collected over various periods ranging from the long rainfall record at Darkes Forest to the most recent water quality and flow monitoring stations which were established in 2007. Rainfall trends over different time periods can be a relevant factor in interpreting hydrological data. Trends in past rainfall can be seen in rainfall residual plots[4] which show departures from average rainfall. Rainfall trends over three time periods are shown below. In each case the rainfall residuals are shown relative to the average rainfall over the period being considered. The first period shown on Figure 5 covers the period 1900 to date. It shows a trend of generally below average rainfall between 1900 and 1949 followed by a period of generally wetter than average rainfall over the remainder of the record.

[4] Rainfall residual plots are formulated by subtracting actual rainfall from the average and then accumulating these residuals over the assessment period. Periods where the cumulative rainfall residual slopes downward correspond to below average rainfall. Upward sloping cumulative residuals indicate above average rainfall. The steepness of the cumulative residual line reflects the relative magnitude of the departure from average conditions. The residual plots shown in this report have not been corrected for seasonal effects.

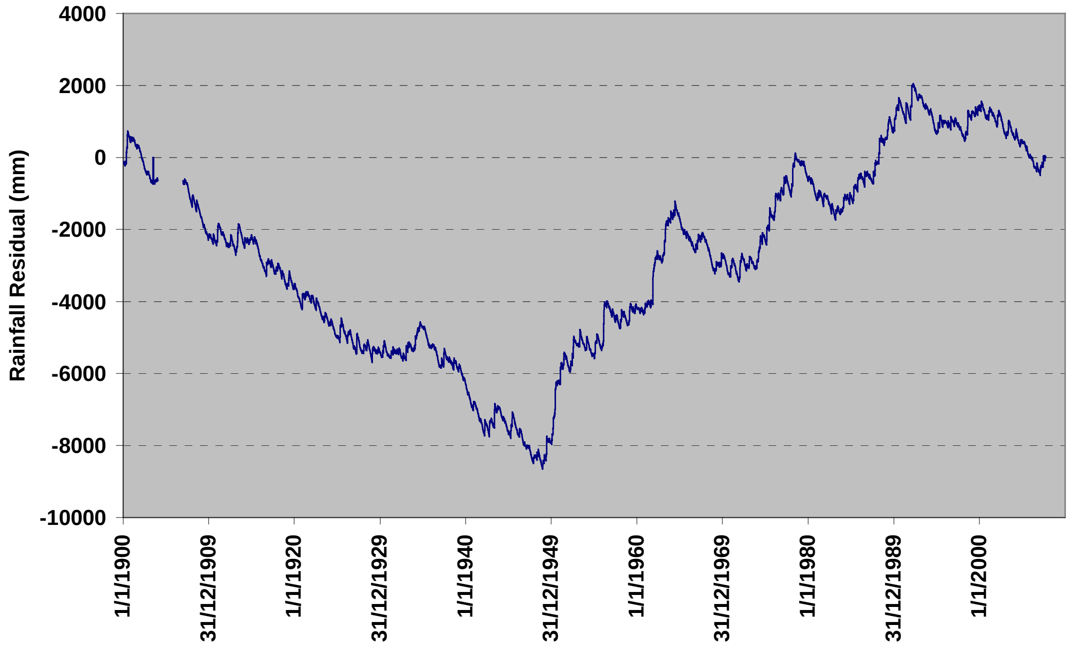


Figure 5 Rainfall Residuals – Darkes Forest Rain Gauge 1900 to 2007

The second figure in this series (Figure 6) shows rainfall trends over the period 1940 to 2007 – corresponding to the period since Woronora Dam was constructed and the period where hydrological water quality data from the reservoir is generally available. Rainfall residuals over this period have included several cycles of above average followed by below average rainfall which have typically lasted for 10 - 15 years. These patterns appear to have been influenced by the Southern Oscillation Index (SOI). The most recent period (starting in 1992) has generally seen below average rainfall but which is not dissimilar to other periods of below average rainfall in the last 50 years.

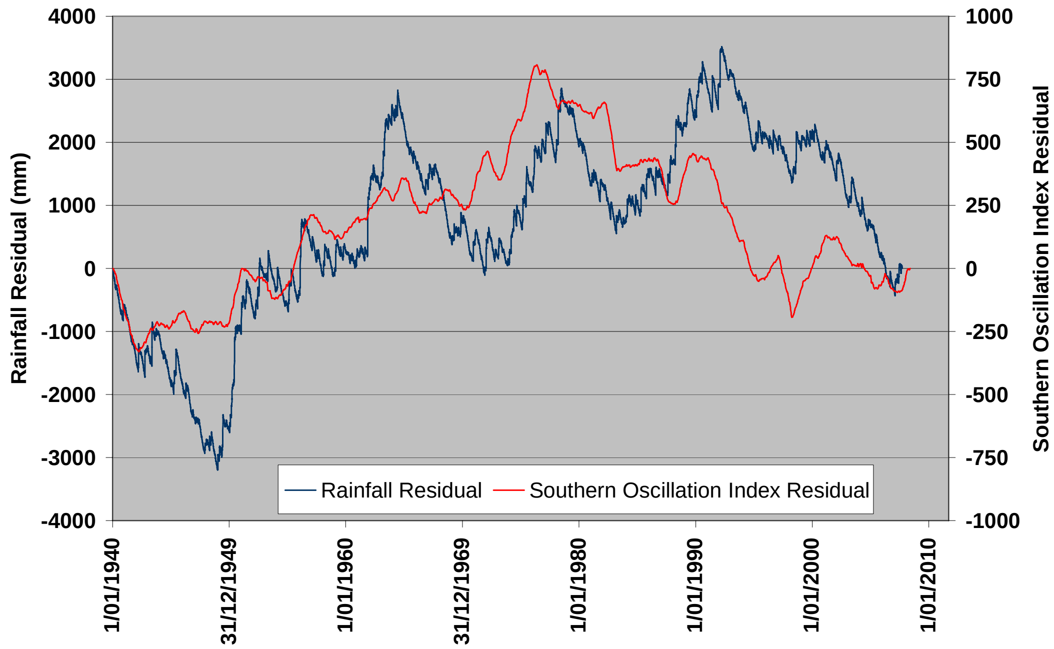


Figure 6 Rainfall and SOI Residuals – Darkes Forest Rain Gauge 1940 to 2007

The third figure in this series (Figure 7) shows the rainfall residual since 1995 - corresponding to the period since longwall mining commenced. The overall trend evident in this plot is a weak trend of higher than average rainfall from 1995 until 2000 which was followed by a stronger trend of generally below average rainfall from 2000 to early 2007 followed by a period of higher than average rainfall. These general trends are overlayed by seasonal variability and possibly show the influence of El Niño and La Niña episodes - as indicated by changes in the SOI.

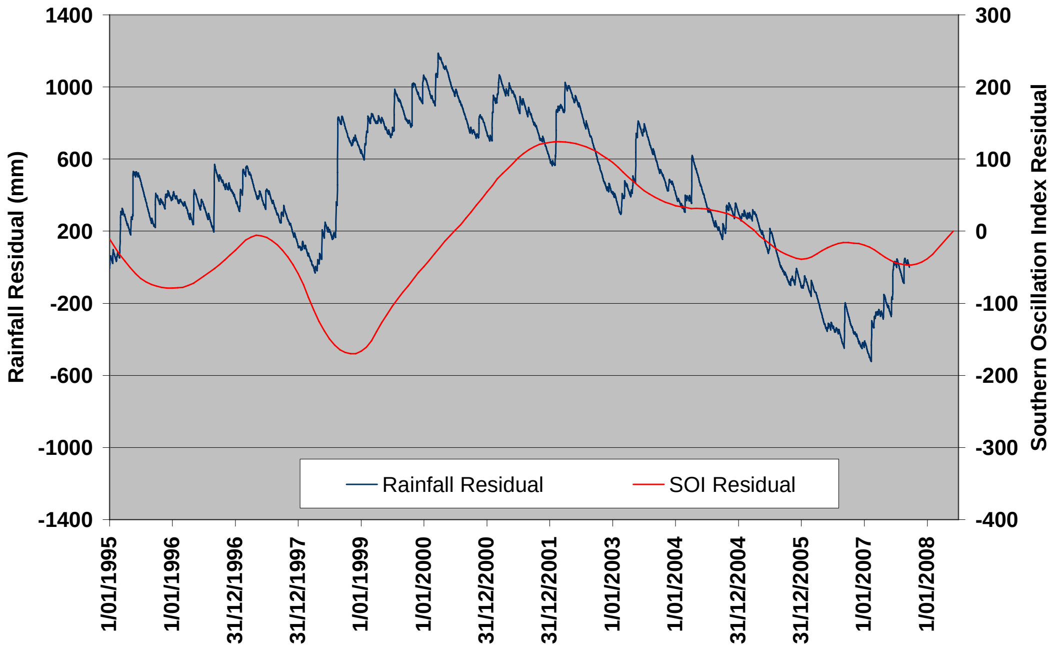


Figure 7 Rainfall and SOI Residuals – Darkes Forest Rain Gauge 1995 to 2007

2.3 Regional Catchments and Streamflow

The proposed mine development area is predominantly within the Waratah Rivulet catchment which is a major tributary inflow to the Woronora Reservoir and other tributaries that flow direct to the Woronora Reservoir – refer Figure 2. There is a small component of the mining area which drains eastward to Cawley's Creek and Wilson's Creek which drains to the Hacking River. Waratah Rivulet commands a catchment of some 22 km^2 above the inundation limits of the Woronora Reservoir. Overflows from the dam flow into the lower reaches of Woronora River and ultimately into the Georges River which flows into Botany Bay. The other significant catchment in the region is the Nepean River which flows north ultimately joining the Hawkesbury River on the northern outskirts of Sydney.

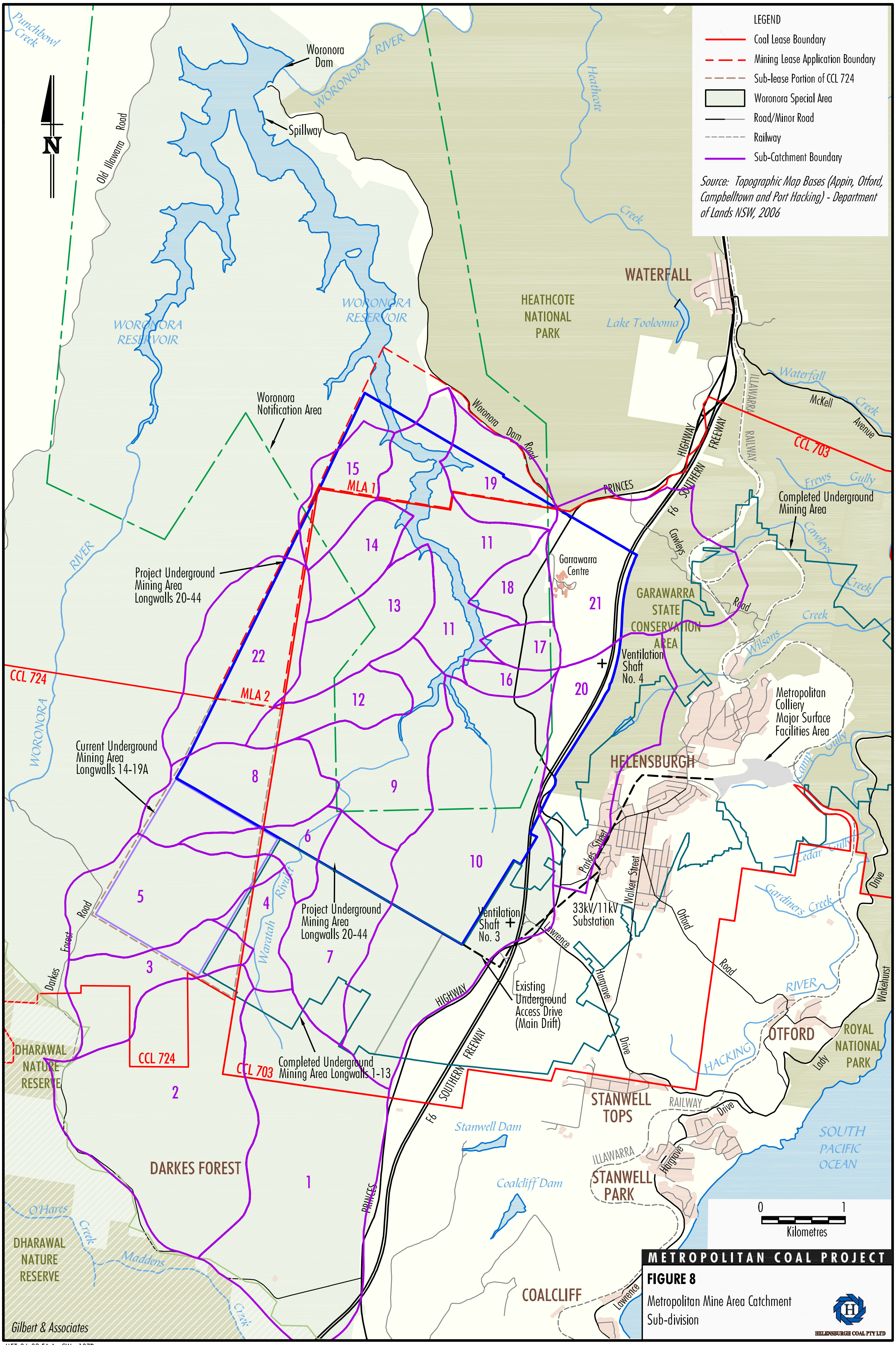
The closest gauged catchment is O'Hares Creek which is south of the Woronora catchment. The Department of Water and Energy (DWE - formerly the Department of Natural Resources) operated two gauging stations on O'Hares Creek. The most upstream site (GS210002) is some 5 km south-west of the mine and was operated between 1924 and 1930. This station commands a catchment area of 16 km^2. The headwater areas of O'Hares Creek – above this stream gauge location – comprise mostly undisturbed Hawkesbury Sandstone terrain similar to the Waratah Rivulet catchment. The second site (GS210200) is located approximately 20km north-east of the mine near the town of Wedderburn. This station commands a catchment of some 73 km^2 and has been in operation since 1978.

Daily recorded streamflow data was sourced for these two stations from the DWE database. The mean annual runoff from the downstream station is equivalent to some 367 mm or about 26% of average rainfall at Darkes Forest.

2.4 Longwall Mine Area Catchments

For descriptive purposes the Waratah Rivulet catchment has been subdivided into 21 sub-catchments. The catchment subdivision provides a convenient means of describing the main features and their distribution within the overall mine area catchments in a manner which enables these features to be matched to existing and proposed longwall mining activities. The catchment subdivision was based on internal watersheds bounding large tributaries and portions of tributaries which have either large drainage networks (stream order 3 or above) or which drain a large proportion (10% or more) of the total catchment or that contain particular features. The adopted catchment subdivision is shown in Figure 8 below.

The key attributes of these sub-catchments are summarised in Table 2 below.



METROPOLITAN COAL PROJECT

FIGURE 8

Metropolitan Mine Area Catchment Sub-division

Table 2 Summary of Mine Area Catchments and Sub-Catchments

Sub-catchment No.	Local Catchment/Sub-Catchment	Location	Past Mining Activities	Proposed Mine Activities
1	Upper Waratah Rivulet	Headwaters down to confluence with Flat Rock Creek	Old bord and pillar workings	None
2	Flat Rock Creek	Headwaters to confluence with upper Waratah Rivulet	Old bord and pillar workings	None
3*	Forest Gully	Left bank tributary of Waratah Rivulet	Un-mined in western extremity; old bord and pillar workings in southern extremity; LW 11,12,13,14 & 15	None
4*	Waratah Rivulet from Flat Rock Creek to Un-named tributary confluence		LW 9,10,11,12,13 & 14	None
5*	Un-named tributary	Left bank tributary of Waratah Rivulet	Upper sections outside mine area; mid sections LW 18,19&19A; lower sections LW 13,14,15,16 &17	None
6*	Waratah Rivulet Un-named Tributary to Eastern-Central Tributary		Gate Road and LW 11, 12, 14, 15, 16; includes Flat Rock Crossing	LW 20, 21 & 22
7	Eastern Central Tributary	Right bank tributary of Waratah Rivulet	LW 5, 6, 7, 8, 9 & 10	LW 20, 21 & 22
8*	Reference Tributary	Left bank tributary of Waratah Rivulet	Approved LW 17, 18, 19 & 19A	LW 20, 21, 22, 23 & 24
9	Waratah Rivulet Eastern-Central Tributary to Eastern Tributary confluence		None	LW 22 to 33
10	Eastern Tributary	Major right bank tributary	LW 1, 2, 3 & 4	LW 20 to 36
11	Lower Waratah Rivulet from Eastern Tributary to upstream end mine area in Woronora Reservoir		None	LW 33 to 44
12	Left bank upland swamp tributary 1	Small left bank tributary draining direct to Woronora Reservoir	None	LW 23 to 31

* Sub-catchments within the Current Underground Mining Area.

Table 2 (Continued) Summary of Mine Area Catchments and Sub-Catchments

Sub-catchment No.	Local Catchment/Sub-Catchment	Location	Past mining activities	Proposed mine activities
13	Left bank upland swamp tributary 2	Small left bank tributary draining direct to Woronora Reservoir	None	LW 26 to 39
14	Left bank upland swamp tributary 3	Small left bank tributary draining direct to Woronora Reservoir	None	LW 31 to 39
15	Left bank upland swamp tributary 4	Small left bank tributary draining directly to Woronora Reservoir	None	LW 34 to 43
16	Right bank upland swamp tributary 1	Small right bank tributary draining directly to Woronora Reservoir	None	LW 33 to 36
17	Right bank upland swamp tributary 2	Small right bank tributary draining directly to Woronora Reservoir	None	LW 35 to 39
18	Right bank upland swamp tributary 3	Small right bank tributary draining directly to Woronora Reservoir	None	LW 37 to 43
19	Right bank upland swamp tributary 4	Small right bank tributary draining directly to Woronora Reservoir	None	Parts of LW 41 to 43 in southern extremity of catchment
20	Upper Wilson's Creek	Upper reaches of easterly flowing tributary of the Hacking River	None	Eastern extremities of LW 32 to 37
21	Upper Cawley's Creek	Upper reaches of easterly flowing tributary of the Hacking River	None	LW 37 to 44
22	Upper Honeysuckle Creek	Upper reaches of Tributary which flows into Woronora Reservoir	None	Western ends of LW 22 to 24 in southern extremity of catchment, through to LW34 in northern extremity

The key hydraulic and geomorphologic characteristics of the sub-catchments are summarised in Table 3 below.

Table 3 Hydraulic and Geomorphic Attributes of the Sub-Catchments

Sub-catchment No.	Local Catchment/Sub-Catchment	Location	Catchment Area (ha)	Stream Order	Average stream gradient (m/km)	Stream Length (km)	Comments
1	Upper Waratah Rivulet	Headwaters down to confluence with Flat Rock Creek	578	3	26	3.9	Overlying old bord and pillar workings and largely undisturbed catchment. Moderately steep incised gully lines.
2	Flat Rock Creek	Headwater catchment to confluence with upper Waratah Rivulet	546	3	38	3.64	Overlying old bord and pillar workings and largely undisturbed catchment. Lower reaches dominated by Flat Rock Swamp.
3	Forest Gully	Left bank tributary of Waratah Rivulet	158	2	59	2.36	Small tributary on left bank of Waratah Rivulet. Moderately steep incised gully with numerous small in-stream pools.
4	Waratah Rivulet from Flat Rock Creek to Un-named tributary confluence	Mid reach of Waratah Rivulet	76	4	6	1.64	Mid section of Waratah Rivulet overlying longwalls 10, 11 and 12. In-stream Pools A, B, C and E.
5	Un-named tributary	Left bank tributary of Waratah Rivulet	234	3	51	2.76	Small tributary on left bank of Waratah Rivulet. Moderately steep incised gully with numerous small in-stream pools.

Table 3 (Continued) Hydraulic and Geomorphic Attributes of the Sub-Catchments

Sub-catchment No.	Local Catchment/Sub-Catchment	Location	Catchment Area (ha)	Stream Order	Average stream gradient (m/km)	Stream Length (km)	Comments
6	Waratah Rivulet from Un-named Tributary to Eastern-Central Tributary	Mid reach of Waratah Rivulet to confluence of the Reference Tributary	91	4	20	1.02	Mid section of Waratah Rivulet mostly downstream of current longwall mining. In-stream Pools F, G and G1, H, I, J, K, L, M, N, and O.
7	Eastern Central Tributary	Right bank tributary of Waratah Rivulet	205	2	43	2.78	Medium sized tributary on right bank of Waratah Rivulet. Moderately steep incised gully with numerous small in-stream pools
8	Reference Tributary	Left bank tributary of Waratah Rivulet	201	3	61	2.8	Medium sized tributary on left bank of Waratah Rivulet. Moderately steep incised gully with numerous small in-stream pools.
9	Waratah Rivulet Eastern Tributary to Reservoir inundation limit	Right bank tributary of Waratah Rivulet	215	4	12	2.6	Lower section of Waratah Rivulet In-stream Pools P, Q, R, S, T, U, V and W.
10	Eastern Tributary	Major right bank tributary	670	3	26	5.4	Main mid-reach tributary of Waratah Rivulet. Moderately steep incised valley with numerous in-stream pools. Pools in lower reaches are larger and similar to pools in Waratah Rivulet.

Table 3 (Continued) Hydraulic and Geomorphic Attributes of the Sub-Catchments

Sub-catchment No.	Local Catchment/Sub-Catchment	Location	Catchment Area (ha)	Stream Order	Average stream gradient (m/km)	Stream Length (km)	Comments
11	Woronora Reservoir Inundation Area	Downstream of Waratah Rivulet	269	N/A	N/A	3.7	Downstream of Waratah Rivulet arm of Woronora Reservoir.
12	Left bank upland swamp tributary 1	Small left bank tributary draining direct to Woronora Reservoir	90	2	77	1.96	Small headwater catchment in mid reaches of Waratah Rivulet. Contains large upland-headwater swamp.
13	Left bank upland swamp tributary 2	Small left bank tributary draining direct to Woronora Reservoir	155	2	62	2.1	Small headwater catchment in mid reaches of Waratah Rivulet. Contains large upland-headwater swamp.
14	Left bank upland swamp tributary 3	Small left bank tributary draining direct to Woronora Reservoir	93	1	65	1.84	Small headwater catchment in lower reaches of Waratah Rivulet. Contains large upland-headwater swamp.
15	Left bank upland swamp tributary 4	Small left bank tributary draining directly to Woronora Reservoir	102	2	69	1.3	Small headwater catchment in lower reaches of Waratah Rivulet. Contains large upland-headwater swamp.
16	Right bank upland swamp tributary 1	Small right bank tributary draining directly to Woronora Reservoir	35	1	122	0.82	Steep, inaccessible head water gully.

Table 3 (Continued) Hydraulic and Geomorphic Attributes of the Sub-Catchments

Sub-catchment No.	Local Catchment/Sub-Catchment	Location	Catchment Area (ha)	Stream Order	Average stream gradient (m/km)	Stream Length (km)	Comments
17	Right bank upland swamp tributary 2	Small right bank tributary draining directly to Woronora Reservoir	42	1	144	0.9	-
18	Right bank upland swamp tributary 3	Small right bank tributary draining directly to Woronora Reservoir	64	1	133	0.98	-
19	Right bank upland swamp tributary 4	Small right bank tributary draining directly to Woronora Reservoir	122	3	63	1.12	-
20	Upper Wilson's Creek	Upper reaches of easterly flowing tributary of the Hacking River	288	3	52	3.1	-
21	Upper Cawley's Creek	Upper reaches of easterly flowing tributary of the Hacking River	353	3	51	2.92	-
22	Upper Honeysuckle Creek	Upper reaches of Tributary which flows into Woronora Reservoir	266	2	28	2.82	Medium sized catchment with relatively large upland swamp in its headwaters.

2.5 Camp Creek

The processing operations at the Helensburgh Pit Top area are contained within the Camp Creek catchment – refer Figure 2. Camp Creek commands a catchment area of some 3.8km^2 at its confluence with the Hacking River. The Hacking River flows into Port Hacking and the South Pacific Ocean. The key statistics of these catchments are summarised in Table 4 below.

Table 4
Summary – Local and Regional Catchments

Catchment Name	Total Catchment Area (km^2)	Predominant Landuse
Camp Creek	3.8	Undisturbed remnant bushland
Hacking River	117.3	Mixed urban and bushland

3.0 EXISTING SURFACE WATER MANAGEMENT – HELENSBURGH PIT TOP FACILITIES AREA

The existing coal washery and load out facilities are located in a steep-sided valley adjacent to the town of Helensburgh and next to Camp Gully (refer Figure 2). Helensburgh Gully, to which some of the town drains, passes beneath the site via a tunnel and drains into Camp Gully. Runoff from most of the catchment upslope of the washery, workshop and stockpile areas is diverted around the north of the site and either into Helensburgh Gully or Camp Gully. Runoff from the administration/bathhouse area (from roofs and paved or grassed areas) drains to Camp Gully, while runoff from the washery, workshop and stockpile areas is collected in the site water management system.

The site water management system comprises a series of collection dams and treatment systems. It is operated to minimise off site release of site runoff and to provide a water supply for non-potable requirements on site. Figure 9 shows a detailed schematic of the water management system, the key features of which are described below:

- A pair of excavated **"Turkey's Nest" dams** at the most downhill (easterly) point of the site. The main (most downhill) dam collects runoff from the product coal stockpile and coal rejects areas. Any spill from the sediment dams (refer below) also reports to the Turkey's Nest dams. Water is pumped from the lower dam to the adjacent upper Turkey's Nest (which has a limited catchment) as required to maximise the freeboard in the lower dam during/following rainfall events. Any release from the Turkeys' Nest dams flows to Camp Gully. The catchment area of the Turkey's Nest dams is estimated at 6.1ha.

- A series of three **sediment ponds** are located on the northern side of the site. The first of these collects runoff from the ROM coal stockpile and truck wash areas. The first dam spills into either the second or third pond to facilitate settling of sediment. The catchment area of the sediment ponds is estimated at 2.9ha.

- A concrete-lined sump, known as the "**Taj**" captures runoff and incidental spills from the majority of the washery and workshop areas. The catchment area reporting to the Taj is estimated to be 4.7ha. The Taj also receives pumped inflow from the underground mine and drainage from the truckwash facility. Water from the Turkey's Nest dams and sediment ponds can also be pumped to the Taj. Spill from the Taj would flow to the sediment ponds.

- Water from the Taj is used to feed two **water treatment plants**. One of these (the larger capacity) is used to supply the washery directly and for dust suppression (truckfill) use and would also be used for the proposed underground tailings paste plant. The second treatment plant discharges treated water to a discharge tank for release under a discharge licence to Camp Gully. The discharge tank can also supply water to other tanks which in turn are used for supply to the underground operations, dust suppression and the washery. During and following wet weather the water provided by the treatment plants can be used to supply the requirements of the coal washery and underground mine.

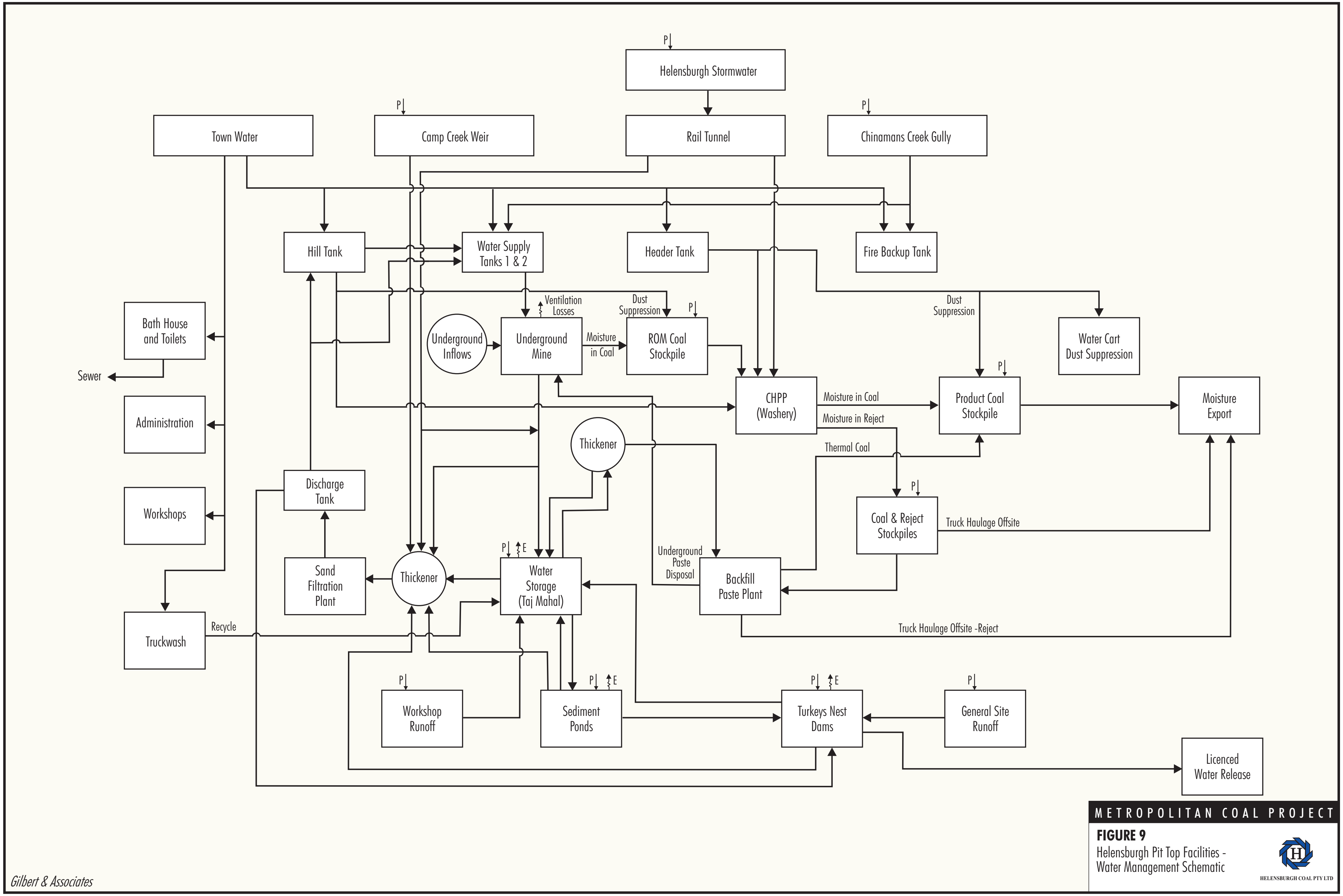


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FIGURE 9
Helensburgh Pit Top Facilities - Water Management Schematic

HELENSBURGH COAL PTY LTD

MET-06-02 EA AppSW_003C

- Site make-up supply is drawn, in part, by pumping from a **weir on Camp Gully**. Water is pumped to the second of the treatment plants prior to use.

- Additional site make-up supply is drawn from a disused **rail tunnel** which contains stormwater runoff from Helensburgh. Water from the rail tunnel is pumped either to the Taj, direct to the washery or to the second water treatment plant.

- The differential site make-up supply is sourced from **Helensburgh town water**. Town water is used to supply the potable requirements of the bathhouse, administration and workshop, the truckwash facility and to top-up tanks which provide water to the underground mine, coal washery and for dust suppression.

The main uses of water on site are to supply underground mining operations (for cooling and dust suppression) and for the coal washery. Water is recycled from underground operations to the Taj, with some water lost through ventilation. Minimal make-up is produced by mine groundwater inflow as the underground mine is essentially dry. Water is exported from the coal washery in product coal and coal rejects.

During 2006 and 2007, HCPL has undertaken a significant upgrade of the operational water management system to increase recycling and reduce make-up water demand from Sydney Water in accordance with the Metropolitan Colliery Water Savings Action Plan (Sydney Water, 2007).

The Project would continue to build on the Metropolitan Colliery initiatives undertaken to date under the Metropolitan Colliery Water Savings Action Plan (Sydney Water, 2007) to increase the efficiency of water use and minimise the requirement for make-up water and off-site water releases. Recommended water conservation and water saving initiatives in the Water Savings Action Plan include:

- permanent monitoring, meter replacement and ongoing water management;
- underground leak detection and repair;
- repair of baseflow in truck wash;
- repair of baseflow in header to washery;
- repair of baseflow in stockpile sprays; and
- disconnection of non-potable uses in washery.

4.0 SIMULATED LIFE OF PROJECT PERFORMANCE OF WATER MANAGEMENT SYSTEM

The Project water management system would generally be based on the existing water management system. The system would be upgraded to address existing water treatment plant quantity limitations and augmented where necessary to address the key additional Project components, such as:

- the upgraded CHPP and coal reject paste plant; and
- underground goaf injection of coal reject paste to the mine void.

Additional water storage capacity (approximately 1 megalitre [ML]) would also be provided.

A daily time step water balance model of the water management system was developed based on a simplified form of the system described above and shown in Figure 9. The aim of the model was to predict system discharge/spill and make-up requirements for predicted future production rates and a range of different climatic scenarios.

The model was set-up to simulate mine water management system operation in the 23 years from 1 to 23, with proposed coal wash tonnages as given in Table 5. Table 6 lists operational parameters used in the model, derived from the site Water Savings Action Plan[5] and information supplied by HCPL.

Table 5
Provisional Mine Schedule

Year	Total ROM Coal (Mtpa)	Total Coking Coal (Mtpa)	Total Thermal Coal (Mtpa)	Total Coal Reject (Mtpa)
1	1.80	1.53	0.03	0.24
2	1.91	1.62	0.03	0.26
3	2.13	1.81	0.03	0.29
4	2.50	2.12	0.04	0.34
5	2.45	2.08	0.04	0.33
6	2.60	2.21	0.04	0.35
7	2.61	2.22	0.04	0.35
8	2.61	2.22	0.04	0.35
9	2.72	2.31	0.04	0.37
10	2.86	2.43	0.04	0.39
11	2.91	2.48	0.04	0.39
12	3.06	2.60	0.05	0.41
13	3.10	2.63	0.05	0.42

[5] Sydney Water (2007). "Metropolitan Colliery Water Savings Action Plan". NSW Department of Commerce, Water Savings Group, Document No. 33466, Sydney, September.

Table 5 (Continued)
Provisional Mine Schedule

Year	Total ROM Coal (Mtpa)	Total Coking Coal (Mtpa)	Total Thermal Coal (Mtpa)	Total Coal Reject (Mtpa)
14	2.99	2.54	0.05	0.40
15	3.19	2.71	0.05	0.43
16	3.02	2.56	0.05	0.41
17	3.03	2.58	0.04	0.41
18	2.86	2.43	0.04	0.39
19	2.97	2.53	0.04	0.40
20	3.03	2.58	0.04	0.41
21	3.15	2.68	0.04	0.43
22	2.80	2.38	0.04	0.38
23	2.60	2.21	0.04	0.35
Total	**62.90**	**53.46**	**0.94**	**8.50**

Table 6
Water Management System Model Key Operational Parameters

Demand		
Truck Wash		0.026 ML/d
Underground		0.671 ML/d
Coal Wash*		153 L/ROM tonne
Bath House		0.027 ML/d
Stockpile Sprays		0.009 ML/d
Paste Plant Makeup		0.4 ML/d
Supply (ML/d)		
Underground Mine		0.151
Rail Tunnel		0.036
Pump Capacities (ML/d)		
Turkey's Nests to Treatment Plant		3.28
Treatment Plant Capacity		4.32
Sediment Ponds to Treatment Plant		0.69
Sediment Ponds to Taj		4.32
Camp Ck Weir to Treatment Plant		1.73
Dam Capacities & Normal Operating Volumes (NOV)		
Storage	*Capacity (ML)*	*NOV (ML)*
Turkey's Nests	7.61	2
Sediment Ponds	4.36	2
Taj	0.52	0.05

* Includes water truck dust suppression demand

Runoff from the catchments of the three main mine storages was simulated using a rainfall-runoff model. Rainfall and evaporation data for Helensburgh from 1889 to 2007 inclusive were sourced using the Department of Natural Resources and Mines (QLD) Silo patched point data set[6]. The patched point data set uses original Bureau of Meteorology measurements for Helensburgh, but with interpolated data (from surrounding stations) used to fill ("patch") any gaps in the observation record. Twenty three (23) year rainfall totals through the 119 years of available data were compiled and different 23-year "windows" chosen corresponding to different statistical exceedence probabilities of occurrence.

Key model results for different probability 23-year rainfalls are summarised in Table 7.

Table 7
Water Balance Model Results
(Averaged over 23-year Mine Life)

	10%-ile Dry 23-Year Period	**Median 23-Year Period**	**10%-ile Wet 23-Year Period**
Inflows (ML/year)			
Rainfall Runoff	112	122	136
From Underground	55	55	55
From Camp Gully Weir	567	563	561
From Rail Tunnel	13	13	13
Town Water	114	115	112
TOTAL	861	868	877
Outflows (ML/year)			
Coal Washing	418	418	418
Other Site Use	395	395	395
Evaporation	12	12	12
Licensed Discharge	33	39	45
Turkey's Nest Spill	3	4	7
TOTAL	861	868	877
Licensed Discharge Days/year	16	18	20
Turkey's Nest Spill Days/year	1	1	2

[6] http://www.nrw.qld.gov.au/silo/

5.0 SURFACE WATER RESOURCES WITHIN THE PROPOSED UNDERGROUND MINING AREA

The catchments and main sub-catchments within the existing and proposed underground mine development area are listed in Tables 2 and 3 in Section 2 of this report. The principal catchments within the underground mining area comprise the lower reaches of Waratah Rivulet – below Flat Rock Crossing, Reference Tributary, the lower reaches of the Central Eastern and Eastern Tributaries and a series small first and second order tributary catchments of Waratah Rivulet which drain directly to the Woronora Reservoir.

Parts of the proposed underground mining area are also overlain by the headwaters of Cawley's and Wilson's Creeks which drain in an easterly direction away from Woronora Reservoir. MSEC (2008) predicted subsidence movements associated with these latter catchments are relatively small. MSEC predicted valley closure and up-sidence levels are low and below levels where fracturing of bed rock is expected. The predicted tilts and tensile stresses are also relatively minor. Given the low level of predicted subsidence effects no material impact to these surface water resources is expected and they have not been assessed in any further detail.

5.1 Lower Reaches of Waratah Rivulet

The stream channel in the lower reaches of Waratah Rivulet – downstream of Flat Rock Crossing is characterised by a gently meandering, relatively shallow, wide channel with a sandstone bed. The channel has an irregular longitudinal profile – refer Figure 10 which contains a series of in-stream pools that have formed in local depressions in the bed rock and behind rock bars. These are interspersed by and steeper chutes, cascades and small waterfalls.

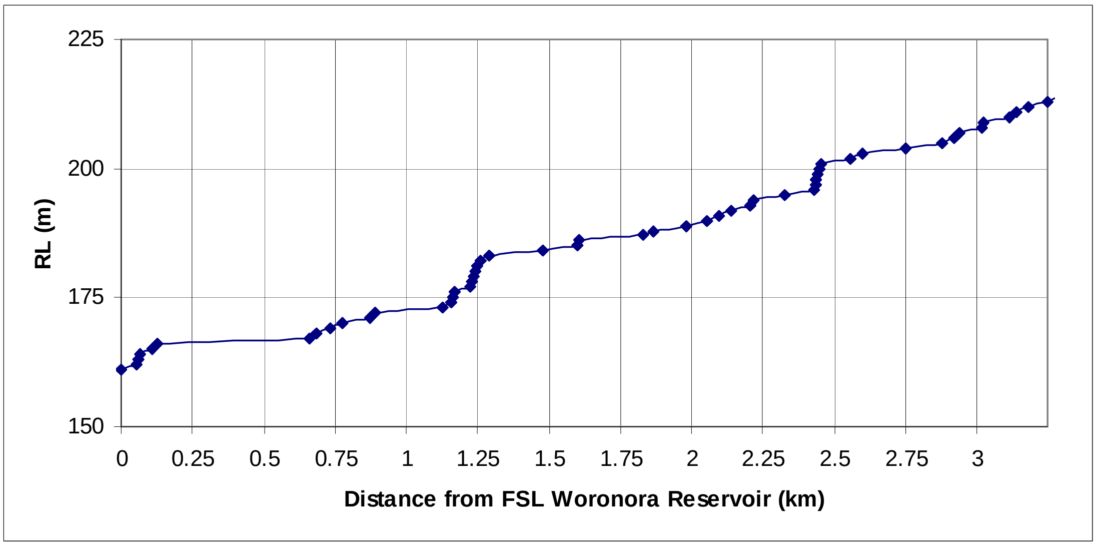

Figure 10 Bed Profile of Waratah Rivulet below Flat Rock Crossing

The average bed gradient over this reach is 24m per kilometre (2.4%) which is hydraulically steep[7] and compares with an average gradient of 34m per kilometre over the section of Waratah Rivulet upstream of Flat Rock Crossing to the Flat Rock Creek confluence near the upstream limit of past longwall mining. Flows during and following the frequent rainfall events typical of the area are characteristically chaotic, high energy and high velocity. These conditions typically prevent the build up of loose sediment or vegetation in the stream bed. – refer Plate 1 below.

Plate 1 High Flow in Waratah Rivulet

During dry periods, flow is characterised by shallow, wide sections of slow moving (non turbulent) flow in the flatter sections and pools interspersed by narrow, shallow fast moving flows over the steeper in-connecting cascades and rock bars – refer Plate 2.

Plate 2 Waratah Rivulet Downstream (Source: MSEC, 2008)

[7] Hydraulically steep in the sense that flow would normally be in the supercritical regime which is characterised by shallow, high velocity and high turbulence.

There are also extensive reaches where the bed is covered in large boulders which appear to be the weathered remnants of former rock bars or collapsed overhangs where the stream undercuts the banks and cantilevers fail along rock joints. The flow in these sections is frequently not visible and dominated by specific pathways through the boulder maze. There have been 17 pools mapped downstream of Flat Rock Crossing by MSEC (2008). These pools are typically 0.5 to 1.5m deep at their deepest and between 30 and 100m long. They are similar in form to the pools C, D E and F upstream of Flat Rock Crossing.

Flow rates have been monitored at the SCA gauging station in the lower reaches of Waratah Rivulet near where it enters the Woronora Reservoir since February 2007. There is also coincident water quality data comprising continuous salinity (as measured by electrical conductivity) as well as continuous measurements of pH and turbidity. Water samples have also been collected regularly since the monitoring site was established in September 2006 for detailed chemical laboratory analysis.

5.2 Reference Tributary

The Reference Tributary (also referred to as the “Tributary B” in earlier studies) appears as sub-catchment 8 on Figure 8 and is characterised by:

- shallow swale-like alluvial channel in the elevated relatively flat plateau areas which occur in the headwater of the catchment;
- simple relatively wide channel with low primary banks in the steeper mid reaches;
- a channel form which typically comprises a series of alternating steep chutes and cascades interspersed by in-stream pools that form in natural depressions in the predominantly competent sandstone bedrock exposed in the mid sections of the catchments;
- limited bed sediment deposits which are restricted to areas with locally flatter bed slopes and in the bottom of some of the larger deeper pools; and
- dense riparian vegetation but generally with relatively little in-stream vegetation.

Key hydraulic characteristics of the Reference Tributary have been assessed from the available 1:25,000 scale topographical mapping and indicative channel dimensions observed during site reconnaissance. These characteristics are summarised below:

Characteristic	Value
Catchment area	1.91 km^2
Stream length	3.0 km
Maximum elevation	352m AHD
Minimum elevation	195 m AHD
Average bed slope	5.3%

The following hydraulic characteristics have been assessed for flows corresponding to the estimated 1 in 2 year peak flow.

Hydraulic Characteristic	**Value**	**Units**
Typical stream width	6.0	m
Flow depth	0.25	m
Bed slope	0.053	-
Bed friction factor (Mannings 'n')	0.035	-
Flow area	1.2	m^2
Discharge	3.4	m^3/s
Average flow velocity	2.1	m/s
Average bed shear stress	115	kN/m^2
Specific stream power	1.8	kW/m

These hydraulic characteristics confirm that during the frequent occurrences of runoff producing storms, flow in the Reference Tributary would comprise shallow, high energy and high velocity flow.

5.3 Eastern Tributary

The Eastern Tributary which appears as sub-catchment 10 on Figure 8, flows in a northerly direction from its headwaters near the southern limits of longwalls 1 and 2 and overlies the eastern end of proposed Longwalls 20 to 30. It commands an area of 6.7 km^2 and is long and narrow in shape. The valley floor is typically 60 to 100m below the surrounding ridgeline. In its upper and middle reaches the stream is characterised by:

- simple relatively wide channel with low primary banks;
- a channel form which typically comprises a series of alternating chutes and cascades interspersed by small in-stream pools that form in natural depressions in the predominantly competent sandstone bedrock exposed in the mid sections of the catchments;
- limited bed sediment deposits which are restricted to areas with locally flatter bed slopes and in the bottom of some of the larger deeper pools; and
- dense riparian vegetation but with relatively little in-stream vegetation.

In its lower reaches the stream channel becomes wider and the bed profile flatter. The pools in the area tend to be larger (longer and deeper than those upstream – refer Plate 3).

Plate 3 In-Stream Pool in Lower Reaches of Eastern Tributary

5.4 Upland Swamps and Associated Tributary Catchments

A number of tributaries drain direct to Woronora Reservoir and comprise small catchments containing headwater upland swamps.

Upland swamps on the Woronora Plateau occur in small headwater valleys that are characteristically sediment choked and swampy (Young, 1986). Topographically, upland swamps occur in the higher parts of the Woronora Plateau. They generally occupy gently-sloping and trough-shaped valleys, where the plateau is least dissected (Young, 1986). The upland swamp catchments in the Project area tend to be narrow with limited contributing catchment outside the swamp areas themselves. Mapping of upland swamps and associated vegetation in the Project area is provided in Bangalay Botanical Surveys (2008).

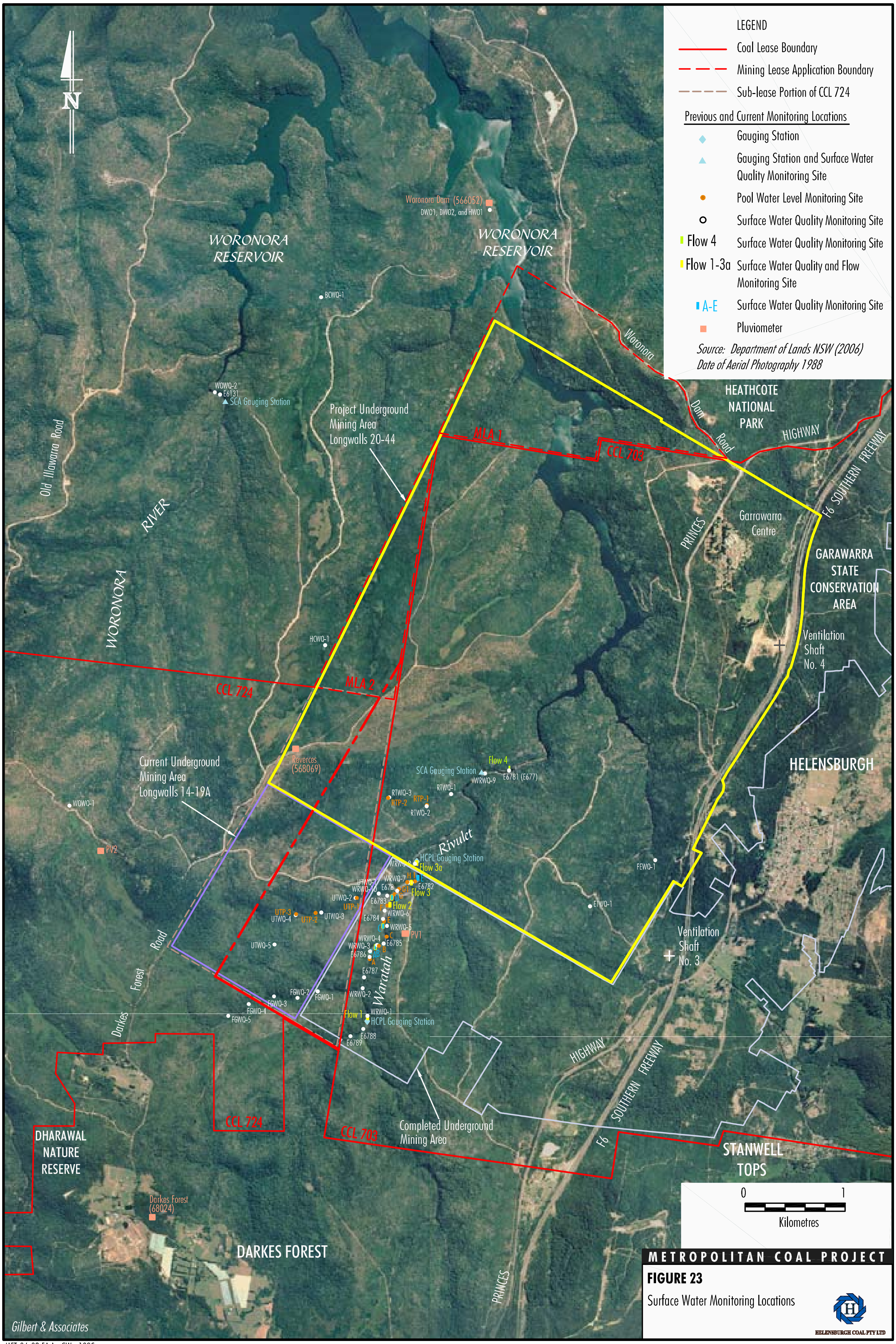

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FIGURE 23

Surface Water Monitoring Locations

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Groundwater flow within the Hawkesbury Sandstone Formation is largely horizontal, as vertical permeability is very low (Heritage Computing, 2008). The Hawkesbury Sandstone provides a low permeability base on which the sediments and organic matter rest (*ibid*.). The Hawkesbury Sandstone is also the predominant source of sediment for the upland swamps; erosion of the sandstone on the plateau surface supplies largely medium-coarse sand to the valleys in which the swamps lie (*ibid*.). The sandy sediment accumulation in the swamps traps rainfall infiltration, seepage and low-flow runoff.

The eastern part of the Woronora Plateau has a favourable climate for upland swamp formation. Average rainfall exceeds average evaporation in all months of the year (Young, 1986). The rainfall saturates the accumulating swamp material and cannot drain away quickly enough due to low floor slope, low permeability base and rainfall higher than evaporation (Heritage Computing, 2008).

The dominant components of the water balance of upland swamps are incident rainfall and run-on drainage from adjacent catchment areas, and evapotranspiration losses from the dense vegetation. There are also smaller slow moving drainage flows which report as baseflow in downslope water courses. Losses to underlying groundwater are considered to be negligible. Monitoring of shallow groundwater water levels in three instrumented swamps in the project area are shown in Figure 12 below.

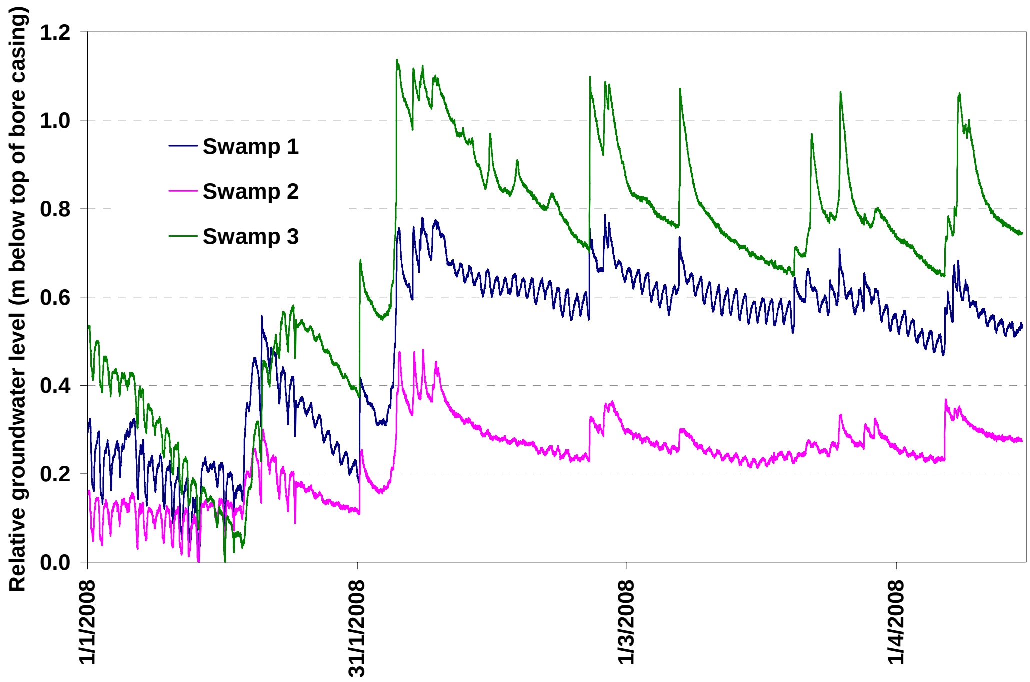


Figure 12 Water Level Monitoring Upland Swamps

It is clear from this plot that the monitored swamps have responded rapidly to rainfall which is the only significant source of water. The recession rates following rainfall are consistent with ongoing evapotranspiration loss and slow drainage which would appear as baseflow in downstream water courses. Soil moisture levels in the swamps would be expected to be persistently high.

In contrast, in-valley swamps are located lower in the catchments. These swamps are not formed as perched and isolated systems and have potential for interaction with underlying and adjacent shallow groundwater and greater interaction with adjacent catchment areas. Whilst there are no in-valley swamps within the proposed underground mining area there is one in-valley swamp which was undermined during the mining of Longwalls 7 and 8 which is predicted to be further marginally affected by subsidence movements during mining of Longwalls 20 to 24 (MSEC, 2008). The magnitude of these additional movements are predicted to be small in comparison to the movements that have already occurred and it is considered highly unlikely that there will be any change to swamp hydrology as a result of future mining.

5.5 Upland Swamp Tributary Catchments

There are three tributaries in the lower reaches of Waratah Rivulet (on the western side of the Rivulet), which contain relatively large upland swamps. They appear as sub-catchments 12, 13 and 14 on Figure 8. The swamps occur in the headwaters and upper sections of these catchments. The swamps are orientated along the sub-catchment valleys with moderate longitudinal slopes. They are elevated above the Woronora Reservoir level. The swamps terminate at rock bar type outcrops upstream of the plunge points where the creek bed descends via steep chutes and waterfalls onto the Waratah Rivulet or Woronora Reservoir below – refer Figures 13, 14 and 15 which illustrate the bed profiles of these catchments.

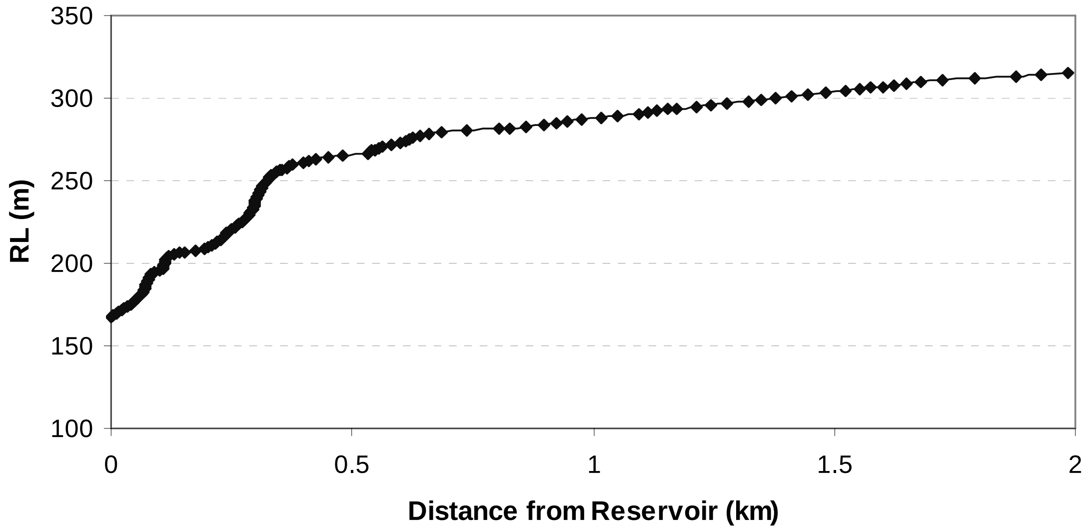


Figure 13 Tributary 12 Bed Profile

The gradient of the swamp in the upper section of this catchment averages about 28 m/km or 2.8%. The average gradient in the steep section downstream of the plunge point is 246 m/km or 24.6%.

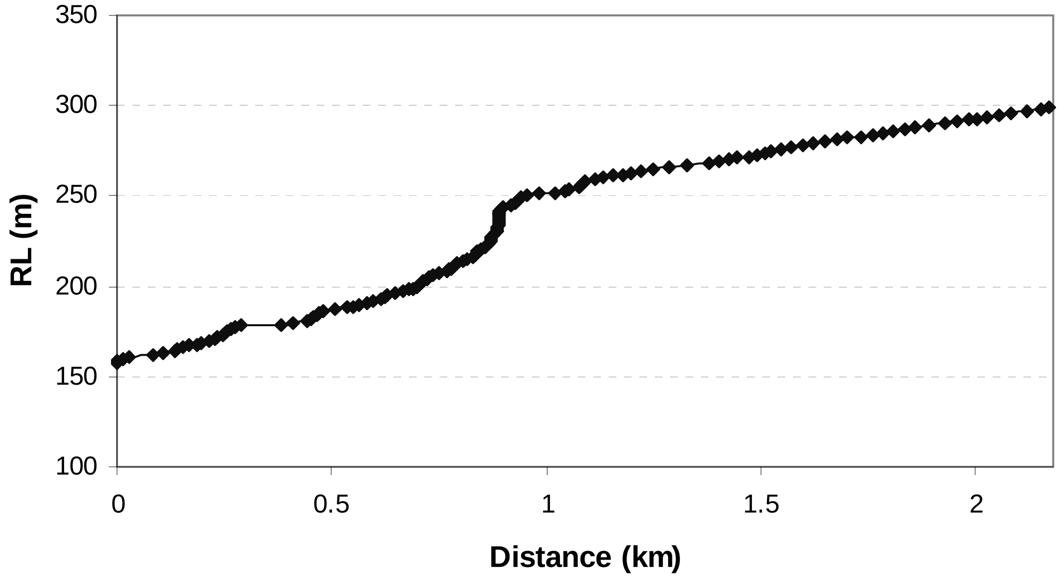


Figure 14 Tributary 13 Bed Profile

The gradient of the swamp in the upper section of this catchment averages about 38 m/km or 3.8%. The average gradient in the steep section downstream of the plunge point is initially 498 m/km or 49.8% and averages about 100m/km or 10% over the section leading down to the reservoir water level.

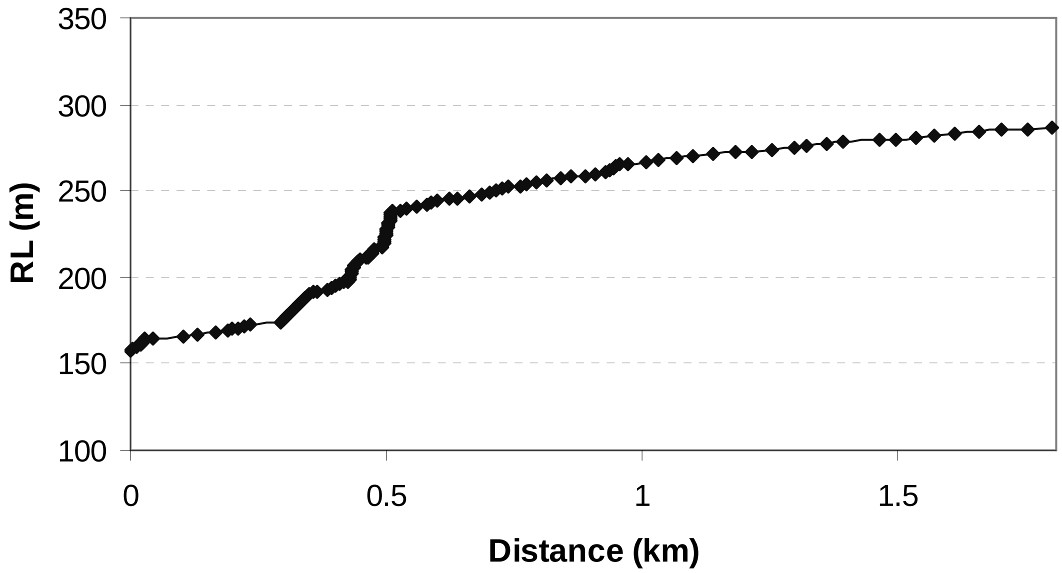


Figure 15 Tributary 14 Bed Profile

The gradient of the swamp in the upper section of this catchment is about 30 m/km or 3%. The average gradient in the steep section downstream of the plunge point is 275m/km or 27.5%.

Whilst the bed gradients along the swamps are moderate and similar to the mid sections of Waratah Rivulet and its tributaries, the swamps in these catchments have a very flat cross sectional profile and support dense vegetation which prevents the development of high velocity surface flows. The swamps comprise accumulated deposits of alluvial material comprising silty sands and clays within which a perched water system forms due to the elevated low permeability underlying sandstone bed rock. The Upland Swamps in these catchments occupy a large proportion, typically 50 to 70%, of the total catchment above the swamp outlet. This further limits the potential for runoff flows from these areas following intense rainfall events.

5.6 Woronora Reservoir Inundation Area

As described in MSEC (2008), the area between the Reservoir surface water level, and the Full Supply Level is considered as land prone to inundation (refer Plate 4). The inundation area is characterised by alluvial deposition in the reservoir bed.

Plate 4 Inundation Area – Woronora Reservoir (Aerial Photo: 2005)

6.0 PREDICTED SUBSIDENCE AND SUBSIDENCE EFFECTS WITHIN THE PROPOSED UNDERGROUND MINING AREA

Predictions of subsidence movements associated with the proposed underground longwall mine development area have been made by Mine Subsidence Engineering Consultants Pty Ltd[8]. MSEC have made specific predictions along the main watercourses and for specific water resource features within the mine area. Predictions were made in regard to the physical effects of longwall mining at the surface which are quantified in terms of:

- vertical displacement measured in mm - which has been denoted as subsidence where the displacement is downward or up-sidence where it is upward;
- tilt which is the rotational movement expressed in mm/m as positive rotation where it is downward or negative where it is upward;
- strain being horizontal movements being either tensile (where there is an increase in horizontal dimension) or compressive (where there is a decrease in the horizontal dimension) both expressed in mm/m; and
- valley closure which is foreshortening of the valley width dimension measured in mm perpendicular to the valley axis.

These movements are predicted using empirically based index methods which are calibrated to the upper bound of past observations in the area. In terms of effects or impacts on water courses and other natural surface water related features such as upland swamps, the relevant parameters are tilt, strain and valley closure. Quantitative information on these parameters has been provided in terms of maximum incremental values (anywhere) along Waratah Rivulet, maximum cumulative values and maximum total values. The reader is referred to the MSEC (2008) report for a fuller description and definition of these terms. At a general level, the incremental values are parameter values calculated for mining of a particular longwall panel, cumulative parameters are calculated for mining of all proposed longwall mine panels and total values are calculated on basis of all proposed longwall panels as well as past mining activities.

6.1 Subsidence Related Predictions for Waratah Rivulet

The MSEC predicted maximum incremental, maximum cumulative and maximum total tilts and strains along Waratah Rivulet are summarised in Table 8 below.

Table 8
Summary of MSEC Subsidence Predictions – Waratah Rivulet

	Incremental	Cumulative	Total
Maximum tilt (mm/m)	6.6	6.9	7.0
Maximum compressive strain (mm/m)	1.8	1.7	1.7
Maximum tensile strain (mm/m)	1.3	1.3	1.3

The maximum predicted tilts and strains occur over the first few longwall panels and hence during the first few years of the Project.

[8] Refer MSEC (2008).

One of the key processes responsible for local surface water impacts is the development of sub-surface fracture networks beneath water courses. These fracture networks provide a pathway for a surface water to migrate downstream beneath the bed of the affected (fractured) section of water course. Whilst there is some uncertainly as to the exact mechanisms responsible for the creation of these networks (refer MSEC, 2008), it is generally agreed that valley closure movement and up-sidence are key parameters along with stresses, stress fields and geological anomalies inherent in the original near surface/creek bed rock strata. The MSEC predicted maximum predicted up-sidence, valley closure and compressive strain due to closure are summarised in Table 9 below.

Table 9
Summary of MSEC Predictions of Up-sidence and Valley Closure Parameters – Waratah Rivulet

	Incremental	Cumulative	Total
Maximum up-sidence (mm)	354	790	795
Maximum closure (mm)	378	960	965
Maximum compressive strain due to closure (mm/m)	-	17.4	17.5

The maximum predicted up-sidence and closure values also occur over the early Longwalls 21 to 25. Predicted valley closure values are affected by the height of the adjacent valley which reduces downstream of Longwall 25. The area inundated by the Woronora Reservoir extends upstream to a point corresponding to proposed Longwall 28.

MSEC (2008) note that fracturing of sandstone creek beds has been observed in the Southern Coalfields – including in the already undermined sections of Waratah Rivulet, where the incremental compressive strains due to valley closure have exceeded 2mm/m in the stream bed. The MSEC predicted maximum incremental compressive strains due to valley closure are 17.4mm/m over Longwall 24. The predicted valley closure and associated compressive strains are similar but somewhat less than the values already experienced along Waratah Rivulet (*ibid*). MSEC note that based on past experience the most likely locations for fracturing of the sandstone bed rock to occur are where movements are greatest (generally the first 5 long wall panels), where geological features such as naturally intense jointing occur, in areas of thinly bedded strata and where prominent rock bars occur.

MSEC (2008) has predicted the maximum valley closure and up-sidence movements at the prominent rock bars that have been mapped along Waratah Rivulet within the study area. Whilst these parameter values vary they are all within the range where fracturing of bed rock and the capture and transport of a portion of total surface flow as underflow could occur. Based on experience with existing longwalls it is considered likely this will occur to some degree at most if not all these rock bars.

6.2 Subsidence Related Predictions for Tributaries

MSEC (2008) have also provided predictions of subsidence movement parameters for four main tributaries of Waratah Rivulet – including predictions of valley closure and associated compressive strains. As with the predictions for Waratah Rivulet itself, these values are both consistent with values already experienced in tributaries affected by past longwall mining at Metropolitan Colliery, and in excess of values considered by MSEC to cause fracturing of bed rock.

7.0 OBSERVED EFFECTS OF PAST LONGWALL MINING ON WARATAH RIVULET AND ITS TRIBUTARIES AND ASSESSMENT OF IMPACTS OF THE PROPOSED UNDERGROUND MINING

7.1 Observed Effects on Flow Waratah Rivulet

The observed effects of subsidence on Waratah Rivulet are well documented. Significant 'underflow' is known to occur via the fracture network that has formed as a result of valley closure, up-sidence and compression of the rock strata along and beneath subsided reaches of the Rivulet. It is known from extensive field tests that this fracture system comprises a series of large open cracks, which have a horizontal or sub-horizontal orientation[9]. Different fracture systems have been detected up to 15m below the bed of the Rivulet. The fracture network has been mapped through the rock bar known as WRS3 which separates a major pool on Waratah Rivulet known as Pool A from the next downstream pool known as Pool B. The fracture network in this area is known to be hydraulically connected to the bed of the Rivulet upstream of the rock bar which separates these two pools. The fracture network has also been mapped in the rock bar downstream of Pool F in association with restoration works recently completed in this area – refer Section 8.

This fracture network can convey significant flows below the surface. At times when flow exceeds the hydraulic capacity of the network, surface flow will occur in these areas. The hydraulic capacity of the network is not constant along the entire affected reach - as is readily apparent if one inspects the impacted section of Waratah Rivulet during dry weather. Surface flow is seen to "disappear", and then "reappear" (or at least partially reappear) and then may disappear again after finally reappearing downstream of the longwall area. The area which has had the highest subsurface flow capacity appears to be the reach around WRS3 and Pool A.

Extensive analysis of streamflow data and data on inflows to Woronora Reservoir since 1977 has shown that there has been no loss of water to the reservoir as a result of mining. This conclusion is supported by the results of the groundwater investigations.

7.1.1 Review of Available Data

Streamflow data is available for the Woronora Reservoir tributaries (Waratah Rivulet and Woronora River) from the SCA gauging station on Waratah Rivulet (GS2132102 - established in February 2007, 20.2 km^2 catchment area) and from the SCA gauging station on the Woronora River (GS2132101, 12.4 km^2 catchment area).

These gauging stations were both established in February 2007, however the latter record contains some periods of lost data. Figure 16 shows the locations of the gauging stations relative to the Woronora Reservoir. The Waratah Rivulet station encompasses the area of longwall mining, while the Woronora River catchment is unaffected by longwall mining activities. Data has also been obtained from the Department of Water and Energy (DWE) gauging station on O'Hares Creek at Wedderburn (GS213200).

[9] Refer MSEC (2008).

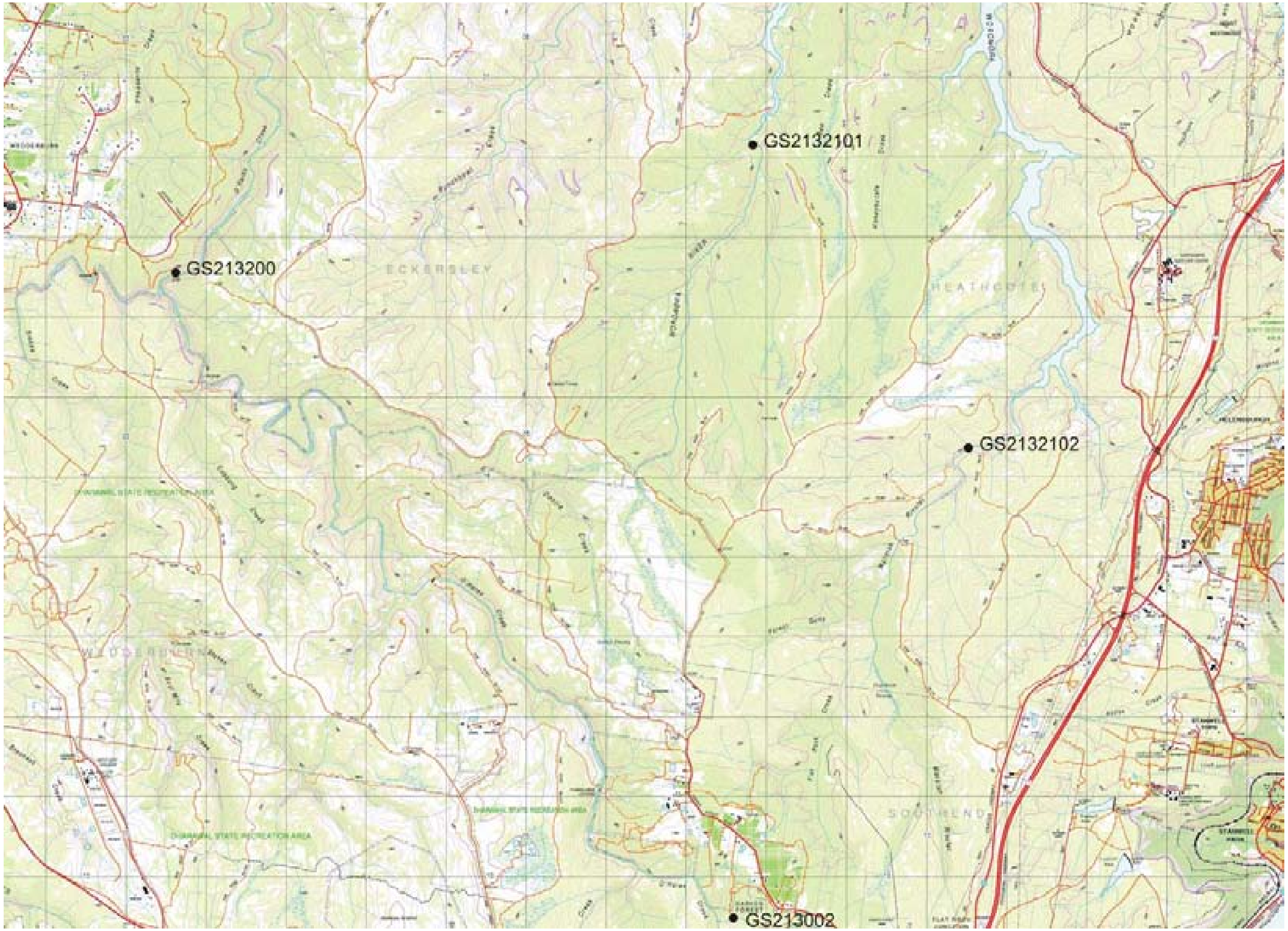


Figure 16 Gauging Station Locations

The O'Hares Creek catchment is located immediately south and west of the Woronora Dam catchment. GS213200 has been in operation since 1978 and has a catchment area of 73 km^2. This station is the nearest available, still operating gauging station to the Woronora Dam catchment.

Figures 17 and 18 show concurrent streamflow data from the three gauging stations described above. In the plot, streamflow has been expressed on a per unit catchment area basis (in mm) to allow direct comparison of flow magnitudes without having to adjust for contributing catchment area. Two plots are shown – the upper plot shows all recorded flows, while the lower plot emphasises the lower flow range.

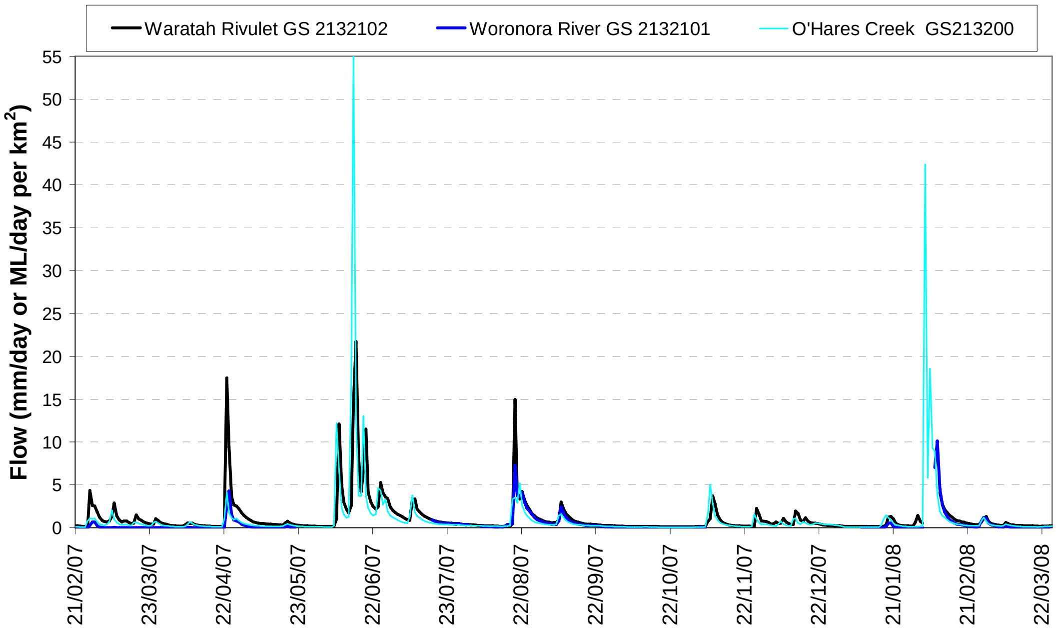


Figure 17 Recorded Streamflow Hydrographs – Waratah Rivulet, Woronora River and O'Hares Creek

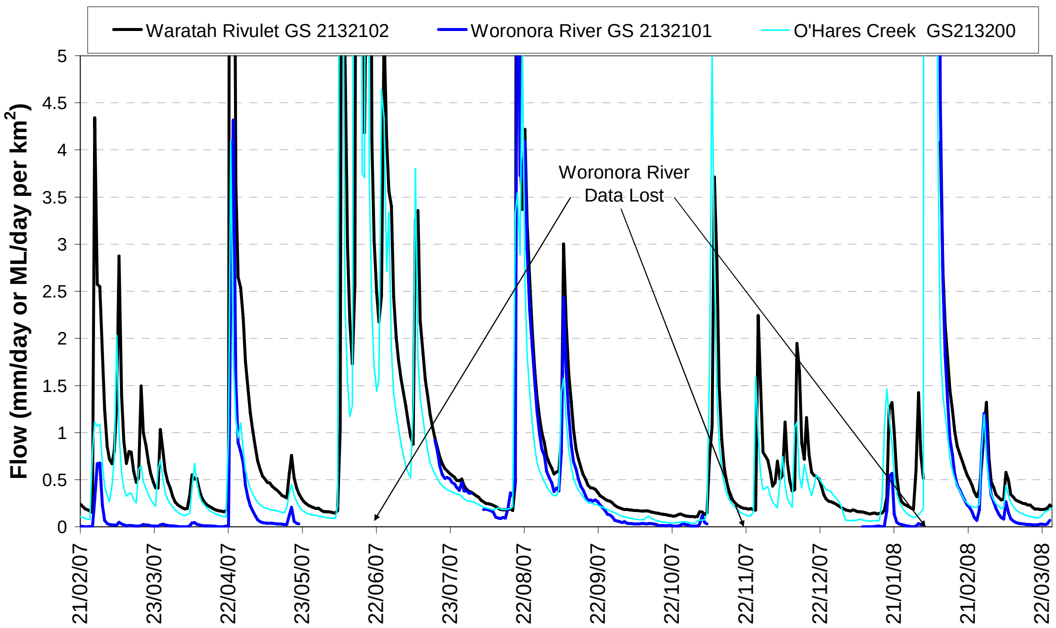


Figure 18 Recorded Concurrent Streamflow Hydrographs – Waratah Rivulet, Woronora River and O'Hares Creek

The following comments are made regarding these comparisons:

- The streamflows (both magnitudes and patterns of flow) recorded at the three sites are very similar.
- Waratah Rivulet appears to be the highest yielding of the three catchments in total over the period of record, although O'Hares Creek has higher peak flows. This may be a reflection of the slightly less dense vegetation evident in the O'Hares Creek catchment as evidenced on regional topographic mapping (refer Figure 16).
- The Woronora River appears to be the lowest yielding of the three streams, although the amount by which recorded flow is lower than the other two stations varies significantly with time – being much lower in February-April 2007 and only slightly lower in later months and even higher than O'Hares Creek flow at times.

Figure 19 below shows the recorded streamflow data for Waratah Rivulet with flow plotted on a log scale to emphasise low flows. This plot indicates that there is no evidence of flow loss at low flows in periods of prolonged dry weather and flow recession as might be expected if flow were being affected by mining activity.

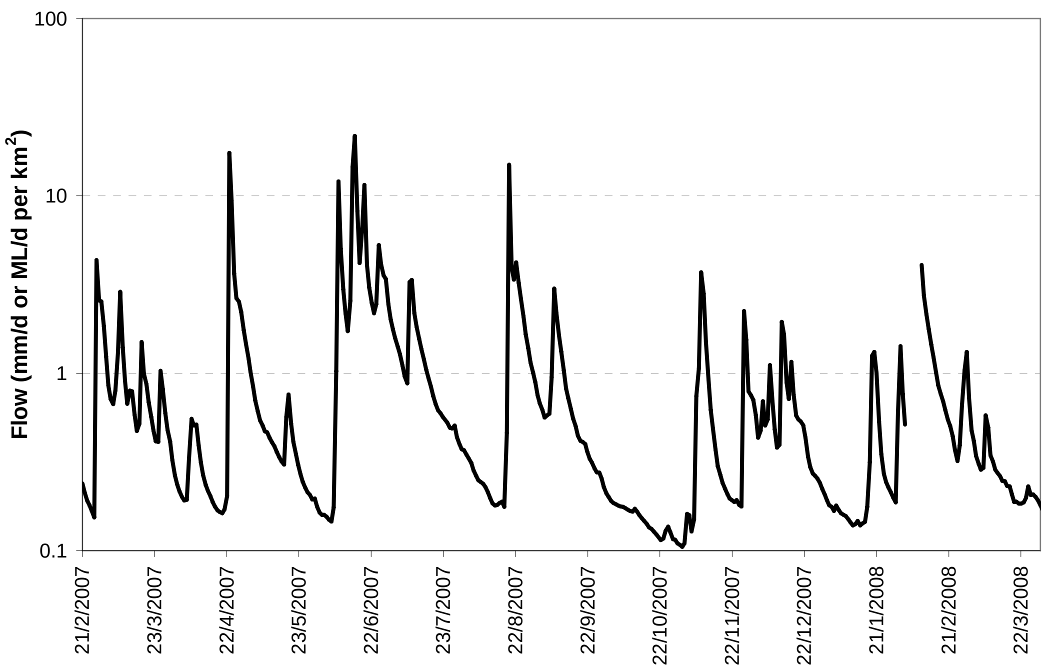


Figure 19 Recorded Streamflow Hydrograph GS2132102 Waratah Rivulet

Table 10 below provides a summary analysis of low flows for the above three gauging stations (for the period from mid-February 2007).

Table 10
Comparison of Gauging Station Recorded Low Flows (from 21-Feb-07 to 25-Mar-08)

Gauging Station	% of Days Flow is Below	
	0.01mm/d	0.1mm/d
GS2132102 Waratah Rivulet	0.0%	0.0%
GS213200 O'Hares Creek at Wedderburn	0.0%	14.3%
GS2132101 Woronora River	17.2%	58%

The data in Table 10 again emphasises the persistence of low flows in the Waratah Rivulet catchment when compared with adjacent catchments – which is not what would be expected if the streamflow of this catchment were affected by mining.

7.1.2 Streamflow Modelling

A streamflow model was calibrated to the Waratah Rivulet and O'Hares Creek gauging station data (there was insufficient continuous data from the Woronora River station to permit model calibration). The model used was the nationally recognised Australian Water Balance Model (AWBM). The AWBM is a catchment-scale water balance model that estimates streamflow from rainfall and evaporation. Key parameters in the AWBM are:

- Average surface storage capacity (S_{av}): the average capacity (in mm) of the surface storage component of the model – once the model surface storages are filled, they spill to generate either runoff or baseflow recharge. This may be thought of as similar to catchment interception capacity which is the amount of rainfall required to saturate a catchment before runoff occurs.
- Baseflow Index (BFI): the proportion of spill from the model surface stores that recharges the baseflow store. Baseflow is derived from slow drainage of groundwater and dominates the flow hydrograph during periods of no rainfall.
- Recession Constant (K): the rate at which baseflow diminishes in the absence of rainfall.

Table 11 below shows the calibrated values of these three parameters for the two gauging stations and also for a third gauging station: GS213002 O'Hares Creek at Darkes Forest – a DWE gauging station on the upper reaches of O'Hares Creek (16 km^2 catchment area) which operated from 1924 to 1930[10]. GS213002 is even closer to the Woronora Dam catchment than GS213200 (refer Figure 16).

[10] The DWE also operated a streamflow gauging station on Waratah Rivulet (GS213001) from 1925 to 1942 (this was subsequently drowned by the construction of the Woronora Dam and the creation of Lake Woronora), however the data from this station (a manual daily-read gauge) was found to be inconsistent with local rainfall data and was not used.

Table 11
Comparison of Calibrated AWBM Parameters

Gauging Station	S_{av} (mm)	BFI	K
GS213002 O'Hares Creek at Darkes Forest	399	0.11	0.98
GS213200 O'Hares Creek at Wedderburn	276	0.21	0.965
GS2132102 Waratah Rivulet	311	0.33	0.955

The following comments are made regarding the data in Table 11:

- Overall the calibrated values are very similar and reflect the nature of the catchments.
- The S_{av} values are quite high when compared with other Australian catchments, which is consistent with the dense vegetation coverage of the catchments.
- The BFI values are quite low (less than 0.35) and reflect the generally fast-draining nature of the steep, sandstone catchments. Baseflow is however an important component of the catchment hydrology in sustaining flows through dry periods – the GS213200 data indicates that O'Hares Creek at Wedderburn has never ceased to flow in its recorded period (since 1978).

Figure 20 below shows a plot of recorded data at the Waratah Rivulet gauging station and AWBM generated flows – derived from catchment rainfall and regional evaporation data. Figure 20 shows that the model gives a very good fit to the observed data.

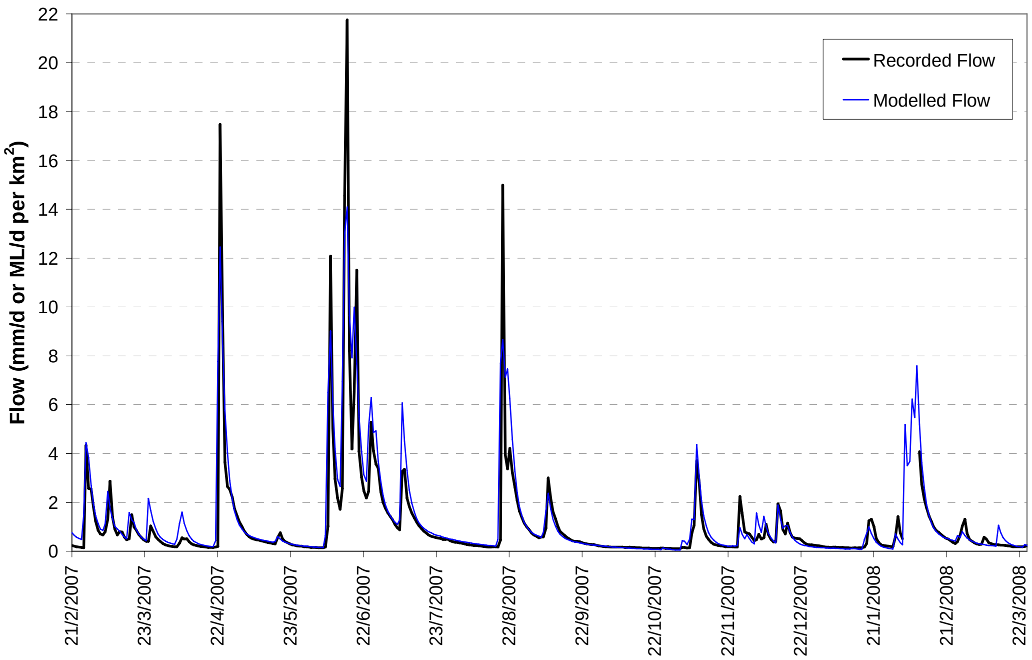


Figure 20 Recorded and Modelled Streamflow Hydrograph GS2132102 Waratah Rivulet

The streamflow model was also used to introduce a loss function to simulate how the Waratah Rivulet flows would be expected to behave if a loss of water from the catchment was occurring. As can be seen in Figure 21, the effect of flow loss is a significant departure from observed flows during periods of low flow. Over the period of observed flows (post February 2007), flow losses of 0.05 mm/day per km^2 or larger would have been clearly evident. Smaller flow losses would be evident during periods of lower flows.

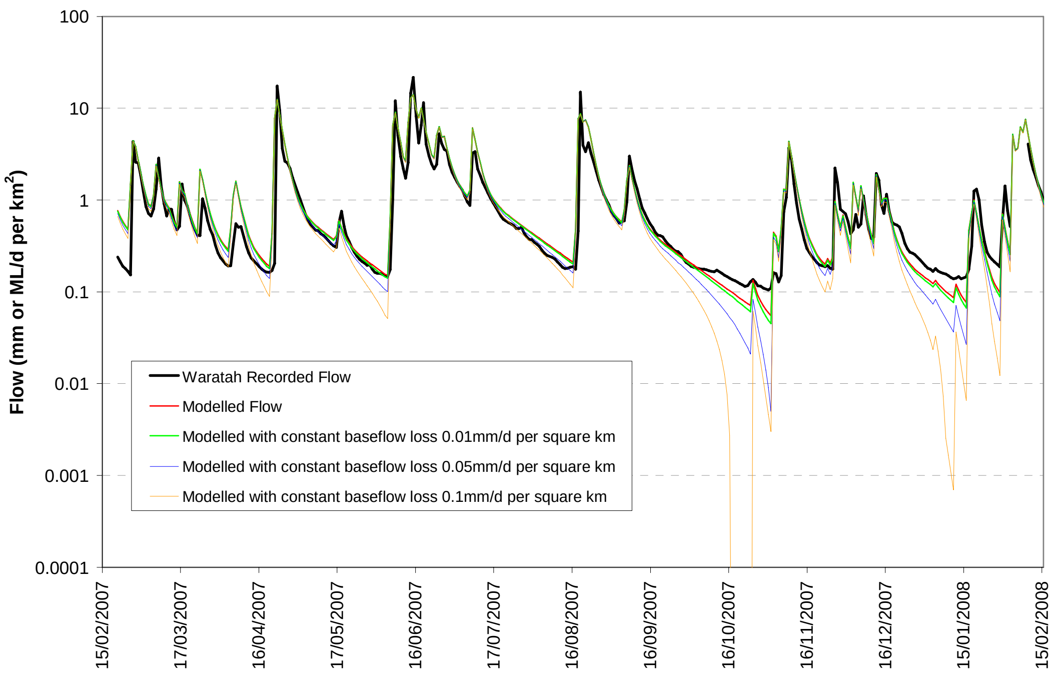


Figure 21 Recorded and Modelled Streamflow Hydrograph GS2132102 Waratah Rivulet (with a Loss Function)

7.1.3 Reservoir Inflow Estimation from Recorded Data

Recorded daily Woronora Reservoir extraction and concurrent storage volume data has been provided by the SCA for the period since 1977. Data on spill volumes from the dam has been provided for the period since late 1987. By allowing for direct rainfall on the reservoir (rainfall data sourced from regional records) and evaporation[11], estimates of stream inflow to the reservoir from its 75 km^2 catchment could be made for the period since late 1987 and since 1977 for period when the dam was not spilling. Inflows were estimated according to the equation:

Inflow = Change (reduction) in storage + Evaporation + Spill + Extraction - Rainfall

[11] Allowance was also made for fluctuation in reservoir surface area with time.

7.1.4 Reservoir Inflow Modelling

In order to assess if calculated stream inflow exhibited any notable changes since the commencement of mining, the calibrated AWBM of the Waratah Rivulet was used to calculate reservoir inflows for the period of available concurrent reservoir data. Results of this analysis compared against inflows estimated from recorded data are shown in Figure 22 on a cumulative basis since 1977. Periods of no recorded reservoir spill or reservoir extraction data were excluded from the cumulative totals. Longwall mining commenced in 1995.

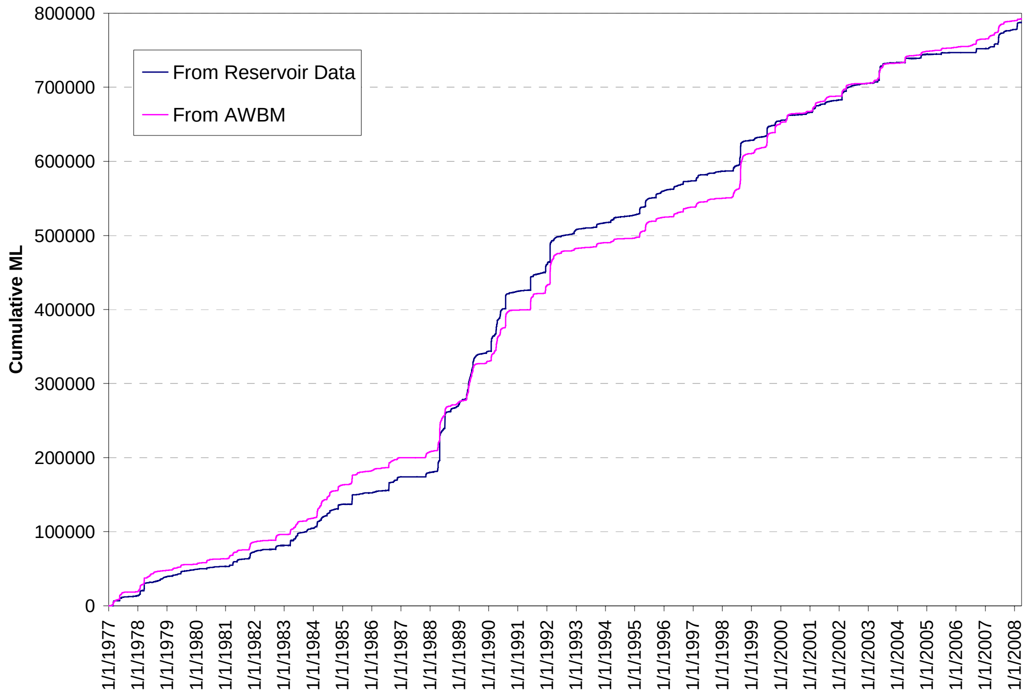


Figure 22 Woronora Dam Inflow

Figure 22 shows that there has been no discernable departure of the model predicted inflows from those calculated from recorded data following commencement of mining in 1995.

7.1.5 Conclusions

Based on the above analysis it is concluded that:

1. On the basis of recorded data from streamflow gauging stations in the area, streamflow patterns and magnitudes in the region are consistent.
2. Recorded streamflow data from Waratah Rivulet indicates that there is no evidence of flow loss at low flows in periods of prolonged dry weather and flow recession as might be expected if flow were being affected by mining activity.
3. A streamflow model was able to be calibrated to recorded streamflow data on Waratah Rivulet. The model fit is very good, model parameters are consistent with other regional stations and reflect the nature of the catchments.

4. The model used does not have a loss term and it was found that it was not possible to obtain as good a fit if a loss term was introduced into the model – confirming that the observed behaviour is consistent with no losses occurring from the catchment.
5. There has been no discernable departure of streamflow model-predicted inflows to the Woronora Reservoir from those calculated using recorded reservoir data following commencement of mining.
6. Based on the above and the subsidence assessment undertaken by MSEC (2008), future proposed mining is not expected to have an effect on catchment yield.
7. These conclusions are also consistent with conclusions reached by Heritage Computing (2008) in their groundwater study report.

7.2 Observed Effects on Water Quality in Waratah Rivulet

7.2.1 Water Quality Data

There has been extensive water quality monitoring conducted at a large number of sites along Waratah Rivulet, its tributaries and surrounding catchments over a number of years. Monitoring data collected by both the Sydney Catchment Authority and HCPL has been compiled. Monitoring site locations are shown on Figure 23 below.

Assessment of this data set has been approached by grouping locations into common reaches so as to reduce a large number of sampling site locations into a smaller number (8) of common reaches.

The reaches and sampling sites they incorporate are summarised in Table 12.

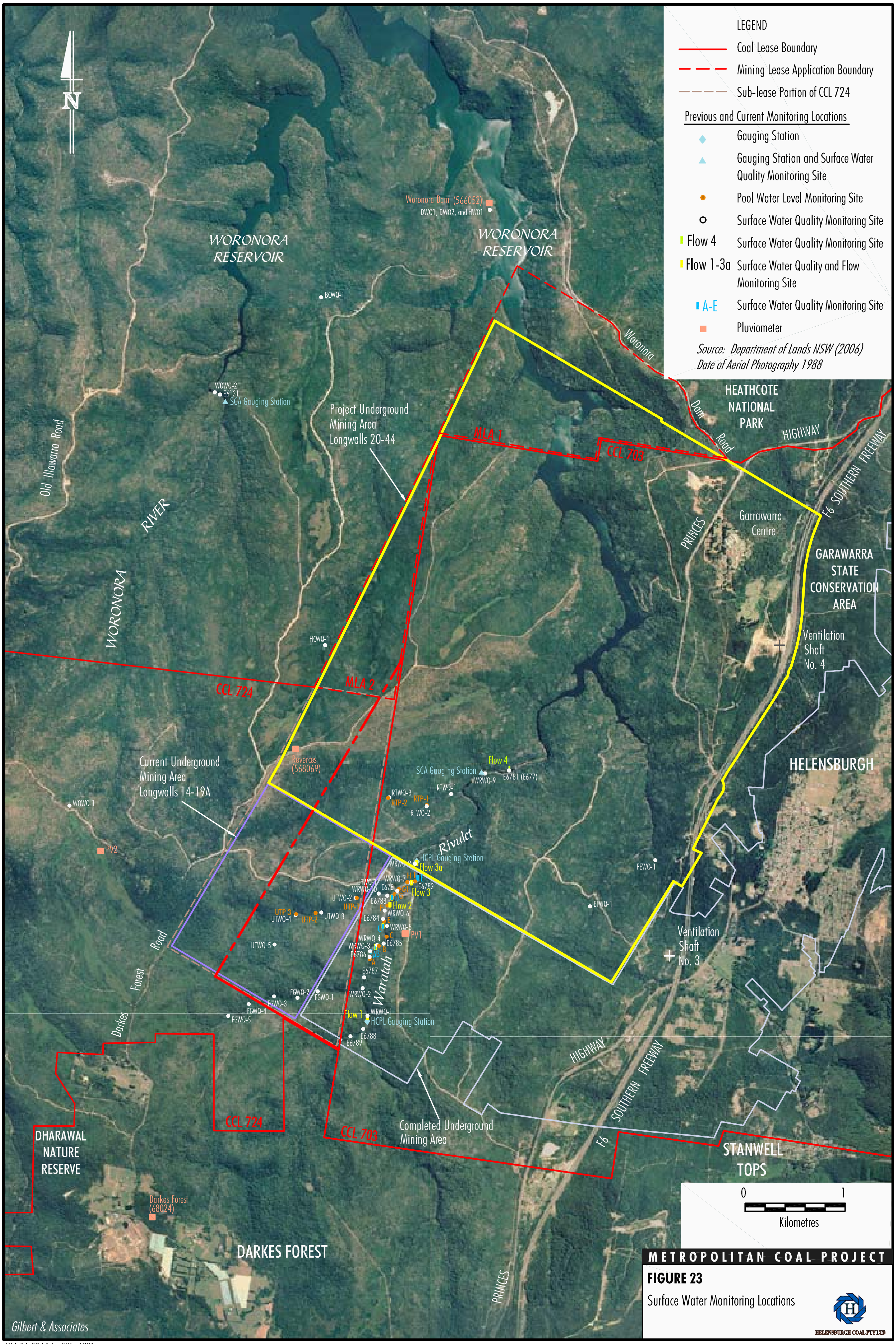
Table 12
Summary of Water Quality Monitoring Sites – Waratah Rivulet

Reach Number	Sampling Site Numbers	Location
1	WRWQ1, Flow 1, E6788, E6789	At/near confluence of Flat Rock Creek and Waratah Rivulet (upstream). Overlying LW10 & 11.
2	WRWQ2, Site A, E6787, E6786, WRWQ3	From confluence of Forest Gully to WRS3. Overlying LW11 & 12.
3	WRWQ4, Site B, E6785	WRS3 area. Overlying LW12.
4	WRWQ5, Site C, E6784	Downstream WRS3. Overlying LW12.
5	WRWQ6, Flow 2, Site D, E6783	Reach upstream of Tributary D confluence. Overlying LW12.
6	WRWQ7, Flow 3, Site E, E6782, E678	Downstream of Un-Named Tributary inflow to Flat Rock Crossing. Overlying LW12.
7	WRWQ8, Flow 3a	Downstream of Flat Rock Crossing. End of LW12.
8	WRWQ9, Flow 4, E667 (E6781)	Downstream of current LW panels and near inflow to Woronora Reservoir.

Water samples collected at these sites have been analysed for a wide set of indicator parameters. The parameters monitored at each site are not consistent as the sites were installed for differing reasons over time. The common set for which a comprehensive data suite has been derived includes general indicators (pH, electrical conductivity, oxidation/reduction potential, turbidity and dissolved oxygen); metals (aluminium, barium, cobalt, iron, manganese, strontium and zinc); common anions and cations (calcium, chloride, magnesium, nitrate, sodium, potassium and sulphate); and nutrient indicators (Total Nitrogen and Total Phosphorous).

In general, water quality at all sites has been good with concentrations of most indicators being low relative to the recommended ANZECC (2000) guidelines for the protection of aquatic ecosystems in upland rivers default trigger levels. The effects of subsidence on water quality have been most noticeable in localised and transient changes (spikes or pulses) in iron, manganese and to a lesser extent aluminium. Comparison of recorded concentrations for iron, manganese, pH, conductivity and dissolved oxygen are shown in the following series of plots for the various reaches listed in Table 12 – refer Figures 24 to 28 below.

A tabulated summary of the surface water quality monitoring results is provided in Attachment A.



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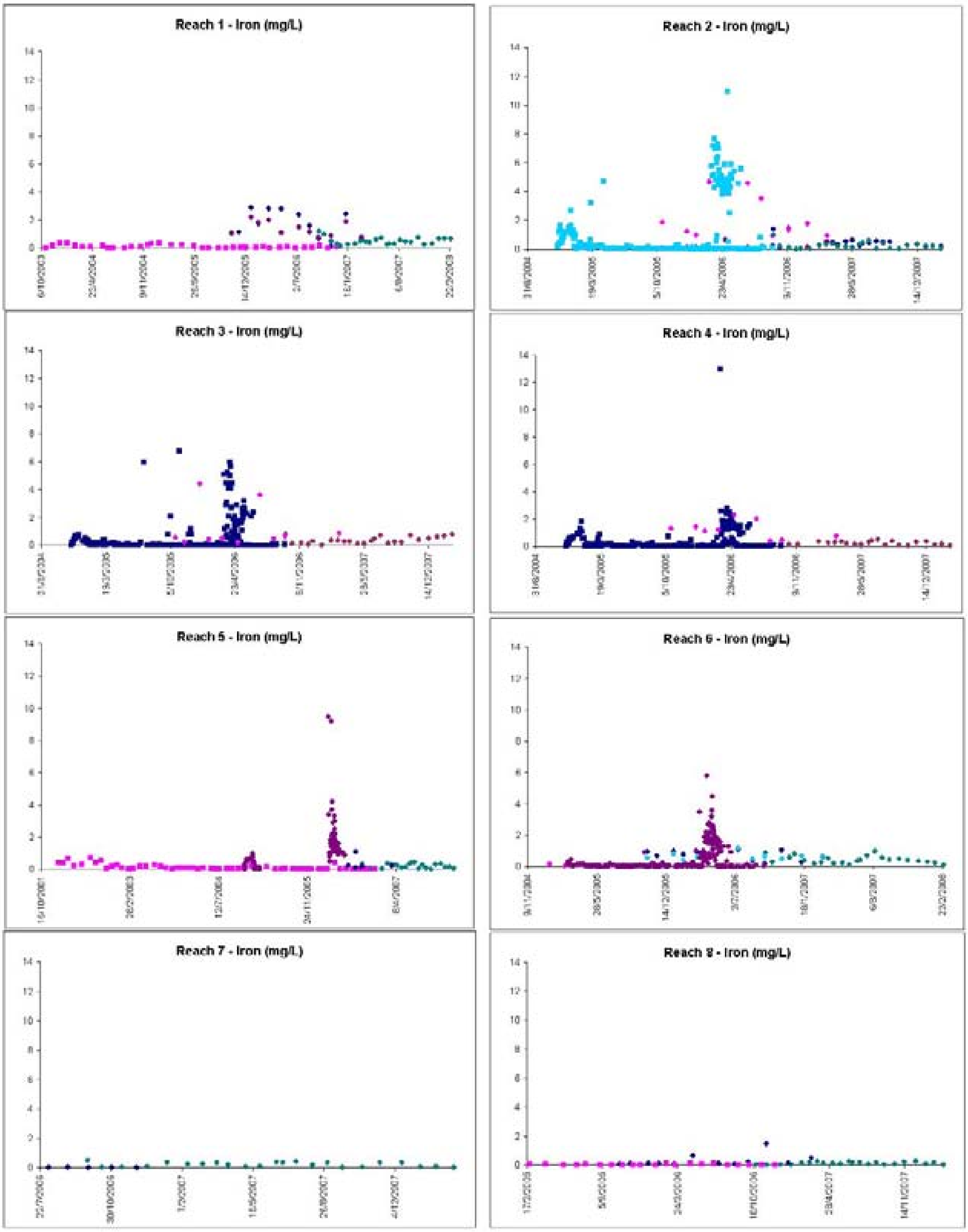


Figure 24 Observed Iron Concentrations Waratah Rivulet

Note: – concentration scale is 0 to 14 mg/L
– Woronora Reservoir Bulk Water Supply Agreement maximum limit 1mg/L
– iron concentration results reflect a combination of dissolved and total iron values

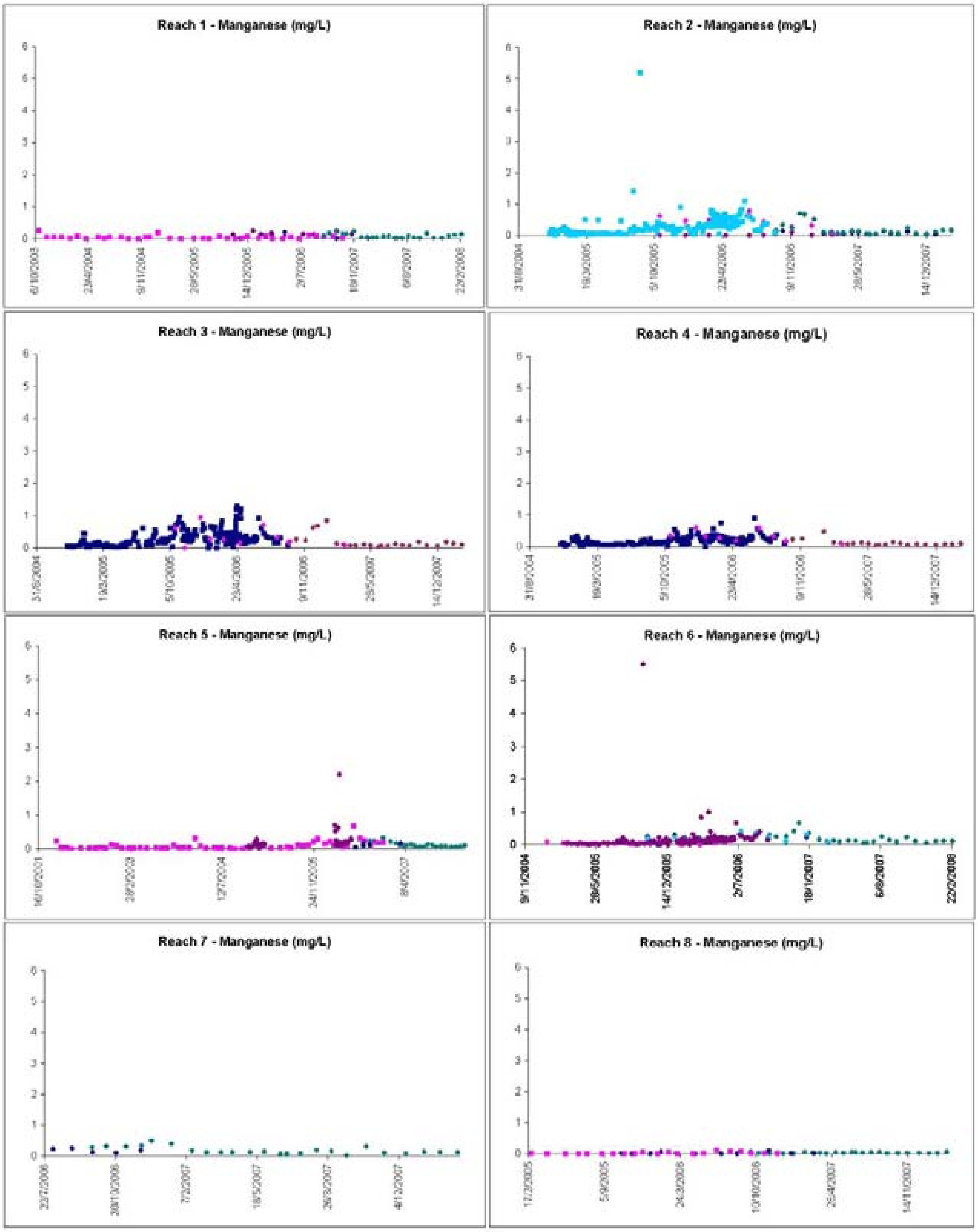


Figure 25 Observed Manganese Concentrations Waratah Rivulet

Note: – concentration scale is 0 to 6 mg/L

– Woronora Reservoir Bulk Water Supply Agreement maximum limit 0.1mg/L

– manganese concentration results reflect a combination of dissolved and total manganese values

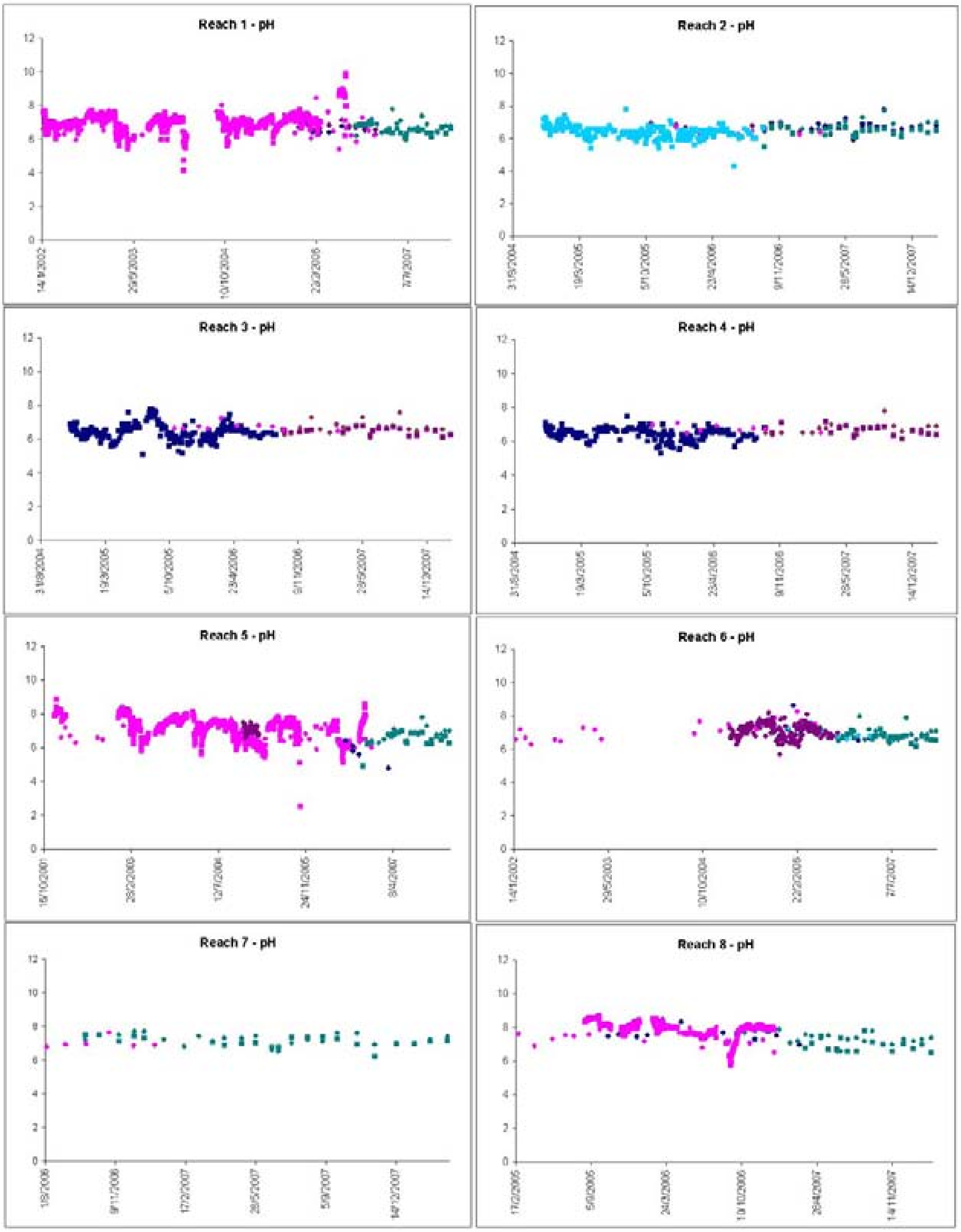


Figure 26 Observed pH Waratah Rivulet

Note: – pH scale is 0 to 12 units
– Woronora Reservoir Bulk Water Supply Agreement maximum limit 7.5; minimum limit 5.1

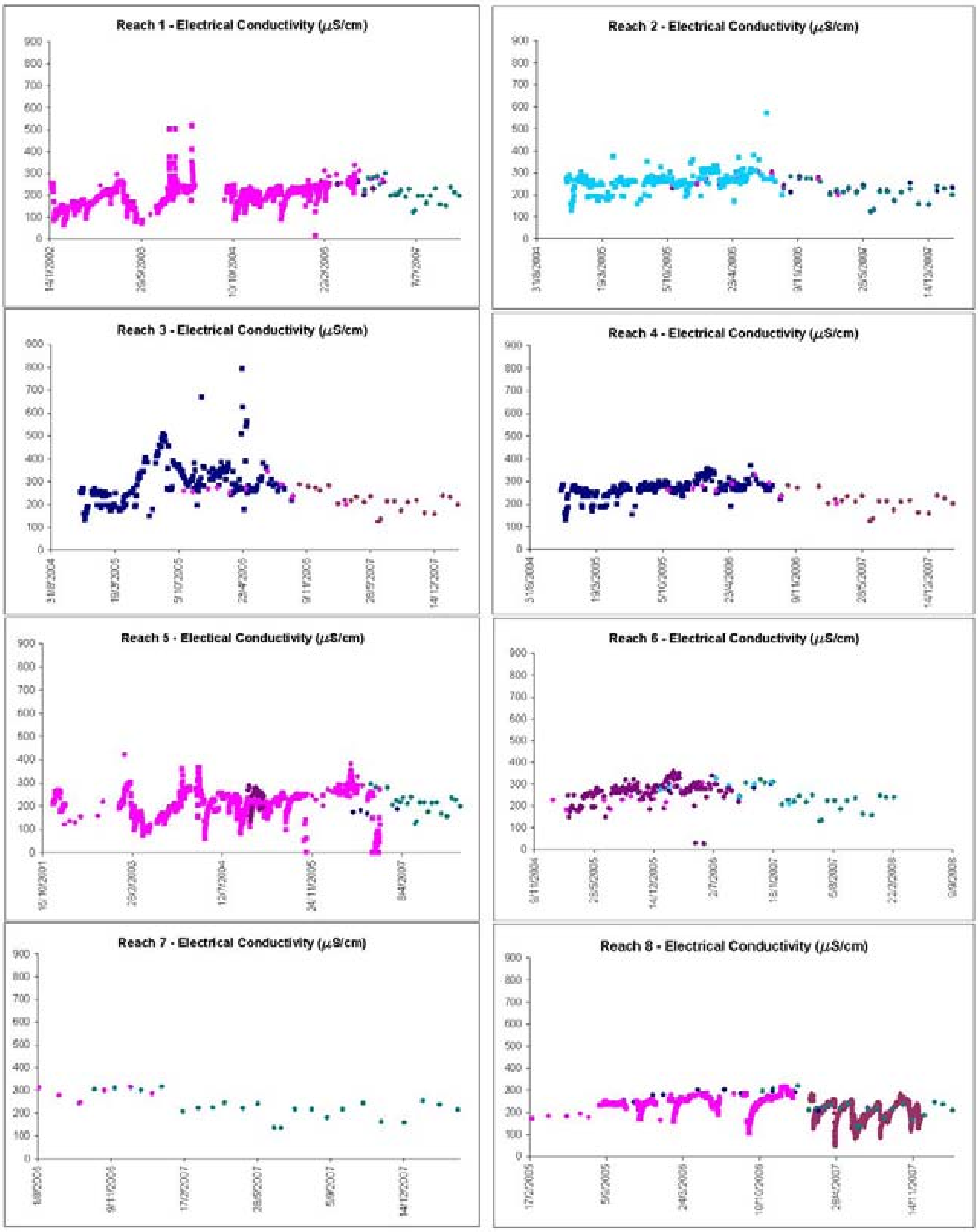


Figure 27 Observed Electrical Conductivities Waratah Rivulet

Note: – EC scale is 0 to 900 µS/cm

– recommended ANZECC guideline (maximum) for protection of aquatic ecosystems in upland rivers 350 µS/cm

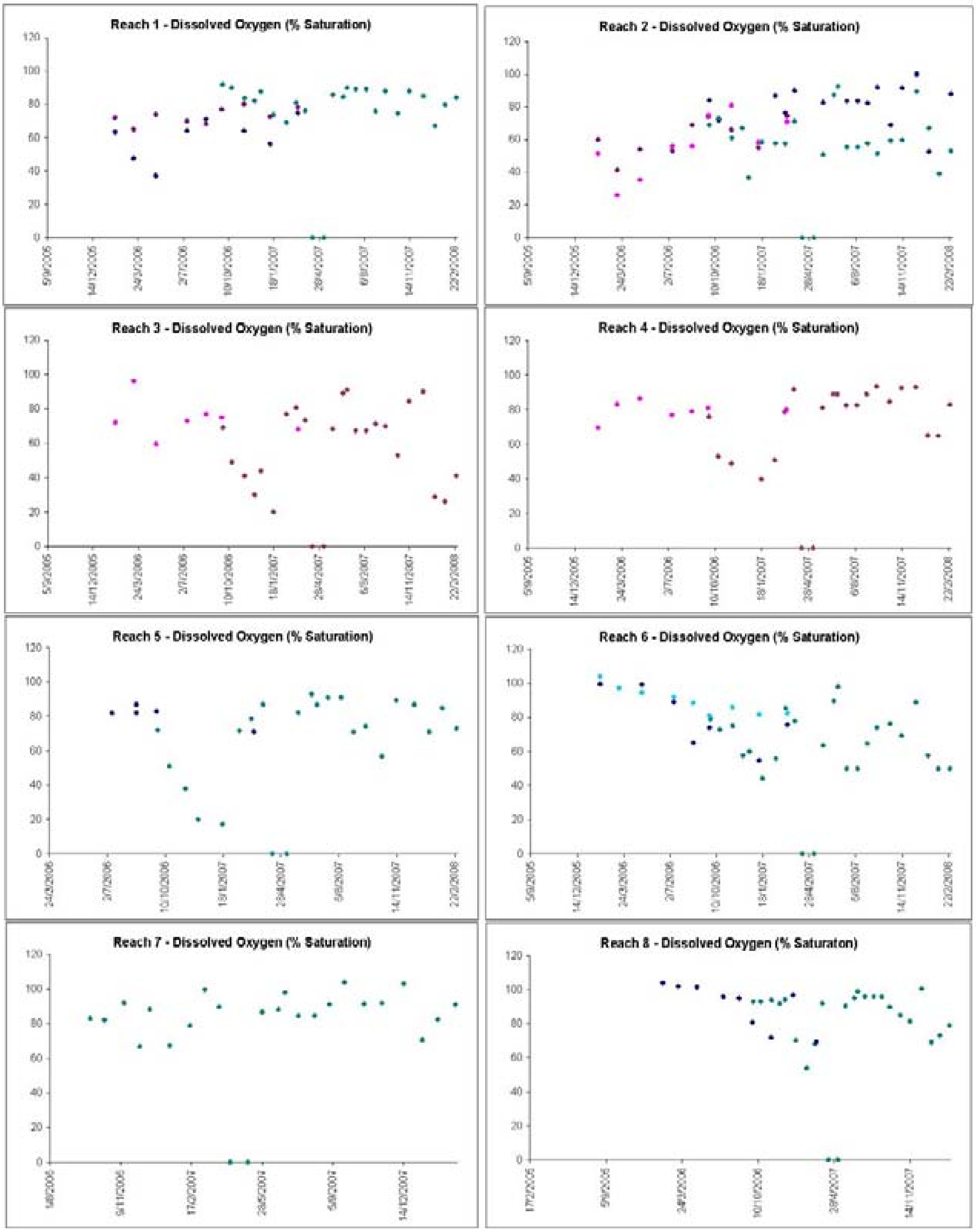


Figure 28 Observed Dissolved Oxygen Saturation Waratah Rivulet

Note: – DO scale is 0 to 120%

– recommended ANZECC guideline for protection of aquatic ecosystems in upland rivers 90 - 110%

It is apparent from these graphs that subsidence effects have resulted in isolated episodic pulses in iron, manganese and electrical conductivity in the middle reaches (i.e. those overlying LW 11 and 12) of Waratah Rivulet. The most likely mechanism for this appears to be flushing of minerals from freshly exposed fractures created by up-sidence and valley closure. By nature the pulses are isolated and non persistent. It is also apparent that these pulses have not had any measurable effect on water quality in Woronora Reservoir downstream – refer Figure 29.

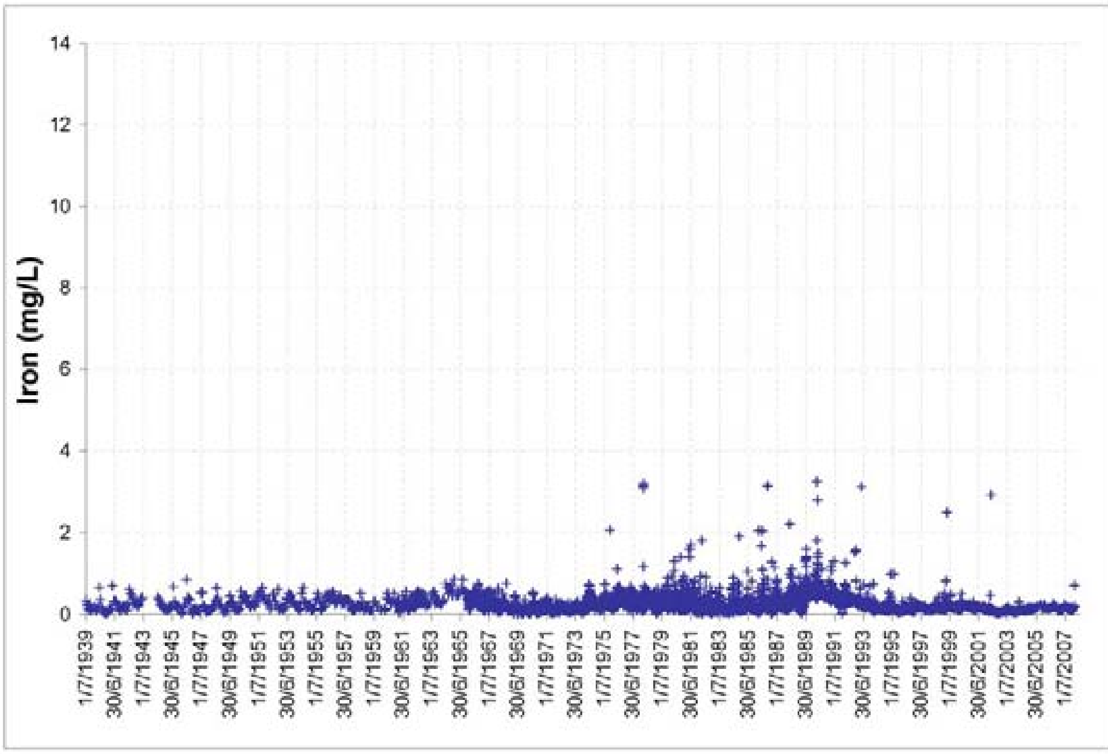


Figure 29 Recorded Iron Concentrations Woronora Reservoir 1939 to 2007

Recorded iron concentrations in Woronora Reservoir have not changed (increased) in the period since longwall mining commenced (1995) and in particular they have not been affected by the observed pulses seen in some upstream reaches in 2006.

Similar trends are evident with manganese concentrations in Woronora Reservoir which have not changed (increased) in the period since longwall mining commenced (1995). Whilst the available data on manganese commences much more recently than iron (1986 compared to 1939) the trends in manganese concentrations over period that data is available mirror the trends in iron concentration – refer Figure 30.

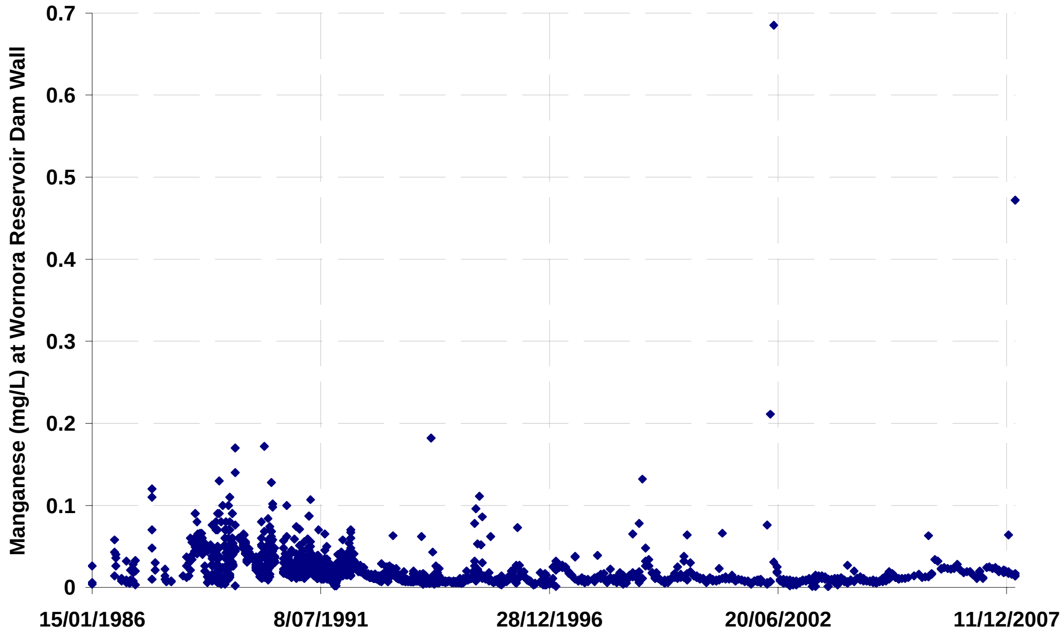


Figure 30 Recorded Manganese Concentrations in Woronora Reservoir

7.2.2 Interpretation and Implications for Water Quality in Waratah Rivulet

In general the effects of mining on water quality have been for isolated and transient increases in some metals and minor associated increases in electrical conductivity which can be linked in time with subsidence induced fracturing of the creek bed. The overall water quality of most indicator parameters has not been noticeably affected. There does not appear to be any link between subsidence effects and dissolved oxygen or the pH of water.

Iron can be seen to form orange coloured flocs which 'precipitate' out. The elevated concentrations recorded in some sample results may reflect flocs present in the sample water. The effect of subsidence on water quality in the Project area is expected to be similar to that already observed – transient pulses of iron, and to a lesser extent, manganese, aluminium and conductivity increases which would likely occur following any instances of fresh cracking of the creek bed. There is no evidence or reason to expect upward trends in water quality parameters or persistent change to water quality as a result of subsidence effects.

MSEC (2008) report that no gas emissions have previously been observed during mining beneath the Waratah Rivulet at the Metropolitan Colliery. The emission of gases at the surface that have been encountered elsewhere in the Southern Coalfield generally tends to be short-lived temporary events. There is also no evidence or reason to expect any adverse water quality effects as a result of gas emissions in Waratah Rivulet.

7.3 Observed Effects on In-Stream Pools in Waratah Rivulet

As described in Section 5, Waratah Rivulet contains a series of in-stream pools which have formed in natural depressions in the bed rock and frequently behind locally elevated rock bars. Six distinct pools (Pools A to F) have been identified within the reach between Flat Rock Crossing (near the downstream end of current longwall mine area) and the Flat Rock Creek confluence upstream of the longwall mine area – refer Figure 31. Another 18 pools in total (Pools G to W) have been identified in the reach between Flat Rock Crossing and the inundation limits of Woronora Reservoir – refer Figure 31 below. The series of pools are located upstream and downstream of the four main rock bars (WRS5, WRS6, WRS7 and WRS8) along the Waratah Rivulet.

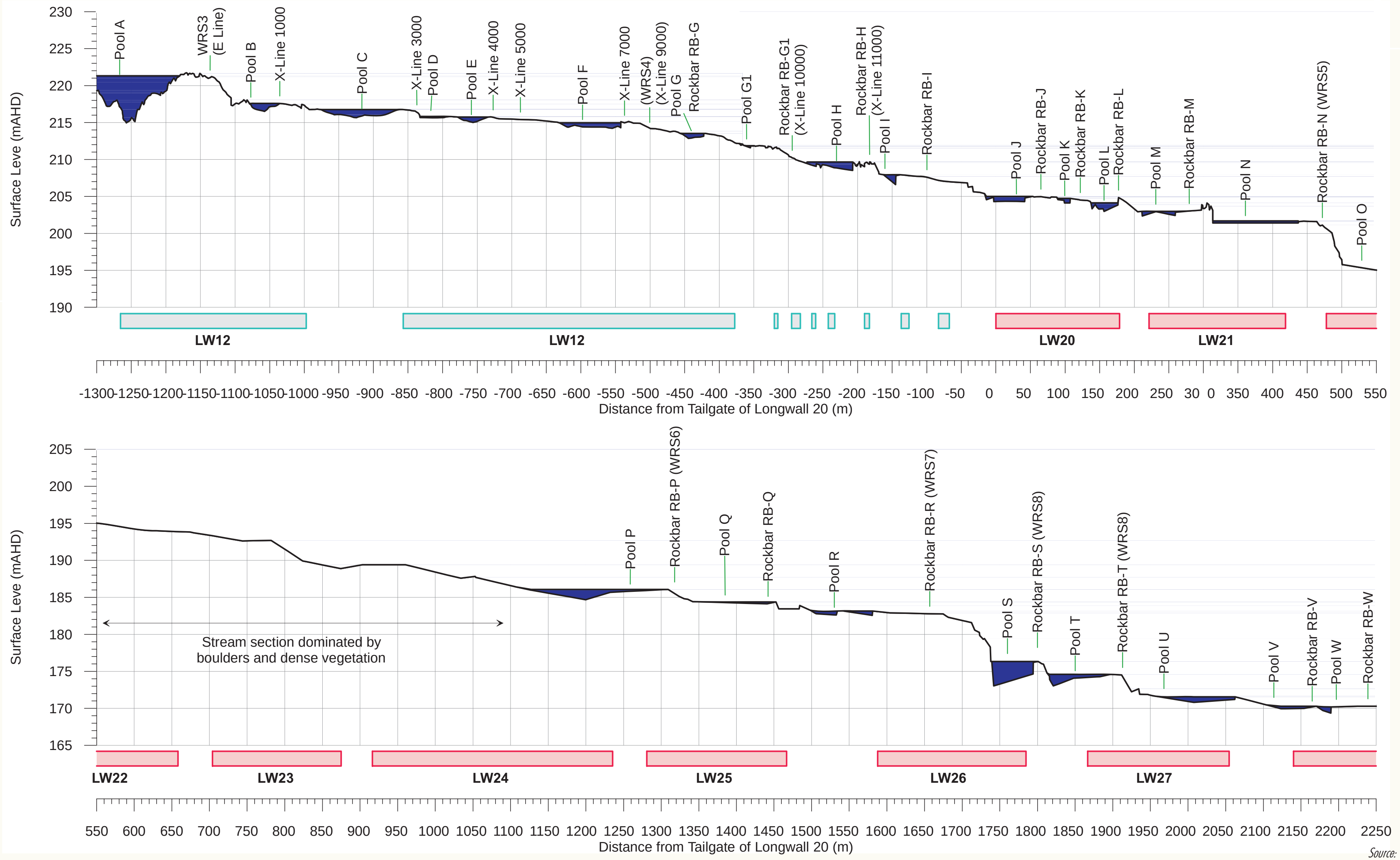
As outlined in Section 6.1, past longwall mining beneath Waratah Rivulet and its tributaries has resulted in up-sidence, valley closure and associated dilation and compression/shear induced fracturing of the bed rocks. There have been monitored effects on pool water levels, frequency of flow connecting in-stream pools and effects on water quality. In particular up-sidence in Waratah Rivulet has resulted in the development of extensive and, in places, interconnected and hydraulically conductive subsurface fractures which extend to 15 m below the bed level. These fracture networks are typically orientated parallel to the stream bed and can in some reaches convey significant flows below the surface. Surface flow can infiltrate into this network via the surface expression of cracks that connect into the subsurface fracture network. Whilst the water level in pools will naturally decline during dry periods as a result of evaporation from the pool surface and movement of surface water to the groundwater in areas where the stream bed is above the surrounding groundwater level - such as at rock bars, the additional leakage of water via subsidence induced cracks results in artificially rapid decline in pool water level and a reduction in the frequency that pools are full and overflowing.

At times when upstream flow exceeds the hydraulic capacity of the fracture network and the connecting surface cracks, excess surface inflow will cause the pool level to rise. As discussed in Section 7.1 above, the hydraulic capacity of the fracture network is not constant along the entire affected reach and as a consequence loss of inter-pool connectivity does not occur between all pools at the same time with some pools remaining connected for much longer during protracted drought than in others. Further, as discussed later in this report the degree of flow diversion has been observed to reduce with time as a result of natural healing or in-filling process.

During prolonged dry periods when flows recede to low levels, the number of instances where loss of flow continuity between pools increases with a greater proportion of these lower flows being conveyed entirely in the subsurface fracture network.

7.3.1 Observed Water Levels in Pools along Waratah Rivulet

Flow rates in Waratah Rivulet have been estimated over the period 1 January 2002 until 10 February 2008 using a catchment model calibrated against flows observed at the SCA gauging station near the catchment outlet. Analysis of this record indicates that there have been two periods of abnormally persistent low flows – refer Figure 32.



Source: MSEC (2008)

METROPOLITAN COAL PROJECT

FIGURE 31

Longitudinal Section of Waratah Rivulet showing In-Stream Pools

HELENSBURGH COAL PTY LTD

Gilbert & Associates

MET-06-02 EA AppSW_005D

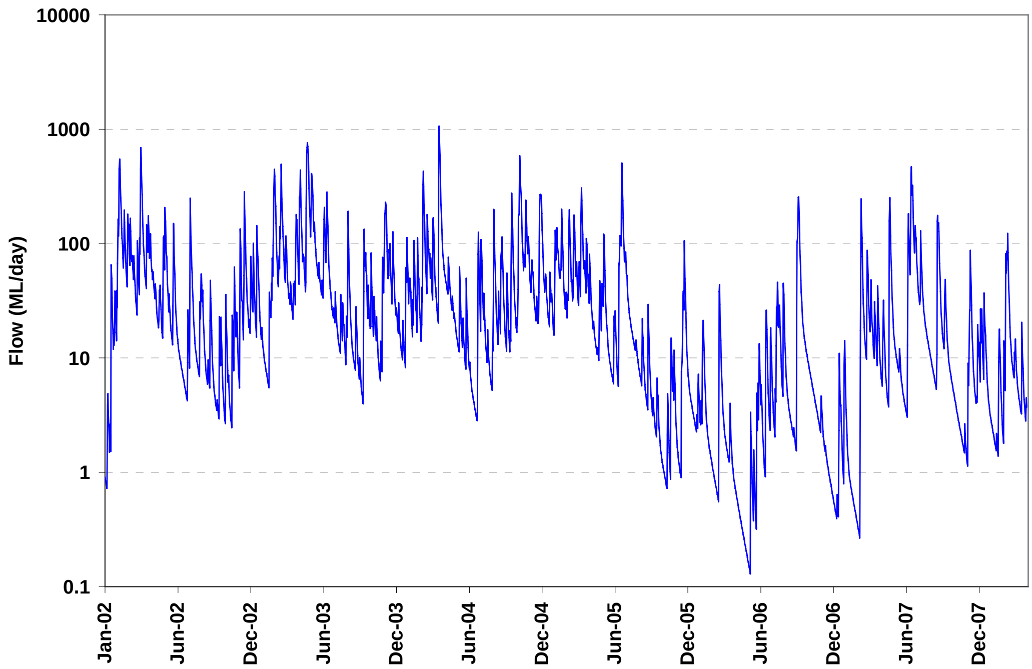


Figure 32 Simulated Inflows to Woronora Reservoir (January 2002 to February 2008)

The first was experienced from the beginning of March until the end of May 2006 and the second from late December 2006 until February 2007. Whilst the simulated inflow to the Woronora Reservoir did not cease during either of these periods, the persistence, particularly low flows would have resulted in loss of surface flows and declining pool levels in the upstream sections of Waratah Rivulet which have been affected by longwall mining. Water levels have been recorded on a daily basis in 9 pools (Pools A, B, C, E, F, G, G1, H, and I) since 20 September 2005. Automatic water level sensors were also installed in Pool A on 28 February 2007 and in Pool F on 8 March 2007.

Pool A is significantly larger than the other pools both in terms of length and depth. Monitoring data indicates that subsidence has had a much larger effect on water levels in Pool A than in any of the other pools which overlie the current mine area. This is believed to be a consequence of the exceptionally large and deep nature of Pool A and the unusually large downstream rock bar which is known to have been intensely jointed prior to mining and therefore more prone to the effects of valley closure. Pool level data on the other affected pools in Waratah Rivulet has been examined to assess the range of effects subsidence has had on pool levels. Pools A to F were undermined by Longwalls 11, 12 and 13 whilst Pools G and G1 are within the angle of draw of past longwall mining including Longwalls 12, 13 and 14.

Pool A has shown a markedly different response to the other pools with water level falling rapidly and significantly between storm events. Storm events appear as rapid, large increases in water level – refer Figure 33.

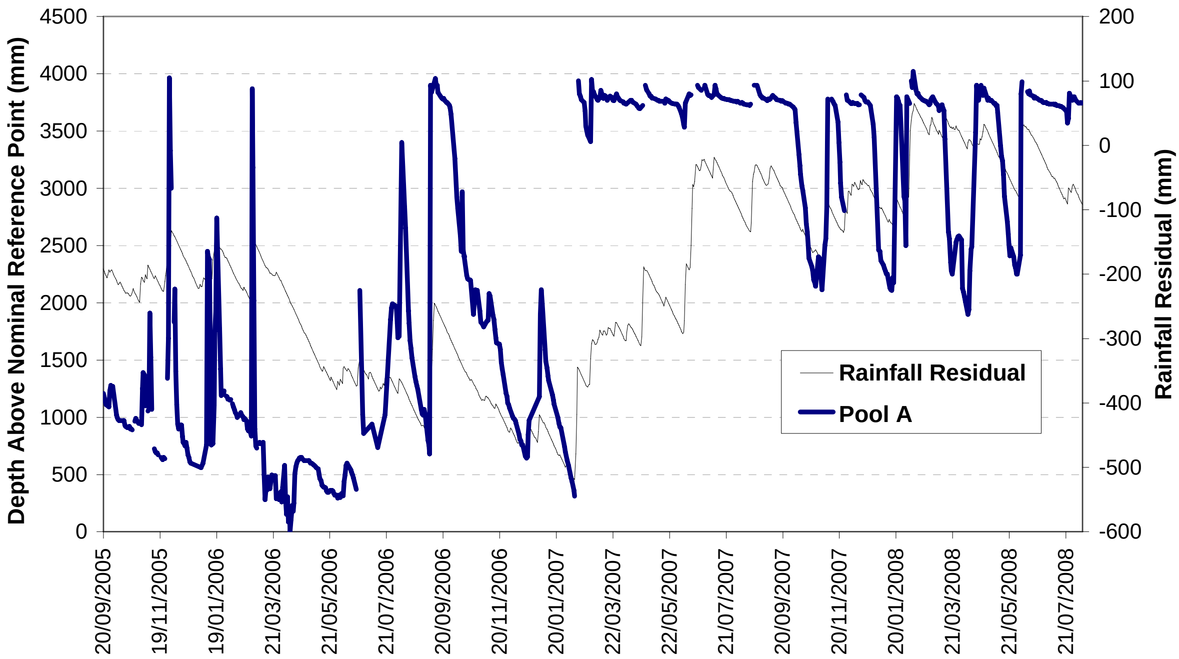


Figure 33 Monitored Pool Levels in Pool A

It is apparent that leakage rates into the subsurface network changed (reduced) significantly after the large runoff event in February 2007. Water balance analysis of the pool supports the view that there has been a significant reduction of underflow through the Pool A rock bar after the February 2007 event. This would indicate a process by which fractures are being closed or "clogged" over time (i.e. some degree of natural healing).

Water levels and changes in water level in Pools B, C and E has been similar with, relative to Pool A, slow declines in water level between storm events followed by rapid recovery during and for some time following these events. Figure 34 shows a plot of monitored levels in Pools B, C and E and rainfall residual for the same period.

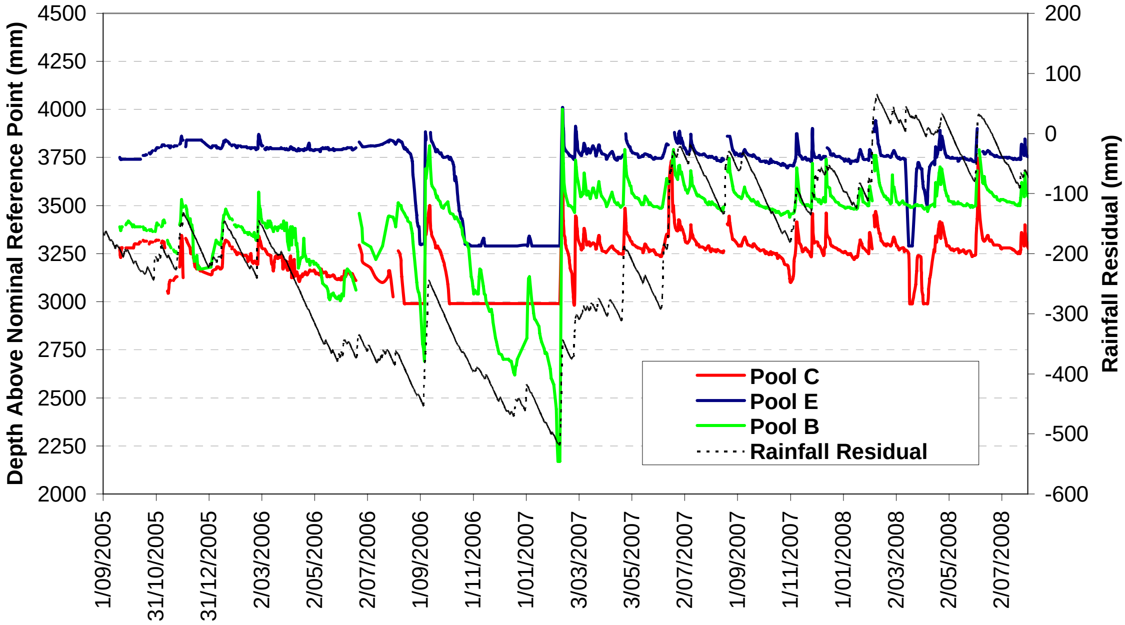


Figure 34 Monitored Pool Levels in Pools B, C and E

Pools B, C and E have remained at least partially full over the entire monitoring period (September 2005 to July 2008). During the more typical periods (September 2005 until August 2006 and from February 2007 until July 2008), the water level in Pools B and C oscillated between overflow level (full) and a low level of about 0.5m below full. During the unusually dry period (October 2006 until February 2007) the water level in Pools C and E fell below the reference water level whilst pool B fell by more than a metre from its full level. All three pools have regularly overflowed since February 2007. The trend of higher pool levels post February 2007, recovering to levels which occurred prior to the October 2006 to February 2007 dry spell, is consistent with the overall trend in rainfall over the monitoring period as illustrated by the pattern of rainfall residuals which show a declining (below average) trend prior to February followed by an period of above average rainfall after that time.

The water level behaviour in the unaffected/downstream pools (i.e. Pools G1, H and I) has been similar with water levels remaining relatively steady between flow events which appear as isolated small spikes in water level – refer Figure 35.

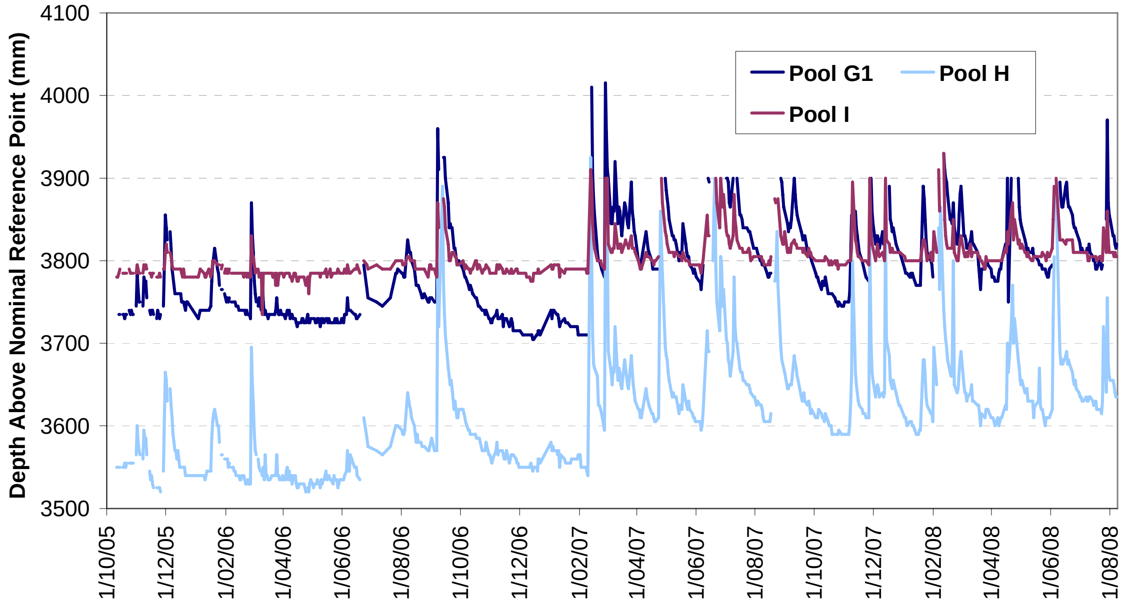


Figure 35 Monitored Pool Levels in Pools G1, H and I (Downstream of Longwall Mine Effects)

It is apparent from Figure 35 that the water levels in some unaffected pools, do periodically fall below their “cease to flow” level particularly during dry periods where inflows are low as is evident in the recorded water levels in Pools G1 and H.

7.3.2 Inter-Pool Surface Flow

During periods of low flow, subsidence affected sections of Waratah Rivulet between pools have been observed to “dry out” with surface flows being conveyed via the sub-surface fracture network to downstream sections. This behaviour has also been observed in some unaffected sections of the Eastern Tributary downstream of any subsidence effects – i.e. it is a natural phenomenon, albeit less extensive than that observed in the subsidence affected reaches of Waratah Rivulet. Observations of flows along different reaches of Waratah Rivulet between Pool A and Pool G confirm that flows are sufficient to provide a continuous connection between some pools at times when there is no continuous flow connecting other pools. There are also some inter-pool reaches with “micro-pools” and shallow depressions in the bed rock which hold water during dry spells – refer Plate 5.

Plate 5 Micro-Pools – Waratah Rivulet

Inter-pool connecting flows observed downstream of the subsidence affected section of Waratah Rivulet typically comprise shallow, rapid flow across the generally smooth surface of bed rock between local depressions – refer Plate 6.

Plate 6 Typical Inter-Pool Section of Waratah Rivulet During Low Flow

A typical inter-pool reach which has been affected by subsidence induced underflow during low flow conditions is shown on Plate 7 below.

Plate 7 Typical Subsidence Affected Inter-Pool Section of Waratah Rivulet During Low Flow

As can be seen on the longitudinal section reproduced in Figure 31, the distance between the end of one pool and the start of another varies but is generally similar to the lengths of the pools. The average distance between Pools A to N is about 60m.

7.3.3 Effect of Flow on Water Quality in Pools

Streamflow and electrical conductivity records from the SCA Waratah Rivulet gauging station near the inflow to Woronora Reservoir is shown on Figure 36 below.

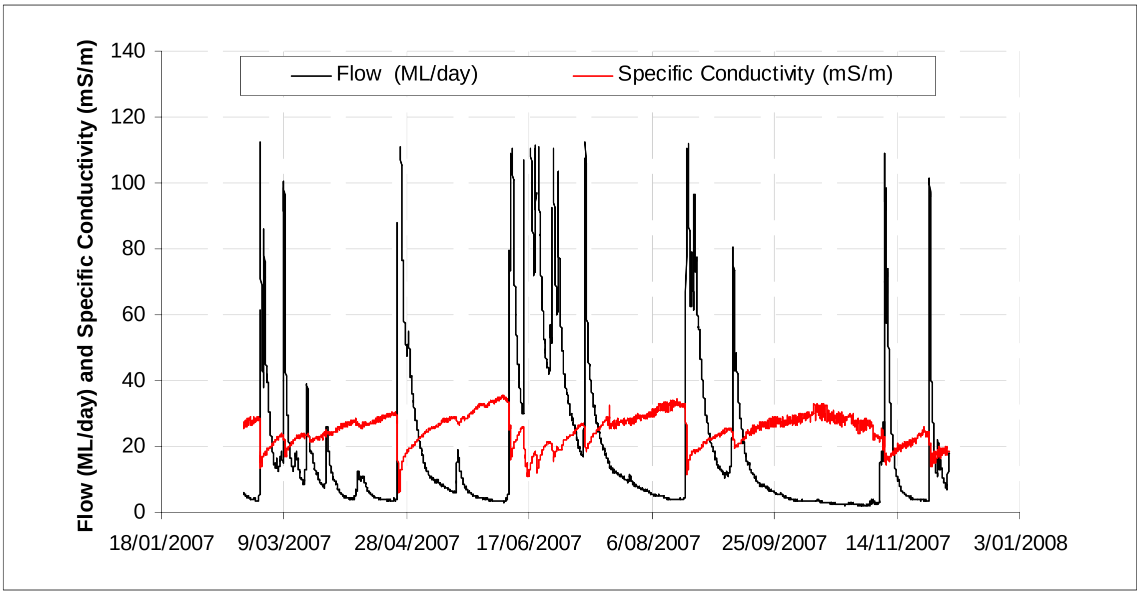


Figure 36 Waratah Rivulet Gauging Station – Observed Flow and Conductivity

It is clear from this plot that measured conductivity is negatively correlated with flow. During periods of low flow, conductivity values are seen to be relatively steady. Similar behaviour has been observed at the gauging station on Woronora River, which has not been affected by longwall mining – refer Figure 37.

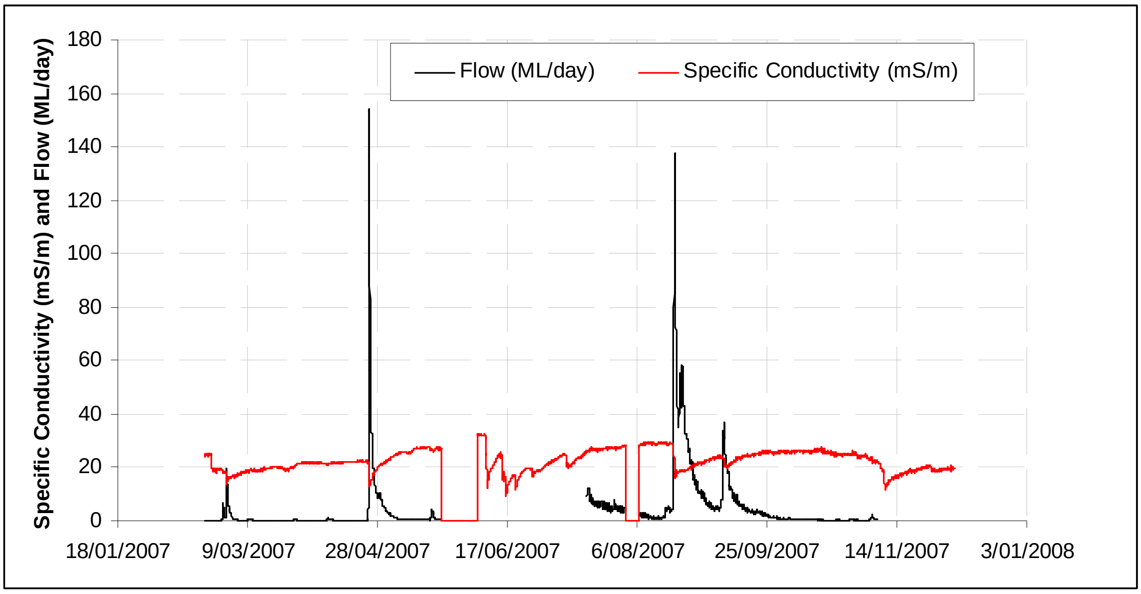


Figure 37 Woronora River Gauging Station – Observed Flow and Conductivity

This inverse relationship between flow and salinity is consistent with solutes present in elevated concentrations in groundwater relative to surface water. Analysis of water quality data collected in pools affected by subsidence indicates that iron concentrations spike due to the effects of subsidence – via a mechanism of iron and other minerals present in the bed rock being exposed due to subsidence induced fracturing and being flushed out. This occurs in distinct episodes which can be linked to subsidence movements and development of fracture networks in the bed rock. Figure 38 shows simulated flows and associated iron concentrations in Waratah Rivulet over the period from January 2002.

There are several episodes where iron has been elevated – the first occurred in January 2005 and there have been several since that time. The most noticeable occurred in March 2006 which corresponded to subsidence associated with Longwall 12. It also corresponded to a protracted period of unusually low flows. Iron concentrations were also elevated in period from late 2006 until the high rainfall event in February 2007 – relative to concentrations measured after that date.

This suggests that there is also an inverse correlation between iron and flow in the local pools which was not present prior to 2005. These effects are not seen in pools downstream of the subsidence affected section of the Waratah Rivulet. The overall iron concentrations are however low and not environmentally significant.

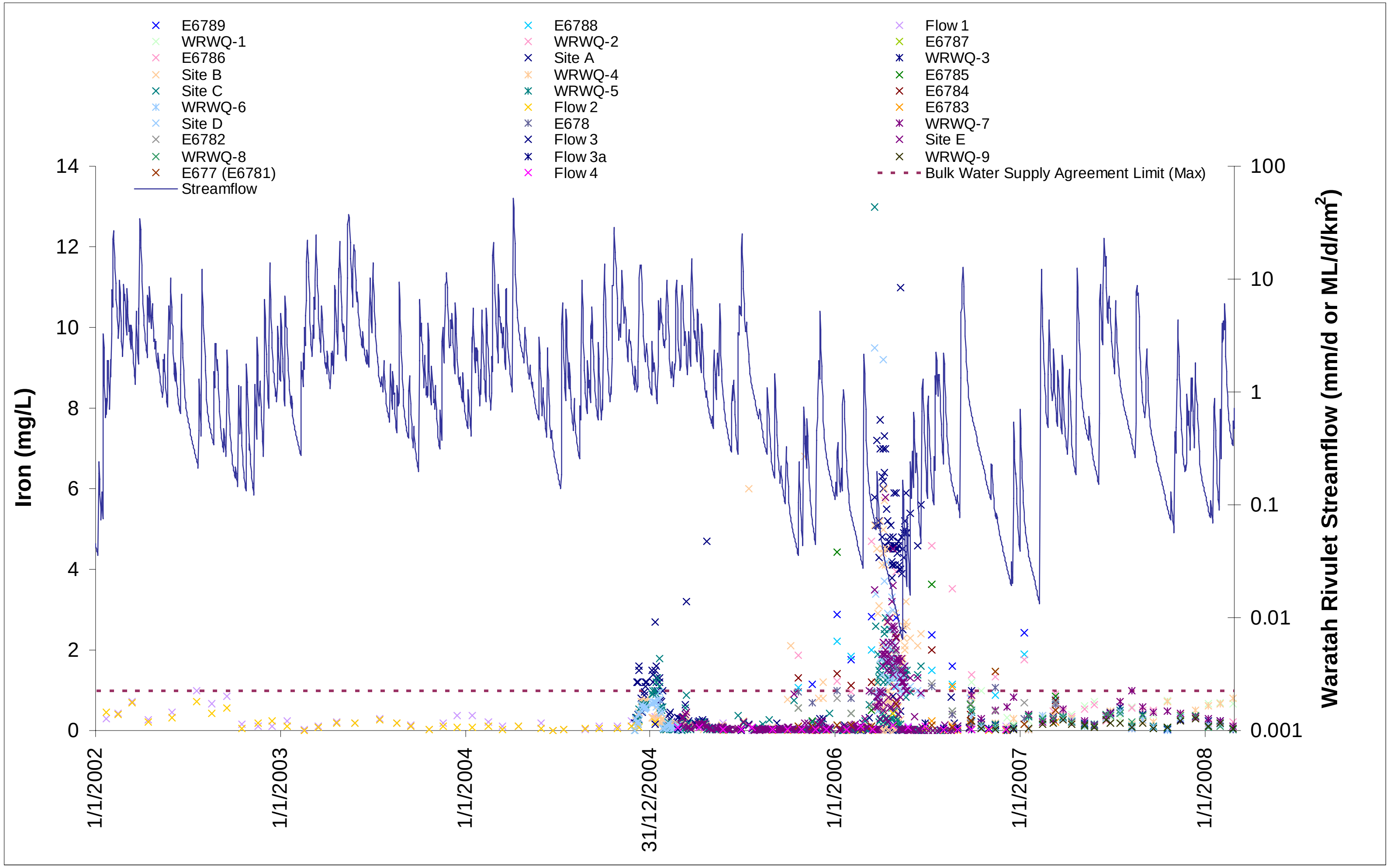


Figure 38 Simulated Flow and Iron Concentrations Waratah Rivulet

Note: – the iron concentration results reflect a combination of dissolved and total iron levels.

7.4 Observed Effects on Tributaries

The tributaries of Waratah Rivulet contain numerous in-stream pools. The tributary pools are however much smaller, in plan area, depth and volume relative to runoff flow rates, than those on the rivulet itself. The water level in a number of these tributary pools has been monitored as part of the LW 14 to 17 monitoring commitments. Figure 39 shows recorded pool water levels in two pools (UTP1 and UTP3) in the "Unnamed Tributary" (sub-catchment 5 in Figure 8) which overlies LW 14, 15 and 16. Pool UTP1 has been undermined by LW 14 whilst Pool UTP3 overlies LW 16 which had not been undermined. The effects of subsidence from LW 14 on UTP1 are apparent in the post September 2007 response where the effects of leakage can be seen in lower pool levels during the longer recessionary periods. As with most pools in the tributaries, UTP1 is small in comparison with flow volumes generated by rainfall-runoff events and the pool response during wet periods appears to be un-affected by the presence of the pool. In the longer recessionary periods however the monitored pool level can be seen to decline below the cease to flow level at a rate faster than it did prior to being undermined. This response is consistent with capture and underflow of small flows.

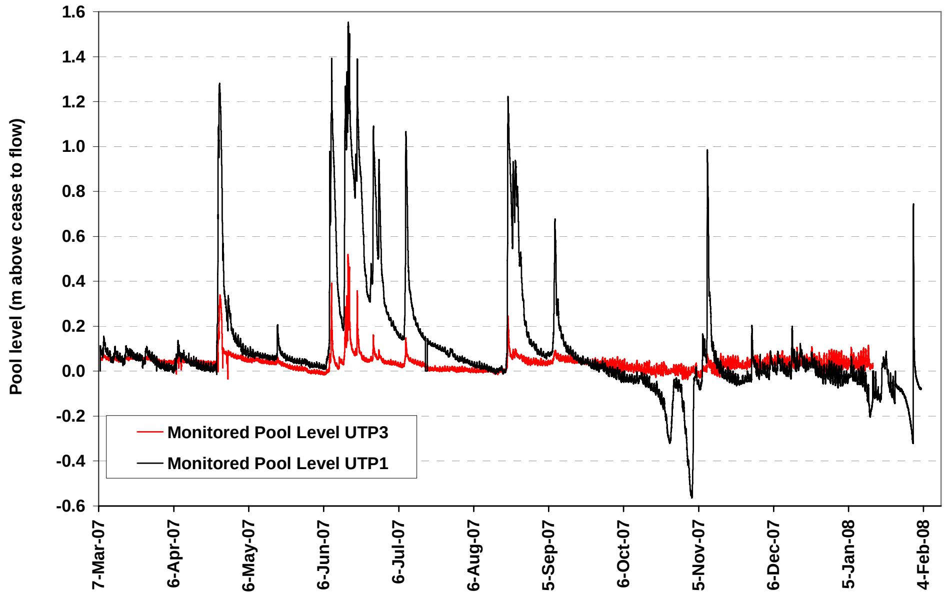


Figure 39 Monitored Pool Water Levels – UTP1 and UTP3

Based on MSEC (2008) subsidence predictions, this type of effect would be expected to occur to varying degrees in tributary pools above the underground mining area as a result of up-sidence and valley closure. Similarly, the natural healing processes referred to in Section 7.3.1 above would also be expected to occur to a degree over time.

7.5 Observations from Field Reconnaissance

Reconnaissance of the subsidence affected reaches of the Eastern Tributary was undertaken on the 29th March 2006, the 20th February 2007 and on the 26th July 2007. The Eastern Tributary was undermined by Longwall 2 in 1996 and it has potentially been affected by Longwalls 2 and 3. However it has not been affected by longwall mining over the last 10 years and as such it is provides the opportunity to assess the effects of longwall mining on tributary pools and also natural remediation in the medium term.

The first observations on 29th March 2006 corresponded to a significant dry spell with an average rainfall of 1.1 mm/day over the previous 30 days and a maximum daily fall of only 5.4 mm during this period. The reconnaissance on 20th February 2007 was preceded by 5 dry days which followed major falls of 93.6, 60.6 and 83.4 mm in the 3 days prior. The final reconnaissance conducted on 26th July 2007 corresponded to a relatively dry period with an average of 2.2mm of rainfall recorded over the previous 26 days and no rainfall over the 13 days leading up to the inspection.

During the first and driest inspection, a number of pools were observed upstream from the northern end of the longwall area. One dry pool (Plate 8) and several non flowing pools (Plate 9) were observed. There was a small flow observed at the crossing of Fire Road 9J downstream of the Longwall area (Plate 10).

Plate 8 – Dry Pool Eastern Tributary – 29th March 2006

Plate 9 – Non Flowing Pool Eastern Tributary – 29th March 2006

Plate 10 – Eastern Tributary from the Fire Road Crossing Downstream of Longwall Mine Area – 29th March 2006

The second inspection covered a longer section of the tributary, starting from near the headwaters and progressing downstream to near the fire road crossing. There were no dry pools observed over this reach although some pools had no observable overflow. Ten significant pools were observed and most contained clear water with sand deposits visible in the bottoms of some pools. Plate 11 shows the first pool encountered near the upstream end of the main watercourse. It comprised a shallow rock bed depression with occasional sand deposits in the bed and banks.

Plate 11 – Pool in the Eastern Tributary overlying Longwall 2 – 20th February 2007

Plate 12 below shows a pool observed approximately mid way along Longwall 2. The bed of the pool appeared to be fractured sandstone. The pool was full and overflowing.

Plate 12 – Pool in the Eastern Tributary – 20th February 2007

Plate 13 is the pool which had been dry during the first reconnaissance in March 2006 – refer Plate 8.

Plate 13 – Pool in Eastern Tributary – 20th February 2007 Looking Downstream (note iron staining)

The third reconnaissance also involved extensive inspection of the tributary over the entire Longwall 2 area. Again there were no dry pools observed with most pools being full or near full. Plate 14 is a photograph of the same pool as that shown in Plates 8 and 13.

Plate 14 – Pool in Eastern Tributary – 26th July 2007 Looking Upstream

The observations of pools on the Eastern Tributary and the monitored pool levels on Un-named Tributary indicate that subsidence effects on tributary pools above the proposed underground mining area are likely to be variable. The observations also indicate that although mine subsidence has the potential to increase the rate of leakage (and consequently pool level recession) of pools, it is likely that a portion of the pools subject to mine subsidence effects will hold some water during prolonged dry periods. These latter pools would remain full during most typical wetting and drying cycles.

It is considered likely that some pools may also tend to self heal over time – particularly in lower energy reaches where bed load moves through pools and silt and organic matter settles out of the water column during flow recessions.

8.0 PRELIMINARY ASSESSMENT OF THE EFFECTS REMEDIATION TRIAL USING PUR INJECTION ON POOL LEVELS IN POOL F

HCPL has conducted a remediation trial using polyurethane (PUR) at a rock bar known as WRS4 in the Waratah Rivulet. The objective of the remediation trial was to investigate the effectiveness of PUR grouting products and associated injection methods in reducing the hydraulic conductivity of the fractured rock mass. Successful remediation of the WRS4 rock bar was confirmed through measurement of the decrease in hydraulic conductivity and further evidenced by the return of water flowing over the rock bar.

Key outcomes of the trial reported by HCPL (2008) include:

- PUR injection can be conducted without environmental harm.
- Fracture spaces can be successfully filled from <1mm fine cracks to larger (>100mm) voids.
- The hydraulic conductivity of the overall rock mass was decreased to the extent that the rock bar once again acted as a natural weir to maintain the persistence of its upstream pool.
- The injection products and method of injection could be applied to other rock bars along Waratah Rivulet.

Effects to water levels in Pool F were first reported during the mining of Longwall 12 in October 2005. Pool levels were further affected by mining of LW 13.

Water levels in Pool A were also affected by mining of Longwall 12 and subsequent longwalls. Pool A has not been fully remediated and continues to show obvious signs of subsidence induced underflow.

Pool H is located a significant distance downstream of current longwall mining activities and of Pool F. It has not been affected by subsidence or its far field effects. Pool H is of a similar size to Pool F and has similar pool/rock bar morphology. Comparison of recorded water level behaviour in these three pools before and after the remediation trials at Pool F provides a means of assessing the success of the trial.

During periods of significant rainfall and runoff in Waratah Rivulet, the water level in subsidence impacted pools is similar to pools unaffected by subsidence. Under these flow conditions pools and their downstream rock bars become “drowned out”. During dry periods when flows in the rivulet are in a low, recessionary regime, the water level in pools affected by subsidence recedes much faster than is the case in unaffected pools. Water levels in natural pools will decline below their ‘cease to flow’ level (i.e. stop overflowing) if the combined effects of evaporation from the pool surface and slow leakage through the downstream rock is greater than inflow rate.

Figure 40 shows recorded pool water levels in the 3 pools from 20th September 2005 to 1st August 2008. It is readily apparent that water levels in both Pools A and F have regularly declined rapidly during low flow periods whilst water levels in Pool H have generally remained near the CTF (zero) level. Water levels in Pool A have receded further at least in part because the pool is significantly deeper than Pool F.

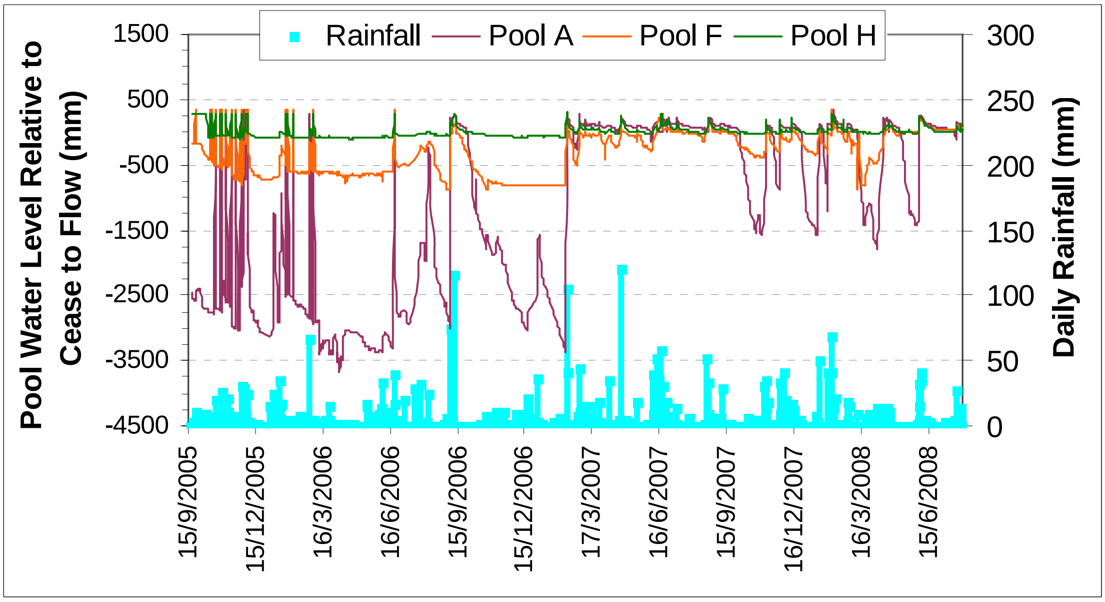


Figure 40 Monitored Water Levels in Pools A, F and H (September 2005 to July 2008)

Figure 41 shows the last 6 months of the recorded data. The remediation trial commenced on 17th March 2008 and was completed on 13th May 2008. There is an obvious comparative difference in water level response in Pool F prior to 18th April 2008 and pool levels after this date. Water levels in pool F have mirrored those in Pool H after 18th April 2008 but not before. Water levels in Pool A continued to show the effects of subsidence during this period.

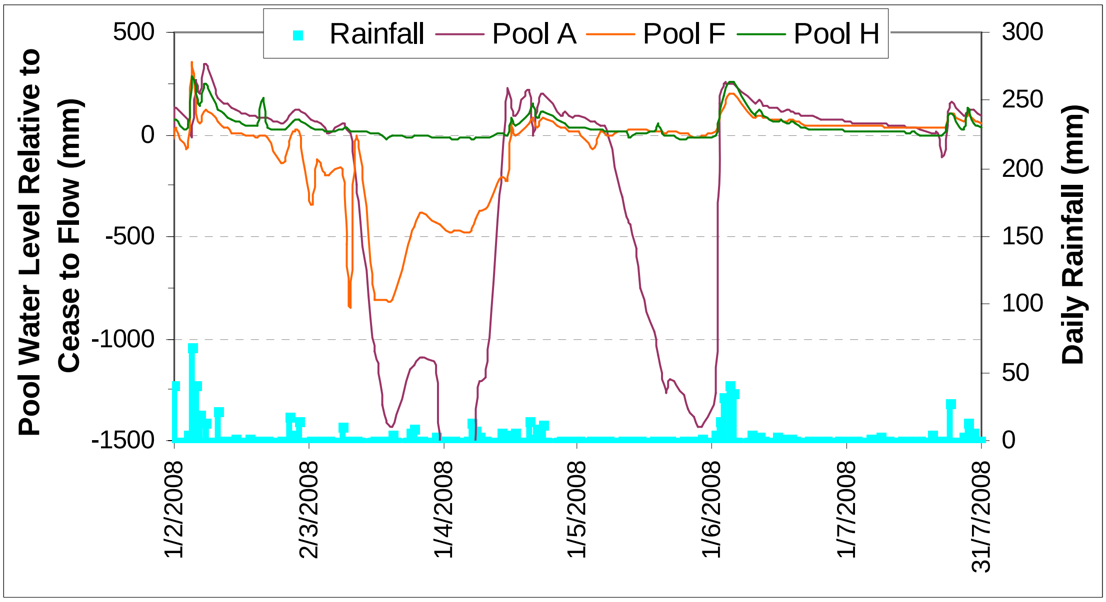


Figure 41 Monitored Water Levels in Pools A, F and H (February to July 2008)

Figure 42 shows a further magnification of the period from near the end of the trial until 16th June 2008. This clearly shows water level responses in Pool F have mirrored those in Pool H (i.e. have been similar to natural pool behaviour). As indicated above, this behaviour is in stark contrast to the water level responses in Pool A over this period. The rainfall over this period is also shown on Figure 42. There was 138mm of rainfall recorded in the period 13th May to 13th June 2008 with no rain recorded from 13th to 29th May 2008. This indicates that any residual leakage in Pool F is low relative to low flows which were likely to have occurred over this period.

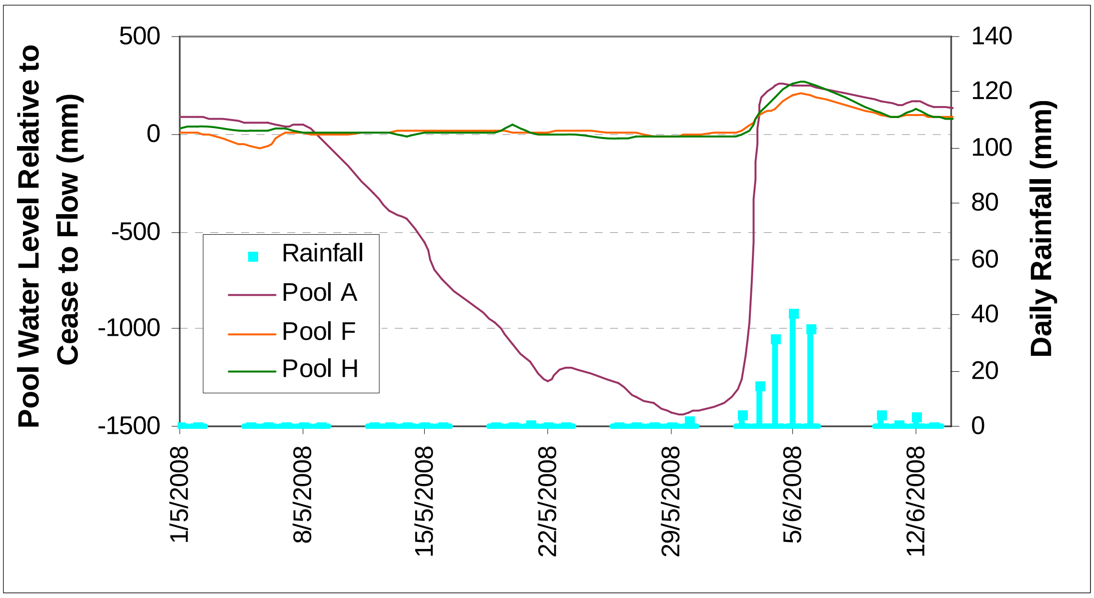


Figure 42 Monitored Water Levels in Pools A, F and H (May to June 2008)

The collection of pool level data over time will facilitate the quantification of residual leakage rates in Pool F. However the conclusion can be drawn that water levels in the pool have behaved in a similar fashion to those in a natural pool after the trial. Flows in the Rivulet since remediation are also likely to have been low during the period from 13th to 29th May 2008 – during which time the pool water levels responses in Pool F are indistinguishable from those recorded Pool H. It can therefore be concluded that water level responses in Pool F have changed markedly as a result of the PUR trial.

9.0 ASSESSMENT OF IMPACTS OF PROPOSED PROJECT ON SURFACE WATER RESOURCES

The subsidence effects of the proposed longwall mining on Waratah Rivulet and its tributaries are predicted to be of a similar nature to those that have been observed during the mining of Longwalls 1 to 15 (refer Section 7).

Surface and sub-surface cracking has the potential to alter, albeit at a small local scale, the movement of water in the plateau and hillslope areas above the proposed mining area. However, the magnitude of the predicted subsidence effects is considered too small to influence the hydrological processes in these areas and is unlikely to have any real effect on the soil moisture regime.

The anticipated changes in channel gradients (as predicted in MSEC, 2008) would cause localised increases and decreases in flow energy/velocities. Increases in flow energy in steeper sections may in turn result in bed, or more likely, bank erosion. The extent of any erosion effects would depend principally on the strength of bank materials and the integrity of the riparian vegetation. Based on observation of similar streams that have been affected by subsidence, it is expected that bank erosion would be relatively minor and comprise a slow retreat of the bank until a new dynamic equilibrium is reached. MSEC (2008) also indicates that the potential for changes in stream alignment due to mine subsidence is low. The steep and incised nature of the local watercourses is such that alignment change is not a real possibility and it has not occurred in any subsided areas at the Metropolitan Colliery to date.

Swamp grades vary naturally and the predicted maximum mining-induced tilts are generally orders of magnitude lower than the existing natural grades within the swamps (e.g. estimated maximum natural grades of approximately 30 mm/m to 100 mm/m).[12] The predicted tilts would not have any significant effect on the localised or overall gradient of the swamps or the flow of water. The dominant hydrological processes affecting moisture in the swamps are infiltration of incident rainfall resulting in retention of a shallow perched groundwater system in the swamp sediments, and losses to evapotranspiration. Any minor mining-induced tilting of the scale and nature predicted is not expected to significantly increase lateral surface water movements which are small in relation to the other components in the swamp water balance.

A comprehensive analysis of stream flow data and data on the yield behaviour of Woronora Reservoir show that past mining has had no discernable effect on flow entering the reservoir or yield from the reservoir – refer Section 7.1 above. Detailed groundwater analysis (refer to Appendix B of the Environmental Assessment) indicated that the geological and hydrogeological regimes at the Metropolitan Colliery area are such that there is no mechanism by which mining could result in a detectable loss of groundwater contribution to reservoir yield.

[12] The in-valley swamp overlying previously mined Longwalls 7 and 8 has an estimated maximum natural grade of approximately 75 mm/m.

Past mining has however caused localised effects on Waratah Rivulet and its tributaries above the previously mined area. Significant 'underflow' is known to occur via the fracture networks that have formed as a result of valley closure, up-sidence and compression of the rock strata along and beneath subsided reaches of the Rivulet and its tributaries. It is known from extensive field tests that this fracture system comprises a series of large open cracks, which have a horizontal or sub-horizontal orientation. These effects have been assessed and are described in more detail in Sections 7.3 above.

There is extensive observational evidence that the fracture network can convey significant flows below the surface. At times when flow exceeds the hydraulic capacity of the network, surface flow will occur in these areas. Water level monitoring and water balance modelling suggest that the hydraulic capacity of the subsurface network may be in the region of 0.5 ML/day in some places. This fracture flow capacity estimate is considered conservative as it has been obtained from a water balance analysis of Pool A where the effects of subsidence are likely to have been greater than has been experienced in other pools due to its unique (large) size and because the downstream rock bar is thought to have been naturally more jointed than is apparent in the other pool rock bars on Waratah Rivulet.

All the investigations undertaken to date however show that subsidence induced underflow re-emerges downstream of the subsidence area with no evidence of flow loss to Woronora Reservoir. This is consistent with the findings of Southern Coalfield Inquiry (NSW Government, 2008):

> *"No evidence was presented to the Panel to support the view that subsidence impacts on rivers and significant streams, valley infill or headwater swamps, or shallow or deep aquifers have resulted in any measurable reduction in runoff to the water supply system operated by the Sydney Catchment Authority or to otherwise represent a threat to the water supply of Sydney or the Illawarra region."*

An appreciation of the effect flow capture and underflow can have on the frequency and duration of low flows in an affected water course can be gained by assuming that the fracture network would capture and transfer water up to a maximum rate after which all additional flow would occur as surface flow. The effect this situation would have on the frequency of flows at the SCA Waratah Rivulet gauging station has been assessed for a conservative fracture network capacity of 0.5 ML/day – refer Figure 43.

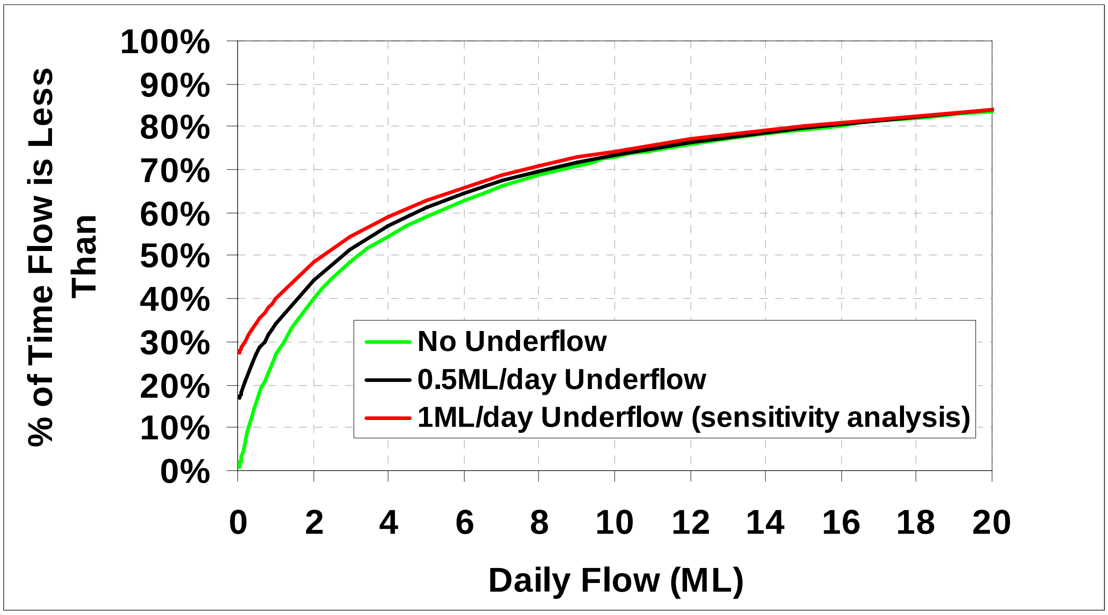


Figure 43 **Low Flow Duration Curves for Lower Waratah Rivulet (Underflow Capacities of 0.5 ML/day and Sensitivity Analysis of 1.0 ML/day)**

A sensitivity analysis was also undertaken assuming a larger underflow of 1 ML/day based on the assessed underflow rate at Pool A (which is expected to be larger than any of the other smaller pools and rock bars to be encountered on Waratah Rivulet above the proposed mining area).

Figure 43 shows that the effects will be most noticeable at low flows and on the frequency of no flow. The effects on the frequency and magnitude of high flows by comparison would be negligible. The results illustrate that with an underflow capacity of 0.5 ML/day, the average frequency of no flow days might be expected to increase from about 2% of days to 15% of days, and the average frequency of low flows (less than 2 ML/day) increase from 36% to 40% of days. The simulated effect at moderate and higher flows (as represented by flows greater than 10 ML/day), are for negligible change (less than 0.5%).

As indicated in the sensitivity analysis, the corresponding changes for a larger 1 ML/day underflow rate are for the frequency of no flow days to increase from 2 to 28% of days and for the frequency of flows sufficient for at least observable flow between pools (i.e. >2 ML/day) would reduce from 60% to 52% of days.

Whilst it is not possible to predict the exact location and hydraulic capacity of individual subsurface fracture networks that may be caused by the proposed future longwall mining, it can be predicted with a high level of confidence that similar shallow fracture networks would occur due to up-sidence and valley closure as those that have been observed as a result of past longwall mining upstream on Waratah Rivulet.

The effects in terms of capture and underflow of small flows and the consequences for flow persistence and connectivity between pools is likely to be similar to that which has already been observed.

The hydraulic capacity of the fracture network would vary along the affected reach. Observations of flows along different reaches of Waratah Rivulet between Pools A and G confirm that flows are sufficient to provide a continuous connection between some pools at times when there is not continuous flow connecting other pools. During prolonged dry periods when flows recede to low levels, the number of instances where loss of flow continuity between pools increases with a greater proportion of these flows being conveyed entirely in the subsurface fracture network.

The localised effects of capture and underflow of small flows on the magnitude and frequency of residual flows can be gauged quantitatively by the flow frequency shown in Figure 43. The underflow rates used in developing these flow curves was based on an assessment of the hydraulic capacity of the fracture network associated with Pool A and its downstream rock bar. For the reasons explained above, it is expected that this underflow rate might be near the upper end of likely fracture flow capacity that may develop in the lower reaches of Waratah Rivulet due to Longwalls 20 to 44.

Observational evidence and monitoring confirm that pool water levels will be similarly affected by fracturing of the bed rock. During periods of significant rainfall and runoff in Waratah Rivulet, the water level in subsidence impacted pools would be the same as pre-subsidence levels to pools unaffected by subsidence. Under these flow conditions pools and their downstream rock bars would become “drowned out”. During dry periods when flows in the rivulet are in a low, recessionary regime the water level in pools affected by subsidence would recede much faster than is the case in unaffected pools. The effects of subsidence on typical tributary pools can also be seen as lower pool levels during the longer recessionary periods with little observable effect during periods of normal stream flow. Observation of pools in the Eastern Tributary and in tributaries of Waratah Rivulet indicate that a portion of the pools subject to mine subsidence effects hold some water during prolonged dry periods. These pools remain full during most typical wetting and drying cycles. There is also evidence that natural clogging can occur over time reducing long-term leakage rates.

Subsidence effects have also been seen to translate into localised effects on water quality. The monitored effects have been isolated, episodic pulses in iron, manganese and electrical conductivity in the middle reaches in areas directly affected by fracturing of bed rock. There does not appear to be any link between subsidence effects and dissolved oxygen or the pH of water. The most likely mechanism for the observed increases in iron and other metals is for flushing of minerals from freshly exposed fractures created by up-sidence and valley closure. By nature the pulses are isolated and non-persistent. It is also clear that these pulses have not had any measurable effect on water quality in Woronora Reservoir downstream.

The effect of subsidence on water quality is expected to be similar to that already observed – transient pulses of iron, and to a lesser extent, manganese, aluminium and conductivity increases which would likely occur following any instances of fresh cracking of the creek bed. There is no evidence or reason to expect upward trends in water quality parameters or persistent change to water quality as a result of subsidence effects.

There is also no evidence or reason to expect any adverse water quality effects as a result of gas emissions in the mine development area (if any) as gas releases are short-lived temporary events, are released directly to the atmosphere, and would not have time to dissolve in any surface water which is present.

As water releases from the pit top to Camp Gully which flows to the Hacking River would continue to be constrained by the existing Environmental Protection Licence (EPL) 767, it is expected there would be no discernible change in downstream water quality. HCPL continue to implement the Surface Water Management Plan prepared to meet the requirements of pollution reduction programme (PRP) 7 in the EPL.

Based on the above, it is expected that there would be no measurable change in downstream water quality as a result of the Project.

9.1 Cumulative Surface Water Impacts

The assessment of impacts of the Project on surface water resources in this report has considered the cumulative effects of past longwall mining at the Metropolitan Colliery in that the hydrological modelling of the potential effects on the Waratah Rivulet includes the influence of existing upstream mining developments.

On this basis, it is expected that cumulative surface water impacts would have no measurable change in downstream water quality and is not expected to have an effect on catchment yield.

9.2 Effects of Climate Change on Predicted Surface Water Impacts

Recent (post 1950) changes to temperature and other climate variables are evident in many parts of the world including Australia. The IPCC (2007) has, in its most recent assessment concluded that:

> "*most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. Discernible human influences now extend to other aspects of climate, including ocean warming, continental average temperatures, temperature extremes and wind patterns.*"

Predicting future climate using global climate models is now undertaken by a large number of research organizations around the world. In Australia much of this effort has been concentrated in the CSIRO and the Australian Bureau of Meteorology. The CSIRO has recently published a comprehensive assessment of future climate change effects on Australia (CSIRO, 2007). The CSIRO has included assessments based on the predictions from 23 selected climate models from research organisations around the world. Model predictions were made for a range of different future greenhouse emission scenarios adopted by the IPCC.

The CSIRO has used predictions of future climate from these various models to formulate probability distributions for a range of climate variables including temperature, rainfall potential evaporation, snow cover and drought.

Predictions in respect of future rainfall and potential evapotranspiration are of particular relevance to stream flow. The model predictions are made relative to 1990 conditions for 2030, 2050, 2070 and 2100. Predictions for 2030 are relatively insensitive to future emission scenarios because they largely reflect greenhouse gases that have already been emitted. Longer term predictions become increasingly sensitive to future emission scenarios.

9.2.1 *Future Rainfall*

There is large variability inherent in rainfall in Australia and predictions of future rainfall also vary significantly between the models used in the CSIRO study. Predictions of future precipitation in southern eastern Australia are generally for decreased rainfall but increases in rainfall per day and for the number of dry days (defined as days with less than 1mm of rainfall). Future seasonal rainfall predictions for the Metropolitan (Helensburgh) area have been obtained using the CSIRO's OzClim[13] system for the medium impact (Max Planck: ECHAM5/MPI-OM) Global Climate model, with medium climate sensitivity and the A1B[14] emission scenario for years 2030 and 2100 – refer Table 13 below.

Table 13 Percentage Change in Seasonal Rainfall Relative to 1990 – Helensburgh Region (from Max Planck: ECHAM5/MPI-OM)

Season	2030	2100
Summer	0.3	0.9
Autumn	-1.8	-6.1
Winter	-6.1	-21.3
Spring	-4.2	-14.4

As noted above however there is a large variability in the prediction of future rainfall of between the various models and the simulated results above are considered to reflect the "middle ground".

Based on these predictions there would be reduced rainfall in the non-summer periods with a slight increase in summer. This reflects a lessening of the current temperate rainfall patterns toward a more sub-tropical regime.

9.2.2 *Future Potential Evapotranspiration*

Predictions of future potential evapotranspiration are more closely aligned to temperature change predictions. In the Illawarra – Helensburgh region the median of the model predictions for the A1B emission scenario are for a slight increase by 2030 (2 to 4%) increasing to between 4 and 8% by 2050 and 2070. The increases are expected to be greater in autumn and winter and lesser in spring and summer.

[13] http://www.csiro.au/ozclim/home.do

[14] A1B emission scenario refers to expected emissions for a future characterized by very rapid economic growth, a global population that peaks in mid century and declines thereafter and a substantial reduction in regional differences in per capita income. It assumes rapid introduction of new and more efficient technologies and a balance between fossil fuel and non-fossil energy sources.

Combined with the predicted change in rainfall patterns these potential evapotranspiration changes would produce more pronounced seasonal patterns of runoff in the region with on average increasing runoff in summer and reduced runoff in the autumn, winter and spring. Relative to the current flows, which are more winter dominated, this might lead to a more uniform pattern of flows. Overall there would also be a tendency for reduced overall runoff but with the possibility of some larger flow events in summer. The predictions of change to future rainfall and potential evaporation by 2100 would be expected to translate into a significant reduction in yield from local catchments with flow on effects to the water supply dams – including Woronora Reservoir.

The effects on yield to Woronora Reservoir would occur irrespective of any affects of longwall mining in the catchment. Longwall mining is however predicted to have localised effects on pools and the frequency of interconnected flows between pools. Unfortunately the CSIRO has not made definitive (quantitative) assessments about the effects of predicted future rainfall and potential evapotranspiration patterns on the persistence of dry spells and hence low flows. General predictions of future drought as it relates to rainfall deficit are included in CSIRO (2007) and suggest that that there could be up to 20% more drought months (were soil moisture is constraining to agriculture), over most of Australia and up to 40% more droughts by 2070 in eastern Australia.

A climate change induced decrease in annual average rainfall and rainfall frequency has the potential to result in a reduction in low flow persistence, an increase in the frequency of low pool water levels and a reduction in inter-pool connection. The predicted small increase in summer rain and rainfall intensity might increase low flow persistence in summer which is likely to be the currently dominant time for low pool water levels and loss of inter-pool connection to occur. Climate-change induced reductions in winter and spring rainfall by 2100 would be expected to result in significant change to the flow regime irrespective of any mining impacts.

10.0 RECOMMENDED SURFACE WATER MONITORING

The current surface water monitoring programmes have been developed in consultation and with the approval of the SCA and in accordance with their monitoring protocols.

The current stream flow and water quality monitoring regime provides a sound basis for assessing impacts within the current mine area. Whilst it is acknowledged that there is insufficient, and for some aspects, no site specific baseline (pre-mine) data available for the affected catchments, sound control monitoring has been implemented which has and will continue to provide a sound basis for assessing impacts.

Additional monitoring will be required to assess localised effects on surface water resources and pre-mining data collection activities have already commenced. The following outline provides details of recommended ongoing monitoring activities for surface water in the Longwall 20 to 44 area. Recommendations for additional monitoring are discussed below.

Rainfall and Potential Evaporation

There are currently 4 pluviometers in the mine area - 2 are owned and operated by HCPL (Waratah pluviometer near Flat Rock Crossing and Woronora River near upper swamp) and 2 are owned and operated by the SCA/BOM (Reverces Trig station – 568069 and Woronora Dam - 566052). There are also longer term daily read rainfall stations in the area which are operated by the Bureau of Meteorology including the one at Darkes Forest which is now a pluviometer. There was an evaporation pan at the Woronora Dam however it was closed several years ago. The closest operational evaporation monitoring station is at Prospect Reservoir.

It is recommended that the existing pluviometer network be maintained at least over the life of the Project and that an evaporation pan be re-established at or near the Woronora Dam to improve coverage of this key climate variable.

Streamflow

There are currently 2 gauging stations operated by the SCA - one on Waratah Rivulet near the inflow to the reservoir and the other on Woronora River near its inflow to the Reservoir. These are key stations for assessing impacts of flows from the catchment which will need to be maintained at least over the active life of the project. HCPL have also established two gauging stations on Waratah Rivulet; one is located near WRS1 downstream of Flat Rock Swamp and the other downstream of Flat Rock Crossing. The 3 stations on Waratah Rivulet are considered adequate to assess effects on flows and the station on the Woronora River provides a control for assessing changes to Waratah Rivulet. The gauging station on O'Hares Creek also provides a valuable reference given its relatively long record.

It is recommended that the existing gauging stations on Waratah Rivulet, Woronora River and O'Hares Creek be maintained at least over the duration of the Project.

Streamflow Water Quality

Stream water quality has been monitored at a large number of sites on Waratah Rivulet. HCPL currently routinely collects samples from 9 sites along Waratah Rivulet and from sites on the Reference Tributary and Woronora River gauging station. Sampling sites have also been established by HCPL on the Eastern Tributary, Honeysuckle Creek, Bee Creek and on the upper reaches of the Woronora River. The SCA have conducted monitoring of water quality in Woronora Reservoir since 1939.

It is recommended that the existing monitoring regime conducted by HCPL on Waratah Rivulet continue and that it be supplemented by ongoing monitoring in the Eastern Tributary, Woronora River, Honeysuckle Creek and Bee Creek. Sampling in Woronora Reservoir as conducted by the SCA should also continue.

Pool Water Levels

Monitoring of water levels in most of the accessible pools along Waratah Rivulet is undertaken by HCPL using daily manual observations. Continuous measurement of pool water levels are also undertaken at Pool A and Pool F. Monitoring of tributary pools is also conducted in the Un-named and Reference Tributaries.

It is recommended that water level monitoring of all major pools on Waratah Rivulet continue at least until the completion of the project. It is recommended that continuous monitoring, by way of an upgrade to the manual daily monitoring be implemented on these pools prior to each pool being undermined. It is also recommended that water levels in 2 representative pools on Woronora River be monitored using continuous water level monitoring devices – for control monitoring. It is also recommended that water levels in the main pools which occur in the lower reaches of the Eastern Tributary be monitored using continuous monitoring instruments. The storage characteristics (volume versus level) and cease to flow levels of all monitored pools should be determined by survey.

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ATTACHMENT A

Surface Water Quality Monitoring Summary

Table A-1
Surface Water Quality Monitoring Summary – pH, EC, Turbidity, DO

Reach/Position on Local Watercourse	Site	Sampling Period			No. of Samples	pH			Electrical Conductivity (µS/cm)			Turbidity (NTU)			Dissolved Oxygen (% Saturation)		
						Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Median	Min.	Max.	Median
1 - Waratah Rivulet upstream of the confluence with Forest Gully	E6789	17/11/2005	-	12/03/2007	11	4.2	9.9	6.8	15.2	880.0	221.2	0.0	998.0	8.6	37.1	92.0	76.0
	E6788	20/10/2005	-	12/03/2007	11												
	Flow 1	22/01/2002	-	4/01/2007	1294												
	WRWQ-1	27/09/2006	-	15/04/2008	26												
2 - Waratah Rivulet downstream of confluence with Forest Gully, upstream of Site A	WRWQ-2	27/09/2006	-	15/04/2008	21	4.3	7.8	6.6	110.0	570.0	227.5	0.0	100.0	9.0	26.0	100.0	67.0
	E6787	20/10/2005	-	12/03/2007	11												
	E6786	20/10/2005	-	12/03/2007	11												
	WRWQ-3	27/09/2006	-	15/04/2008	26												
	Site A	1/12/2004	-	23/09/2006	290												
3 - Waratah Rivulet downstream of Site A, upstream of E6785	Site B	1/12/2004	-	23/09/2006	290	5.1	7.8	6.6	110.0	795.0	242.8	0.0	116.0	5.5	20.1	96.0	68.4
	WRWQ-4	27/09/2006	-	15/04/2008	26												
	E6785	20/10/2005	-	12/03/2007	10												
4 - Waratah Rivulet downstream of E6785, upstream of E6784	WRWQ-5	27/09/2006	-	15/04/2008	24	5.3	7.8	6.7	110.0	370.0	235.0	0.2	28.0	5.9	39.9	93.6	81.0
	Site C	1/12/2004	-	23/09/2006	290												
	E6784	20/10/2005	-	12/03/2007	9												
5 - Waratah Rivulet downstream of E6784, upstream of confluence with Unnamed Tributary	WRWQ-6	27/09/2006	-	15/04/2008	25	2.6	8.8	6.7	0.04	422.0	212.3	0.0	379.2	3.4	17.4	92.9	82.0
	Flow 2	14/12/2001	-	4/01/2007	1220												
	E6783	10/07/2006	-	12/03/2007	5												
	Site D	1/12/2004	-	19/06/2006	113												
6 - Waratah Rivulet downstream of confluence with Unnamed Tributary, upstream of Site E	E678	20/10/2005	-	12/03/2007	12	5.7	8.6	7.4	27.0	360.0	253.6	0.0	20.0	3.7	43.0	104.0	75.7
	WRWQ-7	27/09/2006	-	15/04/2008	26												
	E6782	20/10/2005	-	12/03/2007	11												
	Flow 3	22/01/2002	-	29/05/2005	4												
	Site E	2/03/2005	-	23/09/2006	241												

Table A-1 (Continued)
Surface Water Quality Monitoring Summary – pH, EC, Turbidity, DO

Reach/Position on Local Watercourse	Sites	Sampling Period			No. of Samples	pH			Electrical Conductivity (µS/cm)			Turbidity (NTU)			Dissolved Oxygen (% Saturation)		
						Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Median	Min.	Max.	Median
7 - Waratah Rivulet downstream of Site E, upstream of confluence with Reference Tributary	WRWQ-8	27/09/2006	-	15/04/2008	26	6.2	8.3	7.2	120.0	359.0	235.6	0.5	12.0	2.1	67.0	104.0	88.3
	Flow 3a	3/08/2006	-	4/01/2007	19												
8 - Waratah Rivulet downstream of confluence with Reference Tributary, upstream of Woronora Reservoir	WRWQ-9	27/09/2006	-	15/04/2008	26	5.7	8.7	7.4	107.1	340.0	232.9	<0.005	283.7	<0.005	53.9	106.2	90.3
	E677 (E6781)	20/10/2005	-	22/04/2008	19												
	Flow 4	24/02/2005	-	4/01/2007	422												
Woronora River	WOWQ-1	7/09/2007	-	15/02/2008	10	4.3	7.5	6.0	47.0	251.0	174.7	0.1	3000.0	4.1	55.8	98.2	82.4
	SCA Gauging Station (Woronora R.)	28/09/2006	-	3/12/2007	10328												
	E6131	10/10/2007	-	22/04/2008	9												
	WOWQ-2	12/10/2007	-	15/02/2008	9												
Forest Gully	FGWQ-5	1/08/2006	-	25/02/2008	24	3.7	7.6	4.9	83.0	350.0	160.8	<0.2	38.0	1.9	23.4	100.0	75.0
	FGWQ-4	1/08/2006	-	25/02/2008	24												
	FGWQ-3	1/08/2006	-	25/02/2008	19												
	FGWQ-2	1/08/2006	-	25/02/2008	23												
	FGWQ-1	1/08/2006	-	25/02/2008	22												
Unnamed Tributary	UTWQ-5	3/08/2006	-	26/02/2008	21	3.5	6.4	5.2	55.0	294.0	182.9	<0.05	10.0	1.2	32.9	102.0	75.0
	UTWQ-4	3/08/2006	-	26/02/2008	21												
	UTWQ-3	3/08/2006	-	26/02/2008	22												
	UTWQ-2	3/08/2006	-	26/02/2008	23												
	WRWQ-10 (UTWQ-1)	3/08/2006	-	15/04/2008	34												

Table A-1 (Continued)
Surface Water Quality Monitoring Summary – pH, EC, Turbidity, DO

Reach/Position on Local Watercourse	Sites	Sampling Period			No. of Samples	pH			Electrical Conductivity (µS/cm)			Turbidity (NTU)			Dissolved Oxygen (% Saturation)		
						Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Median	Min.	Max.	Median
Reference Tributary	RTWQ-3	3/08/2006	-	24/01/2008	24	3.9	9.4	5.4	110.0	256.0	182.2	<0.1	13.0	1.6	43.2	108.0	74.5
	RTWQ-2	3/08/2006	-	24/01/2008	24												
	RTWQ-1	3/08/2006	-	24/01/2008	24												
Honeysuckle Creek	HCWQ-1	7/09/2007	-	15/02/2008	10	4.0	5.4	4.5	91.0	198.0	143.0	0.2	11.0	4.3	50.0	94.0	66.4
Bee Creek	BCWQ-1	7/09/2007	-	15/02/2008	10	3.9	4.9	4.5	105.0	224.2	180.4	0.3	7.1	5.6	58.0	98.0	87.7
Eastern Tributary	ETWQ-1	7/09/2007	-	15/02/2008	10	6.0	7.9	6.8	110.0	299.0	181.4	0.5	14.0	5.5	69.0	94.4	80.9
Far Eastern Tributary	FEWQ-1	7/09/2007	-	15/02/2008	10	6.2	7.3	7.0	150.0	250.0	200.0	0.9	16.0	5.6	51.0	88.9	64.4
Woronora Reservoir	DW01	1/06/1953	-	6/03/2008	13777	5.5	8.4	6.6	0.0	6000	105.9	0.1	45.6	1.1	0.3	138.6	93.8
	DW02	30/03/1983	-	12/09/1991	198												
	HW01	3/07/1939	-	24/06/2002	716												

Table A-2
Surface Water Quality Monitoring Summary – Al, Mn, Fe

Reach/Position on Local Watercourse	Sites	Sampling Period			No. of Samples	Aluminium (mg/L)			Manganese (mg/L)			Iron (mg/L)		
						Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median
1 - Waratah Rivulet upstream of the confluence with Forest Gully	E6789	17/11/2005	-	12/03/2007	11	<0.001	0.180	0.010	0.000	0.600	0.050	0.001	2.88	0.300
	E6788	20/10/2005	-	12/03/2007	11									
	Flow 1	22/01/2002	-	4/01/2007	1294									
	WRWQ-1	27/09/2006	-	15/04/2008	26									
2 - Waratah Rivulet downstream of confluence with Forest Gully, upstream of Site A	WRWQ-2	27/09/2006	-	15/04/2008	21	<0.001	1.700	0.020	0.001	5.200	0.200	<0.010	11.00	0.160
	E6787	20/10/2005	-	12/03/2007	11									
	E6786	20/10/2005	-	12/03/2007	11									
	WRWQ-3	27/09/2006	-	15/04/2008	26									
	Site A	1/12/2004	-	23/09/2006	290									
3 - Waratah Rivulet downstream of Site A, upstream of E6785	Site B	1/12/2004	-	23/09/2006	290	<0.001	2.600	0.020	0.005	1.300	0.220	<0.002	6.80	0.125
	WRWQ-4	27/09/2006	-	15/04/2008	26									
	E6785	20/10/2005	-	12/03/2007	10									
4 - Waratah Rivulet downstream of E6785, upstream of E6784	WRWQ-5	27/09/2006	-	15/04/2008	24	<0.001	0.260	0.020	0.005	0.890	0.180	<0.002	13.00	0.140
	Site C	1/12/2004	-	23/09/2006	290									
	E6784	20/10/2005	-	12/03/2007	9									
5 - Waratah Rivulet downstream of E6784, upstream of confluence with Unnamed Tributary	WRWQ-6	27/09/2006	-	15/04/2008	25	<0.001	0.360	0.020	0.000	2.200	0.110	0.001	38.00	0.340
	Flow 2	14/12/2001	-	4/01/2007	1220									
	E6783	10/07/2006	-	12/03/2007	5									
	Site D	1/12/2004	-	19/06/2006	113									
6 - Waratah Rivulet downstream of confluence with Unnamed Tributary, upstream of Site E	E678	20/10/2005	-	12/03/2007	12	0.0004	0.230	0.020	0.005	5.500	0.120	0.006	5.80	0.150
	WRWQ-7	27/09/2006	-	15/04/2008	26									
	E6782	20/10/2005	-	12/03/2007	11									
	Flow 3	22/01/2002	-	29/05/2005	4									
	Site E	2/03/2005	-	23/09/2006	241									

Table A-2 (Continued)
Surface Water Quality Monitoring Summary – Al, Mn, Fe

Reach/Position on Local Watercourse	Sites	Sampling Period			No. of Samples	Aluminium (mg/L)			Manganese (mg/L)			Iron (mg/L)		
						Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median
7 - Waratah Rivulet downstream of Site E, upstream of confluence with Reference Tributary	WRWQ-8	27/09/2006	-	15/04/2008	26	0.0003	0.150	0.010	0.001	0.500	0.120	0.010	0.85	0.096
	Flow 3a	3/08/2006	-	4/01/2007	19									
8 - Waratah Rivulet downstream of confluence with Reference Tributary, upstream of Woronora Reservoir	WRWQ-9	27/09/2006	-	15/04/2008	26	0.001	0.150	0.010	0.001	0.110	0.025	0.020	1.47	0.115
	E677 (E6781)	20/10/2005	-	22/04/2008	19									
	Flow 4	24/02/2005	-	4/01/2007	422									
Woronora River	WOWQ-1	7/09/2007	-	15/02/2008	10	<0.001	0.200	0.041	<0.001	0.052	0.028	<0.001	0.65	0.105
	SCA Gauging Station (Woronora R.)	28/09/2006	-	3/12/2007	10328									
	E6131	10/10/2007	-	22/04/2008	9									
	WOWQ-2	12/10/2007	-	15/02/2008	9									
Forest Gully	FGWQ-5	1/08/2006	-	25/02/2008	24	<0.001	0.750	0.270	0.002	0.550	0.058	<0.001	5.30	0.200
	FGWQ-4	1/08/2006	-	25/02/2008	24									
	FGWQ-3	1/08/2006	-	25/02/2008	19									
	FGWQ-2	1/08/2006	-	25/02/2008	23									
	FGWQ-1	1/08/2006	-	25/02/2008	22									
Unnamed Tributary	UTWQ-5	3/08/2006	-	26/02/2008	21	0.010	0.240	0.085	<0.001	0.990	0.096	<0.001	0.99	0.190
	UTWQ-4	3/08/2006	-	26/02/2008	21									
	UTWQ-3	3/08/2006	-	26/02/2008	22									
	UTWQ-2	3/08/2006	-	26/02/2008	23									
	WRWQ-10 (UTWQ-1)	3/08/2006	-	15/04/2008	34									

Table A-2 (Continued)
Surface Water Quality Monitoring Summary – Al, Mn, Fe

Reach/Position on Local Watercourse	Sites	Sampling Period			No. of Samples	Aluminium (mg/L)			Manganese (mg/L)			Iron (mg/L)		
						Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median
Reference Tributary	RTWQ-3	3/08/2006	-	24/01/2008	24	<0.001	0.290	0.080	0.015	0.120	0.053	0.006	1.00	0.110
	RTWQ-2	3/08/2006	-	24/01/2008	24									
	RTWQ-1	3/08/2006	-	24/01/2008	24									
Honeysuckle Creek	HCWQ-1	7/09/2007	-	15/02/2008	10	0.175	0.620	0.390	0.001	0.010	0.005	0.010	0.340	0.038
Bee Creek	BCWQ-1	7/09/2007	-	15/02/2008	10	0.310	0.660	0.545	0.005	0.030	0.017	0.010	0.140	0.040
Eastern Tributary	ETWQ-1	7/09/2007	-	15/02/2008	10	<0.001	0.062	0.017	0.030	0.100	0.065	0.090	0.500	0.210
Far Eastern Tributary	FEWQ-1	7/09/2007	-	15/02/2008	10	0.040	0.110	0.069	0.003	0.017	0.010	0.130	0.630	0.305
Woronora Reservoir	DW01	1/06/1953	-	6/03/2008	13777	0.010	0.809	0.108	0.001	0.685	0.015	0.010	3.250	0.240
	DW02	30/03/1983	-	12/09/1991	198									
	HW01	3/07/1939	-	24/06/2002	716									