

# **AQUATIC ECOLOGY ASSESSMENT**

## **UPPER LIDDELL SEAM LW 1-8**



**REPORT PREPARED FOR  
ASHTON COAL OPERATIONS PTY LTD**

**MARINE POLLUTION RESEARCH PTY LTD  
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# MARINE POLLUTION RESEARCH PTY LTD

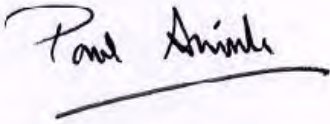
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## **EXECUTIVE SUMMARY**

The Scope of Works for Aquatic Ecology assessment has been developed to meet the relevant consent conditions for the Ashton Coal Project (ACP) in regard to subsidence impacts. Accordingly this report:

- a. Updates the assessment of the existing aquatic ecological environment in the application area,
- b. Assesses possible impacts the revised subsidence predictions may have on the aquatic ecology of Bowmans Creek,
- c. Updates subsidence management measures where appropriate; and
- d. Updates details of the aquatic ecology monitoring program to assess subsidence impacts.

The lower 6km section of Bowmans Creek between the New England Highway and the Hunter River confluence, provides important aquatic ecological functions, including:

- Fish passage between the Hunter River and the remaining 50km of aquatic and fish habitat in Bowmans Creek;
- Off-line fish refuge habitat during extended Hunter River flood events;
- Fish nesting habitat in the form of gravel bars in pools;
- A measure of drought refuge habitat in the form of deeper pools;
- A complex of aquatic ecological habitats with varying depths and different aquatic plants supporting a diverse assemblage of aquatic macroinvertebrate fauna; and
- Riparian vegetation corridors link Hunter River riparian flora through to upper Bowmans Creek and provide foraging and feeding habitat for native fauna.

Whilst this section of the creek provides these important functions, the section is not pristine and some of these functions are compromised by past practices. Fish passage is available intermittently owing to the combined intermittency of flow, the shallow nature of some of the creek sections that dry out or where surface water flow is often through cobbles thus isolating pools. Water quality is also affected by the natural occurrence of saline seepage from outcrops of Permian rock.

Combined aquatic ecology and water quality sampling from 2007 onwards indicates that the major flood in mid 2007 caused a disruption to the available aquatic habitats in Bowmans Creek. This affected both species diversity and community structure, with overall more resilient taxa remaining immediately after the flood.

Over time there has been a stabilisation of habitats and an increase in habitat complexity and this has led to an increase in diversity for the macroinvertebrate assemblage, with a shift to include more pollution/instability intolerant taxa. Over and above this increase in habitat stability, there has been a gradual decrease in overall water availability, with increasing low flow events. Thus, whilst the overall habitat diversity has been restored and more or less maintained, the macroinvertebrate assemblages are now starting to respond to changing water quality conditions.

The impacts of proposed mining on aquatic biota and habitats in Bowmans Creek, the Hunter River and Glennies Creek are expected to be negligible based on the assessment of predicted subsidence induced changes to stream morphology, water quantity and quality. There is not expected to be any significant impact on the availability of drought refuge pools and no significant impact on fish passage within these streams. It is also concluded that there would be no significant impact on fish passage between the Hunter River and Bowmans Creek.

Impacts on the aquatic attributes of the sub-catchment drainages are expected to be negligible from the point of view of the consequences for the receiving waters and for aquatic habitats of Bowmans Creek and the Hunter River, and it is concluded that the impacts on sub-catchment drainages can be managed and mitigated under the existing management framework.

Monitoring for possible impacts of mining from the proposed mine plan relies on:

- Water quality, quantity and stream health monitoring of the network of existing monitoring sites.
- Performance measures, indicators of success and key assessment considerations detailed within the Flora and Fauna (Biodiversity) Management Plan.
- The Trigger Action Response Plan (TARP) - included in the Flora and Fauna (Biodiversity) Management Plan.
- Site specific management plans in place to address subsidence impacts on a site-by-site basis.

Under the current management regime, where perceptible impacts are noted through site monitoring activities, management, incident response and notification procedures are detailed in the TARP. Response plans are then prepared on a case by case basis, with suggested short-term mitigation measures such as minor physical repair works and possible intermittent environment flow supplements as required. These measures are then

implemented until such time that any necessary long-term remediation works have been completed. It is concluded that the present performance measures and monitoring program are adequate to assess mining related impacts to Glennies and Bowmans Creek aquatic ecosystems.

Potential indirect impacts to the Hunter River arising from the risk of mining related bank slumping are currently not considered within the current monitoring framework. Although the risk of subsidence related bank slumping impacts to the Hunter River is assessed as being very low, the addition of longwall specific short-term aquatic ecology monitoring sites in the Hunter River is recommended, to ensure relevant performance measures are met.

The current management options include the following available actions and these would also be implemented on a site by site basis to minimise physical impacts in sub-catchment drainages:

- Small scale draining works and filling of subsided areas to create a free draining landscape and obviate the potential for pooling of water on the surface, as required.
- Potential ponding effects would be assessed on a site by site basis with the option for retention of some formed ponds for stock watering or other purposes and if retained, remediation measures such as stock exclusion and riparian and emergent planting could be implemented to improve aquatic habitat attributes of the retained ponds.
- Remediation of surface cracking where required to reduce the potential for water ingress or to prevent trapping animals.
- Riparian revegetation techniques (stock exclusion and provision of edge and emergent vegetation).
- Provision of a supply of good quality make-up water to be used to restore creek water quality/quantity.

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## **1 INTRODUCTION**

This technical report has been prepared in support of the Extraction Plan for Longwalls 1-8 in the Upper Liddell (ULD) Seam prepared by Ashton Coal Operations Pty. Limited (ACOL). This report addresses the potential subsidence impacts on aquatic ecology and provides measures to monitor potential impacts and to mitigate or minimise potential impacts where required.

A general description of the site locality and Extraction Plan Application Area is provided in Section 1.1 of the Extraction Plan main document. The Extraction Plan describes the operation of the underground mine to date, details of the updated mine plan and Bowmans Creek diversion.

An updated assessment of potential subsidence movements related to ULD LW1-8 has been prepared by SCT Operations Pty Ltd (SCT 2011). These subsidence predictions have been used as a basis for the updated assessment of impacts contained within this report. SCT's analysis and results are contained, in full, as an appendix to the Extraction Plan.

### **1.1 Scope of Works**

The Extraction Plan has been developed to comply with the relevant consent conditions for the Ashton Coal Project (ACP), in particular Development Consent Condition 3.12 (e), which requires "...revised predictions of the potential subsidence effects, subsidence impacts, and environmental consequences of the proposed second workings incorporating any relevant information obtained since the consent". Accordingly the Scope of Works for the Aquatic Ecology assessment report is to:

- e. Update the assessment of the existing aquatic ecological environment in the application area,
- f. Assess possible impacts the revised subsidence predictions may have on the aquatic ecology of Bowmans Creek,
- g. Update subsidence management measures where appropriate; and
- h. Update details of the aquatic ecology monitoring program to assess subsidence impacts.



## 1.2 Study Methods

In order to assess the potential impacts on the aquatic ecology of Bowmans Creek arising from the revised subsidence predictions, the following tasks were undertaken:

- Update the assessment of Bowmans Creek aquatic ecology attributes, based on a review of aquatic ecology monitoring conducted in Bowmans Creek to date.
- Update the previous assessment of subsidence impacts on the aquatic ecology of Bowmans Creek based on the updated ecological data, updated mine plan and revised subsidence predictions.

Specific additional field investigations were not considered necessary as part of this technical assessment as MPR has been undertaking field investigations and reporting for Bowmans Creek stream-health monitoring on behalf of ACOL since 2007. The sampling sites for aquatic ecology and water quality monitoring are shown in Figure 1.

MPR has prepared the aquatic ecology assessments in support of previous Subsidence Management Plan (SMP) applications within the Pikes Gully (PG) Seam (MPR 2008c) and for the Bowmans Creek Diversion EA (MPR 2009f). To date there have been 14 aquatic ecology monitoring surveys in Bowmans Creek including nine conducted by MPR in the study area specifically for ACOL; in Autumn and Spring 2007 2008, 2009, 2010 and in Autumn 2011 during mining operations (MPR 2007b, 2008a, 2008b, 2009b, 2009c, 2009f, 2010a, 2010b, 2011a and 2011b in prep). It was therefore considered that sufficient data was available to support this assessment.

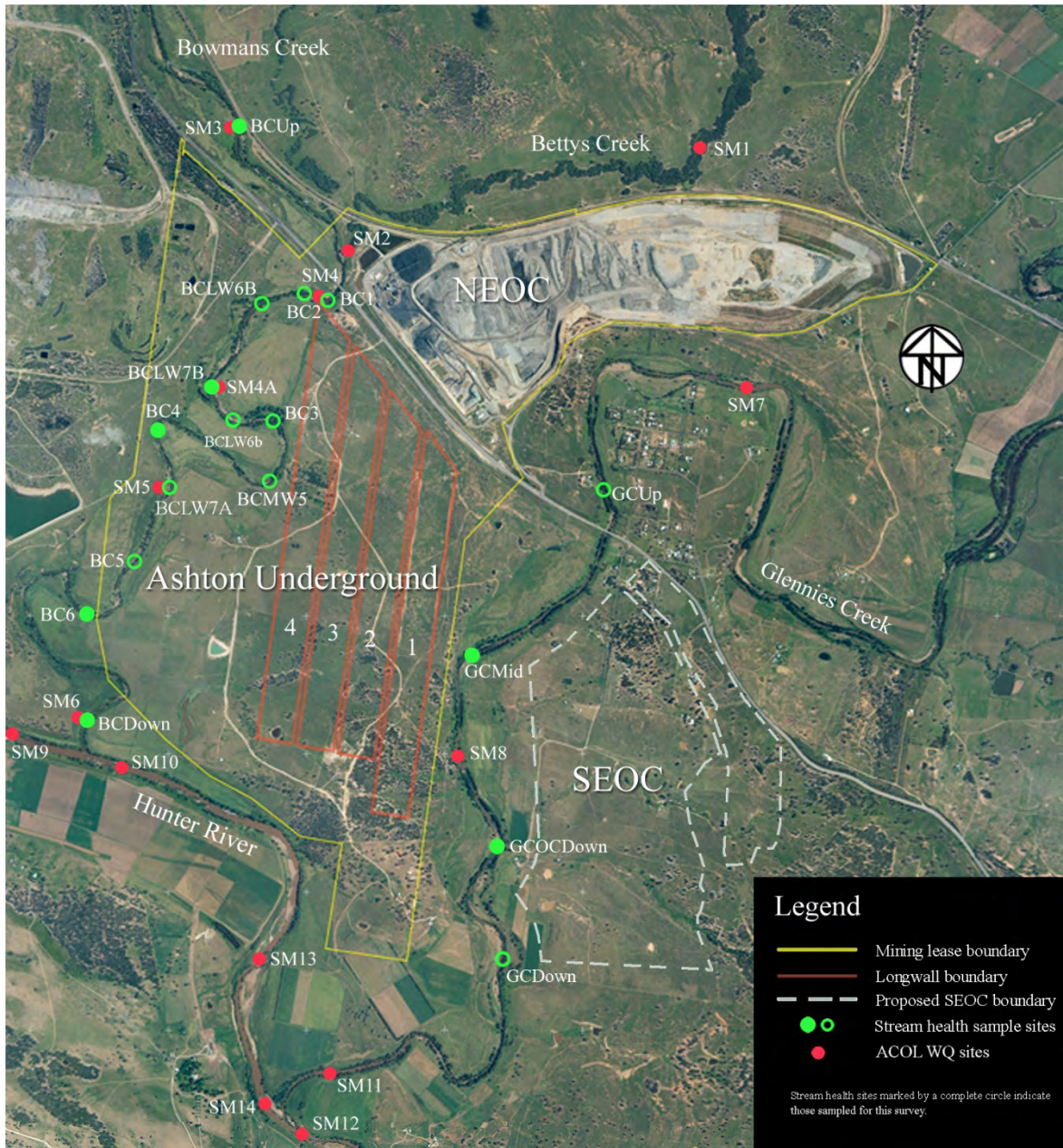


Figure 1 Current ACOL Water Quality and Aquatic Ecology Monitoring Sites on Bowmans Creek, Glennies Creek and Hunter River.

## 2 EXISTING ENVIRONMENT

### 2.1 Updated Site Characteristics

This section provides an overview of aquatic and riparian site characteristics as they relate to this aquatic ecological impact assessment. Note that updated aquatic ecology information is provided in Section 2.2 below.

Bowmans Creek is approximately 56 kilometres (km) long with a catchment area of approximately 265 km<sup>2</sup>. The lower section of Bowmans Creek between the New England Highway and the Hunter River confluence is 6km long of which approximately 4.5km is located within the ACOL Mining Lease. Bowmans Creek experiences variable flow and it is generally perennial, although flow can cease during severe droughts (e.g, for several months preceding the July 2007 flood).

The study site area has been previously disturbed by cattle grazing, weed encroachment, vegetation clearing and rubbish dumping. The riparian vegetation is characterised by a narrow strip of Casuarina woodland with small sections of river red gum open forest near the Hunter River. The most common riparian trees are River Oak (*Casuarina cunninghamiana*) and the introduced Willow (*Salix babylonica*).

The area adjoining the creek riparian vegetation is mostly characterised by continually grazed pasture and relatively isolated patches of open woodland. There is a small remnant area of regenerating bull oak woodland to the east of the oxbow. Land use is predominantly livestock grazing, with some irrigation and cultivation on the Hunter River floodplain. Surrounding land uses consist of rural properties with mining activities occurring immediately to the north of the New England Highway and west of Bowmans Creek.

Minor stream bank erosion occurs on the watercourses with minor sheet and gully erosion on adjacent terraces. Some steep sided banks of Bowmans Creek have been noted to be unstable, as they are typically in areas with limited riparian vegetation with coverage often consisting of grasses, weeds, or well-spaced riparian trees. Whilst active bank erosion has been noted from some areas, annual erosion rates appear to be relatively low to moderate. Submerged bank undercutting at the base of steep sided banks is common along most of the study area creek length.

The bed of Bowmans Creek is incised directly into bedrock (Permian coal measures) in a small number of locations, and is overlain by alluvium in other places. There are three

outcrops of Permian coal measures in the creek-bed of Bowmans Creek. All of these are located outside the area of proposed longwall mining. The upper outcrop is associated with elevated saline groundwater seepage sustained by seepage from the Permian rock outcropping downstream of the New England Highway. The middle rock bar section is located downstream of a large bend at the end of the oxbow, and includes the weir pool for the NSW Office of Water (NOW) stream gauging station. The third outcrop is located in the lower section of the creek outside the ACP lease area.

## **2.2 Bowmans Creek Aquatic Habitats**

The number of pools in the Bowmans Creek study area varies with flow conditions. Most pools are wide (10m) and shallow (to 1m deep) with some deeper pools (to 2.5m deep). Several pools (the top pool and the weir pool) are located within exposed basement rock, although neither is rock-bar constrained. Cobble riffle zones connect most of the pools, and the remaining pools are structured as "chain-of-ponds" type (see Rutherford et al, 2000), with more or less permanent pools (dependent on depth) separated by bars of sediment stabilised with vegetation. Many riffle or narrow pool sections are bordered by exposed cobble beds on one side, with steep sided banks on the other. Pools at the lower end of the study area are steep sided on both sides as the creek erodes down to the level of the Hunter River.

Aquatic vegetation includes both true aquatic plants and edge emergent plants. The range of species and their seasonal occurrence at the monitoring sites are summarised in Table 1 below. Cumbungi (*Typha sp.*) stands are the most commonly encountered emergent macrophyte and often comprise the main vegetation on sediment bars between pools.

MPR (2001) concluded that 'no major barriers to fish migration were found within the Bowmans Creek study area' and all structures are considered suitable for fish passage under a range of flow conditions. Subsequent aquatic habitat surveys between autumn 2007 and spring 2010 confirm that this remains the case.

Table 1 Seasonal Creek Macrophyte Occurrence											
Common Name	Species	Season	Type	Au07	Sp07	Au08	Sp08	Au09	Sp09	Au10	Sp10
		Number of sites	Note 1	N=4	N=4	N=4	N=6	N=6	N=6	N=6	N=5
Cumbungi	<i>Typha sp</i>		Em	2	4	4	4	4	5	4	3
River Clubrush	<i>Schoenoplectus validus</i>		Em					1	3	3	2
Common Reed	<i>Phragmites australis</i>		Em		3	3	3	3	1	2	1
Slender Knotweed	<i>Persicaria decipens</i>		Em		3	4				2	
Water Ribbon	<i>Triglochin sp. (T.microtuberosum?)</i>		Em			1	1	3	3	1	
Watercress*	<i>Nasturtium officinale</i>		Em							3	
Duckweed	<i>Spirodela spp</i>		Fl							3	
Pacific Azolla	<i>Azolla filiculoides</i>		Fl							1	
Water Primrose	<i>Ludwigia peploides</i>		Fl/At					1	1	2	
Sago Pondweed	<i>Stuckenia pectinata</i>		Su			1	3	2	1	4	
Clasped Pondweed	<i>Potamogeton perfoliatus</i>		Su			2	2	1	1	2	1
Curly Pondweed	<i>Potamogeton crispus</i>		Su		1	1				1	
Watermilfoil	<i>Myriophyllum sp</i>		Su				3	5	4	5	4
Elodea*	<i>Elodea canadensis</i>		Su			2					
Notes:	Total Number/Season			1	4	8	6	8	8	13	5

\* Introduced species. Note 1: Em = emergent, Fl = Floating, At = Attached & Su = submerged

### 2.3 Groundwater Dependent Ecosystems

The combined riparian and aquatic ecology report prepared for the Bowmans Creek Diversion (MPR 2009f) concluded that there are no known or likely aquifer/cave ecosystem GDEs in the study area. Aquaterra (2009) indicated that baseflow in the pre-mining condition generally results in small flows from the alluvium to the creek. Thus it is assumed that there is a hyporheic zone between the saturated alluvials and the creek bed. There is generally very little connection between the underlying Permian rock and the alluvium, although in some areas a slight upwelling results in moderately saline conditions in the alluvium. Given the lateral extent of saturated alluvials, it is also concluded that there are probably some parafluvial zones in the creek.

With regard to the degree of dependency of possible aquatic or hyporheic GDEs to baseflow in the Bowmans Creek study area, the following factors are relevant:

- The creek is perennial with some flow of alluvial groundwater to the creek. Water entering the alluvium generally occurs through rainfall runoff and recharge.
- Due to there being surface flow most of the time, riparian, edge emergent vegetation and riffle zone fauna are more dependent on fluctuating surface water levels than on groundwater inflow. Although it should be noted that baseflow from the alluvium to the creek becomes more significant during prolonged drought conditions.
- When there is no surface water during prolonged drought conditions, the baseflow may start to become significant (as encountered in 2006 and 2007 prior to the 2007 flood). Under these conditions there are no riffles, there are only small, disconnected pools remaining and the pool edge vegetation dies off. Salinity of the baseflow also becomes significant in some areas, thus limiting the remaining aquatic macroinvertebrate assemblages that could reside in the pools and limiting the microinvertebrate fauna that could reside in the hyporheic zone.

It is concluded that possible aquatic and hyporheic GDEs in Bowmans Creek within the study area would not be considered significantly dependent on baseflow groundwater. These results and inferences are in line with the more recent modelling of groundwater reported by Aquaterra (2011 in prep) who concluded:

- Bowmans Creek is not highly connected to its alluvium and there are not large quantities of baseflow travelling through the alluvial materials. In reality hydraulic conductivity is relatively low at around 0.5m/d.
- The water quality in the Bowmans Creek alluvium is sometimes poor as (pre-mining) groundwater levels in the underlying Permian are near or slightly above alluvium levels, resulting in upwards leakage in some areas.

#### **2.4 Bowmans Creek Metered Water Quality**

Field (metered) water quality measurements have been made at all aquatic ecology sites in Bowmans Creek during each of the biannual aquatic ecology sampling programs (Autumn 2007 to Autumn 2011) and results are provided in the various monitoring reports. Water quality results obtained during these studies have been summarised as follows:

- For All Bowmans Creek monitoring sites (with the exception of Site SM4), conductivity/salinity and pH values were within the range set for Lowland Rivers by ANZECC (2000) guidelines.
- On five of the nine MPR surveys, mean dissolved oxygen (DO) values (measured as % saturation) were below the range set by ANZECC Guidelines for Lowland Rivers of 85 to 110% saturation.
- Mean seasonal turbidity varied from 4 NTU (Autumn 08) to 24 NTU (Spring 09). For most seasonal surveys turbidity was generally consistent over all sites with one exception in Spring 2009 when turbidity over 12 sites varied from 1.1 NTU (site BC2) to 127.7 NTU (site BCLW7B).

In summary, for all sites where measurements were made, water quality was generally reasonable and acceptable for the maintenance of aquatic ecological function with the following exceptions:

- Creek waters generally had low dissolved oxygen concentrations during low flows and excessive turbidity during high flows.
- Site SM4 pool waters have elevated salinity during low to no flow periods.

## **2.5 Updated Aquatic Ecology Sampling Data**

To date there have been 15 aquatic ecology surveys in various parts of Bowmans Creek (between spring 2001 and spring 2011) that have incorporated sampling for fish and macroinvertebrates, including two that used electro-fishing techniques. A total of 39 edge and 2 riffle habitat sites have been sampled over these surveys. Since the approved Bowmans Creek Diversion Environmental Assessment, which assessed ten of these surveys, there have been five further seasonal aquatic ecology surveys undertaken, in spring 2009 (MPR 2010a), Autumn and Spring 2010 and 2011 (MPR 2010b, 2011 and in prep). Figure 1 shows the location of Bowmans Creek stream health monitoring sites utilised for the most recent surveys.

Seasonal aquatic macroinvertebrate summary statistics for the sampled edge habitats arranged in order of flow rate are presented in Table 2 below and Figures 2 to 5 present the results graphically. Note that the 'between site' comparisons shown in Figures 3 and 5 refer only to the formal ACOL streamhealth monitoring surveys that commenced in Autumn 2007.

Surface stream flow conditions varied between surveys, and between sites within surveys, and the following flow descriptors should be considered when flow conditions are described in the following paragraphs:

- 'dry' represents no surface flows during time of sampling in the majority of site pools,
- 'low flow' represents surface flow conditions encountered at all sites, with generally only trickle flow through riffle zones in the shallow cobble and boulder beds in between pools, and
- 'Medium flow' conditions are more representative of mean flow rates for Bowmans Creek.

With regard to aquatic macroinvertebrate sampling, the following conclusions are made from the combined data:

- To date, a total of 70 aquatic macroinvertebrate taxa (taken to AusRivAS required taxonomic level) have been identified from the combined studies.
- Four of the taxa were recorded from riffle habitats only; riffle beetles (family Elmidae), water pennies (family Psephenidae), fly larvae (family Dolichopodidae) and dobsonflies (family Cordyalidae).
- The majority of the taxa are insects (67%). Other taxa recorded included molluscs (12%) and crustaceans (9%). Arachnids, flatworms, annelid worms, leeches, roundworms and springtails made up the remaining 12% of which none were greater than 2%.
- There were thirteen taxa that were found in Bowmans Creek during six or more of the surveys, and six of those taxa were also common throughout the creek (i.e. occurring at over 75% of total sites sampled); midge fly larvae (sub-family Chironominae), freshwater shrimp (family Atyidae), damselflies (family Coenagrionidae), mayflies (family Caenidae), water boatmen (family Corixidae) and caddis flies (family Leptoceridae).



**Table 2 Macroinvertebrate Summary Statistics for Bowmans Creek (2001 to 2010)**

Flow Condition	Dry	Dry	Dry	Low	Low	Low	Low	Low	Medium	Medium	High	High	High
Flow rate (ML/D)	N/A	0.4	0.4	0.8-0.9	0.7-0.8	1.7	3.36-3.70	4.9-3.8	20-26	28-25	123-129	370-636	840-158
Sampler	MPR	TEL	MPR	MPR	TEL	MPR	MPR	MPR	MPR	MPR	MPR	MPR	MPR
No of Sites	N=2	N=4	N=2	N=6	N=4	N=3	N=6	N=6	N=6	N=4	N=4	N=6	N=4
Season and Year	Sp01	Au06	Au06*	Sp09	Sp05	Sp05*	Au10	Sp08	Au09	Au08	Au07	Sp10	Sp07
Total number invertebrate taxa:	8	31	31	46	33	33	40	37	44	32	25	39	30
Mean number of taxa per site:	5.0	15.5	16.3	21.2	20.5	23	17.5	18.8	19.8	18.8	14	19.0	17
Standard Error:	0.0	1.8	4.7	2.6	1.9	3	2.4	1.8	1.9	1.1	2.5	2.0	1.9
Creek SIGNAL scores:	3.88	3.83	4.59	3.55	4.06	4.43	3.35	3.93	3.75	4.00	2.95	3.55	3.64

\*Represents aquatic ecology surveys undertaken from upstream Bowmans Creek locations.

\*\* Dry represents no surface flows during time of sampling between most site pools.

Low flow is when there is surface flow between all sites, but with generally only trickle flow through riffle zones in the shallow cobble and boulder beds between most pools.

Medium flow is when there is sufficient flow to allow fish passage through most to all of the site

High flow is when there is sufficient flow to allow fish passage through all of the site with no impediments

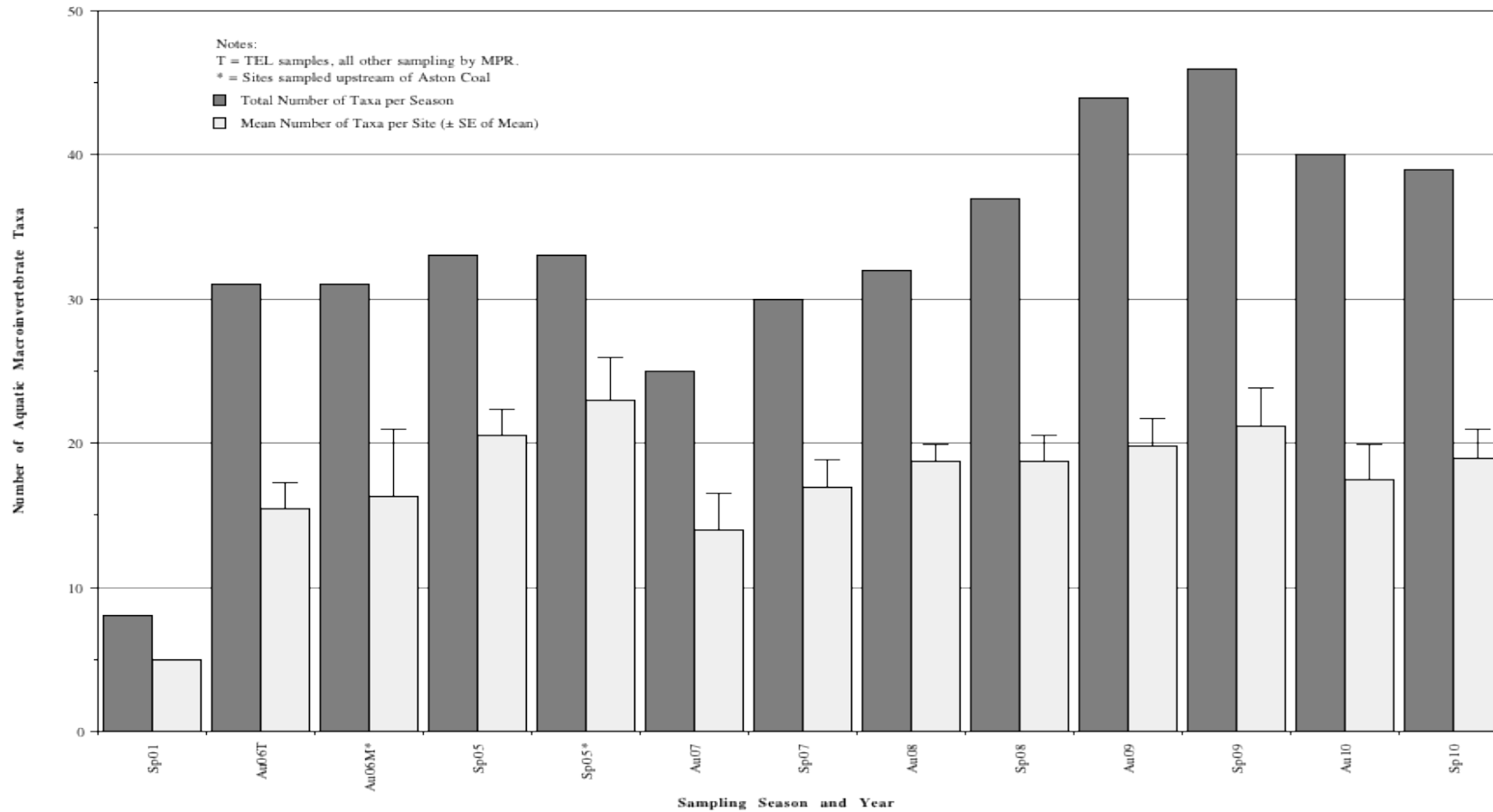


Figure 2 Variation in Bowmans Creek Aquatic Macroinvertebrate Diversity from Spring 2001 to Spring 2010.

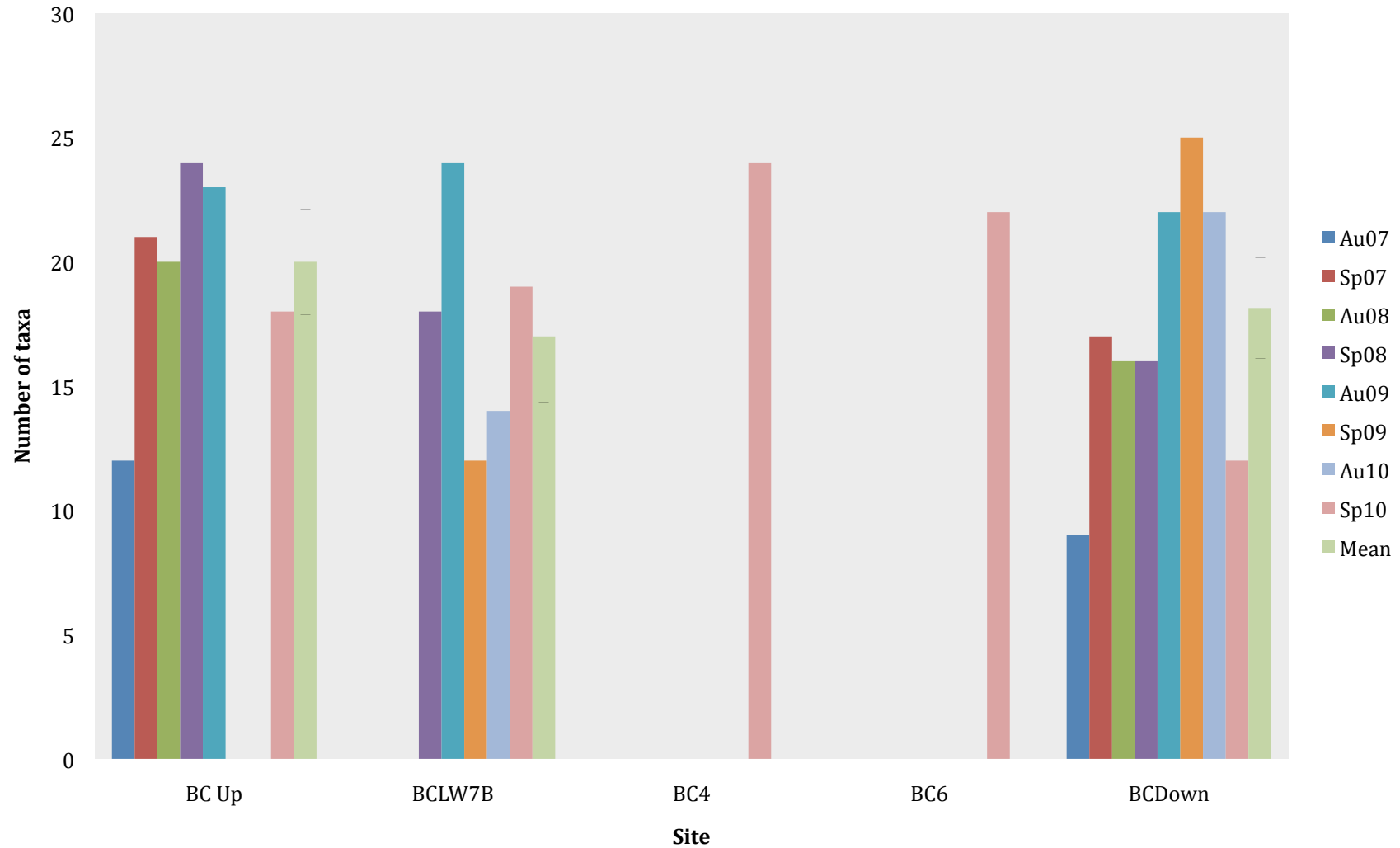


Figure 3 Variation in Individual Site Aquatic Macroinvertebrae Diversity from Autumn 2007 to Spring 2010

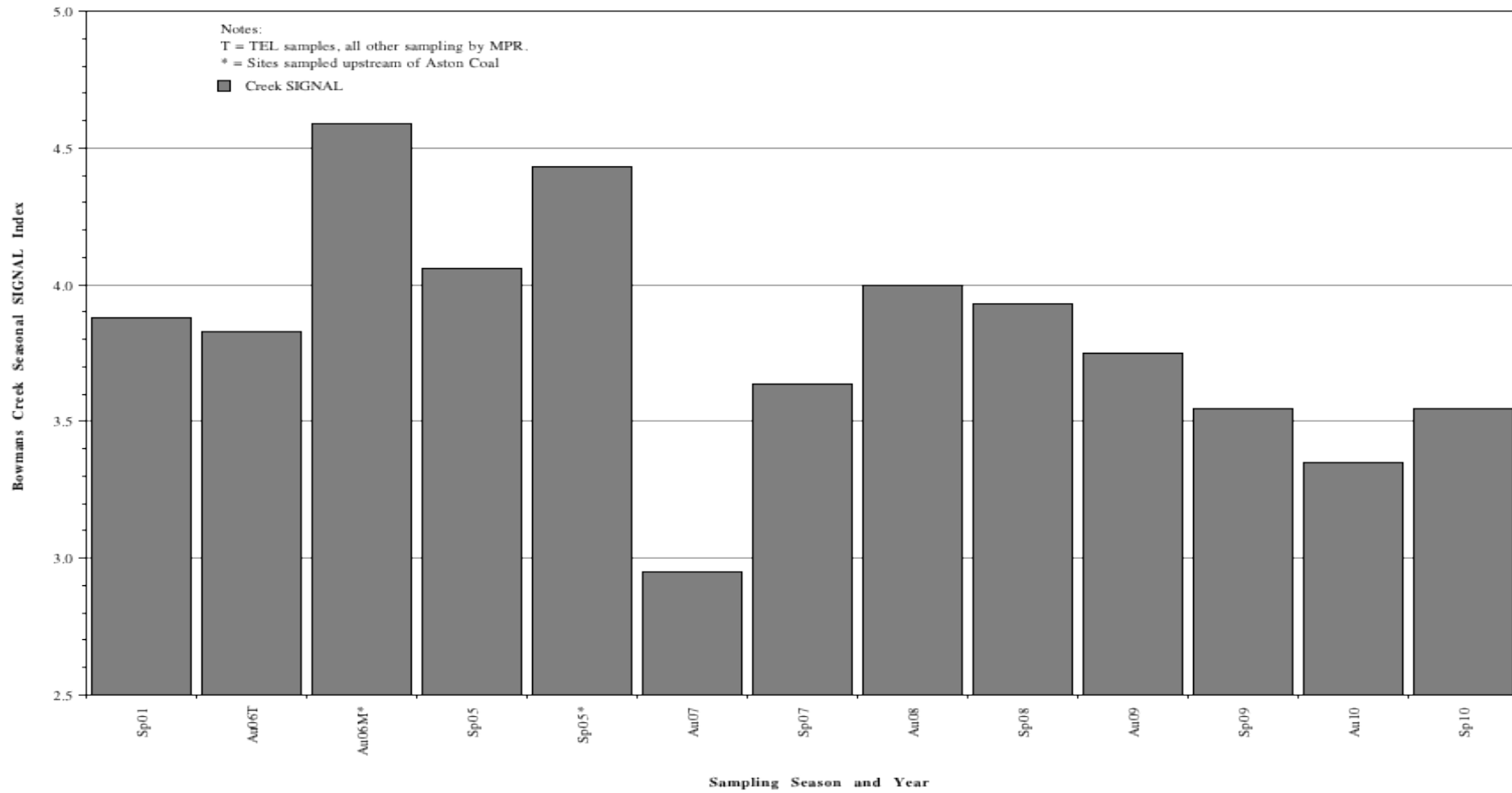


Figure 4 Variation in Bowmans Creek Seasonal SIGNAL-2 Index Spring 2001 to Spring 2010

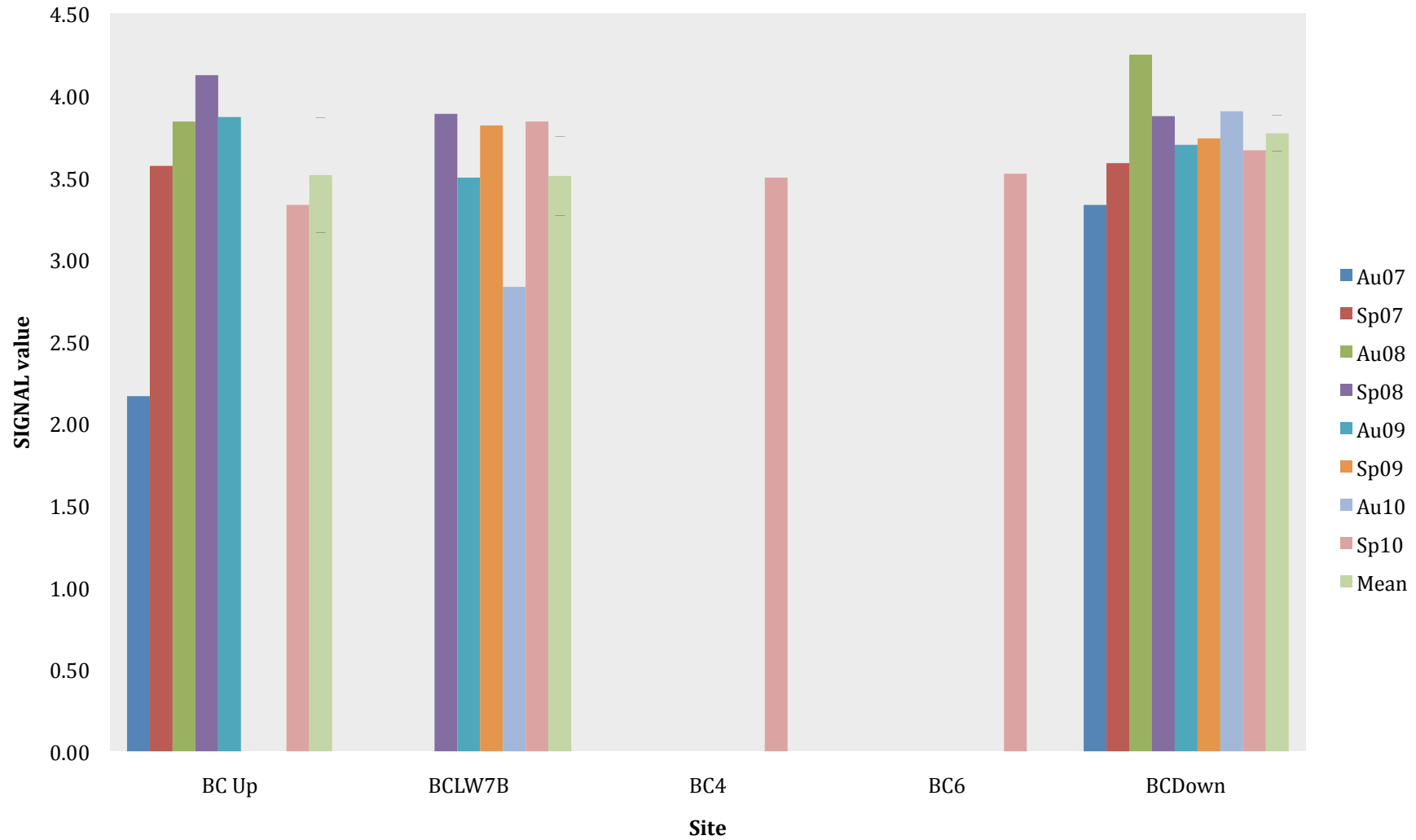


Figure 5 Seasonal Variation in Individual Bowmans Creek Site SIGNAL-2 Index values, Spring 2001 to Spring 2010

Prior to the major flood event in June 2007 (i.e., during or towards the end of extended drought), there were relatively low site SIGNAL scores (spring 2001, 2005 and autumn 2006). The combined site SIGNAL score for the survey immediately following the flood (autumn 2007) was also low and overall creek SIGNAL scores have improved over each consecutive sample season since then, peaking in spring 2008.

The stream health data indicate that the aquatic ecological habitats of Bowmans Creek have been in a state of recovery since the combined extended pre-June 2007 drought and flood in June 2007. For at least one year prior to the flood, sections of Bowmans Creek within the study area were isolated and drying up and there was a marked reduction in the extent and variety of fish and macroinvertebrate fauna. The flood destabilised, swept away or smothered much of the remaining habitat features with silt and most likely scoured much of the macroinvertebrate fauna out of the creek as well.

Since the floods, Bowmans Creek has sustained regular flows throughout the study area, enabling aquatic habitats (macrophyte beds, new logs and new detritus) to re-establish over time with increasing macroinvertebrate site diversity, SIGNAL scores and fish diversity recorded over consecutive seasonal surveys.

In summary, the major flood in mid 2007 caused a disruption to the available aquatic habitats in Bowmans Creek. This affected both species diversity and community structure, with overall more 'pollution-tolerant' (or more likely, 'instability tolerant') taxa remaining immediately after the flood. Over time there has been a stabilisation of habitats plus an increase in habitat complexity. This has led to an increase in diversity for the macroinvertebrate assemblage, with a shift to include more pollution/instability intolerant taxa, resulting in a gradual rise in SIGNAL scores.

Over and above this increase in habitat stability, there has been a gradual decrease in overall water availability, with increasing low flow events. Thus, whilst the overall habitat diversity has been restored and more or less maintained, the macroinvertebrate assemblages are now starting to react to changing water quality conditions.

## 2.6 Fish and other aquatic species

To date there have been 14 fish species recorded from the Bowmans Creek study area, two of which are introduced species (carp and plague minnow - see Table 3). The introduced pest species, plague minnow (*Gambusia holbrooki*), has been the most commonly encountered fish during all aquatic ecology monitoring surveys, generally recorded at every monitoring site sampled in Bowmans Creek.

The following conclusions are made with regard to overall fish habitat attributes in Bowmans Creek in its current configuration:

- Bowmans Creek is perennial with flow only ceasing during extended drought periods.
- Most of the creek line is characterised by shallow elongated ponds separated by cobble or sediment riffles of banks.
- Low flows between pools are often confined to the cobble riffles between pools effectively isolating the pools with respect to fish passage.
- Fish passage can be limited by rock bars in the centre of the creek below the NOW weir pool.
- During moderate flows there is suitable fish passage through the creek and upstream.
- During high flows there is also sufficient water depth for fish passage but passage for smaller species can be limited by the lack of resting or off-line pools.
- There are pools throughout the creek that provide drought refuge, even in extended drought periods as observed in 2001 and 2005/6.
- Many of the pools have gravel to cobble sized beds that provide suitable nesting areas for catfish.
- Habitat complexity is generally good with varying creek substrata (cobble, sediments, detritus and rock), emergent and aquatic plants, and some overhanging edge vegetation.
- There are areas of eroding banks where the riparian vegetation is limited or where banks are destabilised by stock access.
- There is no 'large woody debris' in the form of log-jams, only a few individual fallen trees associated with recent floods.

Table 3					
Fish Species Recorded from Bowmans Creek					
Family	Species	Common name/s	Life cycle*	Recorded	Native/ Introduced
Anguillidae	<i>Anguilla australis</i>	Short-finned Eel	C	✓	N
Anguillidae	<i>Anguilla reinhardtii</i>	Long-finned Eel	C	✓	N
Atherinidae	<i>Craterocephalus amniculus</i>	Darling River Hardyhead	U	✓	N (species of concern)
Cyprinidae	<i>Cyprinus carpio</i>	Common Carp	L	✓	I
Eleotridae	<i>Gobiomorphus australis</i>	Striped Gudgeon	A	✓	N
Eleotridae	<i>Gobiomorphus coxii</i>	Cox's Gudgeon	P	✓	N
Eleotridae	<i>Hypseleotris compressa</i>	Empire Gudgeon	U	✓	N
Eleotridae	<i>Hypseleotris galii</i>	Firetail Gudgeon	U	✓	N
Eleotridae	<i>Philypnodon grandiceps</i>	Flathead Gudgeon	U	✓	N
Eleotridae	<i>Philypnodon macrostomus</i>	Dwarf Flathead Gudgeon	U	✓	N
Mugilidae	<i>Mugil cephalus</i>	Sea Mullet	A	✓	N
Percichthyidae	<i>Macquaria novemaculeata</i>	Australian Bass	C	✓	N stocked
Plotosidae	<i>Tandanus tandanus</i>	Freshwater Catfish	L	✓	N (species of concern)
Poeciliidae	<i>Gambusia holbrooki</i>	Plague Minnow	L	✓	I
Retropinnidae	<i>Retropinna semoni</i>	Australian Smelt	P	✓	N

Key:

- A- Amphidromous (fish that migrate between the estuary and the sea, but not for breeding purposes).
- C- Catadromous (fish that spend most of their lives in freshwater but migrate to the sea to breed).
- P- Potadromous (fish that migrate wholly within freshwater).
- L- Local (species that require fish passage only in their immediate environment).
- U- Unknown

Note\*: Life cycle characteristics referenced from Thorncraft & Harris 2000.



With regard to other possible fauna associated with the Bowmans Creek aquatic habitats, the aquatic ecology study also recorded sightings or calls of amphibians (tadpoles and frogs – see Table 4), observations of ducks and other water birds, long-necked turtles (*Chelodina longicollis*), eastern water dragons (*Physignathus lesueurii lesueurii*) and water skinks. Whilst native water rat *Hydromys chrysogaster*, and platypus *Ornithorhynchus anatinus* are known from Glennies Creek, there have been no records or sightings in the Bowmans Creek study area.

<b>Table 4 Amphibians sighted of heard during aquatic ecology sampling Autumn 2005 to Spring 2010</b>			
Species	Common Name	Records	Dates
<i>Crinia signifera</i>	Common eastern froglet	(all surveys)	
<i>Limnodynastes tasmaniensis</i>	Spotted marsh frog	1	Summer 06
<i>Paracrinia haswellii</i>	Red-groined froglet	1	Spring 07
<i>Litoria peronii</i>	Emerald spotted treefrog	numerous	Spring 07 to spring 08
<i>Litoria latopalmata</i>	Broad-palmed frog	3	Spring 07 to spring 08
<i>Litoria leseuri</i>	Leseur's frog	1	Spring 07
<i>Uperoleia laevigata</i>	Smooth toadlet	1	Autumn 05

### 3 STATUTORY REQUIREMENTS

The proposed activities must be assessed with respect to their potential impact on species or ecological communities listed as threatened under NSW and Commonwealth legislation. The relevant legislation for aquatic biota is the NSW *Fisheries Management Act 1994* (FMA) and the Federal *Environment Protection & Biodiversity Conservation Act 1999* (EPBC) as these list a number of freshwater fish and aquatic macroinvertebrate species as threatened in NSW waters.

In May 2009 there was a report of Southern Purple Spotted Gudgeon (*Mogurnda adspersa*) in Goorangoola Creek, a major sub-catchment creek discharging to Glennies Creek (HCR-CMA Catchment News, Issue 17 May 2009). The Southern Purple Spotted Gudgeon is listed as endangered under the FMA. It is a common aquarium fish and there is a possibility that the Goorangoola Creek population is introduced. Its occurrence is thought to be inversely correlated with presence of plague minnow (*Gambusia holbrooki*), a species regularly observed within the application area (see Table 3). The CMA Catchment News report suggested that other factors such as abiotic parameters, other introduced species, and flow regulation may also impact on the presence of this species.

Whilst its location in upstream Bowmans Creek sites cannot be discounted, to date this species has not been recorded in the Bowmans Creek study area during any of the fish surveys undertaken between Spring 2005 and Spring 2009. If there are Southern Purple Spotted Gudgeons in Bowmans Creek, then it is more likely that they would be found in the upper reaches of the creek.

No species of fish or aquatic invertebrates, as currently listed under the FMA, or the EPBC, were recorded in any of the monitoring conducted to date for ACOL in either the Bowmans Creek or the Glennies Creek study areas, and none are expected.

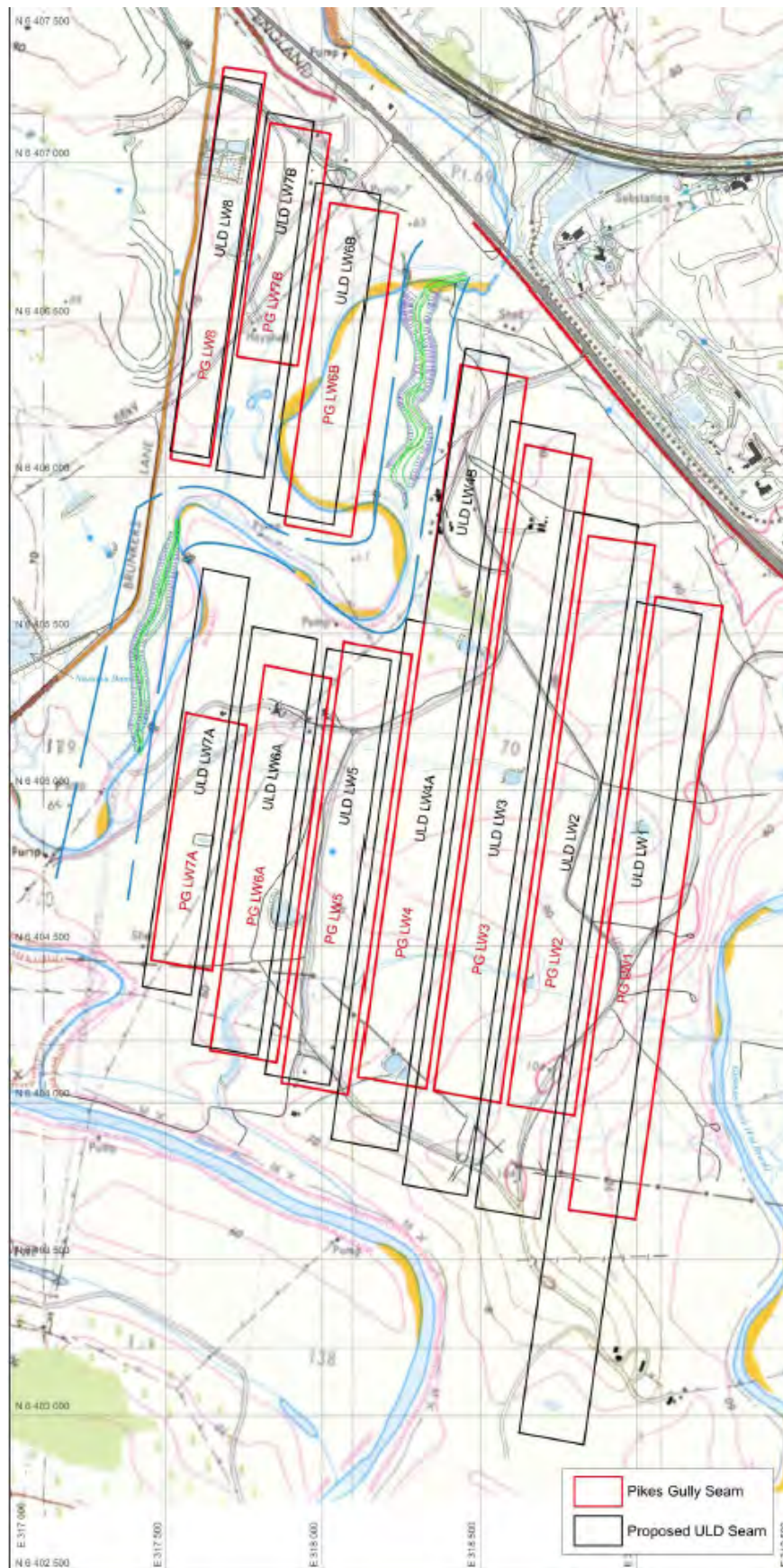
## **4 SUBSIDENCE IMPACTS**

This current assessment considers the impact of mining the Upper Liddell Seam (ULD) for LW1 to LW8 with regard to the current mine plan and revised subsidence predictions - with a view to assess whether these would alter the predictions put forward in the EIS, EA and supporting aquatic ecology assessments.

SCT (2011) have provided revised subsidence estimates for LW1-8 that incorporate the current mine design (Figure 6), allowing for an offset longwall panel arrangement, consideration of relevant site-specific information obtained during secondary extraction in the PG Seam and current data and methods for the estimation of subsidence in multi-seam mining environments. SCT (2011) concluded that, based on a conservative, empirical approach adopted for the purposes of this assessment, maximum subsidence may reach up to 85% of the combined seam thickness.

Incremental subsidence values for areas of multi-seam mining (i.e. where the PG Seam has already been extracted) were adopted for the purpose of identifying and managing subsidence impacts associated with mining of the ULD Seam. These values account for an incremental subsidence range of 2.4-3.4m across the extraction area.

Numeric modelling indicates that whereas in a single seam operation subsidence is generally limited to the extent of the panel, in a multi-seam environment the extent of subsidence may extend into overlying panels. The extent of subsidence in a multi-seam environment is therefore influenced by the geometry of the overlying panel and may extend to the limits of the overlying panel(s). Conversely in areas of single seam mining (where secondary extraction has not been undertaken in the PG Seam above (e.g. southern extents of LW1-4), maximum subsidence is expected to be less than 1.6m and will be greatest over the central part of the panels. The STC (2011) revised predictions are summarised in Table 5.



**Figure 6 Combined PG and ULD Multi-seam Mine Plan**

Panel	Cumulative Maximum Subsidence	Cumulative Maximum Tilt	Cumulative Maximum Strain	Incremental Maximum Subsidence	Incremental Maximum Tilt ULD Seam	Incremental Maximum Strain
	PG + ULD Seam	PG + ULD Seam	PG + ULD Seam	ULD Seam	(mm/m)	ULD Seam
	(m)	(mm/m)	(mm/m)	(m)		(mm/m)
LW1	4.4	235	94	2.9	183	73
LW2	4.0	189	76	2.5	139	55
LW3	4.0	162	65	2.5	119	48
LW4A	3.9	128	51	2.4	93	37
LW4B	3.9	151	60	2.4	110	44
LW5	4.0	103	41	2.5	76	30
LW6A	4.0	100	40	2.5	73	29
LW6B	4.3	132	53	2.8	101	41
LW7A	4.0	89	36	2.5	66	26
LW7B	4.5	116	47	3.0	91	36
LW8	4.4	107	43	3.4 <sup>1</sup>	98	39

The diversion of Bowmans Creek is not expected to be impacted by subsidence; however, subsidence of the excised channel and adjacent floodplain is expected to leave the diversion elevated above parts of the excised creek channel and surrounding landform. This will result in areas of ponding within the excised channel and within subsidence troughs on the floodplain.

Natural features such as trees, sub-catchment drainage lines leading to Bowmans Creek and flat areas will be significantly disturbed by these incremental subsidence values which exceed previous subsidence experienced in the PG Seam.

#### **4.1 Potential Subsidence Impacts to Aquatic Ecology**

The Bowmans Creek Diversion (BCD) EA considered the potential impacts on the aquatic ecology of Bowmans Creek arising from multi-seam mining under LW 5-8. With regard to this assessment the mine plan has been altered; mini-walls under retained sections of Bowmans Creek have been eliminated and the ULD longwalls are to be offset from the PG longwalls (Figure 6). Both these changes to the mine plan are considered beneficial with regard to minimising potential impacts on the aquatic ecology of Bowmans Creek.

The geomorphological impacts of the revised subsidence predictions have also been assessed as not being significantly different than those assessed for the Bowmans Creek Diversion EA (see Gippel 2011).

Consequently the revised subsidence predictions are not substantially different from those used to assess aquatic ecology impacts in the BCD EA. Accordingly, the assessment of potential impacts presented in the BCD EA remains current with the exception of a single beneficial change; that the active sections of Bowmans Creek to be retained will not be significantly impacted by subsidence.

With regard to LW1 to 4, the predicted subsidence impacts are expected to be less than those under LW5 to 8 and the potential impacts on the aquatic ecology of the sub-catchment drainages that flow to Bowmans Creek would be similar to those predicted in the BCD EA. Most of the sub-catchment drainage lines and impoundments within the mining area have been heavily impacted by agricultural practices and currently offer very little in the way of aquatic habitat diversity or drought refuge. Consequently, the potential effects of subsidence and related impacts on the present aquatic ecology of the tributaries and their sub-catchments are considered minor.

Potential effects on aquatic ecosystems are as follows:

- Lowering of sections of sub-catchment drainage lines resulting in ponded or swampy sections plus steeper drainage sections between ponded areas depending on the location of longwalls with respect to overlaying drainage morphology.
- Destabilisation of unconsolidated drainage banks with resultant accelerated bank erosion and increased sedimentation within the drainage line.

One consequence of the offsetting of the ULD longwall panels is that LW1 is located further west in relation to Glennies Creek and LW2 and 3 are closer to the Hunter River with a potential risk of bank destabilisation along the adjoining Glennies Creek and Hunter River banks (Figure 6). Slumping of the stream banks has the potential to smother edge riparian and aquatic habitat, narrow the stream leading to changes in stream hydraulic character and could impact water quality adversely.

However a geotechnical assessment has been undertaken to consider potential impacts to steep slopes adjoining Glennies Creek and the Hunter River and concluded that the risk of mining in the ULD Seam to cause slope instability is very low (Geotech Solutions 2011).

As predicted subsidence impacts do not indicate any significant slumping impacts on either of these stream banks; no additional monitoring and mitigation measures are recommended to address slope stability beyond those ordinarily adopted for management of subsidence impacts caused by underground longwall mining (see also recommendations in Section 6.1).

#### **4.2 Summary of Subsidence Related Impacts on Aquatic Ecology**

The impacts of proposed mining on aquatic biota and habitats in Bowmans Creek, the Hunter River and Glennies Creek are expected to be negligible based on the assessment of predicted subsidence induced changes to stream morphology, water quantity and quality provided above. There is not expected to be any significant impact on the availability of drought refuge pools and no significant impact on fish passage within these streams. It is also concluded that there would be no significant impact on fish passage between the Hunter River and Bowmans Creek.

Impacts on the aquatic attributes of the sub-catchment drainages are expected to be negligible from the point of view of the consequences for the receiving waters and for aquatic habitats of Bowmans Creek and the Hunter River, and it is concluded that the impacts on sub-catchment drainages can be managed and mitigated under the existing management framework.

## 5 PERFORMANCE MEASURES AND MONITORING PROGRAM

As per Conditions 3.9 and 3.12(d) and (f), the proponent is to identify the relevant performance measures/indices and assess the adequacy of the existing monitoring/management framework to address potential impacts.

There has been a formal monitoring program for stream-health and water quality for ACP in Bowmans and Glennies Creeks in-place since Autumn 2007, and this program has been adjusted over time to take account of changing mine plans and the approved Bowmans Creek Diversion.

Long-term stream health monitoring in Bowmans and Glennies Creeks currently utilises a network of water quality monitoring sites sampled monthly and aquatic ecology streamhealth monitoring sites, sampled twice a year in spring and autumn (see Figure 1). Monitoring for possible impacts of mining from the proposed mine plan relies on:

- The existing water quality, quantity and stream health monitoring program.
- Long-term stream health monitoring sites
- Additional short-term 'during mining' aquatic ecology monitoring sites. Each of these sites is brought on-line in the seasonal (i.e. Autumn or Spring) survey prior to mining under each site and would be monitored seasonally once before mining proceeds in proximity to the site and at least twice after mining has passed in proximity of the site.
- Performance measures, indicators of success and key assessment considerations detailed within the Flora and Fauna (Biodiversity) Management Plan
- The Trigger Action Response Plan (TARP) - included in the streamhealth monitoring program and Flora and Fauna (Biodiversity) Management Plan.
- Site specific management plans in place to address subsidence impacts on a site-by-site basis.

As a general guide, where perceptible impacts are noted through current site monitoring activities, the following general procedures, which are detailed further in the relevant TARP, currently apply:

- Undertake additional investigations to ascertain the actual cause (mine-related or other cause) of deteriorating aquatic conditions;
- If mining related, notify relevant government authorities;



- Develop and implement a specific response plan to prevent further impacts, and
- Undertake remediation as required.

Currently response plans are to be prepared on a case by case basis, with suggested short-term mitigation measures such as minor physical repair works and possible intermittent environment flow supplements as required, which may be implemented until such time that necessary long-term remediation works have been completed.

These performance measures, particularly as they relate to the Bowmans Creek Diversion and to mining in the PG Seam, are summarised in Table 6 and would continue to be implemented during extraction of the ULD Seam.

It is concluded that whilst the present performance measures and monitoring program are adequate to assess mining related impacts to Glennies and Bowmans Creek aquatic ecosystems arising from the proposed mine plan, potential indirect impacts to the Hunter River arising from the risk of mining related bank slumping are currently not considered within the current monitoring framework. Although the risk of subsidence related bank slumping impacts to the Hunter River are assessed as being low, the addition of short-term aquatic ecology monitoring sites is recommended in Section 6, to ensure relevant performance measures are met.

**Table 6 Aquatic and Riparian Biodiversity Performance Measures**

Criteria	Performance Measure A	Indicator of Success B	Key Assessment Considerations C
Aquatic Ecosystem health and biodiversity	Manage the impact of the ACP on aquatic habitat quality and biodiversity in Bowmans Creek, Glennies Ck and Hunter River relative to the condition in the catchment.	Aquatic habitat (RCE) scores, macroinvertebrate species diversity, SIGNAL scores and fish diversity in streams and pools do not deteriorate as a result of mining.	1) Does the monitoring and assessment indicate that a performance measure or development consent condition has been exceeded, or likely to be exceeded? 2) Does this exceedence increase the risk for aquatic and/or riparian habitats? 3) What is the nature of the risk? <ul style="list-style-type: none"> <li>• stream health (SIGNAL scores)</li> <li>• macro invertebrate diversity</li> <li>• fish diversity</li> <li>• water quality</li> <li>• habitat connectivity/fragmentation</li> <li>• fish passage</li> <li>• structural elements (RCE scores)</li> </ul> 4) Investigate site specific changes against baseline and upstream and downstream reference sites. What are the potential factors that may have contributed to the consequence i.e. subsidence, inadequate management measure or climatic conditions? 5) What are the potential impacts on the long term viability of the aquatic and riparian habitats?
		Water quality parameters are similar to reference sites or within the default range for lowland rivers set by ANZECC (2000) guidelines for the maintenance of aquatic ecological function.	6) Has the habitat connectivity been affected?
		Habitat extent and linkages	The aquatic and riparian ecosystem within Bowmans Creek is managed and where possible enhanced.
	Ensure fish passage and aquatic ecology of diversion sections is maintained and where possible enhanced.	Fish passage and aquatic ecology of diversion sections to be same or greater opportunity better than pre-construction baseline conditions and in line with trends exhibited in the retained sections of the creek using macro-invertebrate diversity, (SIGNAL index, species lists and RCE scores).	

## **6 CONCLUSIONS AND RECOMMENDATIONS**

### **6.1 Monitoring**

With regard to monitoring in Bowmans Creek and Glennies Creek the existing ACP streamhealth monitoring program is adequate to address potential impacts to these creeks. However the program does not adequately address potential indirect impacts to the Hunter River and should be expanded to include additional monitoring sites in the Hunter River. These additional sites should be brought on-line for the scheduled seasonal (autumn or spring) monitoring prior to mining operations in the relevant longwall. Additional monitoring sites should continue to be monitored post-mining for a period of time, dependent on the actual measured subsidence impacts or as per the aquatic ecology TARP.

The number and location of additional monitoring sites may be adjusted to the final adopted mine plan but should meet the following criteria:

- Sampling of the short-term sites should be scheduled into the regular bi-annual sampling program to incorporate before, and at least two after samples from each site. This will enable direct assessment of mining impacts on individual pools as mining proceeds and facilitate the interpretation of long-term monitoring results. This schedule should also be applied to the fish sampling sites.
- Any decision to continue monitoring of the short-term sites beyond the two post-mining studies should be made on a site by site basis, and only if there is evidence of localised mining or diversion related impact arising from the before/after comparisons.

These recommendations are compatible with the existing stream health monitoring plan that already includes a number of short-term monitoring sites that can be introduced into the aquatic ecology monitoring program on a staged basis as underground mining progresses.

### **6.2 Management, Mitigation and Remediation**

The following actions should be implemented to minimise physical impacts from subsidence in sub-catchment drainages:

- Small scale draining works and filling of subsided areas to create a free draining landscape and obviate the potential for pooling of water on the surface, as required.

- Inspection for surface cracking and stepping after completion of each panel in each seam and remediation where required to reduce the potential for water ingress or to prevent trapping animals.

Where subsidence induced pond formation in the off-stream sub-catchments and drainages cannot be otherwise remediated to drain naturally, riparian revegetation techniques (stock exclusion and provision of edge and emergent vegetation) should also be considered.

Decisions regarding whether this should be done would need to be made on a site-by-site basis as mining progresses. Accordingly, following individual longwall completion, field assessments should be made in the areas overlying longwalls, to ascertain the extent of subsidence impacts on creek and tributary channel ecosystems so that targeted riparian or habitat enhancement/protection measures can be identified.

If there is any significant mining related deterioration in water quality and quantity identified by monitoring, remediation should include provision of a supply of good quality make-up water to be used to restore creek water quality/quantity.

With regard to subsidence-induced ponding in the Bowmans Creek sub-catchment drainages, the general objective of remediation for these areas is to maintain the current agricultural land capability of the site. Where required, earthworks and drainage measures should be implemented to allow these areas to drain to Bowmans Creek and avoid ponding.

It is recommended that the potential ponding effects of longwall mining be assessed on a site by site basis. This assessment could result in the retention of some formed ponds for stock watering or other purposes and if retained, remediation measures such as stock exclusion and riparian and emergent planting could be implemented to improve aquatic habitat attributes of the retained ponds.

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