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# POLLUTION REDUCTION PROGRAM 11 - WEST CLIFF MINE
# WATER DISCHARGE ECOTOXICITY STUDY

## *Executive Summary*

This document reports on the outcomes of the Pollution Reduction Program No. 11 (PRP11) study conducted in May/June 2012 for Endeavour Coal Pty Ltd.

Field monitoring and water sampling (for detailed laboratory chemical analysis and ecotoxicity testing) was conducted by Ecoengineers Pty Ltd. Laboratory analysis of chemical parameters was conducted by ALS Environmental. Ecotoxicological testing was conducted by Ecotox Services Australasia Pty Ltd using the following test organisms; *Ceriodaphnia dubia* (a water flea), *Paratya australiensis* (glass shrimp), *Selenastrum capricornutum (*a green alga*)* and *Melanotaenia splendida splendida* (Eastern Rainbow Fish).

The key findings from the ecotoxicity tests for water discharged from Licensed Discharge Point 10 (LDP10) into Brennans Creek can be summarised as follows:

- No observable ecotoxicity (within experimental error) to the water flea (48 hr test) and the green alga (72 hr test);
- No observable ecotoxicity (within experimental error) to the glass shrimp (96 hr test) and the Rainbow Fish (96 hr test) using a solution renewal protocol which was used to maintain pH control during the longer duration tests.

The key findings from the ecotoxicity tests for operational waters (confined on-site) can be summarised as follows:

- No observable ecotoxicity (within experimental error) to the water flea and the glass shrimp for water obtained from the surface of Brennans Creek Dam (BCD) from a floating off-take (operational water supply);
- Low to moderate ecotoxicity to the water flea and the glass shrimp was observed for process waters (both untreated and clarified) next to the Coal Processing Plant.

The results of the ecotoxicity testing and chemical analysis for samples from within and discharging from BCD, indicate that at the time of sampling, the following parameters did not result in observable ecotoxicity to the test organisms: salinity; trace metals (aluminium, copper, nickel, arsenic, or zinc); and traces of Magnasol 572 coagulant. For the metals, this finding is fully consistent with their aqueous speciation (chemical forms) as determined by hydrochemical modelling in previous Pollution Reduction Programs.

***Background***

West Cliff Colliery operates under Environment Protection Licence 2504 (EPL 2504), constituted under Section 55 of the *Protection of the Environment Act* (NSW) 1997. The EPL regulates, among other things, the discharge of water from the colliery into the Georges River via Brennans Creek. Under the Licence, the Licensee is required to undertake prescribed pollution studies and reduction programs.

Including the present PRP11, a number of pollution reduction programs (PRPs) have now been completed and these included assessments of the ecology of the Georges River (PRP4, PRP6 & PRP9). The previous PRP10 was entitled *Reduction in Salinity from Brennans Creek Dam* and was intended to be done in two stages, PRP10.1 and PRP10.2 PRP10.1 was entitled *Derivation of Salinity Discharge Limits for Brennans Creek Dam.* As specified in the EPL, the aim of PRP10.1 was to:

- *Derive a scientifically justifiable salinity limit that will apply to dry weather discharges from Brennans Creek Dam that flows into the Georges River Catchment.*

A requirement of PRP10.1 was that it considered the NSW Water Quality and River Flow Objectives for the Georges River. In total up to 23 water quality and flow objectives are applicable in various parts of the river and they are designed to assist the community to achieve an acceptable balance between environmental, social and economic needs.

BHP Billiton Illawarra Coal (BHPBIC) commissioned Cardno Ecology Lab Pty Ltd (CEL; formerly The Ecology Lab) to conduct and oversee ecological studies for PRP10.1. Ecoengineers Pty Ltd were also engaged to conduct water chemistry monitoring and modelling and to provide details of operational procedures at West Cliff Colliery, having provided operational and monitoring services to BHPBIC for the West Cliff Water Management System (WMS) since its establishment on 4 August 2004.

PRP 10.1 was completed on 31 March 2010.

The planned PRP10.2 was entitled:

*Investigation of Strategies, Technologies or Works to Achieve the Salinity Discharge Limit*.

It was due for completion by 30 June 2011 but was cancelled because the principal finding of the PRP10.1 study was that salinity was not the primary determinant of aquatic ecotoxicity within Georges River.

The main findings of PRP10.1 were as follows:

- Water quality in the upper Georges River is characterized by naturally variable electrical conductivity (EC; a measure of salinity) which ranges from 100 μS/cm in high flow conditions to at least 1350 μS/cm during dry periods - even in the absence of mine water discharges.
- Since the introduction of the West Cliff Water Management System (in August 2004) the mean EC of the LDP10 discharge to Brennans Creek had been relatively constant at ~2574 μS/cm which is slightly above the default trigger value for lowland rivers for south eastern Australia.
- Chemical speciation modelling indicated that the concentrations and chemical species of As, Ni and Zn in water discharged from the mine are not likely to be ecotoxicologically significant.
- Freshwater invertebrates exhibit a wide range of tolerance to elevated salinity, with the majority of taxa surviving at conductivities as high as 3000 to 12500 μS/cm. Even the most sensitive taxa can be found at around 1250 μS/cm
- Notwithstanding this, the literature clearly indicates that salinity has adverse effects on freshwater biota.

- Tolerances appear to be correlated with the maximum salinities at which species are found in the field.
- Microalgae, particularly diatoms, appear to be more responsive to salinity than macroinvertebrates.
- Surveys of aquatic macroinvertebrates of the Upper Georges River in 1997 had indicated that while the river may have been impacted in the stretches above and below Brennans Creek, it still supported a healthy macroinvertebrate community.
- More recent studies of the upper Georges River for PRP10.1 had indicated that aquatic biota may be less affected by salinity than might be expected from the ANZECC/ARMCANZ (2000) National Water Quality (NWQG) guidelines.
- EC (salinity) correlates only weakly with abundance and composition of macroinvertebrates although it should be noted that regionally, outside of Georges River, gradients of salinity were very weak.
- Ecotoxicological studies elsewhere indicate that invertebrate taxa commonly found in the Georges River, such as mayfly larvae and glass shrimps (*Paratya*), survive in mine water with conductivities ranging from 2000 to 3000 µS/cm. Even the most sensitive test species, the water flea (*Ceriodaphnia*), survived up to 1500 µS/cm.
- However, field translocation experiments showed mortality of glass shrimps (*Paratya*) up to 2300 µS/cm in Brennans Creek. Statistical modelling of these field data suggest that bicarbonate, total suspended solids and possibly residues of Magnasol 572, rather than electrical conductivity, may account for the observed mortality.
- EC (salinity) may not, therefore, be a particularly good indicator of potential toxicity, except where extreme values are encountered.
- Abundant and diverse assemblages of macroinvertebrates can be found in streams with relatively high conductivity, including those receiving mine water discharges. This suggests that the current ANZECC/ARMCANZ (2000) guidelines are overly conservative, at least as applied to Georges River and that there is a need to establish more relevant site-specific trigger values for conductivity.

The PRP10.1 report recommended that:

1. While acknowledging the limitations of the above studies, the results indicate that salinity is only one factor (and probably not the major one) contributing to the observed ecotoxic effects. It is, therefore, recommended that further ecotoxicological tests be conducted to determine the nature of the toxic agent in the mine water discharge.
2. Since no convincing scientific basis was found for setting a salinity limit on the discharge from Brennans Creek Dam, it is recommended that no such limit be set until more is known about the agent causing toxicity and until the outcomes of the Bulli Seam Part 3A process are known.

Consequently, in 2011 PRP11 was inserted into the Mine's Environmental Protection License ('EPL') 2504 as follows:

## U3 PRP11 - Brennans Creek Discharge Toxicity Study (West Cliff Mine)

### U3.1 Pollution Reduction Program 11 - Water Discharge Toxicity Study

**Stage I**

The Licensee must undertake a program to test the whole effluent toxicity of water from Brennans creek dam and from the West Cliff coal preparation plant water treatment plant. The program must include:

- Sampling of both water sources on a fortnightly basis over a six week period;
- Testing for whole effluent toxicity using the test species: *Ceriodapnia dubia* and *Paratya australensis*;
- Additional fish and algal test species to determine whether the toxic effect has changed since testing performed under PRP 10; and
- Chemical analysis for the presence and concentrations of likely toxicants.

The whole effluent toxicity study must be completed and a report outlining the findings must be submitted to the EPA by the Due Date.

Due Date: 26 July 2012

Salinity as expressed by Electrical Conductivity (EC) of the LDP10 discharge to Brennans Creek and hence Georges River has ranged over the 6 years from August 2004 – July 2009 from about 1000 to about 3500 μS/cm, with a relatively constant mean EC of 2497±434 μS/cm (n=1317 measurements). This is a level of salinity which just exceeds the default trigger value for lowland rivers for south eastern Australia in the national water quality guidelines ('NWQG') of 2200 μS/cm (ANZECC/ARMCANZ 2000). Note that other source waters for the Georges River can have salinity values naturally well in excess of the guideline value for upland rivers in south eastern Australia. Furthermore, over the last two years of increased rainfall and improved runoff capture in Brennans Creek catchment the average EC of LDP10 has been 1965±404 μS/cm i.e. is generally below 2200 μS/cm.

Trace concentrations of aluminium (Al), arsenic (As), nickel (Ni) and zinc (Zn) are also present in water discharged to Georges River from BCD. However, it is important to realise that these metals are present in water in a large number of chemical forms (Stumm and Morgan, 1996) but not all these forms are bioavailable and hence may not create an ecotoxic effect (Tessier and Turner, 1996). For this reason the National Water Quality Guidelines (NWQG; ANZECC/ARMCANZ, 2000) explicitly provide a risk assessment 'Decision Tree' approach (refer Figure 3.4.2 in ANZECC/ARMCANZ, 2000) to allow for consideration of the nature of the chemical speciation of such elements to determine what proportion may actually be present in the ecotoxic forms.

It was found (Ecoengineers 2003) that the concentrations of these elements can be shown, on the basis of chemical speciation modelling, to generally not be ecotoxic within the river due to either too low a concentration in the case of As or, in the cases of Al, Ni and Zn, due to complexation of these metals by bicarbonate, a relatively common phenomenon (Stumm and Morgan, 1996; Parkhurst and Appelo, 1999). Bicarbonate complexation significantly reduces the effective concentration of the ecotoxic cationic $Al^{3+}$, $Ni^{2+}$ and $Zn^{2+}$, etc species (Tessier and Turner, 1995; ANZECC/ARMCANZ 2000).

In accord with the requirements of PRP11, Ecoengineers conducted field water quality monitoring, sampling for detailed laboratory chemistry analysis and/or ecotoxicological studies at fortnightly intervals on the following dates at the following locations as shown in **Table 1**.

**Table 1: Key field and laboratory water quality Parameters measured and ecotoxicological tests conducted during PRP11**

| | | Field Water Quality Key Parameters | | | Laboratory Water Quality Key Parameters | | | Ecotoxicological Tests Performed (as per PRP11 testing requirements) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | **Locations** | **pH** | **EC** | **Turb.** | **TSS** | **Dissolved & Total Heavy Metals, particularly Al, Ni & Zn** | **DON, DOC and DON/DOC** | ***Ceriodaphnia* (Water flea) 48 hour acute toxicity** | ***Paratya* (Shrimp) 96 hour acute survival** | ***Selenastrum* (Green alga) 72 hour growth inhibition** | ***Melanotaenia* (Eastern Rainbow fish) 96 hour balance inhibition** |
| **10/05/12** | **Untreated Process Water** | x | x | x | x | x | x | | | | |
| | **Clarified Process Water** | x | x | x | x | x | x | x | x | | |
| | **BCD Surface** | x | x | x | x | x | x | x | x | | |
| **22/05/12** | **Dosed Inflow to Sed. Tanks** | x | x | x | x | x | x | | | | |
| | **Clarified Process Water** | x | x | x | x | x | x | x | x | | |
| | **BCD Surface** | x | x | x | x | x | x | x | x | | |
| **05/06/12** | **Untreated Process Water** | x | x | x | x | x | x | x | x | | |
| | **Clarified Process Water** | x | x | x | x | x | x | x | x | | |
| | **BCD Surface** | x | x | x | x | x | x | x | x | | |
| | **LDP10** | x | x | x | x | x | x | x | x | x | x |
| **27/06/12** | **LDP10** | x | x | x | X | x | x | x | x | | x |

***Key:*** x = measured in accordance with PRP11 requirements

*Outcomes*

The following **Table 2** shows the principle physicochemical outcomes of PRP11 in terms of investigating both field and laboratory-measured relevant major water quality parameters.

**Table 2: Principle water quality parameter values during PRP11 program**

| Location | Field pH | Field EC (µS/cm) | Field Turbidity (NTU) | TSS (mg/L) | Diss. Al (mg/L) | Diss. Ni (mg/L) | Diss. Zn (mg/L) | DOC mg/L | DON (mg/L) | DON/ DOC |
|---|---|---|---|---|---|---|---|---|---|---|
| **Untreated Process Water** [1] | 8.64 ±0.05 (n=2) | 3133 ±547 (n=2) | 787 ±229 (n=2) | 2145 ±1266 (n=2) | 0.17 ±0.01 (n=2) | 0.239 ±0.075 (n=2) | 0.086 ±0.022 (n=2) | 7.0 ±1.1 (n=2) | 0.53 ±0.70 (n=2) | 0.068 ±0.089 (n=2) |
| **Dosed Inflow to Sed. Tanks** [1] | 8.43 | 3440 | 178 | 2130 | 0.40 | 0.283 | 0.101 | 6.5 | 0.89 | 0.137 |
| **Clarified Process Water** [1] | 8.66 ±0.08 (n=3) | 2750 ±99 (n=3) | 32 ±23 (n=3) | 11 ±1 (n=3) | 0.92 ±0.10 (n=3) | 0.190 ±0.015 (n=3) | 0.069 ±0.006 (n=3) | 5.3 ±0.5 (n=3) | 0.47 ±0.28 (n=3) | 0.092 ±0.059 (n=3) |
| **BCD Surface** | 8.79 ±0.03 (n=3) | 1643 ±118 (n=3) | 13 ±4 (n=3) | 2.5 ±0.5 (n=3) | 0.36 ±0.03 (n=3) | 0.086 ±0.010 (n=3) | 0.029 ±0.006 (n=3) | 4.9 ±0.5 (n=3) | 0.23 ±0.12 (n=3) | 0.047 ±0.024 (n=3) |
| **LDP10** | 8.60 ±0.10 (n=2) | 1860 ±52 (n=2) | 19 ±1 (n=2) | 5.0 ±1.4 (n=2) | 0.33 ±0.01 (n=2) | 0.105 ±0.011 (n=2) | 0.045 ±0.000 (n=2) | 5.4 ±0.4 (n=2) | 0.70 ±0.26 (n=2) | 0.133 ±0.057 (n=2) |

***Key:***

n = number of measurements and quoted ± errors (on the mean) are expressed at an estimated one standard deviation level (where applicable for 2 or more measurements).

[1] Process waters were sampled near the Coal Processing Plant (See Appendix for Map).

**Tables 3 and 4** below list the principle ecotoxicological outcomes of PRP11.

**Table 3: Principle results of ecotoxicity tests for on-site water sampling sites.**

| Location | Effluent sample concentration | *Ceriodaphnia* (Water flea) 48 h mean % survival ± SD | *Paratya* (Shrimp) 96 h mean % survival ± SD |
|---|---|---|---|
| **Untreated Process Water** [1] | 100% | 0±0 (n=1) | 0±0 (n=1) |
| | 50% | 90±20 (n=1) | 100±0 (n=1) |
| **Clarified Process Water** [1] | 100% | 32±28 (n=3) | 12±6 (n=3) |
| | 50% | 100±0 (n=3) | 95±6 (n=3) |
| **BCD Surface** | 100% | 100±0 (n=3) | 88±11 (n=3) |

[1] Process waters were sampled near the Coal Processing Plant (See Appendix for Map).

**Table 4: Principle results of ecotoxicity tests for LDP10 discharge from BCD.**

| Test | Effluent sample concentration | *Ceriodaphnia* (Water flea) 48 h mean % survival ± SD | *Paratya* (Shrimp) 96 h mean % survival ± SD | *Selenastrum* (Green alga) 72 h cell density [1] | *Melanotaenia* (Eastern Rainbow fish) 96 h balance inhibition |
|---|---|---|---|---|---|
| **LDP10 Static test**[2] | 100% | 100±0 (n=2) | 60±43 (n=1) | 126±19 [1] (n=1) | 35±19 (n=1) |
| **LDP10 Solution renewal test**[3] | 100% | | 95±10 (n=1) | | 95±10 (n=1) |

***Key***

[1] Cell density ×$10^4$ cells/mL versus USEPA control result (58.4 ×$10^4$ cells/mL)

[2] The static test involved testing of the LDP10 sample with the same water for the duration of the test. This resulted in a drift of pH to levels over pH of 9 which is not consistent with discharge waters from LDP10. This pH drift is caused by the degassing of $CO_2$ from the test solutions. This effect was more significant for the longer duration (96 hr) tests and could have caused an ecotoxic effect which would not have occurred within the EPL-permitted pH range of the LDP10 discharge.

[3] The renewal test involved changing the test water with water from LDP10 (collected at the same time as the initial test solution) at 48 hr. This was done to minimise pH changes during the 96 hr test (see comment regarding Static Test above).

***Assessment***

It can be seen from **Table 3** above that, within the precincts of the Mine Coal Preparation Plant, untreated process water (pre-dosed inflow) passing into the Sedimentation Tanks is ecotoxic to both *Ceriodaphnia* and *Paratya* at a full 100% effluent concentration.

However, at an effluent concentration of 50%, *Ceriodaphnia* survival was 90±20% and 95±10% at an effluent concentration of 25%. Similarly, for *Paratya*, at an untreated process water of both 50% and 25% there was 100±0% survival.

These findings indicate that the ecotoxicity of untreated process water is low to moderate given the effects were confined to the 100% (undiluted) sample only.

Similarly, **Table 3** shows that the clarified process water samples (downstream of the Sedimentation Tanks, within the precincts of the Mine Coal Preparation Plant), exhibited measurable ecotoxicity to both *Ceriodaphnia* and *Paratya* at 100% concentration in each case but it is again noted there was 100% survival of *Ceriodaphnia* (n=3) and 95±10% survival (n=3) of *Paratya* at a 50% concentration.

These findings indicate that the ecotoxicity of clarified process water is low given the effects were confined to the 100% (undiluted) sample only.

It is not clear from the chemical analyses what the source or sources of ecotoxicity to *Ceriodaphnia* and *Paratya* in these waters are. However, what is clear is that the clarified process water, despite having been dosed with the coagulant BASF Magnasol 572 is substantially less ecotoxic than the untreated process water. Chemical markers such as salinity (EC; see **Table 2**) and the conservative tracer chloride, etc., indicate that on some occasions, the clarified process water may be diluted by clean runoff downstream of the Sedimentation Tanks. This would potentially result in lowered ecotoxicity of the clarified process water with respect to the untreated process water. The degree of dilution is not sufficient, however, to fully account for the lowered ecotoxicity, casting doubt on constituents of Magnasol 572 being the toxic agent.

This inference cannot be further explored until an analytical method specifically for measuring trace concentrations of the cationic quaternary ammonium polymeric compound in Magnasol 572 becomes available. At the present time such a method does not exist in Australia and one has not been made available by BASF.

**Table 3** above shows that BCD surface water obtained from a floating off-take in BCD, which is piped underground as the non-potable mine supply, is essentially non-ecotoxic to both *Ceriodaphnia* and *Paratya* within experimental error.

Similarly, water obtained from near the base of BCD which constitutes the EPL licensed mine discharge LDP10 to Brennans Creek was essentially non-ecotoxic to *Ceriodaphnia* and *Selenastrum* (refer **Table 4** above). The increased cell density for the green alga *Selenastrum* compared to the control is likely due to growth of the alga arising from the greater nutrient content of the water compared to the control water.

During ecotoxicity testing of the *Paratya* and the Eastern Rainbow Fish *Melanotaenia* in LDP10 water using a static (no solution renewal) protocol a pH drift occurred during the 96 hr test period. The levels rose above a pH of 9 which is not consistent with discharge waters from LDP10. This pH drift is caused by the degassing of $CO_2$ from the test solutions. This effect was more significant for the longer duration (96 hr) tests and could have caused an ecotoxic effect which would not have occurred within the EPL-permitted pH range of the LDP10 discharge. For example, using the static protocol, ecotoxicity to *Melanotaenia* was observed at 25% sample concentration, whereas even in the treated process waters, no ecotoxicity was observed (within experimental error) in samples at double that concentration (50%).

For this reason, the *Paratya* and *Melanotaenia* tests were repeated using a solution renewal protocol in which the test solution was replaced at 48 hr with LDP10 water. In this renewal test, no ecotoxicity was observed to either *Paratya* or *Melanotaenia* within experimental error (refer **Table 4** above).

It is likely that the significantly reduced ecotoxicity observed for samples from BCD surface and LDP10, relative to the process water samples are at least partly due to their reduced suspended solids concentrations and salinity. For example, salinities for LDP10 and BCD surface samples were lower by 33 - 40% than that of the process water samples (refer **Table 2)**.

However, in noting this, it is also important to understand that decreases in ecotoxicity following a decrease in salinity may simply reflect a reduction in some other parameter for which salinity is merely a proxy, e.g. bicarbonate, or a change in speciation of a toxic trace metal caused by a change in a major ion occurrence. A good example of such a change would be a significant shift in trace metal (Al, Ni, Cu, Zn) speciation away from purely cationic (positively charged) forms, which are known to be ecotoxic, towards neutral and anionic (negatively charged) forms complexed by bicarbonate etc., known to be much less ecotoxic.

**Table 2** shows there is no significant change in either DOC and DON concentrations or DON/DOC ratios in passing from untreated process water through to BCD waters as represented by the LDP10 and BCD surface waters.

This suggests that any soluble organic compounds contributed either by process water or by a minor organic component of the BASF Magnasol 572 (polyaluminium chloride-based coagulant) used in the Sedimentation Tanks are unlikely to be the cause of the ecotoxicity observed in the untreated and clarified process water samples.

However, an alternate explanation would be that DOC and DON measurements are insufficiently precise as a proxy measure for the minor (organic) polymeric quaternary ammonium cationic coagulant present in the Magnasol 572 formulation due to the background levels of coal and shale-derived DOC and DON present in the process water.

In our view, it may be concluded that the results of this PRP11 study program indicate that, at the present time, waters departing BCD are highly unlikely to be ecotoxic to a range of common species ranging from water fleas to fish unless other changes to the water were somehow imposed downstream of BCD, i.e. outside of the precincts of the Mine e.g. in Georges River.

These current findings (of the PRP11 study) do not rule out the possibility of there having been some past ecotoxicological impacts in Brennan Creek or Georges River induced by the LDP10 discharge when salinities in BCD were higher, e.g. above the National Water Quality Guidelines ('NWQG') trigger value for south east Australian lowland rivers of 2200 µS/cm (ANZECC/ARMCANZ, 2000).

It should be noted that, prior to 4 August 2004, LDP10 did not exist and there were no regular discharges from BCD to Brennans Creek and hence to Georges River. This coincided with the Millenium Drought which applied in the region from mid-2001 through to late 2006. Until 4 August 2004, discharges from the Mine occurred only during periods of significant and/or prolonged wet weather, when BCD spilled over its spillway (LDP1 in the EPL).

Consequently, prior to 4 August 2004, Upper Georges River to at least as far north as the confluence with O'Hares Creek and sometimes beyond <u>was strictly an ephemeral watercourse</u>.

Streams and springs draining from the eastern side of Georges River, mantled by shallow Mittagong Formation or Hawkesbury Sandstone-based soils, may have an EC as low as 100 µS/cm and carry a high clay/silt load under high runoff conditions, or EC as high as about 1000 µS/cm under low flow conditions. Streams and springs draining from the west and from parts of the Wedderburn Plateau, which may drain subcatchments mantled by deep to shallow Wianamatta Shale and Shale-based soils, may have an EC as high as 2500 µS/cm under low flow conditions, or as low as 1000 µS/cm and carry a moderate to low clay/silt load under high flow conditions.

The impact of these contrasting major soil landscapes and of the known complex inter-related surface and shallow semi-confined groundwater hydrological regimes associated with the river makes for a relatively complex and variable water quality regime even in the absence of discharges from West Cliff and/or Appin Collieries and urban runoff from Appin Village and the Cataract Scout Park. This geochemical context is largely natural and predates coal mining in the area.

Groundwater-derived springs exist in Georges River to the present day and their existence has been confirmed by numerous past river water quality analyses in the river (above and below such springs) obtained by the BHP Billiton Illawarra Coal Field team and others. Springs arising from the western side of the river are invariably both ferruginous (containing iron and manganese) and saline due to their origins in percolation through Wianamatta Shale. An example of such a spring is shown in Figure 1.

Local depletions or extinctions of populations of some aquatic species which may have existed previously in the river, may have occurred during the Millenium Drought, e.g. due to excessive salinities created during drying out of spring-fed 'semi-permanent' pools. Such extinctions or depletions could also have persisted to the present day.

### *Conclusion*

The results of the ecotoxicity testing and chemical analysis of samples at the time of the PRP11 study showed that ecotoxicity was not evident (within experimental error) in

Brennans Creek Dam or in water being discharged into Brennans Creek via LDP10. This is despite low to moderate ecotoxicity of process waters observed within the precincts of the Mine Coal Preparation Plant.

This indicates that salinity, the concentration of trace metals (aluminium, copper, nickel, arsenic, or zinc), and traces of Magnasol 572 coagulant were not ecotoxic to the test organisms at the levels occurring during the PRP11 study in both BCD surface and LDP10 waters. For the metals, this finding is fully consistent with their concentrations and their aqueous speciation as determined by hydrochemical modelling using PHREEQC modelling software (Parkhurst and Appelo, 1999) using a recent version of the USEPA-endorsed chemical database (MINTEQA2). This approach is consistent with the National Water Quality Guidelines (ANZECC/ARMCANZ, 2000).

We therefore conclude that, in the context of the findings of the present PRP11 study, with discharges from LDP10 having a salinity usually below 2200 µS/cm, it would not be possible to unambiguously ascribe any such absences of expected species in the river to ecotoxicity deriving from West Cliff Mine's LDP10 discharge from BCD.

Dr. Stephen A. Short

Director

**Figure1: Example of a small ferruginous and saline spring on western side of Georges River (11 March 2004).**

**Figure2: West Cliff - Reference Site Location (provided by Illawarra Coal)**

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## *Glossary*

CPP = West Cliff Coal Preparation Plant.

BCD = Brennans Creek Dam the largest (and primary) water storage within the precincts of West Cliff Mine.

Untreated Process Water = Pre-Dosing Inflow into the sedimentation tanks (prior to Magnasol 572 coagulant dosing) located within the Mine Coal Preparation Plant precinct.

Dosed Inflow to Sed. Tanks = Inflow to the sedimentation tanks immediately following the Magnasol 572 coagulant dosing located within the Mine Coal Preparation Plant precinct.

Clarified Process Water = Clarified process water downstream of the Sedimentation Tanks taken (which may on occasion be subject to some dilution by clean runoff from elsewhere) located within the Mine Coal Preparation Plant precinct.

BCD Surface = supply (non-potable) water to West Cliff operations taken from approximately 0.5 m below surface of dam (via the floating off-take).

LDP10 = Licensed mine discharge to Brennans Creek/Georges River piped from a 12.0 m depth in BCD (~0.5 m above bottom of BCD).

Turbidity = a field measure of Total Suspended Solids, expressed in Nephelometric Turbidity Units (NTU).

TSS = Total Suspended Solids determined by laboratory gravimetric analysis.

Al = Aluminium

As = Arsenic

Ni = Nickel

Zn = Zinc

Diss. Al = Dissolved Aluminium

Dissolved Ni = Dissolved Nickel

Dissolved Zn = Dissolved Zinc

Magnasol 572 = a BASF commercial cationic coagulant formulation used to enhance settling and water clarification in the Sedimentation Tanks downstream of the CPP.

PAC = Polyaluminium chloride – an inorganic cationic coagulant being the principal component of Magnasol 572.

PolyDADMAC = poly(diallyl dimethyl ammonium chloride) cationic polymeric flocculant agent

DON = Dissolved Organic Nitrogen, here used as a possible surrogate measure of quaternary ammonium-based polymeric cationic coagulant (as contained in the BASF Magnasol 572 coagulant product used in the Sedimentation Tanks at 2% of the principal active material PAC) or quaternary ammonium-based polymeric flocculation agents (e.g. poly DADMACs) as used in the West Cliff CPP.

DOC = Dissolved Organic Carbon.

DON/DOC = DON/DOC ratio which is also used as a possible surrogate measure of quaternary ammonium-based polymeric cationic coagulant (as contained in Magnasol 572 at ~2% of active ingredient) or quaternary ammonium-based polymeric flotation agents (e.g. polyDADMACs) as used in the West Cliff CPP.

SD = standard deviation