APPENDIX D

WATER QUALITY IMPACT ASSESSMENT (ECOENGINEERS)

WEST CLIFF COLLIERY

COAL WASH EMPLACEMENT

WATER QUALITY IMPACT ASSESSMENT

AND

STAGE 3 EMPLACEMENT

WATER QUALITY MANAGEMENT PLAN

(Version 1)

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ECOENGINEERS PTY/LTD
9 Sunninghill Circuit
Mount Ousley NSW 2519
Tel: 02 4227 4174 / 0410 560 766 Fax: 02 4227 5154
Email: steve@ecoengineers.com.au
ABN 74 078 666 510

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REVISION	**Name:**	S. Short	C. McEvoy, I. Taylor (CFR), B. Blunden (BHPBIC)	S. Short	K. Wilyman
1	**Date:**	04/05/07	21/05/07	22/05/07	23/05/07
	Signature:				
Reviewers Comments:					

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EXECUTIVE SUMMARY

Section 5.1 (e) of the Dendrobium Mine development consent required that further detailed assessment must be undertaken to seek approval for the use of the Stage 3 emplacement area at West Cliff. Section 5.1(e) (vii) of the Dendrobium Mine development consent states that there should be:

- detailed assessment of the potential impact of the proposal on water quality, particularly on Georges River, including details of proposed management and contingency measures to mitigate any potential impacts.

West Cliff Colliery has a Water Management System (WMS) that is designed to be an implementation of best practice mine site water management.

A supplementary management plan governing BCD controlled discharges to Georges River via Licensed Discharge Point 10 (LDP10) was implemented on 2 August 2004 and is based on the following well defined management goals.

1. Minimise volumetrically and chemically, <u>uncontrolled</u> spills over Brennans Creek Dam (BCD) spillway to Georges River past Licensed Discharge Point 1 (LDP1) to minimise aquatic environmental impacts down river in Georges River.
2. Control discharges from the West Cliff WMS to Georges River to a pH equal to or below 8.50 as mandated by EPA.
3. Provide a dry weather environmental flow in Upper Georges River below the confluence with Brennans Creek.
4. Return water levels in BCD to a target value of 11.0 m as quickly as possible after all rainfall-runoff events. This level has been determined by OPSIM system water balance modelling to deliver capture within BCD of 90% all storm runoff from Brennans Creek catchment. That target is maintained in order to provide the maximum volume of catchment runoff for mine operations, to maximise the reliability of a dry weather supply to the WMS, to minimise the circulation and increase of salinity and other pollutants within the WMS and to minimize the salinity of uncontrolled spills from BCD to Georges River.

Taking into account the above pre-existing water management context, the assessment presented in **Section 2.1** of this report shows that the key issues of concern within respect to impact of discharges from the West Cliff WMS (and in this instance an expanded coal wash emplacement to include the proposed Stage 3), are the effect the emplacement may have on salinity and Total Suspended Solids (TSS) in Georges River downriver of the Brennans Creek/Georges River confluence.

Further impact assessment presented in **Sections 2.2 and 2.3** and in **Appendix A** identified that the principal pollutant within the West Cliff WMS which may in part derive from direct runoff from the coalwash emplacement is particulate suspended solids (as measured by TSS). TSS has the potential to impact adversely on:

1. Georges River through uncontrolled spills from BCD via LDP1; and/or
2. Georges River through controlled discharges from BCD via Licensed Discharge Point 10 (LDP10) from the bottom of BCD; and/or

3. underground mining operations through delivery of a dirty supply water with high fine particulate load,

Further, the assessment showed that it is the very fine particulates, typically <5 µm in size, sourced from direct runoff from the coal wash emplacement that particularly poses the most significant risk to water quality in Georges River (via discharges from BCD).

Such very fine particulate matter, unless chemically treated, is very slow to settle.

As this very fine particulate matter is associated with water of the lowest salinity within the WMS, it is likely to persist longest in the surface layers of BCD and hence be discharged over the BCD spillway whenever the storage capacity of BCD is exceeded during heavy or persistent rainfall.

Future goals for improvement of the water quality of discharges off the West Cliff site to Georges River via BCD concurrent with the development of Stage 3 of the Emplacement should be to:

1. decrease the fine particle TSS load of direct runoff waters from the Emplacement entering BCD; and
2. release clean Emplacement subsurface drainage waters to BCD as quickly as possible to provide maximum dilution of peak flows from the Pit Top Area; and
3. detain Emplacement direct runoff peaks flows upstream of BCD within Brennans Creek valley as long as possible to allow these other clean peak flows to enter the Dam beforehand and thus be spilled from the Dam to Georges River if necessary.

These goals should be undertaken in concert with the pre-existing WMS supplementary management plan for BCD that is now operated according to a controlled bottom water discharge system (LDP10) designed to minimize spills over the spillway via LDP1.

Hydrologic modelling of the emplacement presented in **Section 2.4 and Appendixes B and C** describe a hydrologic model developed for the emplacement, and present daily and cumulative (dirty) direct runoff and (clean) subsurface drainage flow predictions for the adopted 10 year Average Recurrence Interval 72 hour design maximum storm. These sections identify quantitatively how an improved management of the entire emplacement can be designed in such a way that:

1. water quality impacts of the whole emplacement, including the proposed Stage 3 on BCD are minimized; and
2. provide contingency measures to mitigate any water quality impacts within BCD and from uncontrolled spills and controlled discharges from BCD to Georges River.

Section 2.4 and Appendixes B and C therefore provide the basis for developing a proposed **Water Quality Management Plan** for the expanded coal wash emplacement to ensure maximum control on water quality within BCD and in discharges from BCD to Georges River.

The proposed new Emplacement Water Quality Management plan for the expanded Emplacement is presented in **Appendix D** and is based upon:

- complete separation of the Pit Top Area water management system from the coal wash emplacement water management system from the inception of Stage 3 of the Emplacement; and
- a system of segregation of clean subsurface drainage from the expanded Emplacement from dirty direct runoff form the expanded emplacement; and
- proposed improved system for the treatment and clarification of all dirty direct runoff from the emplacement based on real time flow measurement and cationic coagulant dosing up to a direct runoff decant rate from a primary catch pond of 20 ML/day,

Hydrologic modelling and basic engineering calculations presented in this report indicate that the proposed new Water Quality Management Plan for the expanded coal wash emplacement should have a very beneficial effect on TSS management in BCD and, by implication, on any waters discharged from BCD to Georges River.

It should particularly reduce the average salinity and TSS concentration of waters discharged to Georges River in an uncontrolled manner over BCD spillway.

By definition, the decommissioning of Pond P4 and passage of the leading edge of the emplacement to the north of Pond P3 removes the possibility of directing excess dirty water flows from the Pit Top Area to Pond P4. This requires that an upgrade of the Pit Top Area water management subsystem needs to be designed and implemented, before or concurrently with the first phase of Stage 3 of the Emplacement.

The proposed separation of Pit Top Area and Emplacement water management systems will enable significant improvements in the efficiency of emplacement water management

Cardno Forbes Rigby have completed an options study for re-development of the Pit Top Area water management system, based on runoff management for up to a design maximum 10 year ARI 72 hour storm.

Each of the options can be expected to lead to a net improvement in the management of dirty water sourced from within the Pit Top Area, including that generated by the Coal Preparation Plant.

Each of the options also require a means of conveying all treated water from the Pit Top Area to BCD and an evaluation of options for that are also under consideration.

It is concluded that these changes to the West Cliff WMS will produce a net beneficial impact on water quality within BCD, and by definition Georges River downstream of the Brennans Creek confluence. While it is difficult to estimate the magnitude of the long term average decrease in TSS produced, it is believed that it should produce a reduction in TSS of at least one order of magnitude during peak discharges over the BCD spillway (LDP1).

1. INTRODUCTION

Ecoengineers Pty Ltd. (Ecoengineers), submits this report to BHP Billiton Illawarra Coal (BHPBIC) and Cardno Forbes Rigby Pty Ltd (Cardno Forbes Rigby) as a water quality management specialist contribution to Cardno Forbes Rigby's preparation of the:

1. Application for Approval of West Cliff Emplacement Stage 3 ;and the
2. Revised West Cliff Coal Preparation Plant Coal Wash Emplacement Management Plan.

1.1 WEST CLIFF WATER MANAGEMENT SYSTEM

The entire West Cliff Colliery site is located within the 4.813 km^2 (481.3 ha) catchment of Brennans Creek. The catchment is largely covered by a mixture of open schlerophyll (Eucalypt) woodland, active and rehabilitated surfaces of coal coalwash emplacement, coal and coalwash stockpiles, roadways and aboveground mine site buildings and related infrastructure.

West Cliff Colliery has a Water Management System (WMS) that is designed to be an implementation of best practice mine site water management. The main management goals of the West Cliff WMS are to:

1. Collect all groundwater inflows affecting active underground workings and pump it to the surface and collect as much runoff from within the Brennans Creek Catchment as possible.
2. Catch, contain and clean all dirty waters on site i.e. within Brennans Creek Catchment.
3. Treat and store all clean water in Brennans Creek Dam (BCD) from where it is used to directly supply the entire site water needs, which include underground mining requirements (longwall shearer, continuous miners, dust suppression etc), Coal Preparation Plant (CPP), and bathhouse facilities with a serviceable clean water supply.
4. Minimise discharges to the receiving aquatic environment (Upper Georges River) and ensure that such discharges comply with the requirements of the site Environment Protection Licence (EPL).

The WMS includes a large number of on site drains and ponds, denoted as Ponds P1 to P7, with a total capacity of approximately 100 ML. The ponds are used to store and detain dirty site runoff, namely coal stockpile and haul road runoff (Ponds P1, P2, P5, P6 and P7), site stormwater runoff (Pond P3), and coal wash emplacement runoff and subsurface drainage (Pond P4). Ponds P1, P2 and P3 are located in the Pit Top Area, Ponds P6 and P7 to the north of the Pit Top Area in a small area dedicated to ROM coal stockpiles and Pond P4 is located in Brennans Creek Valley, just north of the coal wash emplacement.

All water entering these site storages is ultimately discharged to BCD. It is estimated that BCD commands a total catchment area of 450 ha of which about 51 ha (13%) comprises the coal wash emplacement area.

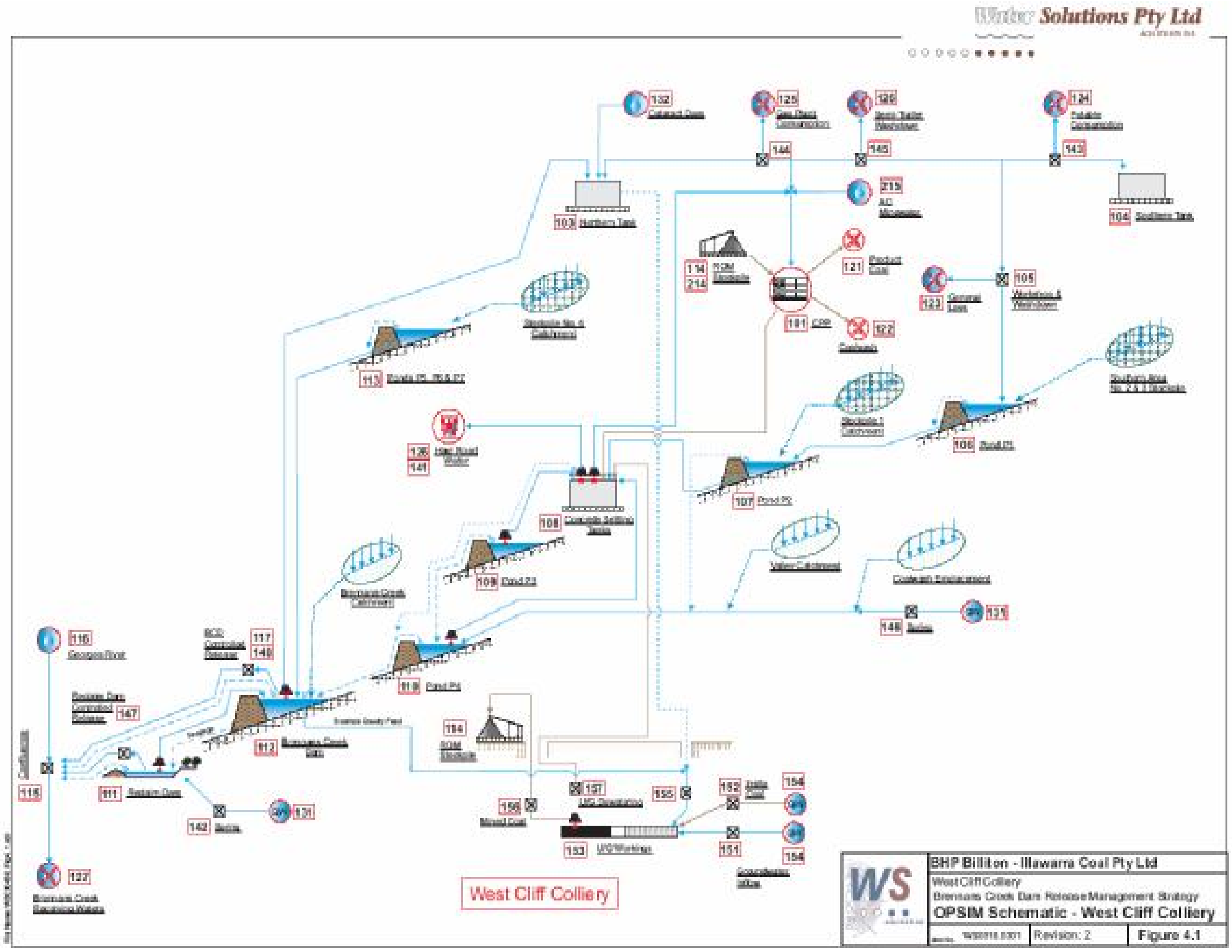
BCD has an estimated volume to its spillway of about 307 ML, at which time its maximum depth behind the dam wall depth is 12.5 m. The mine supply for underground uses is obtained by gravity feed from an inlet at a depth of 4.0 m below the surface.

The WMS also includes a water treatment plant (WTP) based on large concrete settling tanks near the CPP in the Pit Top Area which employs the principles of chemically-assisted coagulation, flocculation and settling.

Water from Ponds P1 and P2 (serving the Washed Coal Stockpile Area, from the Haul Road area, from the Coal Preparation Plant (CPP) and Coal Loader Bins area), from Ponds P6 and P7 (serving the Raw Coal Stockpile Area) and from Pond P4 (serving the coal wash emplacement and overflow from Ponds P2 and P3), may be manually directed-to and treated in the Concrete Settling Tanks WTP located near the CPP, before discharge to BCD or Pond P3.

The following **Figure 1.1** (copied with courtesy of Water Solutions Pty Ltd) is a useful schematic of the WMS.

FIGURE 1.1: SCHEMATIC OF WEST CLIFF WATER MANAGEMENT SYSTEM



Management of the WMS is conducted on a manual basis using visual observations of pond volumes, cumulative pumping rates etc. This is quite normal for mine sites which are required to operate large and relatively complex water management systems.

There are no automated elements to the system other than the dosing of a cationic coagulant and anionic flocculant (supplied by Ciba Specialty Chemicals) to the Concrete Settling Tanks which is made on the basis of flow rate through the Tanks and a Ciba-installed device which samples incoming dirty water, checks settling rate of a dosed sub-sample and adjusts coagulant dosing rates accordingly.

It may also be noted in the above **Figure 1.1** that immediately downstream of BCD lies the Reclaim Pond. The Reclaim Pond was built at the toe of BCD wall in Brennans Creek to catch seepages through the BCD dam wall and other natural ferruginous groundwater springs. The Reclaim Pond was installed by agreement with the Environment Protection Authority (EPA) in 1994.

Through geochemical modelling (Parkhurst and Appelo, 1999) and basic geochemical calculations (principally using chloride as a conservative tracer), Ecoengineers Pty Ltd. (2003) identified that the waters collecting 'naturally' in the Reclaim Pond are comprised of about 75 - 80% of low pH BCD Bottom water (from seepage through or around the BCD dam wall), containing high levels of dissolved carbon dioxide (CO_2), iron (Fe) and manganese (Mn); and about 20 – 25% of a very low salinity groundwater with a chemistry little different to local rainwater.

The lower pH of Reclaim Pond water versus BCD waters is largely a result of the dissolution of carbon dioxide into it during seepage through the dam wall and most of the dissolved Fe and Mn in it is contributed by coalwash dam wall material. In the extreme case, where all the water in the Reclaim Pond becomes saturated with oxygen, a further pH drop of up to about 0.3 pH units may be produced as a result of the precipitation of hydrous iron oxides.

Below the BCD Reclaim Pond, Brennans Creek runs for a distance of approximately 520 m before discharging into Upper Georges River at a point approximately 1 km to the north and east of the township of Appin.

The West Cliff WMS has two EPA licensed discharge points under Environment Protection License (EPL) 2504 for discharge of excess water from the WMS, namely just below the spillway of BCD - Licensed Discharge Point 1 (LDP1) and LDP10 at the outlet of the small Reclaim Pond dam wall.

At the base of BCD is a large drain valve, arbitrarily designated 'POINT 9' which is used to discharge bottom waters from BCD into the Reclaim Pond in a controlled manner and hence to Brennans Creek via LDP10.

This controlled discharge through LDP10 has been operated in accord with a management plan that was developed by Ecoengineers and Water Solutions Pty Ltd over 2001 – 2004 in consultation with EPA, and implemented consistently from 2 August 2004. Daily operation of that plan has been conducted by Ecoengineers on behalf of BHPBIC since that date.

The WMS supplementary management plan governing BCD controlled discharges to Georges River via LDP10 implemented on 2 August 2004 is based on the following well defined management goals.

1. Minimise volumetrically and chemically, <u>uncontrolled</u> spills over BCD spillway to Georges River past LDP1 to minimise aquatic environmental impacts down river in Georges River.

2. Control discharges from the West Cliff WMS to Georges River to a pH equal to or below 8.50 as mandated by EPA. It is noted that this control is affected by employing the unique characteristic of the Reclaim Pond to collect low pH, high Fe and Mn seepage water from the BCD wall and 'shandy' it with water discharged from the large drain valve at the base of BCD wall, thereby obviating the need to install an acid dosing plant.
3. Provide a dry weather environmental flow in Upper Georges River below the confluence with Brennans Creek.
4. Return water levels in BCD to a target value of 11.0 m as quickly as possible after all rainfall-runoff events. This level has been determined by OPSIM system water balance modelling to deliver capture within BCD of 90% all storm runoff from Brennans Creek catchment. That target is maintained in order to provide the maximum volume of catchment runoff for mine operations, to maximise the reliability of a dry weather supply to the WMS, to minimise the circulation and increase of salinity and other chemical pollutants within the WMS and to minimize the salinity of uncontrolled spills from BCD to Georges River. It is recognised that this goal tends to conflict with the goals listed in 1 – 3 above.

Since inception of the revised WMS management plan on 2 August 2004, more frequent and extensive water quality monitoring has occurred around the West Cliff WMS than applied before that.

The following sites, designated as shown and described in **Table 1.1** below, are monitored for temperature, pH and Electrical Conductivity (EC) on a twice weekly basis. In addition, monthly samples are collected from these sites for detailed laboratory analysis for both WMS water quality status monitoring and in accord with the requirements of EPL 2504.

The following parameters are tested on the monthly samples at the laboratory as required for system salinity tracking, potential environmental impact, statutory report, source and provenance tracing, corrosion potential and effects etc:

- pH and EC (to cross check field data), Total Suspended Solids (TSS), Oil and Grease (O&G), and Dissolved Organic Carbon (DOC);
- Major cations and anions (sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), chloride (Cl), iodide (I), fluoride (F), silica (SiO_2), sulfate (SO_4) and Total Alkalinity (T. Alk.);
- Filterable (dissolved) metals aluminium (Al), arsenic (As), barium (Ba), caesium (Cs), copper (Cu), lead (Pb), lithium (Li) manganese 9Mn), nickel (Ni), rubidium (Rb), selenium (Se), strontium (Sr), zinc (Zn), iron (Fe).
- Total Al, As, Cu, Pb, Mn, Ni, Zn and Fe

It is noted that regular monitoring of:

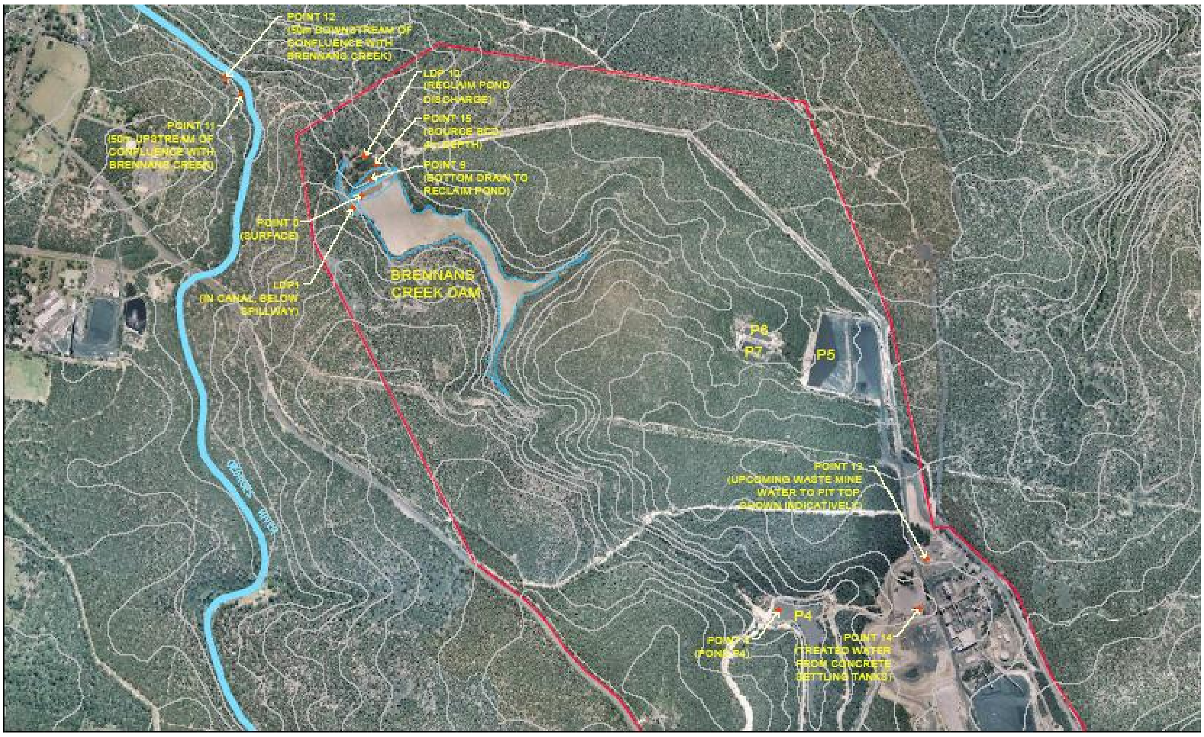
- POINT 15 (i.e. the supply BCD to underground) only commenced on 3 November 2006 at the request of mine management following concerns relating to corrosion of underground equipment; and of
- POINT 4 (i.e. Pond P4) only commenced on 23 August 2006, at a time when water levels in Pond P4 were the lowest ever observed due to advice that Stage 2 of the Emplacement would finish in about 2 years and that an accumulation of water quality data on emplacement outflows would be advisable.

TABLE 1.1: WATER QUALITY MONITORING SITES FOR WEST CLIFF WMS

			Parameters Tested-				
Site Label	**Site Location Description**	**Statutory Testing Requirements**	**pH & EC (twice weekly)**	**TSS, O&G, DOC**	**Major Cations and Anions**	**Total Metals Suite**	**Filterable Metals Suite**
POINT 1	LDP1 in canal below BCD spillway	Yes	Yes	Yes	Yes	Yes	No
POINT 0	Surface of BCD at dam wall	No	Yes	Yes	Yes	No	Yes
POINT 15	Underground water supply sourced from 4.0 m depth in BCD sampled downstream of gaseous chlorine plant	No	Yes	Yes	Yes	No	Yes
POINT 9	BCD Bottom Drain (to Reclaim Pond)	No	Yes	Yes	Yes	No	Yes
POINT 10	LDP10 Reclaim Pond Discharge	Yes	Yes	Yes	Yes	Yes	No
POINT 13	Upcoming waste mine water to Pit Top	No	Yes	Yes	Yes	No	Yes
POINT 14	Treated water returned from Concrete Settling Tanks WTP to BCD	No	Yes	Yes	Yes	No	Yes
POINT 4	Pond P4 serving coal wash emplacement	No	Yes	Yes	Yes	No	Yes
POINT 11	Georges River 50 m upstream of confluence with Brennans Creek	Yes	Yes	No	No	No	No
POINT 12	Georges River 50 m downstream of confluence with Brennans Creek	Yes	Yes	No	No	No	No

The following **Figure 1.2** shows the locations of these sampling sites.

FIGURE 1.2: WEST CLIFF WMS WATER QUALITY MONITORING LOCATIONS



1.2 COAL WASH EMPLACEMENT WATER MANAGEMENT

The coalwash emplacement now occupies much of the southern end of the Brennans Creek valley as shown in the following photograph taken in late 2004.

Stage 1 of the emplacement may be seen near the top of the above photograph and most of Stage 2 in the centre of the photograph. The southern end of Pond P4 may be seen near the bottom of the photograph.

Coalwash emplacement (valley filling) in Stage 1 and Stage 2 has progressed over a 31-year period in a northerly direction down the Brennans Creek valley. All of Stage 1 and part of Stage 2 of the Coalwash Emplacement has undergone rehabilitation with local soils and revegetation with native plant species.

The estimated total area of the Stage 1 and present Stage 2 emplacement is currently 50.9 ha. Where practical, West Cliff management aim to keep the active area of actual coal wash emplacement at any one time to approximately 18.0 ha with the remainder rehabilitated or actively undergoing rehabilitation.

At the time of preparation this report, inspection shows the estimated current active area is 20.5 ha. Some 30.4 ha has been rehabilitated or is undergoing rehabilitation with the coalwash already covered with soils, mulch and timber to inhibit erosion.

Under the present operations management, all direct surface runoff from the rehabilitated areas or areas already undergoing rehabilitation is directed by table drains to clean water diversion drains running down the valley along both the western and eastern sides of the emplacement.

Stage 1 of the emplacement was equipped with an extensive dendritic network of subsurface drainage pipes in each drainage line or gully based on perforated agricultural pipes (‘ag pipes’) wrapped in geofabric and surrounded by a protective gravel filter sheath.

This network of agricultural pipes was developed progressively as Stage 1 was filled. They report by gravity feed to a main drain line that passes down the original channel of Brennans Creek beneath Stage 1 of the emplacement. Vertical inspection pipes were installed at periodic intervals down the main drain line to allow inspection of the drainage system if required.

When Stage 2 of the emplacement was commenced, the main subsurface drain for Stage 1 was connected into the top end of the new main drain for Stage 2 and development of the same type of system of a dendritic network of subsurface drainage pipes in each drainage line or gully carried out progressively through the filling of Stage 2. Again vertical inspection pipes were also installed at periodic intervals (approximately every 100 metres) down the main drain line.

This means that all subsurface drainage from both Stage 1 and Stage 2 of the emplacement reports to the northern end of Stage 2.

As the main line of the subsurface drainage system is of necessity located at the lowest elevation in the emplacement area at all times, this also implies that this drainage system will require connection to the upslope end of the subsurface drainage system for the proposed Stage 3 of the Emplacement.

Subsurface drainage from the emplacement generally carries a very low suspended solids load except for immediately after major storm events when it may have some fine particle coal wash-based turbidity as shown in the following photograph.

Conversely, direct runoff from the active filling area of the Emplacement is consistently dirty water containing suspended coal wash fines and is designated herein as 'blackwater' as shown in the following photograph.

The present emplacement water management system is operated as follows:

1. All subsurface drainage from the entire area of both Stage 1 and Stage 2 reports to the main subsurface drainage line at the northern end of Stage 2 and, unless it is caught and diverted would report to Pond P4. Pond P4 has a total volume of about 45 ML.
2. All direct dirty runoff from the active area of Stage 2 (i.e. where coalwash is currently being placed and surfaces are as yet un-rehabilitated) reports to Pond P4.
3. Pond P4 also receives excess stormwater overflows from Pond P2 and P3 in the Pit Top Catchment Area.
4. Pond P4 is fitted with a pump and return pipeline to return water from Pond P4 to the Concrete Settling Tanks for treatment.
5. Pond P4 is not fitted with a low flow floating off take and only spills to Brennans Creek (and thence BCD) via a side channel spillway.

Operation of the emplacement water management system contains no automated elements and is conducted on a manual basis according to visual inspections of the status of storage volume in Pond P4. Presently West Cliff management have available to them, in the management of the Stage 1 & 2 emplacement, only two strategies for optimizing the operation and performance (in terms of detention and treatment of blackwater) of Pond P4, namely:

1. Collect all emplacement subsurface drainage in a small coffer dam at the foot of the current active emplacement area and divert that generally clean water into the western diversion drain nearby. This diverts this relatively clean water to the valley below Pond P4 and hence to BCD. This strategy reduces unnecessary dilution of the blackwater running of the active area of the emplacement. This strategy commenced on 17 March 2007 following a period of relatively wet weather since January 2007. Implementation of this strategy was prompted by to the occurrence of a 72 hour, nearly 1 in 2 years Average Recurrence Interval (ARI) storm which delivered rainfall of 92 mm on 11 February, 59 mm on 12 February and 63 mm on 13 February totalling 214 mm over those 3 days.
2. When the hydraulic load on the Concrete Settling Tanks WTP permits, pumping blackwater to the WTP for treatment before release to BCD. This strategy is routinely employed but has become very restricted in scope in recent years as the sizing of the WTP (and hence the required area and hydraulic residence time for adequate settling of coagulated fines) has become significantly constrained in capacity due to expansion and upgrading of the CPP and its consequent higher ROM coal and water throughput.

It is estimated that Stage 2 will be completed to the top end of Pond P4 in 12 – 15 months at which time construction of one or more new ponds further down Brennans Creek valley will need to be finalised before the emplacement progresses. This critical transition is dependent upon statutory approvals of Stage 3 of the emplacement. As the Stage 3 emplacement then progresses down Brennans Creek valley, Pond P4 will be filled, and hence be unavailable to take excess overflows from Ponds P2 and P3. The new replacement pond or ponds to service the expanded emplacement will be further down Brennans Creek Valley and therefore pumping excess blackwater contained in them up to the Concrete Settling Tanks WTP for treatment also becomes impractical.

2. EMPLACEMENT WATER QUALITY IMPACT ASSESSMENT

2.1 BACKGROUND INFORMATION AND KEY ISSUES FOR ASSESSMENT

There is extensive data in the Southern Coalfield on the typical mineralogical composition, and leaching characteristics of coal wash derived from Bulli Seam and Wongawilli Seam coking coal mining (e.g. Ward, 1980; Sinclair Knight Merz, 1998; BHP Steel, 1999).

There is also extensive data on, and competent assessments of impact for typical water qualities of surface runoff from, subsurface drainage from and groundwater contamination from large coal wash emplacements in the Southern Coalfield/Illawarra Region (e.g. Forbes Rigby Pty Ltd., 1993, 1999, 2000, 2001, 2004, 2005; Cardno Forbes Rigby Pty Ltd., 2006; Ecoengineers Pty Ltd., 2006b, 2006c).

The consensus with respect to water quality impacts of coal wash deriving from the large number of studies published is that coal wash is relatively benign material with:

- the major potential off site surface water quality impacts being those derived simply from excessive suspended coal wash fines, salinity and in specific environments possible soluble nitrogen-based nutrients; and
- the major potential off site groundwater impact being increased salinity and soluble nitrogen-based nutrients which groundwaters may emerge in groundwater-dependent ecosystem e.g. small streams.

There is no evidence for the export of significant concentrations of toxic heavy metals or organic compounds from large coal wash emplacements. There are a few instances of oils and fuels associated with an emplacement causing a visible off site impact and these were invariably associated with specific instances of truck or earth working machinery diesel or lubricating oil spills.

The salinity that is often associated with direct runoff or subsurface drainage from the coal wash emplacement derives simply from the entrained water (from the CPP) contained in the ‘fresh’ wet coal wash at the time of its actual emplacement.

In the West Cliff WMS, the major source of salinity is moderately saline groundwaters that enters underground workings and is pumped to the surface with the waste mine water, where it is supplied to the CPP for washing the ROM coal. A further, but lesser, increment of salinity is added through leaching from the coal and the shales associated with the ROM coal within the CPP and a minor increment in cleaner water being returned to BCD is contributed by the chloride from the polyaluminium chloride-based cationic coagulant used in the Concrete Settling Tanks WTP.

Studies show that very little extra salinity is contributed (to the WMS) by leaching of salts from the solid coal wash once it is emplaced.

There is a minor redistribution of the relative proportions of major cations in subsurface drainage from the emplacement (relative to water in the coal wash exiting the CPP). This is due to cation exchange processes on clays and feldspars within the coal wash and dissolution of traces of ankerite (a calcium/magnesium/iron/manganese carbonate isomorphous with calcite and siderite) in the coal wash. This causes calcium and magnesium in ratio to sodium (the major cation) to be higher in emplacement drainage by comparison with waste water leaving the CPP (or WTP).

Subsurface drainage from the emplacement invariably contains higher levels of dissolved Fe and Mn and a lower pH than waste water leaving the CPP (or WTP).

Subsurface drainage from the emplacement is generally less saline than waste water exiting the CPP due to infiltration of fresh rainwater into the body of the Emplacement and its detention within the mass of coal wash.

In the specific case of the West Cliff coal wash emplacement, the two parameters of key relevance with respect to potential water quality impacts off site in Georges River are salinity (which is measured via EC) and TSS, a measure of the concentration of coal wash fines suspended in the water.

Operation of the West Cliff WMS along the lines adopted in August 2004 and described above in Section 1.1 has had the effect of significantly minimising both the salinity and volume of uncontrolled discharges from the Brennans Creek Catchment which would otherwise occur via the spillway of Brennans Creek Dam.

EC of the LDP10 discharge to Brennans Creek and hence Georges River has ranged over the last two and nine months early August 2004 from about 2300 to about 3100 uS/cm, with a relatively constant mean EC of 2702±196 uS/cm at the one standard deviation level.

This is a level of salinity which exceeds the default trigger value for lowland rivers for southeastern Australia in the national water quality guidelines of 2200 uS/cm (ANZECC&ARMCANZ, 2000)

However, recent bioassessment studies of Upper Georges River (The Ecology Lab, 2006), strongly indicate that locally, aquatic macroinvertebrates can, and do, acclimatize to salinity levels particularly within about the 1000 – 4000 μS/cm (TDS approx. 625 - 2500 mg/L) range.

The TEL studies in Upper Georges River reported in 2006 were conducted after August 2004, i.e. after implementation of the improved West Cliff WMS management operating regime as described above in **Section 1.1**, whereby dry weather in the River is thoroughly dominated by the controlled, continuous discharge from BCD via LDP10 to Upper Georges River via Brennans Creek.

Benthic macroinvertebrate population and diversity studies conducted by The Ecology Lab (TEL) (2006) suggest that the ecological health of the Upper Georges River below the Brennans Creek confluence, by comparison with pristine baseline sites established by them around the Southern Coalfield Region, is good.

The outcomes of the The Ecology Lab (2006) studies are in accord with Rutherford and Kefford (2005) who, most recently, comprehensively reviewed the current Australian literature base relating salinity to aquatic ecotoxicity and pointed out that the Australian scientific database indicating evidence for ecotoxicity induced by TDS up to about 2000 mg/L (i.e. up to EC about 3200 uS/cm) is very sparse, particularly with respect to sub-acute (chronic) effects and only two macroinvertebrate taxa (families) appear susceptible.

It is noted that there have been in the past minor concerns associated with trace concentrations of As, Ni and Zn contained in water discharged to Georges River from BCD.

However, it has been found that the concentrations of these elements can be shown, on the basis of chemical speciation modelling, to not be significant ecotoxicologically within the River due to either too low a concentration in the case of As or, in the case of Ni and Zn, to complexation of these metals by carbonate, a relatively common phenomenon (Stumm and Morgan, 1996). Carbonate complexation significantly reduces the effective concentration of the ecotoxic cationic Ni^{2+} and Zn^{2+} species (Tessier and Turner; Parkhurst and Appelo, 1999; ANZECC&ARMCANZ, 2000; Ecoengineers Pty Ltd., 2003).

The export of coal and coal wash fines into Georges River from the West Cliff site via BCD, has the potential to:

- reduce water clarity and light transmission; and
- coat the bed of the River with such materials,

thereby interfering with the normal processes of algal primary productivity in the water column and the respiratory processes and activity of bacteria, attached algae and benthic macroinvertebrates.

Therefore the key issues of concern within respect to impact of discharges from the West Cliff WMS, and in this instance the coal wash emplacement is the effect the Emplacement may have on salinity and TSS in Georges River downriver of the Brennans Creek confluence.

The major concerns in terms of impact within the WMS are regarding the quality of water supplied from BCD to the underground operations deriving from the salinity, chloride (Cl) concentration and TSS concentrations, particularly with respect to potential for increased corrosion and blockage of filters protecting underground machinery and corrosion (M. Small, pers. comm.).

It has been observed that Cl is strongly correlated with salinity with variation in salinity accounting for approximately 70% of the variation in Cl levels of water supplied from 4.0 m depth in BCD (POINT 15) to the underground operations.

2.2 EMPLACEMENT-INDUCED WATER QUALITY IMPACTS

Assessment of the water quality impacts of the West Cliff Coal Wash Emplacement over time is best conducted by examination of the relationship between rainfall and water quality on:

- firstly, Pond P4, the initial receptor of all of the subsurface drainage from the Emplacement and direct runoff from the active area; and
- secondly on BCD, the primary water storage of the West Cliff WMS, to which Pond P4 reports, either directly in indirectly via the Concrete Settling Tanks WTP as noted in **Section 1.2** above,

particularly with respect to EC and TSS.

Figure 2.1 shows the relationship between salinity (as measured by EC) and rainfall in Pond P4 since monitoring of P4 commenced in late August 2006.

As can be seen, immediately following major storm events, relatively low salinity water flows into Pond P4 and this represents the component of direct runoff generated by the emplacement relatively quickly following storm events.

The relatively high salinities observed in Pond P4 between early October 2006 and end January 2007 probably reflect the discharge of excess water from Pit Top Area Ponds P2 and possible P3 as neither direct runoff or subsurface drainage from the emplacement typically exceeds an EC of 2500 µS/cm.

FIGURE 2.1: RELATIONSHIP BETWEEN EC POND P4 AND RAINFALL AUGUST 2006 – APRIL 2007

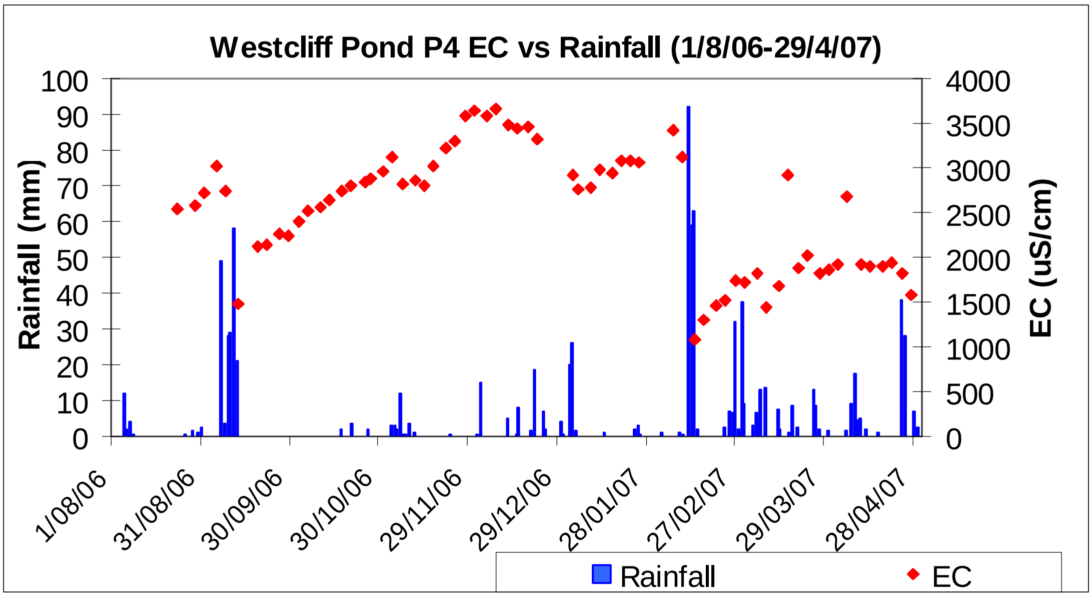
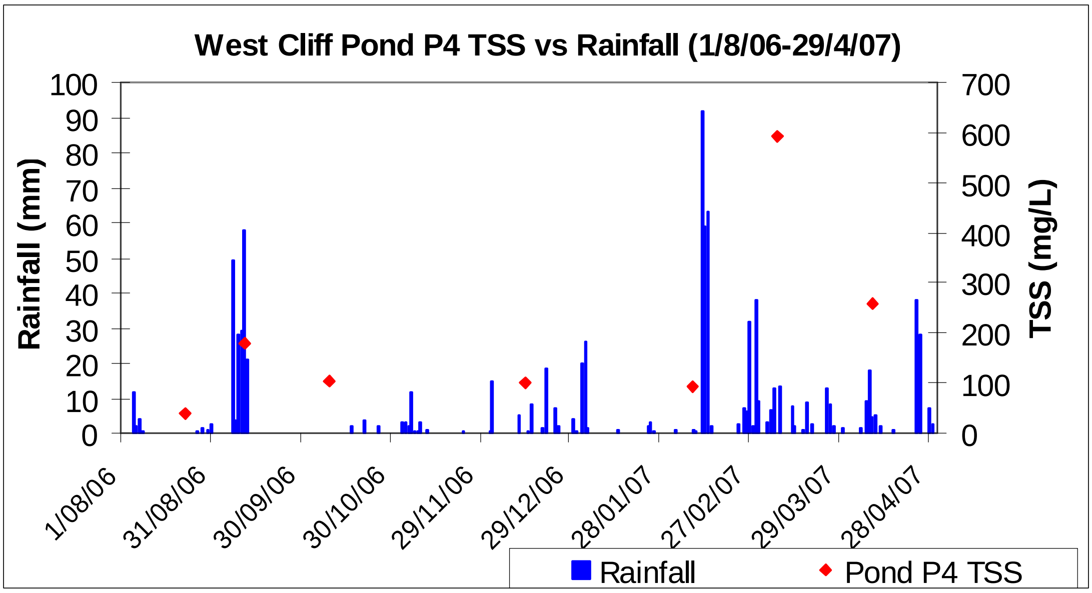


Figure 2.2 shows the relationship between TSS (as measured in monthly grab samples) and rainfall in Pond P4 since monitoring of P4 commenced.

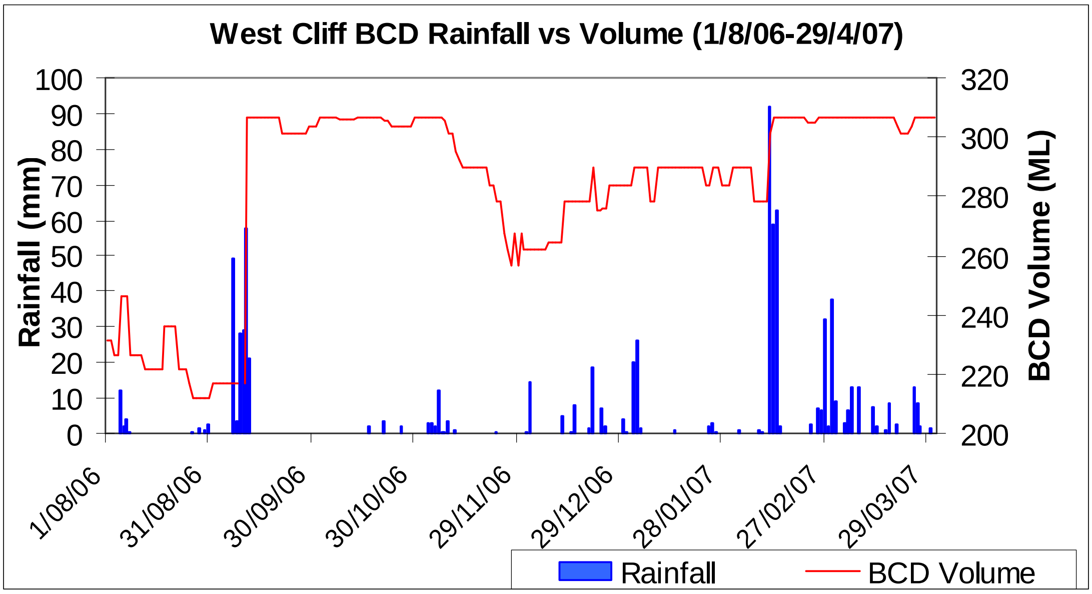
FIGURE 2.2: RELATIONSHIP BETWEEN TSS POND P4 AND RAINFALL AUGUST 2006 – APRIL 2007



As can be seen the major storm event between 11 and 13 February 2007 increased the TSS concentration of water contained (and possibly spilling from) Pond P4 very considerably. Note that the scale for TSS for Pond P4 is substantially larger than the equivalent scale for TSS for BCD shown in **Figure 2.3** below.

Figure 2.3 below shows the relationship between volumes of water captured in BCD and rainfall in surface waters of BCD over the same period i.e. since late August 2006.

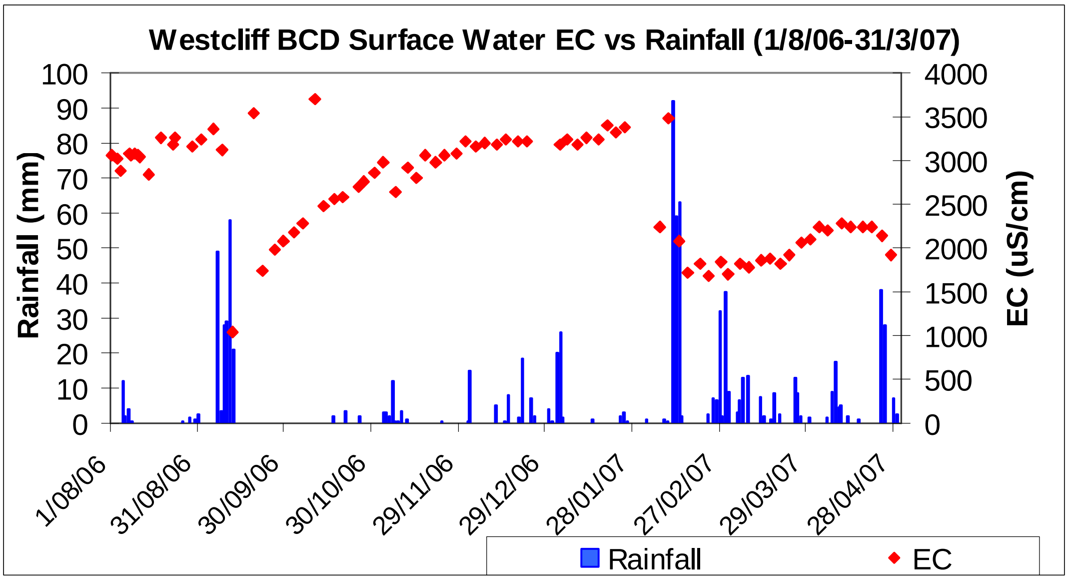
FIGURE 2.3: RELATIONSHIP BETWEEN RAINFALL AND VOLUME HELD IN BCD AUGUST 2006 – APRIL 2007



In the early stages of this period water level in BCD was dropped to 10.6 m (207 ML), an extremely low level of storage but which was quickly restored to maximum capacity following capture of the major proportion of outflow from a very large storm event between 7 and 12 September 2006.

Figure 2.4 below shows the relationship between salinity (as measured by EC) and rainfall in surface waters of BCD over the same period i.e. since late August 2006.

FIGURE 2.4: RELATIONSHIP BETWEEN EC OF BCD SURFACE WATERS AND RAINFALL SINCE SEPTEMBER 2006



Similarly, again between early October 2006 and end January 2007 the ECs of surface waters in BCD probably largely reflect direct discharge of treated Pit Top Area water from the Concrete Settling Tanks WTP, directly to BCD (bypassing Pond P4).

Figure 2.5 below shows the relationship between TSS and rainfall in surface waters of BCD over the same period i.e. since late August 2006.

FIGURE 2.5: RELATIONSHIP BETWEEN TSS OF BCD SURFACE WATERS AND RAINFALL SINCE SEPTEMBER 2006

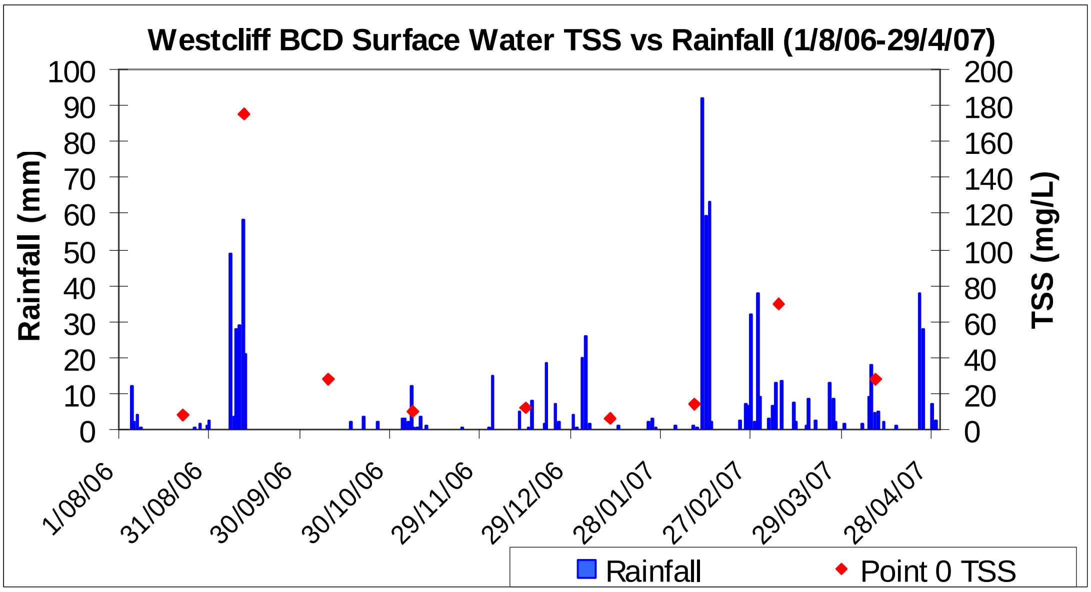
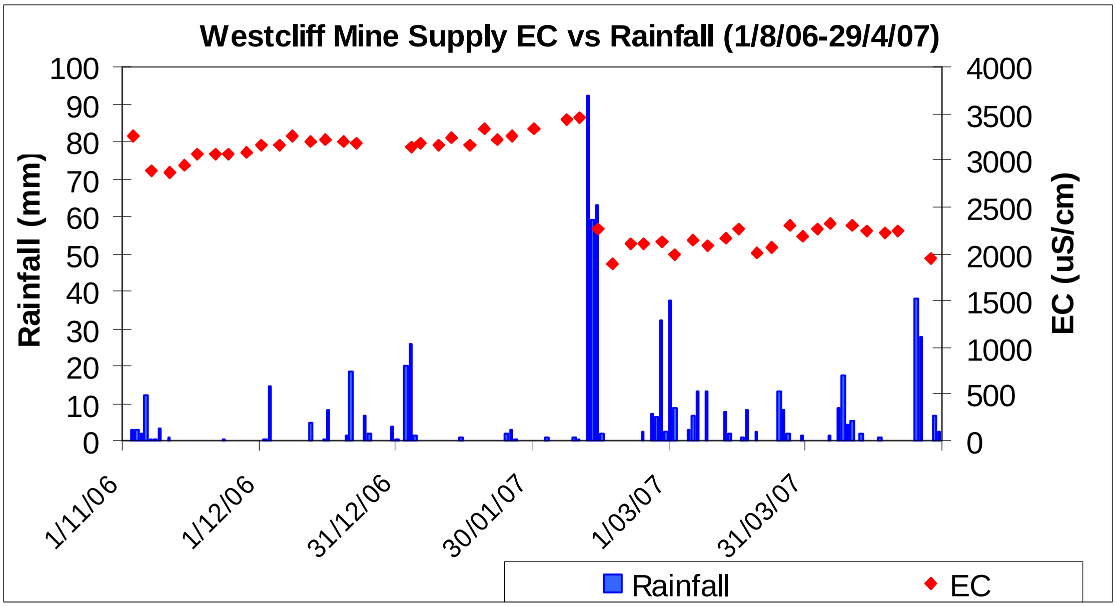


Figure 2.6 below shows the relationship between salinity (as measured by EC) and rainfall in waters taken from a depth of 4.0 m in BCD as being supplied underground via POINT 15 (downstream of chlorination plant) over the period since November 2006.

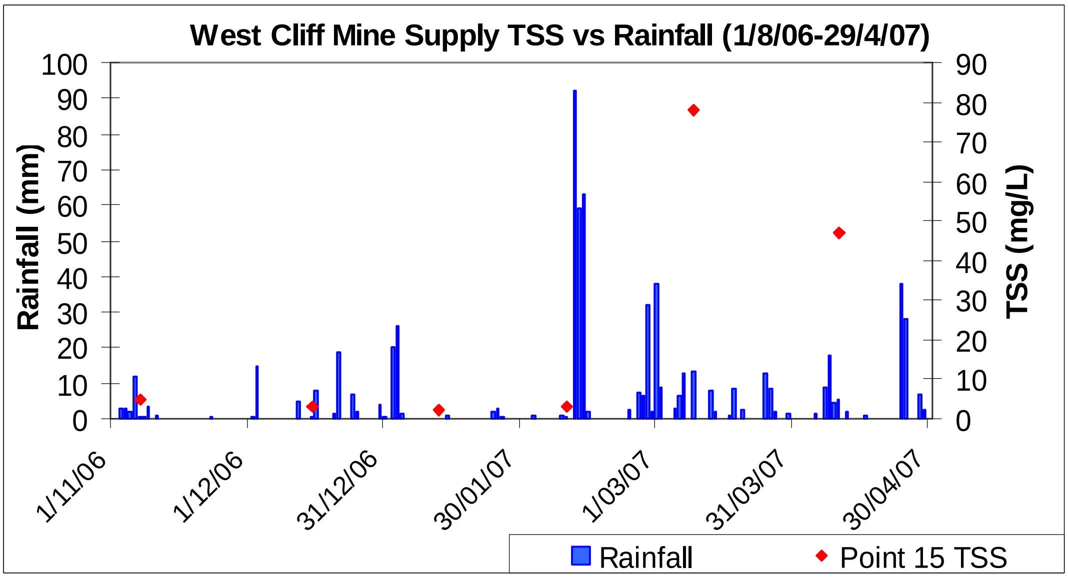
FIGURE 2.6: RELATIONSHIP BETWEEN EC OF WEST CLIFF MINE SUPPLY WATER AND RAINFALL SINCE NOVEMBER 2006



It can clearly be seen that capture of a significant body of site runoff and subsurface drainage from the coal wash emplacement has a significant beneficial effect in reducing the salinity (and hence Cl level) of water supplied to underground.

Figure 2.7 below shows the relationship between TSS and rainfall in waters taken from a depth of 4.0 m in BCD as being supplied underground via POINT 15 (downstream of chlorination plant) over the period since November 2006.

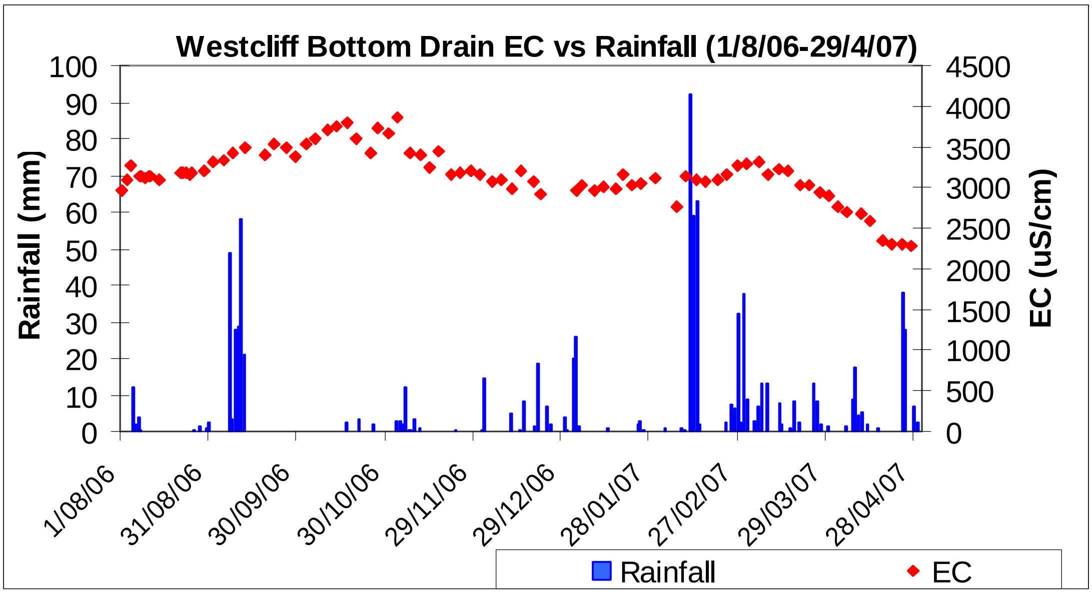
FIGURE 2.7: RELATIONSHIP BETWEEN TSS OF WEST CLIFF MINE SUPPLY WATER AND RAINFALL SINCE NOVEMBER 2006



It can be seen that, conversely, capture of a significant body Pit Top area runoff and runoff from the coal wash emplacement has a significant adverse effect in increasing the turbidity of water supplied to underground.

Figure 2.8 below shows the relationship between salinity (as measured by EC) and rainfall in waters taken from a depth of 12.0 m in BCD as being discharged via the Drain Valve (POINT 9) to the Reclaim Pond (prior to discharge via LDP10).

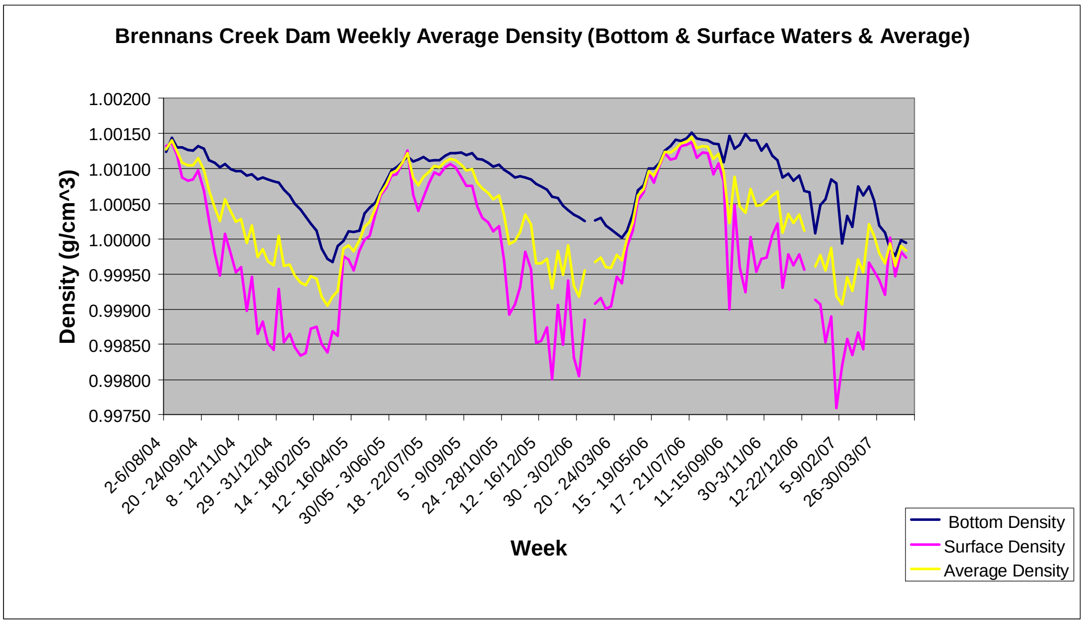
FIGURE 2.8: RELATIONSHIP BETWEEN EC OF BCD BOTTOM WATERS AND RAINFALL SINCE SEPTEMBER 2006



It can be seen that rainfall has very little influence on the salinity of BCD bottom waters (and by inference waters discharged through LDP10), unless the rainfall event is particular large (e.g. the 214 mm, 11 -13 February 2007 event) some time after which water of lower salinity may appear near the bottom of BCD.

BCD underwent its annual turnover in mid April 2007, as shown in **Figure 2.9** below, so that salinity throughout the dam equalized at that time and the dam will stratify through the coming winter months on the basis of water temperature rather than salinity.

FIGURE 2.9: DENSITIES OF WATER IN BCD AUGUST 2004 – APRIL 2007



However, as the following **Figure 2.10** shows there has been a considerable capture of fresh water in BCD since the beginning of 2007 so that the average EC of the dam is now around 2200 µS/cm rather than the average of 3000 µS/cm characteristic of the previous two and a half below average rainfall years.

FIGURE 2.10: SALINITIES WITHIN BCD AUGUST 2004 – APRIL 2007

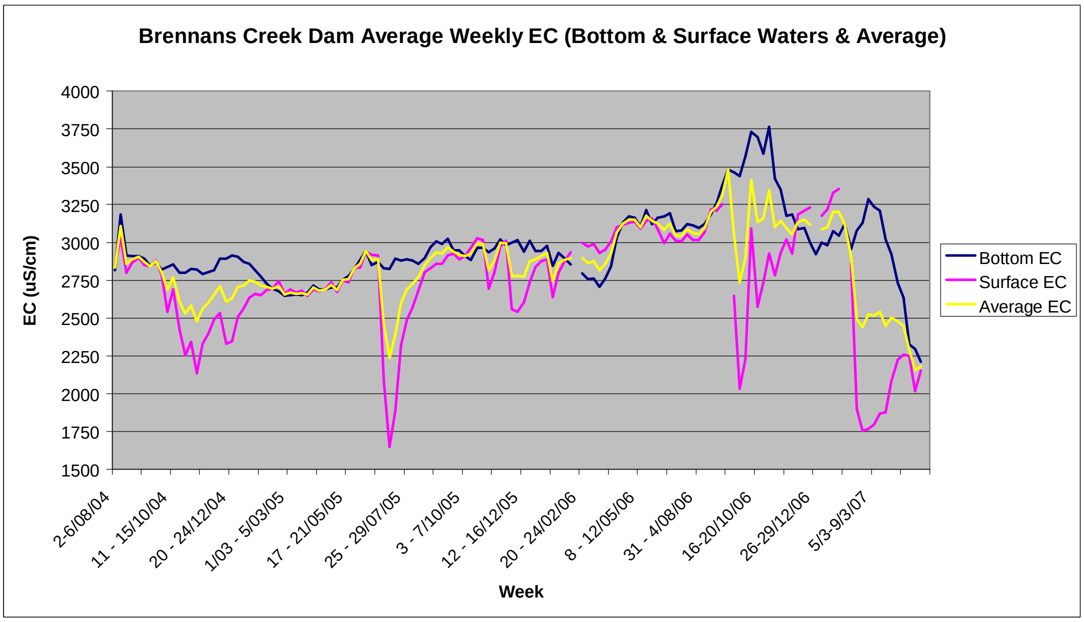
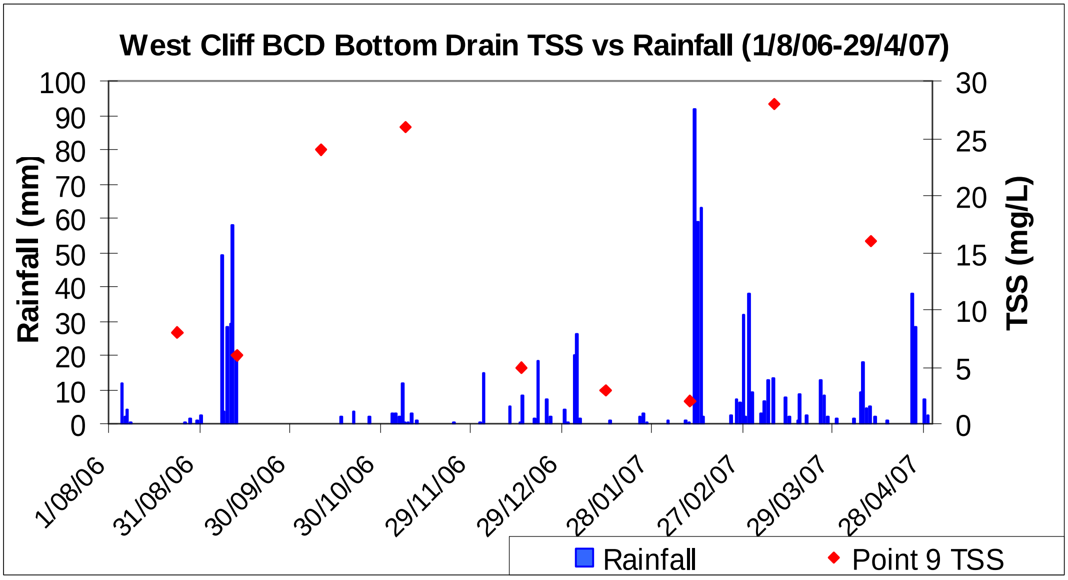


Figure 2.11 below shows the relationship between TSS and rainfall in waters taken from a depth of 12.0 m in BCD as being discharged via the Drain Valve (POINT 9) to the Reclaim Pond (prior to discharge via LDP10 TO Georges River).

Note the significant rises in TSS of POINT 9 waters following the significant storm events of 7 – 12 September 2006 (188.5 mm over 6 days), and of 11 – 13 February 2006 (214 mm over 3 days).

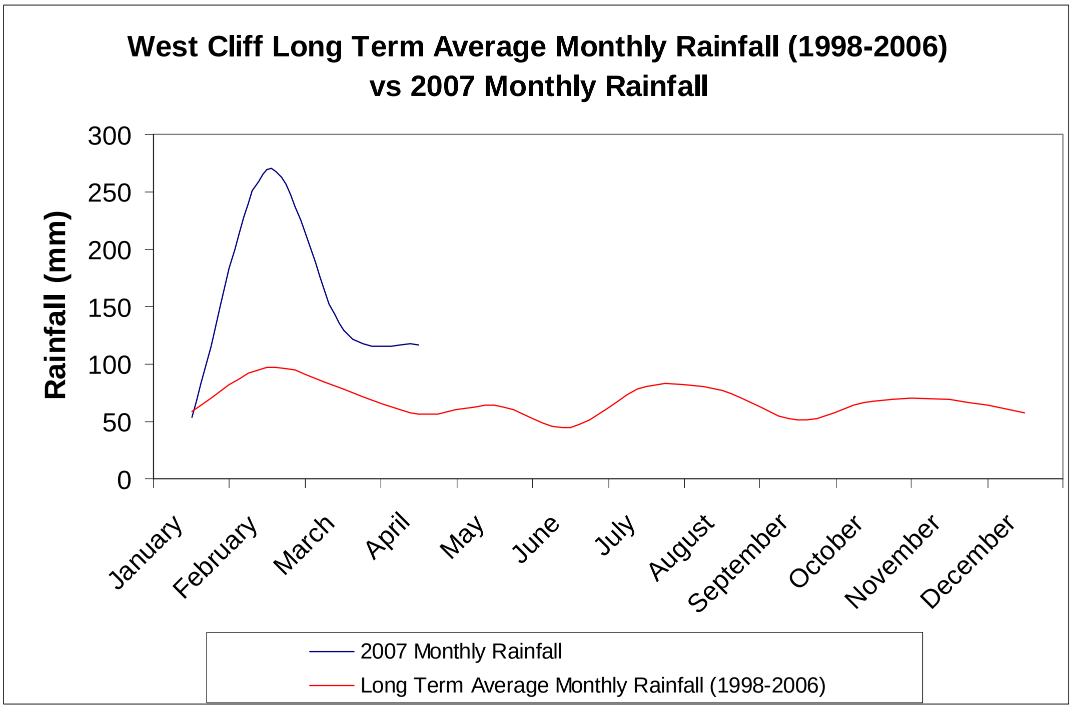
FIGURE 2.11: RELATIONSHIP BETWEEN TSS OF BCD BOTTOM WATERS AND RAINFALL SINCE SEPTEMBER 2006



It can be seen by comparison of **Figures 2.5 and 2.11** that TSS concentration in bottom waters released from BCD Bottom Drain (POINT 9) to the Reclaim Pond and hence to LDP10 does rise in response to capture of significant volumes of dirty water in BCD following major rainfall/runoff events but that the suspended material reaches the bottom of the dam after a considerable lag time of the order of one month.

Hydraulic capacity stresses on both water management in the Pit Top area and of the coal wash emplacement, and consequent increased adverse water quality impacts from TSS on BCD have became particularly apparent since September 2006 when the drought affecting the region effectively 'broke' for the West Cliff site, and more particularly since January 2007 as illustrated in the following record of average monthly rainfalls since the beginning of 2007.

FIGURE 2.10: LONG TERM AVERAGE MONTHLY RAINFALLS AT WEST CLIFF 1998 – 2006 COMPARED WITH RAINFALLS JANUARY – MARCH 2007



It has long been well known that the range of coal wash fine particles sizes is such that the particles at the smallest end of the range are generally very small indeed – typically 0.5 – 5 µm in size (e.g. Winders, Barlow and Morrison Pty Ltd., 1987).

In the absence of chemical treatment of blackwater with coagulants and even flocculants, the smallest size range fraction of coal wash particles <5 µm are very slow to settle indeed.

Such fine particles sizes have recently been verified by us for the West Cliff context from laser particles sizing studies of samples collected from POINT 4 (Pond P4), POINT 15 (supply to underground), and POINT 14 (return water from Concrete Settling Tanks WTP to BCD) locations.

Note that these samples were collected on 2 March 2007 on the last day of a week of very high rainfall totalling 94.4 mm.

Reports detailing the outcomes of these particle size studies are attached in **Appendix A**. Samples collected one week later from these sites exhibited TSS concentrations for POINT 4, POINT 15 and POINT 14 of 592, 78 and 46 mg/L respectively.

It should be particularly noted from the sizing data presented in **Appendix A** that:

1. Over 95% of the TSS accumulating in Pond P4 had a particle size less than 5 µm;
2. Over 43% of the TSS in waters discharged from the Concrete Settling Tanks WTP had a particle size greater than 5 µm; and
3. Over 95% of the TSS in waters supplied to the underground operations from 4.0 m depth in BCD also had a particle size less than 5 µm.

Taking account of the fact that the water sample collected from Pond P4 had a TSS concentration of 592 mg/L, much greater than the concentration of TSS in the water discharged from the Concrete Settling Tanks WTP, these particle sizing data show quite clearly that it is the blackwater collecting in Pond P4, dominated as it is by dirty, direct runoff from the emplacement which contributes most significantly to the TSS concentration of waters supplied to both any controlled discharges to Georges River via BCD Bottom Drains and hence LDP10 and to the underground operations via monitoring POINT 15.

2.3 SUMMARY OF IMPACTS

The clear implication from an assessment based on the information presented above in **Section 2.2** and in **Appendix A** is that the principal pollutant is fine particle suspended solids (as measured by TSS). Direct runoff from the coalwash emplacement has the potential to impact adversely on:

- Georges River through uncontrolled spills from BCD via LDP1; and/or
- Georges River through controlled discharges from BCD via LDP10; and/or
- underground mining operations through delivery of a dirty supply water with high fine particulate load,

However, the above assessment also shows that it is the very fine particulates sourced from direct runoff from the coal wash emplacement that particularly poses the most significant risk to water quality in Georges River.

This is because such water, unless chemically treated, is very slow to settle. As this water is associated with water of the lowest salinity within the WMS, it is likely to persist longest in the surface layers of BCD and hence be forced over the BCD spillway whenever the storage capacity of BCD is exceeded.

Given that BCD is now operated according to a controlled bottom water discharge system (LDP10) designed to minimize spills over the spillway via LDP1, the next goals for improvement of the water quality of discharges off the West Cliff site to Georges River via BCD should be to:

- decrease the fine particle TSS load of direct runoff waters from the emplacement entering BCD; and
- release clean emplacement subsurface drainage waters to BCD as quickly as possible to provide maximum dilution of peak flows from the Pit Top Area; and
- detain emplacement direct runoff peaks flows upstream of BCD within Brennans Creek valley as long as possible to facilitate treatment and allow these other clean peak flows to enter BCD beforehand (and hence be more liable to spill over the spillway to Georges River).

2.4 EMPLACEMENT HYDROLOGIC MODELLING

Given that uncontrolled overflows from BCD (the other route for discharge to the external aquatic receiving environment) are now controlled more efficiently and limited since inception of the new BCD water level management system in August 2004 (refer **Section 1.2**), it may be concluded that improved management and control of the export of blackwater from the emplacement should be the primary goal of existing and future emplacement water management.

However, as noted above, thus far water management of the emplacement has been conducted on a manual basis using visual assessment of storage levels in Pond P4 etc.

This implies that, for improved management of the existing emplacement and of the proposed Stage 3, a hydrologic model needs to be constructed of the existing emplacement to properly quantify the outflows that occur as a result of site precipitation.

Prior experience with mine site water management suggests such a model must have the following minimum long term capabilities:

1. to estimate total daily outflows from the emplacement under all rainfall regimes on the basis of daily rainfall to a typical precision of (say) ±10%; and
2. to allocate total daily outflows from the emplacement into the two types of waste water generated, namely direct runoff and subsurface drainage to an individual typical precision of say ±5% under all rainfall regimes; and
3. to estimate daily direct runoff and subsurface drainage to an individual typical precision of say ±10% for the magnitude of the chosen design maximum storm.

It is well known that coal wash emplacements absorb, by infiltration, a significant fraction of precipitation as it is simply not possible to compact the coal wash sufficiently to give permeabilities similar to that of nearly impervious surfaces.

A study conducted by Ecoengineers Pty Ltd in February 2005, using a constant head permeameter to determine the typical permeabilities (saturated hydraulic conductivities) of coal wash beneath a fully rehabilitated part of Stage 1 of the emplacement area gave, at 5 different sites, permeabilities ranging between 9.8 mm/hour and 0.62 mm/hour.

From this data we estimate that the broad scale lognormal mean saturated permeability for emplaced coal wash should lie in the range of about 1.80+3.33/-1.17 mm/hour (43+80/-28 mm/day) at the ±one standard deviation level.

These considerations suggest that while rainfall intensities greater than about 5 mm/hour should lead to runoff, during any 24 hour period where total water input to the emplacement (i.e. rainfall plus entrained water in placed coalwash) exceeded (say) 0.6 mm but did not exceed the relatively high value of approximately 120 mm/day, a substantial fraction of incident rainfall could be expected to penetrate the emplacement to subsequently appear as subsurface drainage from it.

Water stored within the saturated base layers of the emplaced coalwash may be considered to constitute a perched groundwater system.

The RUNOFF (version 2005) model was used for a conceptual synthesis of the runoff hydrograph entering Pond P4. This mature, non-distributed model was developed and refined by Prof. Adriaan Van De Griend and associates at the Free University of Amsterdam over many years. (e.g. Van de Griend and Seyhan, 1985; Van de Griend et al., 1986; Seyhan and Van de Griend, 1997; Van de Griend et al., 2002, 2003).

We have successfully employed this model many times, ranging from an examination of outflows (i.e. both direct runoff and groundwater seepages) from a large cement kiln dust dump in New Zealand (Egis Consulting Australia Pty Ltd.,

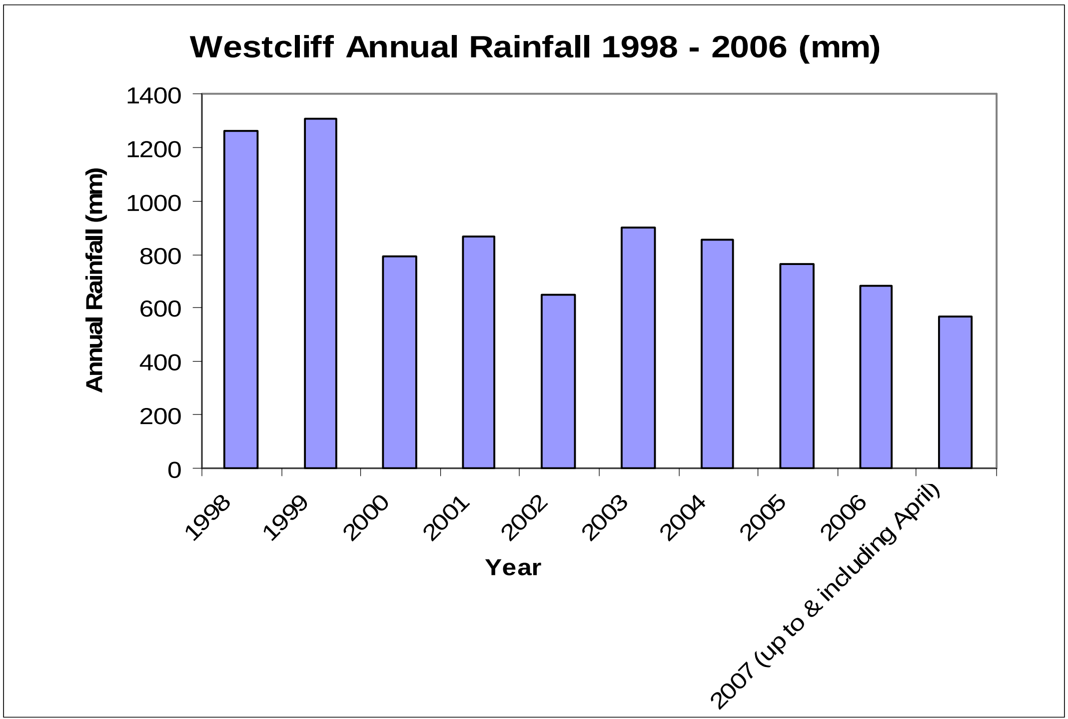
1999) to most recently, outflows from pristine sandstone-based headwater catchments potentially affected by mine subsidence (e.g. Ecoengineers Pty Ltd., 2006) and to a properly gauged 631-day period of outflow from the 32.0 ha Tahmoor Colliery coal wash emplacement (Ecoengineers Pty Ltd., 2007).

A detailed description of the model itself and the design maximum storm modelling also undertaken for this project is attached in **APPENDIX B.**

The model simulation period chosen for developing the RUNOFF2005 model of the existing emplacement was the 250 day period between 6 September 2006 and 13 May 2007. Our hydrologic model of the existing emplacement model was developed and refined by careful reference to this period because:

1. At the start of the period, BCD had the lowest level ever following an extended dry period and hence baseflows drainage rate into BCD could be assured to be the lowest possible i.e. <0.1 ML/day. As previously noted, a date around 6 September 2006 can be more or less identified as the 'breaking of the drought' in so far as it affected West Cliff Colliery.
2. It was known from visual observations by Ecoengineers' employees that the volume of water stored in Pond P4 at 1 January 2007 was about 20 ML.
3. Verbal advice supplied by Mr. Steve Allmann and Mr. Ryan Boardman who operate the WMS regarding the behaviour of Pond P4 over the aforementioned very wet period 11 February 2007 to 13 February 2007 indicated that Pond P4 commenced overtopping the night before 6:30 am on the morning of Monday 12 February.
4. Data from measurements of daily subsurface drainage rate were available from daily reading taken from an impeller-type flow meter placed on the emplacement subsurface drainage outlet on 17 March 2007 with such rate data available through to 20 May 2007, providing a means of validating the predictions of the model with respect to absolute subsurface flow rates and their recession behaviour.
5. Rainfall over the period 6 September – 13 May 2007 was 855.3 mm, equivalent to an annual rainfall of 1250 mm – much higher by 39% than the average rainfall at West Cliff over 1998 – 2006 of 898.0 mm as shown in the following **Figure 2.11**, and closer to the typical rainfall patterning in a pre-1998 average rainfall year for West Cliff.

FIGURE 2.11: RAINFALL AT WEST CLIFF 1998 - 2007



Reservoir coefficient Jd for the direct runoff system (refer **Appendix B**) was set at 1 hour and the channel travel time tau (refer **Appendix B**) also set to 1 hour for the 20.5 ha of active area of the Emplacement active based on discussions with Mr. Anthony Barthelmess of Cardno Forbes Rigby related to his WBNM modelling of the emplacement design storm (Sobinoff et al. 1983).

Given that these response times are relatively short in terms of daily intervals (i.e. <<10%) it is expected that the model's predictive performance with respect to direct runoff is relatively insensitive to their magnitudes up to a range of several hours.

Other model parameters relating to the subsurface drainage (baseflow) components (expressed by the Jd, A, B, and gamma parameters, refer **Appendix B**) of the model were initially based on our experience with prior hydrologic model fitting to an actual 631 day hydrographic record for the 32.0 ha Tahmoor Colliery coal wash emplacement (Ecoengineers Pty Ltd., 2007).

It was found that very little alteration to the magnitude of these parameters (from our Tahmoor model) was required to fit the subsurface flow rate data available – providing a measure of confidence in our West Cliff model.

The model also took into account the daily input of water to the Emplacement provided by the dumping of the (wetter) Dendrobium coalwash and the (less wet) West Cliff coalwash each day (generally) into the estimated 20.5 ha of the active area of the entire (estimated 50.9 ha) Stage 1 & 2 Emplacement.

Data supplied to us by BHPBIC management showed that the tonnage of Dendrobium coalwash emplaced from September 2006 - April 2007 averaged 3346 tonne/day. At an average moisture content of 11.5% this would supply 385 m^3/day of water to the active area of the emplacement. The tonnage of West Cliff coalwash emplaced from September 2006 - April 2007 averaged 3073 tonne/day. At an average moisture content of 9%, this would supply 277 m^3/day of water to the active area of the emplacement. Thus about 662 m^3/day in total was being added to the

20.5 ha active area on average each day over the model development period. This is equivalent to an added rainfall of 1.3 mm/day over the entire 50.9 ha emplacement and therefore not a trivial amount over the long term.

However, this water is not added to the entire Emplacement but only to the active filling area (20.5 ha) which constitutes 40.3% of the Emplacement. Therefore the model had to be modified by weighting to change the proportion of the entire Emplacement generating both direct runoff and seepage as follows.

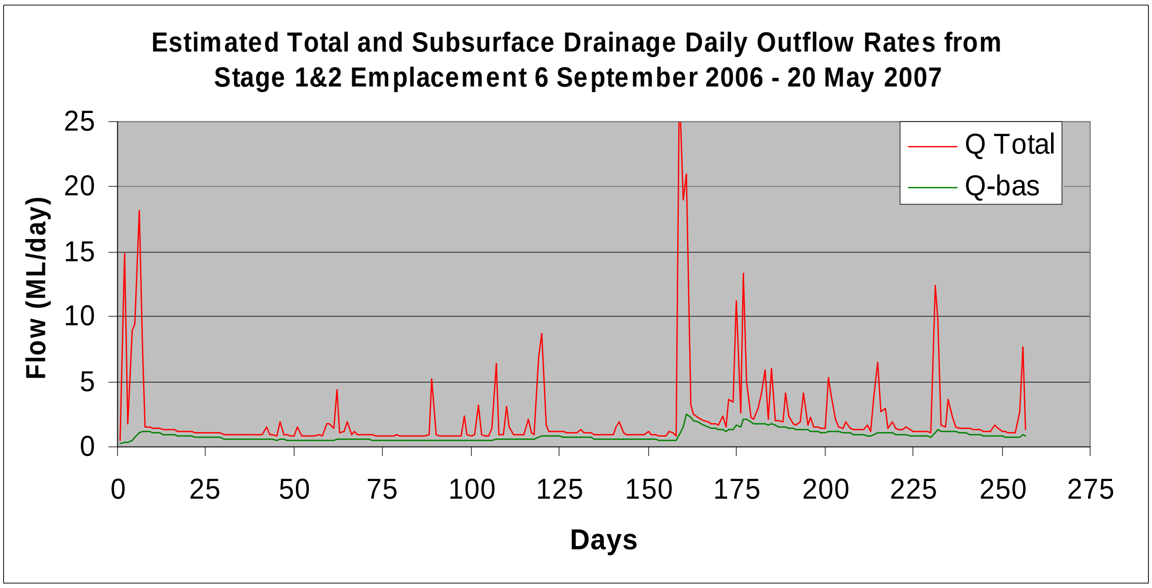
Over the 250 day model trial period to 13 May 2007 the total rainfall was 855.3 mm and on average the total water added via the entrained water in the coalwash was 1.3 x 250 = 375 mm. Thus the total water load on the Emplacement over the 250 days was 855.3 + 325 = 1180.3 mm.

The total water allocation to the rehabilitated area was therefore 855.3 x 30.4/50.9 = 510.8 mm and the total water allocation to the active area was 855.3 x 20.5/50.9 + 325 = 669.5 mm. Therefore the hydrologically weighted size of the active area as a fraction of the whole Emplacement (once the extra water from the dumped coalwash is taken into account) is not really 40.3% but actually 669.5/1180.3 = 56.7% and the hydrologically weighted area of the rehabilitated area is of course 510.8/1180.3 = 43.3%.

The true hydrologic fraction of the active filling area was therefore set in the model to 56.7% of the 50.9 ha and the 'rainfall record' was 'adjusted' to add an extra 1.3 mm/day to the 250 day model trial period.

Figure 2.12 below shows the model-predicted magnitudes of total outflow and subsurface drainage from the emplacement over a 257 day period between 6 September 2006 and 20 May 2007.

FIGURE 2.12: MODEL ESTIMATED TOTAL OUTFLOWS AND SUBSURFACE DRAINAGE FROM EXISTING COAL WASH EMPLACEMENT 6 SEPTEMBER 2006 – 20 MAY 2007



The model estimates that between 1 January 2007 and the end of 11 February 2007 some 84.3 ML flowed from the emplacement into Pond P4. Adding this increment to the estimated 20 ML contained in Pond P4 on 1 January, this means that a total excess of 59 ML over the 45 ML volume of Pond P4 was generated over this time period.

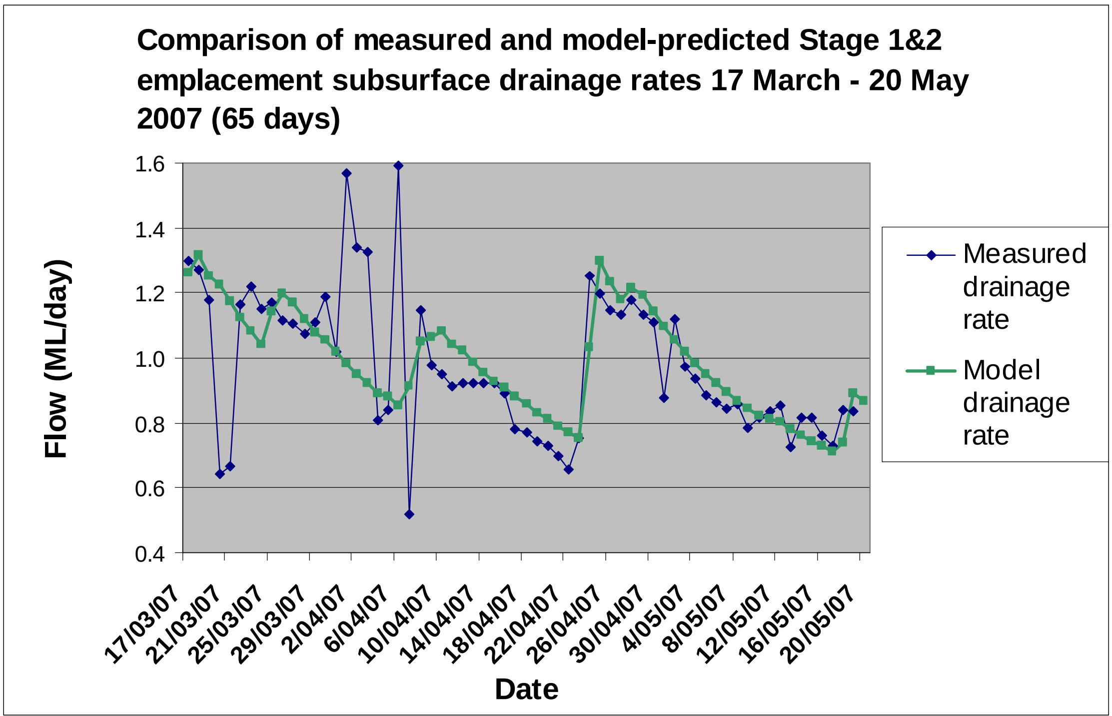
Allowing for an estimated recycling of approximately 53 ML through the Concrete Settling Tanks WTP for treatment over this period, this implies that some 5 – 10 ML had spilled from Pond P4 to BCD before the end of Sunday 11 February, in accord with the verbal advice from Mr. Allmann and Mr. Boardman, and provides some supporting validation of the model.

Model-estimated total outflow from the emplacement over the 250 day period between 6 September 2006 and 13 May 2007 was equivalent to 1078 mm. Subtracting the 375 mm contributed by the added coalwash, this means that 753 mm was due to natural outflows.

This suggests that evapotranspiration (ET) from the emplacement over this relatively wet period was only 102 mm or 0.41 mm/day. However, if the only significant ET occurred from the 30.4 ha of the emplacement which had been, or was undergoing rehabilitation, this is equivalent to an ET of 0.69 mm/day. This is a similar value to that recently determined by us for the whole of the smaller 32 ha Tahmoor Colliery coalwash emplacement (0.74 mm/day) which has a smaller active filling area (Ecoengineers Pty Ltd., 2007).

The following **Figure 2.13** shows the comparison between the model predictions and measured daily subsurface drainage rates between 17 March 2007 and 13 May 2007.

FIGURE 2.13: COMPARISON BETWEEN MODEL-PREDICTED AND MEASURED EMPLACEMENT SUBSURFACE DRAINAGE RATES 17 MARCH – 5 MAY 2007



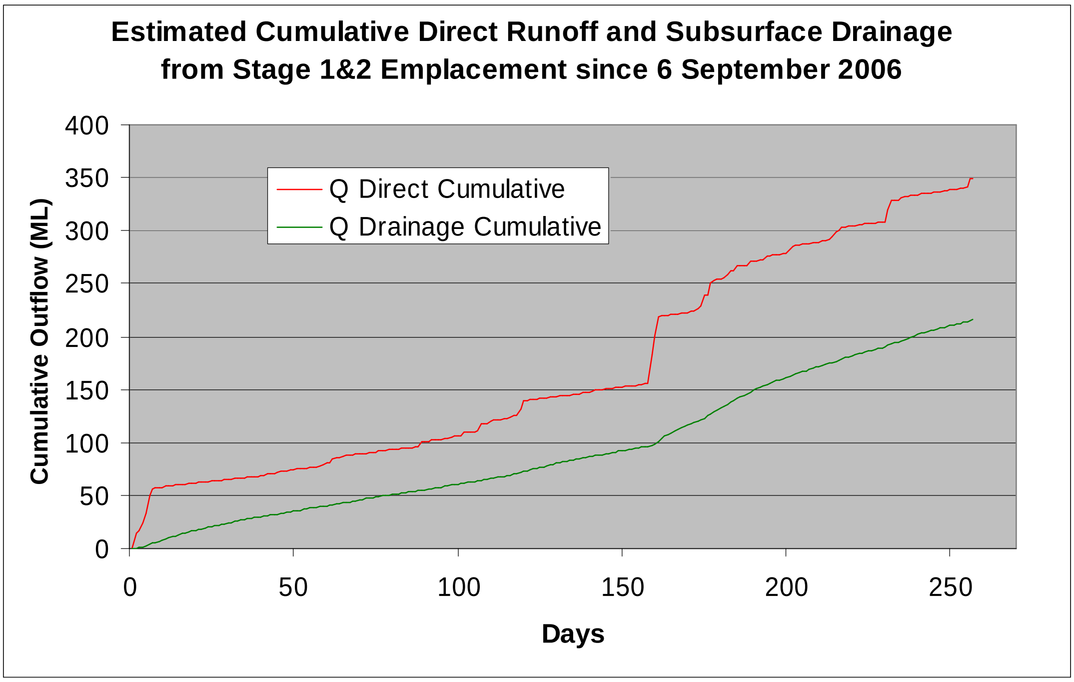
Some variations in the measured drainage rate prior to 8 April are known to have derived from operating difficulties with the impeller-style flow meter employed whereby full bore flows in the pipe were not achieved and air was being drawn into the pipe upstream of the flow meter. However, most to the variation between the measured and model-predicted subsurface drainage rates would no doubt arise because the model has, of necessity assumed an average daily rate of coalwash emplacement with constant moisture contents.

Notwithstanding, as can be seen in **Figure 2.13** above, the model provides an excellent description of the typical magnitude and rate of recession of subsurface drainage rates following rainfall events. This provides some confidence that the model is accurately allocating outflows to the groundwater-driven subsurface drainage mechanism.

This provides a good measure of validation that the model is able to successfully predict emplacement subsurface drainage rates following rainfall events that recharge the substantial perched groundwater storage located within the mass of coal wash in the emplacement.

The following **Figure 2.14** provides a comparison of the model-estimated cumulative direct runoff volumes and cumulative subsurface drainage volumes generated by the emplacement since 6 September 2006.

FIGURE 2.14: MODEL-ESTIMATED CUMULATIVE EMPLACEMENT DIRECT RUNOFF AND SUBSURFACE DRAINAGE VOLUMES 6 SEPTEMBER 2006 – 20 MAY 2007



Findings of the modelling are that; over the 257 day period from 6 Sept 2006 – 20 May 2007, which exhibited cumulative rainfalls characteristic of a pre-2001 (pre-drought) average rainfall year:

- estimated total volume of direct runoff (349 ML) significantly exceeded the total volume of subsurface drainage (216 ML); and
- total outflow from the emplacement for those 257 days or over 8 months (i.e. 564 ML) significantly exceeded the total capacity of BCD to its spillway (~307 ML) by a factor of about 80%.

This is in accord with the evidence that BCD spilled to Georges River via LDP1 over two sustained intervals during the model period (refer **Figure 2.3 above**).

The modelling therefore strongly indicates that over the period 6 September 2006 – 20 May 2007:

1. the Stage 1 and 2 coal wash Emplacement was a major contributor, via Pond P4, to inflows to BCD; and that
2. outflow from the subsurface drainage system contributed almost 40% the total outflow from the emplacement.

These conclusions indicate that optimization of the treatment of outflows from the existing and proposed Stage 3 coal wash emplacement can be achieved by:

1. Collection of emplacement-derived blackwater containing fine particle suspended solids in one or more ponds sized appropriately and subjected therein to both passive and chemically assisted sedimentation to remove coalwash-based particulate suspended solids.
2. Diversion of all or most clean subsurface drainage away from such water treatment ponds directly to BCD via perimeter clean water diversion drains. Modelling shows that, over the long term, this would improve the efficiency of the backwater treatment system and reduce hydraulic loads (and hence chemical coagulant costs) on the post Stage 3 emplacement dirty runoff treatment system by some 40% or so.

3. PROPOSED STAGE 3 EMPLACEMENT CATCH PONDS DESIGN AND OPERATION

While detailed design of the Stage 3 emplacement treatment pond system is yet to be finalised, a concept design that would significantly improves water quality treatment for the entire coal wash Emplacement from inception of Stage 3 has been prepared following the studies described above.

The conceptual treatment train is based on the following core principles:

1. The necessary separation of Pit Top Area runoff from emplacement outflow following the decommissioning of Pond P4 and passage of the leading edge of the emplacement to the north of Pond P3. At this time there will no longer be opportunity to discharge waters from the Pit Top Area directly to Brennans Creek valley, and an alternate route to BCD would need to be provided.
2. Diversion of clean emplacement subsurface drainage directly to BCD.
3. Maintenance of an appropriate detention volume for emplacement direct runoff up to and including a 10 year ARI, 72 hour design maximum storm.
4. *In situ* real time flow rate monitoring of direct runoff from the emplacement up to and including a 10 year ARI, 72 hour design maximum storm, with dosing of a cationic coagulant to the direct runoff stream up to that criterion.

It is noted that the decommissioning of Pond P4 and passage of the leading edge of the emplacement to the north of Pond P3 requires that an upgrade of the Pit Top Area water management subsystem will need to be designed and implemented.

In our view this is likely to require:

- decommissioning of the Concrete Settling Tanks WTP due to it lack of capacity (i.e. insufficient area and hydraulic residence time); and
- conversion of Pond P3 in the interim to a primary settling pond with coagulant and flocculant dosing; and
- construction of suitable discharge route to conduct Pit Top Area waters to BCD; and
- construction of an additional Pond P4a to accommodate a design maximum 10 year ARI, 72 hour storm for the Pit Top Area (which does not apply at present).

Our hydrologic model of the existing emplacement used a value of 20.5 ha for the area of active filling which is some 14% greater that the BHPBIC-declared likely average for the area of active emplacement at any one time.

Direct runoff rates for the design maximum storm as described in **Section 2.3** and **Appendix C** therefore have a built in factor of safety of 14% if the active fill area is kept closely to the stated design average of 18.0 ha.

We have assumed that the active working area of emplacement will always be at least 18 ha at any one time and will not exceed (say) an area 15% larger (20.7 ha).

Therefore, on the basis of the model described in **Section 2.2** above, the modelling of an adopted 10 year ARI, 72 hour design maximum storm as described in **Appendix C** it is proposed that the following water management principles be adopted for the Stage 3 Emplacement Water Quality Management Plan.

1. There is no need to restrict total dirty runoff collection to a single catch pond. However, minimum pond size downstream of the emplacement of each catch pond should be sized to capture and treat the first flush of direct runoff i.e. the first day's runoff from the design maximum storm. Pond volume should therefore be a designed to a Hydraulic Residence Time (HRT) of at least 24 hours to contain the 1st days runoff, to allow passive settling of coarse coal wash and to allow for 10% live capacity loss due to prior sludge buildup. In accord with standard practice the aspect ratio (length/width) of the catch pond should be at least 3 (Goldman et al. 1986).
2. It is proposed that each phase of Stage 3 be served by two sequential catch ponds sited down Brennans Creek valley. The 1st two such catch ponds could be designated EP1 and EP2 for example. As each phase approached completion, and filling of the first catch pond is imminent, a new catch pond would need to be constructed, designated EP3 and so on.
3. It is proposed that the upstream of each pair of catch ponds be reserved for 1st flush detention/passive settling of the 1st days runoff of up to a design maximum 10 year ARI 72 hour storm, and provide decantation via floating offtake up to a maximum design rate of 20 ML/day (0.22 m^3/s) to a 2nd pond while dosing a cationic coagulant up to that maximum design dosing rate. It can be shown that decantation in this manner is a practical proposition as described in **Appendix C** (Hannan, 1995).
4. Experience with coal wash and coal fines management indicates that the fine particle settling rate in the presence of a cationic coagulant dosed at the appropriate concentration would be at least 1 mm/s or 86 m/day. Allowing for a factor of safety 10 – 15 for turbulence effects this would ensure a clean water column depth developing at a rate of at least 5.7 m/day.
5. Coagulant dosing may be achieved by fitting a Parshall flume or similar flow measuring device to the inlet to the 2nd pond (EP2 etc), generating a flow rate signal (covering at least the 2 – 20 ML/day range) to control a mobile, bank-mounted dosing plant at the inlet to the 2nd catch pond.
6. In order to keep the 1st pond as dry as possible over the long term, all subsurface drainage should be routed to either the 2nd pond with an option to close that off and route to a point downstream of the 2nd pond. In the first few days of a much increased subsurface drainage rate, subsurface drainage is sometimes black but always quickly clears over 2 - 3 days. This means that there should be a facility to treat, in the 2nd pond, up to the first 5 ML or so of subsurface drainage.
7. The minimum <u>total</u> water treatment pond volume downstream of the emplacement should be designed to a 10 year ARI 72 hour storm and allow for approximately 3 – 5 ML of loss of live storage volume in each pond due to accumulated sludge, at any one time.
8. It is proposed that both catch ponds be fitted with staff level gauges and volume calibration curves established for each by analysis of AUTOCAD survey data.
9. Access should be provided to each catch pond by an excavator or front end loader for regular de-sludging during dry weather periods.

The benefits of this system as outlined above would be that future management of actual and potential water quality impacts of the expanded emplacement will be effectively separated from water management of the Pit Top Area, as is required following the decommissioning of Pond P4 and passage of the leading edge of the emplacement to the north of Pond P3. This would provide much improved management of emplacement-generated dirty direct runoff.

4. IMPACT ASSESSMENT FOR GEORGES RIVER

Condition 5.1(e) (vii) of the Dendrobium Mine development consent states that there should be:

- detailed assessment of the potential impact of the proposal on water quality, particularly on Georges River, including details of proposed management and contingency measures to mitigate any potential impacts.

In compliance with this requirement, **Sections 1.1 and 1.2** above provide a full description of the existing West Cliff Water Management System (WMS) and the management sub-system for the present Stage 1&2 phases of the Emplacement.

It is noted that **Section 1.1** includes a description of how the WMS was modified in 2004 to provide an improved method of controlled discharges of excess water to Georges River in such a way that the risk potential ecological impacts on the River were minimized more than before.

Sections 2.1, 2.2 and 2.3 above provide a full assessment of the potential impacts of the present Stage 1&2 phases of the emplacement on BCD and on Georges River

Section 2.4 above present a hydrological model of the existing emplacement and identifies how that model shows an improved management of the entire emplacement could be designed in such a way that the impacts of the whole emplacement, including the proposed Stage 3, can be both optimally managed and provide contingency measures to mitigate any water quality impacts within BCD and from uncontrolled and controlled discharges from BCD to Georges River.

Appendix B and C describes the hydrologic model developed for the emplacement and present predictions for the design maximum storm.

Section 2.4 and Appendixes B and C describes the basis for developing the proposed **Water Quality Management Plan** for the expanded coal wash emplacement. The Plan will form the basis for proposed management and contingency measures, including the proposed Stage 3, to ensure maximum control on water quality within BCD and in discharges from BCD to Georges River.

The proposed new Emplacement Water Quality Management plan described in **Appendix D** for the expanded Emplacement is based upon:

- complete separation of the Pit Top Area water management system from the coal wash emplacement water management system from the inception of Stage 3 of the Emplacement; and
- a system of segregation of clean subsurface drainage from the expanded emplacement from dirty direct runoff form the expanded emplacement; and a
- proposed improved system for the treatment and clarification of all dirty direct runoff from the emplacement based on real time flow measurement and cationic coagulant dosing up to a direct runoff decant rate from a primary catch pond of 20 ML/day,

This should provide much greater factors of safety with respect to the quality of waters delivered to BCD and to Georges River via uncontrolled spills over BCD spillway.

Detailed hydrologic modelling and basic engineering calculations indicates that the proposed new Water Quality Management Plan should have a very beneficial effect on TSS management in BCD and by implication in any waters discharged from BCD to Georges River. It should also reduce the average salinity of waters discharged to Georges River in an uncontrolled manner over BCD spillway.

The decommissioning of Pond P4 and passage of the leading edge of the Emplacement to the north of Pond P3 removes the possibility of directing excess dirty water flows from the Pit Top Area to Pond P4. This requires that an upgrade of the Pit Top Area water management subsystem needs to be designed and implemented, before or concurrently with the first phase of Stage 3 of the Emplacement.

Cardno Forbes Rigby have identified options for re-development of the Pit Top Area water management system (based on runoff management for up to a design maximum 10 year ARI 72 hour storm). These include:

1. Decommission Concrete Settling Tanks WTP and upgrade Pond P3 to a primary settling pond for coagulant and flocculant-based chemically-assisted settling and installation of a centreline baffle to improve flow path Length to Width (L/W) Ratio of 3.
2. Decommission Concrete Settling Tanks WTP and upgrade Pond P3 to a primary settling pond for passive settlement of coarse particulates and construction of a new Pond P4A northwest of P3 (just off the eastern margin of the Stage 3 Emplacement) with an appropriate capacity for coagulant and flocculant-based chemically-assisted settling.

Either of the above options also require a means of separately conveying all treated water from the Pit Top Area to BCD by route that does not pass through the Stage 3 emplacement.

Option 2 above has been described as the preferred option in the Stage 3 Emplacement Application report.

The proposed separation of Pit Top Area and Emplacement water management systems will enable significant improvements in the efficiency of emplacement water management

It is concluded that these changes to the West Cliff WMS will produce a net beneficial impact on water quality within BCD and by definition Georges River downstream of the Brennans Creek confluence. While it is difficult to estimate the magnitude of the long term average decrease in TSS produced, it is believed that it should be at least one order of magnitude during peak discharges over the BCD spillway (LDP1).

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APPENDIX A

PARTICLE SIZE ANALYSIS REPORTS FOR POND P4 (‘POINT 4’), TREATED WATER FROM CONCRETE SETTLING TANKS WATER TREATMENT PLANT (‘POINT 14’), AND UNDERGROUND WATER SUPPLY FROM BCD (‘POINT 15’) COLLECTED ON 2 MARCH 2007

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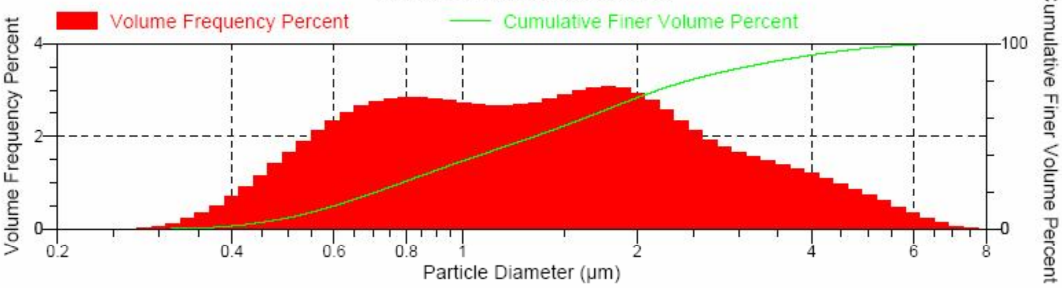
Saturn DigiSizer 5200 V1.09 Saturn DigiSizer 5200 V1.11 5200 LSHU V2.01 S/N 227 Page 1

Sample: Pond P4
Operator: Stephen
Submitter: Eco Engineers
File: L:\...\2910\000-387.SMP

Test Number:	3	Model:	Fraunhofer, 1.331
Analyzed:	7/03/2007 1:24:41PM	Material:	Fraunhofer / Water
Reported:	7/03/2007 3:23:09PM	Background:	Water RI 1.331
Background:	7/03/2007 11:09:48AM	Smoothing:	Medium

Combined Report

Volume Frequency vs. Diameter



Summary Report

Analysis Conditions

FlowRate: 12.0 l/m
Circulation time: 120 sec
Ultrasonic intensity: 50 %
Ultrasonic time: 120 sec

Particle Properties

Refractive Index: (Re)0.000, (Im)0.000
Density: 1.000 g/cm³
Smoothing: Medium
Truncate intensity data: No
Minimum signal fraction: 16.0 %

Analysis Liquid Properties

Refractive Index: 1.331
Viscosity: 0.798 cp
Temperature: 29.070 °C

User Parameters

Parameter 1: 0.000 Parameter 2: 0.000 Parameter 3: 0.000

Sample

Sample Concentration: 0.00124 %
Obscuration: 15.7 %

Volume Distribution Arithmetic Statistics

		Std Dev of 3			Std Dev of 3
Mean	1.679	0.001	Mode	1.784	0.000
Median	1.332	0.002			

Peaks

Peak Number	% of Dist.*	% of Dist. Std Dev of 3	Mean	Mean Std Dev of 3	Median	Median Std Dev of 3	Mode
1	46.2	0.1	0.774	0.000	0.757	0.002	0.797
2	53.8	0.1	2.456	0.004	2.090	0.007	1.784

* Peaks must comprise at least 5.00 % of the distribution.

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Saturn DigiSizer 5200 V1.09   Saturn DigiSizer 5200 V1.11   5200 LSHU V2.01 S/N 227   Page 2

Sample: Pond P4
Operator: Stephen
Submitter: Eco Engineers
File: L:\...\2910\000-387.SMP

Test Number:	3	Model:	Fraunhofer, 1.331
Analyzed:	7/03/2007 1:24:41PM	Material:	Fraunhofer / Water
Reported:	7/03/2007 3:23:09PM	Background:	Water RI 1.331
Background:	7/03/2007 11:09:48AM	Smoothing:	Medium

Report by Size Class

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Volume Finer (Percent)	Volume Frequency (Percent)	Cum. Vol. Standard Deviation (3 tests)
7.718	7.286	7.499	100.0	0.0	0.0
7.286	6.879	7.079	99.9	0.1	0.0
6.879	6.494	6.683	99.8	0.1	0.0
6.494	6.131	6.310	99.6	0.2	0.0
6.131	5.788	5.957	99.2	0.4	0.0
5.788	5.464	5.623	98.7	0.5	0.0
5.464	5.158	5.309	98.1	0.6	0.0
5.158	4.870	5.012	97.4	0.7	0.0
4.870	4.597	4.732	96.5	0.9	0.0
4.597	4.340	4.467	95.5	1.0	0.0
4.340	4.097	4.217	94.4	1.1	0.0
4.097	3.868	3.981	93.2	1.2	0.0
3.868	3.652	3.758	91.9	1.3	0.0
3.652	3.447	3.548	90.5	1.4	0.0
3.447	3.255	3.350	89.0	1.5	0.0
3.255	3.073	3.162	87.5	1.6	0.0
3.073	2.901	2.985	85.8	1.7	0.0
2.901	2.738	2.818	84.0	1.8	0.0
2.738	2.585	2.661	82.1	1.9	0.1
2.585	2.441	2.512	79.9	2.1	0.1
2.441	2.304	2.371	77.6	2.4	0.1
2.304	2.175	2.239	75.0	2.6	0.1
2.175	2.054	2.113	72.2	2.8	0.1
2.054	1.939	1.995	69.3	2.9	0.1
1.939	1.830	1.884	66.2	3.0	0.1
1.830	1.728	1.778	63.2	3.1	0.1
1.728	1.631	1.679	60.1	3.0	0.1
1.631	1.540	1.585	57.1	3.0	0.1
1.540	1.454	1.496	54.2	2.9	0.1
1.454	1.372	1.413	51.4	2.8	0.1
1.372	1.296	1.334	48.7	2.7	0.1
1.296	1.223	1.259	46.0	2.7	0.1
1.223	1.155	1.189	43.4	2.6	0.1
1.155	1.090	1.122	40.7	2.7	0.0
1.090	1.029	1.059	38.0	2.7	0.0
1.029	0.972	1.000	35.3	2.7	0.0
0.972	0.917	0.944	32.5	2.8	0.1
0.917	0.866	0.891	29.7	2.8	0.1
0.866	0.818	0.841	26.9	2.8	0.1
0.818	0.772	0.794	24.0	2.8	0.1
0.772	0.729	0.750	21.2	2.8	0.1
0.729	0.688	0.708	18.5	2.8	0.0
0.688	0.649	0.668	15.8	2.7	0.0
0.649	0.613	0.631	13.3	2.5	0.0
0.613	0.579	0.596	11.0	2.3	0.1
0.579	0.546	0.562	8.9	2.1	0.1
0.546	0.516	0.531	7.0	1.9	0.1

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Saturn DigiSizer 5200 V1.09 Saturn DigiSizer 5200 V1.11 5200 LSHU V2.01 S/N 227 Page 3

Sample: Pond P4
Operator: Stephen
Submitter: Eco Engineers
File: L:\...\2910\000-387.SMP

Test Number: 3
Analyzed: 7/03/2007 1:24:41PM
Reported: 7/03/2007 3:23:09PM
Background: 7/03/2007 11:09:48AM

Model: Fraunhofer, 1.331
Material: Fraunhofer / Water
Background: Water RI 1.331
Smoothing: Medium

Report by Size Class

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Volume Finer (Percent)	Volume Frequency (Percent)	Cum. Vol. Standard Deviation (3 tests)
0.516	0.487	0.501	5.3	1.6	0.1
0.487	0.460	0.473	3.9	1.4	0.1
0.460	0.434	0.447	2.8	1.1	0.1
0.434	0.410	0.422	1.9	0.9	0.1
0.410	0.387	0.398	1.2	0.7	0.1
0.387	0.365	0.376	0.7	0.5	0.1
0.365	0.345	0.355	0.4	0.3	0.1
0.345	0.325	0.335	0.2	0.2	0.1
0.325	0.307	0.316	0.1	0.1	0.0
0.307	0.290	0.299	0.0	0.1	0.0
0.290	0.274	0.282	0.0	0.0	0.0
0.274	0.259	0.266	0.0	0.0	0.0

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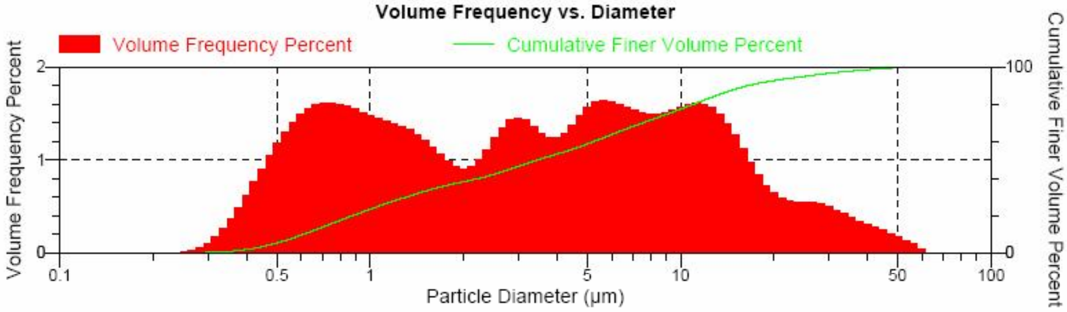
Sample: Point 14
Operator: Stephen
Submitter: Eco Engineers
File: L:\...\2910\000-388.SMP

Test Number:	3	Model:	Fraunhofer, 1.331
Analyzed:	7/03/2007 2:32:57PM	Material:	Fraunhofer / Water
Reported:	7/03/2007 3:19:08PM	Background:	Water RI 1.331
Background:	7/03/2007 11:09:48AM	Smoothing:	Medium

Combined Report

Volume Frequency vs. Diameter



Summary Report

Analysis Conditions

FlowRate: 12.0 l/m
Circulation time: 120 sec
Ultrasonic intensity: 50 %
Ultrasonic time: 120 sec

Particle Properties

Refractive Index: (Re)0.000, (Im)0.000
Density: 1.000 g/cm³
Smoothing: Medium
Truncate intensity data: No
Minimum signal fraction: 16.0 %

Analysis Liquid Properties

Refractive Index: 1.331
Viscosity: 0.798 cp
Temperature: 31.840 °C

User Parameters

Parameter 1: 0.000 Parameter 2: 0.000 Parameter 3: 0.000

Sample

Sample Concentration: 0.00083 %
Obscuration: 7.2 %

Volume Distribution Arithmetic Statistics

		Std Dev of 3			Std Dev of 3
Mean	6.763	0.102	Mode	5.641	2.847
Median	3.451	0.020			

Peaks

Peak Number	% of Dist.*	% of Dist. Std Dev of 3	Mean	Mean Std Dev of 3	Median	Median Std Dev of 3	Mode
1	38.7	0.1	0.958	0.002	0.857	0.004	0.752
2	15.1	0.1	3.005	0.004	2.965	0.005	2.994
3	18.3	0.9	5.949	0.112	5.842	0.098	5.641
4	27.9	1.0	17.40	0.142	13.73	0.207	11.25

* Peaks must comprise at least 5.00 % of the distribution.

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Saturn DigiSizer 5200 V1.09 Saturn DigiSizer 5200 V1.11 5200 LSHU V2.01 S/N 227 Page 2

Sample: Point 14
Operator: Stephen
Submitter: Eco Engineers
File: L:\...\2910\000-388.SMP

Test Number: 3
Analyzed: 7/03/2007 2:32:57PM
Reported: 7/03/2007 3:19:08PM
Background: 7/03/2007 11:09:48AM

Model: Fraunhofer, 1.331
Material: Fraunhofer / Water
Background: Water RI 1.331
Smoothing: Medium

Report by Size Class

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Volume Finer (Percent)	Volume Frequency (Percent)	Cum. Vol. Standard Deviation (3 tests)
64.938	61.306	63.096	100.0	0.0	0.0
61.306	57.876	59.566	99.9	0.1	0.0
57.876	54.639	56.234	99.9	0.1	0.1
54.639	51.582	53.088	99.7	0.1	0.1
51.582	48.697	50.119	99.5	0.2	0.2
48.697	45.973	47.315	99.3	0.2	0.2
45.973	43.401	44.668	99.1	0.2	0.2
43.401	40.973	42.170	98.8	0.3	0.2
40.973	38.681	39.811	98.5	0.3	0.2
38.681	36.517	37.584	98.2	0.3	0.2
36.517	34.475	35.481	97.8	0.4	0.2
34.475	32.546	33.497	97.4	0.4	0.2
32.546	30.726	31.623	96.9	0.5	0.2
30.726	29.007	29.854	96.4	0.5	0.2
29.007	27.384	28.184	95.9	0.5	0.2
27.384	25.852	26.607	95.3	0.5	0.2
25.852	24.406	25.119	94.8	0.5	0.2
24.406	23.041	23.714	94.2	0.5	0.2
23.041	21.752	22.387	93.7	0.6	0.2
21.752	20.535	21.135	93.1	0.6	0.2
20.535	19.387	19.953	92.4	0.6	0.2
19.387	18.302	18.836	91.7	0.7	0.2
18.302	17.278	17.783	90.9	0.8	0.2
17.278	16.312	16.788	89.9	1.0	0.2
16.312	15.399	15.849	88.7	1.1	0.2
15.399	14.538	14.962	87.5	1.3	0.2
14.538	13.725	14.125	86.1	1.4	0.2
13.725	12.957	13.335	84.6	1.5	0.2
12.957	12.232	12.589	83.0	1.6	0.2
12.232	11.548	11.885	81.4	1.6	0.2
11.548	10.902	11.220	79.8	1.6	0.2
10.902	10.292	10.593	78.2	1.6	0.2
10.292	9.716	10.000	76.6	1.6	0.2
9.716	9.173	9.441	75.1	1.5	0.2
9.173	8.660	8.913	73.6	1.5	0.2
8.660	8.175	8.414	72.1	1.5	0.2
8.175	7.718	7.943	70.6	1.5	0.2
7.718	7.286	7.499	69.1	1.5	0.2
7.286	6.879	7.079	67.5	1.5	0.2
6.879	6.494	6.683	65.9	1.6	0.2
6.494	6.131	6.310	64.3	1.6	0.2
6.131	5.788	5.957	62.7	1.6	0.2
5.788	5.464	5.623	61.1	1.6	0.2
5.464	5.158	5.309	59.5	1.6	0.2
5.158	4.870	5.012	57.9	1.6	0.2
4.870	4.597	4.732	56.4	1.5	0.2
4.597	4.340	4.467	55.0	1.4	0.2

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Saturn DigiSizer 5200 V1.09 Saturn DigiSizer 5200 V1.11 5200 LSHU V2.01 S/N 227 Page 3

Sample: Point 14
Operator: Stephen
Submitter: Eco Engineers
File: L:\...\2910\000-388.SMP

Test Number: 3
Analyzed: 7/03/2007 2:32:57PM
Reported: 7/03/2007 3:19:08PM
Background: 7/03/2007 11:09:48AM

Model: Fraunhofer, 1.331
Material: Fraunhofer / Water
Background: Water RI 1.331
Smoothing: Medium

Report by Size Class

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Volume Finer (Percent)	Volume Frequency (Percent)	Cum. Vol. Standard Deviation (3 tests)
4.340	4.097	4.217	53.7	1.3	0.2
4.097	3.868	3.981	52.5	1.2	0.2
3.868	3.652	3.758	51.3	1.2	0.1
3.652	3.447	3.548	50.0	1.3	0.1
3.447	3.255	3.350	48.6	1.4	0.1
3.255	3.073	3.162	47.2	1.4	0.1
3.073	2.901	2.985	45.7	1.5	0.1
2.901	2.738	2.818	44.3	1.4	0.1
2.738	2.585	2.661	43.0	1.3	0.2
2.585	2.441	2.512	41.7	1.2	0.1
2.441	2.304	2.371	40.6	1.1	0.1
2.304	2.175	2.239	39.6	1.0	0.1
2.175	2.054	2.113	38.7	0.9	0.1
2.054	1.939	1.995	37.8	0.9	0.1
1.939	1.830	1.884	36.9	0.9	0.1
1.830	1.728	1.778	35.9	1.0	0.0
1.728	1.631	1.679	34.8	1.1	0.0
1.631	1.540	1.585	33.7	1.1	0.0
1.540	1.454	1.496	32.4	1.2	0.0
1.454	1.372	1.413	31.2	1.3	0.0
1.372	1.296	1.334	29.8	1.3	0.0
1.296	1.223	1.259	28.5	1.4	0.0
1.223	1.155	1.189	27.1	1.4	0.1
1.155	1.090	1.122	25.6	1.4	0.1
1.090	1.029	1.059	24.2	1.5	0.1
1.029	0.972	1.000	22.7	1.5	0.1
0.972	0.917	0.944	21.2	1.5	0.1
0.917	0.866	0.891	19.6	1.5	0.1
0.866	0.818	0.841	18.1	1.6	0.1
0.818	0.772	0.794	16.5	1.6	0.1
0.772	0.729	0.750	14.9	1.6	0.1
0.729	0.688	0.708	13.2	1.6	0.1
0.688	0.649	0.668	11.6	1.6	0.1
0.649	0.613	0.631	10.1	1.6	0.0
0.613	0.579	0.596	8.6	1.5	0.0
0.579	0.546	0.562	7.2	1.4	0.0
0.546	0.516	0.531	5.9	1.3	0.0
0.516	0.487	0.501	4.7	1.2	0.1
0.487	0.460	0.473	3.7	1.0	0.1
0.460	0.434	0.447	2.8	0.9	0.1
0.434	0.410	0.422	2.0	0.8	0.1
0.410	0.387	0.398	1.4	0.6	0.1
0.387	0.365	0.376	0.9	0.5	0.1
0.365	0.345	0.355	0.6	0.4	0.1
0.345	0.325	0.335	0.3	0.3	0.0
0.325	0.307	0.316	0.2	0.2	0.0
0.307	0.290	0.299	0.1	0.1	0.0

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Saturn DigiSizer 5200 V1.09 Saturn DigiSizer 5200 V1.11 5200 LSHU V2.01 S/N 227 Page 4

Sample: Point 14
Operator: Stephen
Submitter: Eco Engineers
File: L:\...\2910\000-388.SMP

Test Number: 3
Analyzed: 7/03/2007 2:32:57PM
Reported: 7/03/2007 3:19:08PM
Background: 7/03/2007 11:09:48AM

Model: Fraunhofer, 1.331
Material: Fraunhofer / Water
Background: Water RI 1.331
Smoothing: Medium

Report by Size Class

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Volume Finer (Percent)	Volume Frequency (Percent)	Cum. Vol. Standard Deviation (3 tests)
0.290	0.274	0.282	0.0	0.1	0.0
0.274	0.259	0.266	0.0	0.0	0.0
0.259	0.244	0.251	0.0	0.0	0.0

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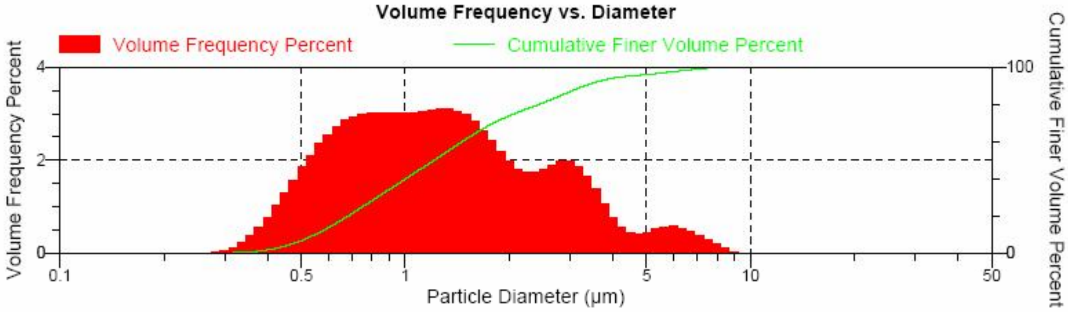
Saturn DigiSizer 5200 V1.09 Saturn DigiSizer 5200 V1.11 5200 LSHU V2.01 S/N 227 Page 1

Sample: Point 15
Operator: Stephen
Submitter: Eco Engineers
File: L:\...\2910\000-386.SMP

Test Number:	3	Model:	Fraunhofer, 1.331
Analyzed:	7/03/2007 12:36:18PM	Material:	Fraunhofer / Water
Reported:	7/03/2007 3:25:06PM	Background:	Water RI 1.331
Background:	7/03/2007 11:09:48AM	Smoothing:	Medium

Combined Report

Volume Frequency vs. Diameter



Summary Report

Analysis Conditions

FlowRate:	12.0 l/m	Ultrasonic intensity:	50 %
Circulation time:	120 sec	Ultrasonic time:	120 sec

Particle Properties

Refractive Index: (Re)0.000, (Im)0.000
Density: 1.000 g/cm³
Smoothing: Medium
Truncate intensity data: No
Minimum signal fraction: 16.0 %

Analysis Liquid Properties

Refractive Index: 1.331
Viscosity: 0.798 cp
Temperature: 28.450 °C

User Parameters

Parameter 1: 0.000 Parameter 2: 0.000 Parameter 3: 0.000

Sample

Sample Concentration: 0.00040 %
Obscuration: 5.6 %

Volume Distribution Arithmetic Statistics

		Std Dev of 3			Std Dev of 3
Mean	1.657	0.003	Mode	1.263	0.000
Median	1.213	0.001			

Peaks

Peak Number	% of Dist.*	% of Dist. Std Dev of 3	Mean	Mean Std Dev of 3	Median	Median Std Dev of 3	Mode
1	38.4	N/A	0.675	N/A	0.674	N/A	0.844
2	39.9	N/A	1.481	N/A	1.419	N/A	1.263
3	17.5	N/A	3.136	N/A	3.026	N/A	2.827

* Peaks must comprise at least 5.00 % of the distribution.

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Saturn DigiSizer 5200 V1.09 Saturn DigiSizer 5200 V1.11 5200 LSHU V2.01 S/N 227 Page 2

Sample: Point 15
Operator: Stephen
Submitter: Eco Engineers
File: L:\...\2910\000-386.SMP

Test Number: 3
Analyzed: 7/03/2007 12:36:18PM
Reported: 7/03/2007 3:25:06PM
Background: 7/03/2007 11:09:48AM

Model: Fraunhofer, 1.331
Material: Fraunhofer / Water
Background: Water RI 1.331
Smoothing: Medium

Report by Size Class

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Volume Finer (Percent)	Volume Frequency (Percent)	Cum. Vol. Standard Deviation (3 tests)
9.716	9.173	9.441	100.0	0.0	0.0
9.173	8.660	8.913	100.0	0.0	0.0
8.660	8.175	8.414	99.9	0.1	0.0
8.175	7.718	7.943	99.7	0.2	0.1
7.718	7.286	7.499	99.4	0.3	0.1
7.286	6.879	7.079	99.0	0.4	0.1
6.879	6.494	6.683	98.5	0.5	0.1
6.494	6.131	6.310	98.0	0.5	0.1
6.131	5.788	5.957	97.4	0.6	0.1
5.788	5.464	5.623	96.8	0.6	0.1
5.464	5.158	5.309	96.3	0.5	0.1
5.158	4.870	5.012	95.9	0.4	0.1
4.870	4.597	4.732	95.5	0.4	0.1
4.597	4.340	4.467	95.0	0.4	0.0
4.340	4.097	4.217	94.5	0.6	0.0
4.097	3.868	3.981	93.7	0.8	0.1
3.868	3.652	3.758	92.6	1.1	0.1
3.652	3.447	3.548	91.2	1.4	0.1
3.447	3.255	3.350	89.5	1.7	0.1
3.255	3.073	3.162	87.7	1.9	0.1
3.073	2.901	2.985	85.7	2.0	0.1
2.901	2.738	2.818	83.7	2.0	0.0
2.738	2.585	2.661	81.8	1.9	0.1
2.585	2.441	2.512	80.0	1.8	0.1
2.441	2.304	2.371	78.3	1.7	0.1
2.304	2.175	2.239	76.6	1.7	0.1
2.175	2.054	2.113	74.8	1.8	0.1
2.054	1.939	1.995	72.8	2.0	0.1
1.939	1.830	1.884	70.6	2.2	0.0
1.830	1.728	1.778	68.2	2.4	0.0
1.728	1.631	1.679	65.5	2.7	0.0
1.631	1.540	1.585	62.7	2.8	0.0
1.540	1.454	1.496	59.7	3.0	0.0
1.454	1.372	1.413	56.6	3.1	0.0
1.372	1.296	1.334	53.5	3.1	0.0
1.296	1.223	1.259	50.4	3.1	0.0
1.223	1.155	1.189	47.4	3.1	0.0
1.155	1.090	1.122	44.3	3.0	0.1
1.090	1.029	1.059	41.3	3.0	0.1
1.029	0.972	1.000	38.3	3.0	0.1
0.972	0.917	0.944	35.3	3.0	0.1
0.917	0.866	0.891	32.2	3.0	0.1
0.866	0.818	0.841	29.2	3.0	0.1
0.818	0.772	0.794	26.2	3.0	0.0
0.772	0.729	0.750	23.2	3.0	0.0
0.729	0.688	0.708	20.3	2.9	0.0
0.688	0.649	0.668	17.4	2.8	0.0

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Saturn DigiSizer 5200 V1.09 Saturn DigiSizer 5200 V1.11 5200 LSHU V2.01 S/N 227 Page 3

Sample: Point 15
Operator: Stephen
Submitter: Eco Engineers
File: L:\...\2910\000-386.SMP

Test Number: 3
Analyzed: 7/03/2007 12:36:18PM
Reported: 7/03/2007 3:25:06PM
Background: 7/03/2007 11:09:48AM

Model: Fraunhofer, 1.331
Material: Fraunhofer / Water
Background: Water RI 1.331
Smoothing: Medium

Report by Size Class

High Diameter (µm)	Low Diameter (µm)	Average Diameter (µm)	Cumulative Volume Finer (Percent)	Volume Frequency (Percent)	Cum. Vol. Standard Deviation (3 tests)
0.649	0.613	0.631	14.7	2.7	0.0
0.613	0.579	0.596	12.2	2.5	0.0
0.579	0.546	0.562	9.8	2.3	0.0
0.546	0.516	0.531	7.7	2.1	0.1
0.516	0.487	0.501	5.9	1.8	0.1
0.487	0.460	0.473	4.3	1.6	0.1
0.460	0.434	0.447	3.0	1.3	0.1
0.434	0.410	0.422	2.0	1.0	0.1
0.410	0.387	0.398	1.3	0.8	0.0
0.387	0.365	0.376	0.7	0.5	0.0
0.365	0.345	0.355	0.4	0.4	0.0
0.345	0.325	0.335	0.2	0.2	0.0
0.325	0.307	0.316	0.1	0.1	0.0
0.307	0.290	0.299	0.0	0.0	0.0
0.290	0.274	0.282	0.0	0.0	0.0

APPENDIX B

WHOLE OF EMPLACEMENT HYDROLOGIC MODELLING

B WHOLE OF EMPLACEMENT HYDROLOGIC MODELLING

B.1 SELECTION OF HYDROLOGIC MODEL

The RUNOFF model was developed on the basis of a schematic representation of hydrogeological conditions, related to the structure of soil and hydrogeologic formations and catchment topographical features, as are most other modern models such as the WBNM (Watershed Bounded Network Model) model employed by Cardno Forbes Rigby for studies related to this project (Boyd et al. 1987; Boyd and Cordery, 1989; Boyd et al. 2003; Boyd and Bodrinayke, 2006).

However, unlike the WBNM model it is a non-distributed model which treats the Emplacement as a single hydrologic unit. The advantage of the RUNOFF2005 model over a model such as WBNM in this context is that RUNOFF2005 is specifically designed to model the baseflow (groundwater outflow) component as a appropriately as possible, a matter which is not addressed by WBNM or similar models.

The RUNOFF model therefore uses analytical solutions which were derived for the behaviour of groundwater discharge in terms of a time-variable drainage resistance (Kraijenhoff Van de Leur, 1958; De Zeeuw, 1979). This led to a general equation of the drainage resistance as a function of groundwater discharge which is not restricted to areas with an unconsolidated 'Dupuit-Boussinesq aquifer'.

This physically-based equation was then implemented in a simple, non-distributed conceptual runoff model for the analysis of continuous time series of runoff in the presence of intermittent rainfall using non-linear optimization procedures (Van de Griend and Seyhan, 1985; Van de Griend et al., 1986; 2002).

Such models are called 'non-distributed' because they treat the catchment as a whole and do not differentiate the catchment spatially into different runoff source areas. Similar models which essentially derive from different configurations of the Dupuit-Boussinesq aquifer have been subsequently derived in the United States (e.g. Brutsaert and Lopez, 1998) and also more recently in Australia (e.g. Sloan, 2000) and are relatively widely applied to characterise specific small catchment hydrologic behaviours.

The RUNOFF model, now available as a very mature 2005 version has been refined over more than 20 years, and has been critically assessed against the well known CREAMS, USDAHL, ANSWERS, HYRROM, TOP MODEL and HEC-1 models (Seyhan and Van de Griend, 1997) with favourable outcomes, was considered appropriate for this particular groundwater focussed application (Van de Griend et al., 2003) for the following reasons:

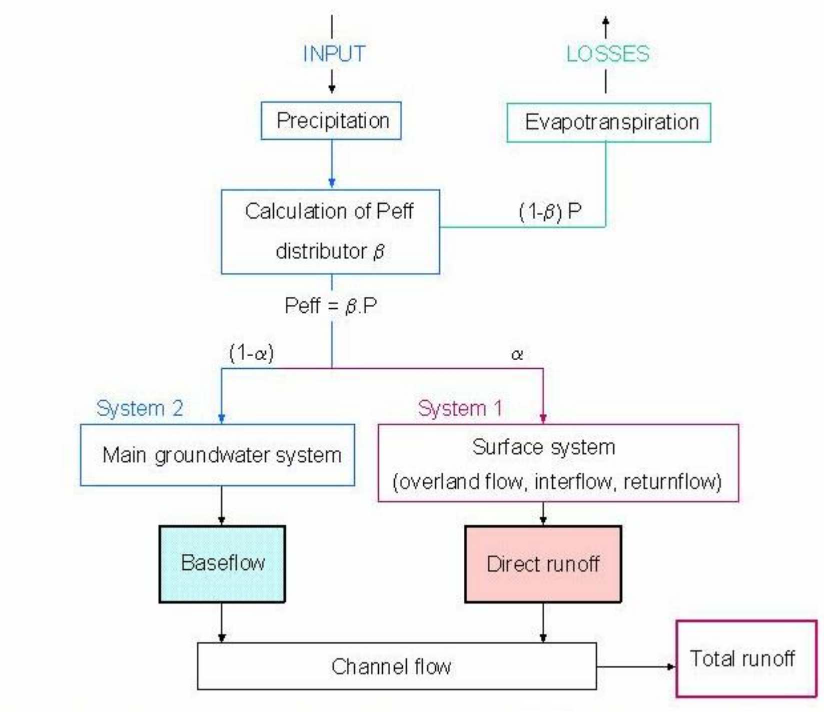
1. The West Cliff Stage 1 and 2 Emplacement is likely to contain a perched groundwater system (based in the mass of emplaced coal wash) that is likely to naturally exhibit a time-variable drainage resistance. Numerous studies over many years have shown that models which ignore the time-variable nature of <u>drainage resistance</u> often lead to significant errors in the analysis and prediction of both baseflow and direct runoff.
2. The RUNOFF model is parsimonious, being neither <u>too simplistic</u> nor <u>too complex</u> for the intended application but, most importantly, is mathematically defensible in its parametric characterization of the critically important

groundwater (baseflow) system. In particular, it enables determination of the all-important *reservoir coefficients* (otherwise known as times of response) for both the direct runoff and groundwater systems.

3. The RUNOFF model also solves for average Evapotranspiration (ET) over the study period, thus eliminating the need to arbitrarily choose a mean daily value for ET which may especially be in error where infiltration rates are such that a significant fraction of the percolating water may pass too quickly below a depth of about 2 m below ground level to be subject to ET processes. ***In our experience, this condition particularly applies in small catchments which have been significantly modified by mining-related activities and contain masses of relatively permeable materials such as waste rock dumps and coal washery reject emplacements.***
4. The model has the desirable facility to subject its derived system parameters to statistical sensitivity analysis enabling easy future parameter refinement in the event that improved hydrographic information becomes available.

Figure B.1 below shows the schematic layout of the catchment hydrological cycle that is the basis of the RUNOFF2005 model (Van de Griend et al. 2002).

FIGURE B.1: SCHEMATIC SHOWING CONCEPTUAL BASIS OF THE RUNOFF2005 MODEL.



The following list defines the hydrologic parameters input-to or output-from the model and identifies their common symbols as they are used and discussed in this report.

Pobs = observed precipitation (rainfall) daily or over the model simulation period (units of mm/day or mm/total simulation period)

β = beta = fraction of P entering catchment. Note that if all water entering the catchment eventually appears as outflow and none is lost to deep storage then the long term β equals the long term runoff coefficient.

ETsim = model simulated evapotranspiration (units of mm/day or mm/year). Therefore ETsim = (1-β)Pobs

Peff = effective precipitation i.e. precipitation entering catchment (i.e. Peff = βP) (units of mm/day or mm/total simulation period).

Peff(t) = β(t) * P(t) where P(t) is the precipitation during interval t. and where β(t) is a time-dependent parameter to relate the effective precipitation Peff to the Antecedent Precipitation Index (API) according to: β(t) = 1 – exp[-γ(API(t)] where:

γ = gamma = a catchment-specific fitting parameter (units of 1/mm) that determines the exponential dependence of β on API(t). Note that the value of β(t) is also specific to the length of the time interval used and that:

Antecedent Precipitation Index, API(t) = [API(t-1) + P(t)](K-API) where K-API is a pre-defined dimensionless model parameter which can be changed optionally. It is based on daily rainfall totals i.e. normalized to 'daily intervals' but automatically recalculated by the model for the actual interval duration. Default value for K-API = 0.75. It can be seen that K-API and gamma are the means by which the model adjusts Peff for the pre-existing wetness of the catchment.

α = alpha = fraction of Peff entering catchment leading to direct runoff (i.e. overland flow and interflow and returnflow).

1 – α = fraction of Peff entering catchment main groundwater system and not reporting to the direct runoff system.

Qobs = actual total volumetric flow past the gauging point daily or over the model simulation period (units of mm/day or mm/total simulation period).

Qsim = simulated total volumetric flow past the gauging point daily or over the model simulation period (units of mm/day or mm/total simulation period).

Qd = simulated volumetric flow past the gauging point contributed by the catchment surface system daily or over the model simulation period (units of mm/day or mm/total simulation period).

Jd = reservoir coefficient of the catchment direct runoff system (units of days).

The reservoir coefficient can be regarded as the bulk recession time constant or timescale of response for the direct runoff system as a whole. The direct runoff system, also sometimes called the quickflow system is taken to be that which produces overland flow and interflow and return flow (i.e. throughflow) from water perched in soils, talus rubble, swamps etc immediately following rain.

If only overland flow is involved then the reservoir coefficient is equivalent to the *time of concentration* of the catchment. *It is assumed, as do all common models, that the direct runoff system drains with a constant drainage resistance.*

Note that within the time span of Jd; (1-exp(-1)) = 0.63 = 63% of the equivalent Instantaneous Rainfall (event) leaves the catchment. Thus Jd in this model is defined slightly differently and is longer that the usual definition of lag times (peak centroid to centroid) adopted in other Australian models such as WBNM.

ΔS' = change in storage of all catchment storages (i.e. for <u>both</u> systems) which drain freely under forces of gravity. Examples of these are: emplaced coal wash, soil or swamp saturated zones, fractured outcrop or bedrock, slope talus rubble etc. This parameter is positive if the direct runoff (quickflow) system is being net recharged and negative if being net discharged (over the simulation period).

Jb = reservoir coefficient of the principal catchment groundwater system (units of days).

The reservoir coefficient can be regarded as the bulk recession time constant for the aquifer as a whole and has been long identified as the *aquifer response time*, *time-scale of response* or *hydrologic response time* (e.g. Terzaghi and Peck, 1948; Kraijenhoff van de Leur, 1958; Domenico and Miflin, 1965; Erskine and Papaioannou, 1997; Manga, 1999; Knight et al. 2005).

As noted, this parameter varies with drainage resistance and therefore will not be fixed but will cover a range of values which the RUNOFF2000 model attempts to estimate. For a non linear time-variable drainage resistance, the reservoir coefficient Jb = $A/Q^{\mathbf{B}}$ where A and B are dimensionless constants fitted by a non-linear optimization technique (the standard Levenberg-Marquardt method).

In the cases of both the Tahmoor and West Cliff coalwash emplacements we have found that the best fit for the groundwater reservoir coefficient has the form Jb = $A/Qb^{1.000}$, which implies that the depth (h) of accumulated perched groundwater in the coalwash is, at all times close to inversely proportional to the length (L) between the drainage boundary (ridgelines) and the respective subsurface drain and that the horizontal hydraulic conductivity (K) of the emplaced saturated coalwash is essentially constant everywhere at depth within the emplacement (Van de Griend et al. 2002). This is an important generic finding with respect to coalwash emplacements and must derive from the essentially homogeneous nature of the (water-holding) coalwash product, a condition which almost invariably does not apply in natural catchments.

ΔS'' = storage change of all catchment storages which hold water against the forces of gravity. Examples of these are: soil or swamp unsaturated zones, depression storages (e.g. dams) and canopy storage in trees. This parameter is positive if these storages are being net recharged and negative if being net discharged (over the simulation period). Over medium (typically one month or more) to long simulation periods ΔS'' is generally zero. In the case of the West Cliff coal wash Emplacement there are no depression storages upstream of Pond P4 and this parameter is thus reduced to zero.

τ = tau = translation time though a short linear channel to the gauging point.

Water Balance = ∑P = ∑Qsim + ∑ET + ΔS

where ΔS = ΔS' + ΔS''

E = Nash-Sutcliffe (model efficiency parameter (Nash and Sutcliffe, 1970) defined as follows:

$$E = 1 - \frac{\sum(Q^t obs - Q^t sim)^2}{\sum(Q^t obs - Q^m obs)^2}$$

where Q^ttobs = observed flow at time t

Q^tsim = model simulated flow at time t; and

Q^mobs = mean of the observed flow values over entire simulation period

B.2 MODELLING THE DESIGN MAXIMUM STORM

It is a NSW EPA policy guideline to require an installed sedimentation basin 'fully contain and treat' all of a 10 year ARI 72 hour storm. To our knowledge, this guideline still does not appear in any NSW Acts or Regulations (NSW EPA, 1996, 1997, Gutteridge, Haskins and Davey Pty Ltd., 1998).

In our view, this ‘guideline’ actually somewhat confuses the roles of water detention (i.e. a drainage or flood mitigation consideration) and water treatment and assumes that the latter is strictly dependent on the former. This is not the case. While the 72-hour storm represents a large volume of runoff the average rainfall intensity (and corresponding discharge) is quite low.

The design runoff that should be selected for sizing water quality controls is considerably different from that used for design of drainage facilities. For example, the damage done to a receiving water ecosystem by uncontrolled pollutant wash-off in 10 – 100 year ARI events is inconsequential compared to the hydraulic damage that results naturally to aquatic habitats from such events. In other words:

- drainage systems are designed for large infrequent runoff events (10, 20, 50 or 100 year ARI); whereas
- design events for runoff quality control are small, frequent events, with durations from the time of concentration of the catchment up to about 2 hours.

Best practice in the NSW coal mining industry favours the use of the peak discharge for the 10 year ARI storm, with the design duration being the time of concentration of the catchment (or subcatchment), to enable sizing of sediment control basins (Hannan, 1995).

Similarly, in the construction industry, a minimum of a 10 year design ARI storm of appropriate duration is typically selected for the design of all parts of ‘cut and fill’ phase sediment control structures subject to major storm through-flow (NSW Dept. of Housing, 1998).

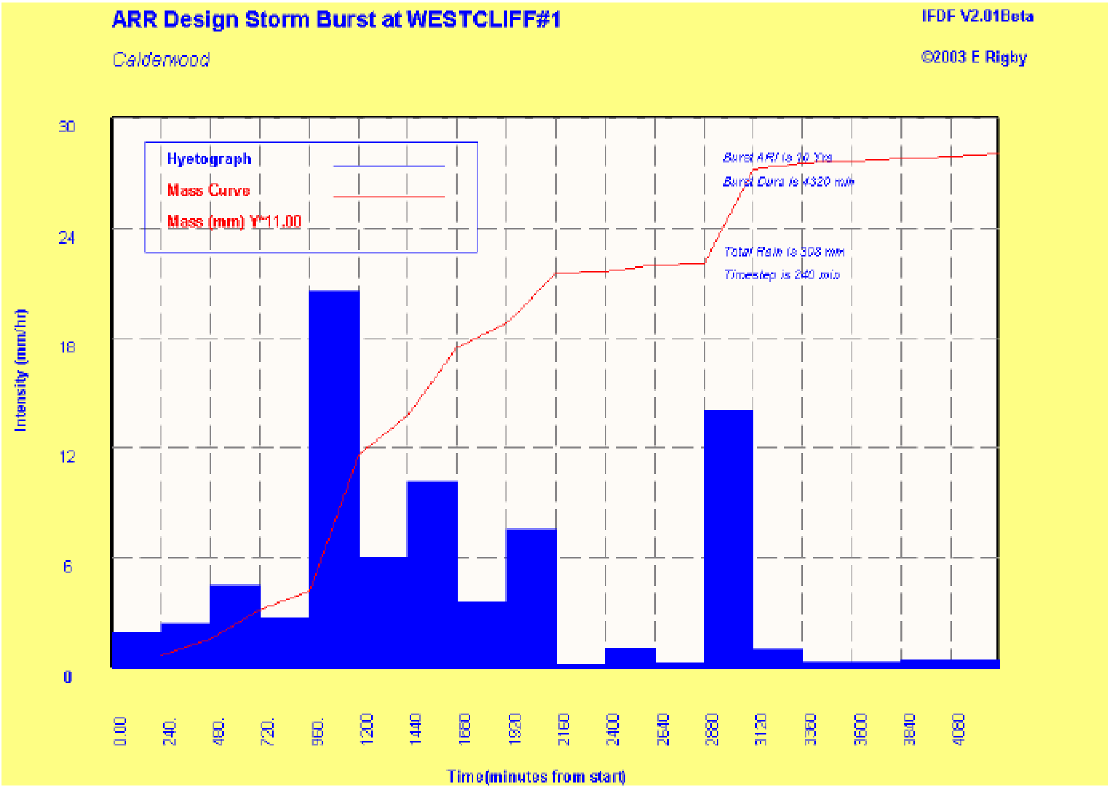
Nevertheless, the design storm still recommended by EPA and generally adopted within the NSW mining industry for many mine sites is the 10 year Average Recurrence Interval (ARI), 72 hour storm.

We have been advised this storm volume has been adopted by Cardno Forbes Rigby for the Stage 3 Emplacement project.

In our view, in the particular context of the West Cliff WMS this is probably a more rationally conservative decision than for some other sites which are discharging directly to the external receiving environment without recycling and reuse. This is because a major guiding principle of Emplacement water management should be to protect BCD as the primary clean water storage for the West Cliff WMS and not inadvertently convert it to a *de facto* sedimentation basin.

Cardno Forbes Rigby have estimated from standard hydraulic engineering principles (Institution of Engineers, Australia, 1998) that the total rainfall over the 72 hour period for such an event would be 308 mm, typically distributed sequentially over each of the three days into daily rainfalls of 150, 90 and 68 mm respectively as shown in **Figure B.6** below.

FIGURE B.6: ESTIMATED WEST CLIFF 10 YEAR ARI 72 HOUR STORM



Modelling the hydrologic effect of 10 year ARI, 72 hour design maximum storm event on the existing Emplacement with our parameter-optimised RUNOFF2005 model produced the outcomes summarised in **Table B.1** below.

TABLE B.1: MODEL OUTCOMES FOR DESIGN MAXIMUM STORM

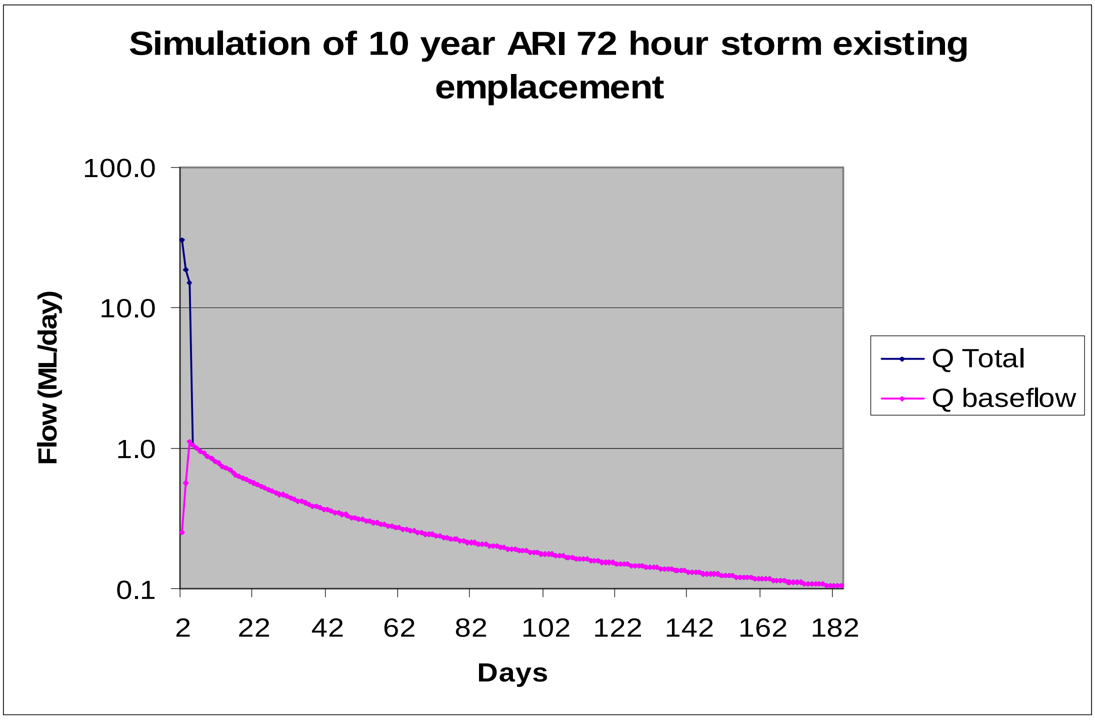
Day	Rainfall (mm)	Total Outflow (ML/day)	Subsurface Drainage (ML/day)	Direct Runoff (ML/day)	Cumulative Outflow (ML)	Cumulative Subsurface Drainage (ML)	Cumulative Direct Runoff (ML)
1	150	30.995	0.238	30.797	30.8	0.2	30.8
2	90	19.000	0.454	18.317	49.7	0.8	49.2
3	68	15.007	1.064	13.839	64.6	1.9	63.2
Total to Day 184	**308**	**65.002**	**1.756**		**112.6**	**49.4**	**63.2**

Our model predicts that after 3 days, a 10 year ARI, 72 hour design maximum storm event would have produced a total outflow of 65.0 ML from the Emplacement, comprising some 62.953 ML of direct runoff and 1.756 ML of subsurface drainage.

These outcomes were compared with equivalent outcomes from a WBNM-based model prepared by Cardno Forbes Rigby for the same storm. The Cardno Forbes Rigby model produced a total outflow from the Emplacement over 3 days of 66.7 ML. The excellent agreement between the RUNOFF2005-estimated total outflow over the 3 days of the maximum design storm (65.0 ML) and that estimated by WBNM (66.7 ML) is considered further validation of the RUNOFF2005-derived model.

The following **Figure 2.16** below shows the predicted peak outflow for the design maximum storm and predicted baseflow recession curve for the subsurface drainage. Drainage rates are predicted to fall to approximately 0.1 ML/day over a 6 month period.

FIGURE B.7: MODEL-PREDICTED TOTAL OUTFLOWS AND SUBSURFACE DRAINAGE BASEFLOWS FOR DESIGN MAXIMUM 10 YEAR ARI 72 HOUR STORM



The model estimates that during the 3 days of the maximum design storm and for at least 6 months following, a total of at least 49.438 ML of subsurface drainage will occur. This is equivalent to at least 97.2 mm of infiltration to the Emplacement over the 3 days of the design storm or at least 1.35 mm/hour,

An average loss rate through the 72 hours of at least 1.35 mm/hour is a not unreasonable value for infiltration by comparison with our field permeametric measurements (best estimate of lognormal mean 1.80+3.33/-1.17 mm/hour) and considering the relatively short duration involved.

Higher rates of infiltration (i.e. greater than an initial loss of 15 mm on the first and third days and a continuing loss of 1 mm/hour) over the 3 days of the maximum design storm would only lead to a lower daily outflow rate and lower total runoff for the 3 days.

A spreadsheet showing the model-predicted daily direct runoff and subsurface drainage rates and the cumulative volumes for a simulation period of 6 months is attached in the following **Appendix D** below.

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APPENDIX C

MODEL-PREDICTED HYDROLOGIC RESPONSE OF THE EXISTING EMPLACEMENT TO A DESIGN MAXIMUM 10 YEAR ARI 72 HOUR STORM

Days Since Storm Commenced	Rainfall mm/day	Total Outflow (ML/day)	Subsurface Drainage (ML/day)	Direct Runoff (ML/day)	Cumulative Total Outflow (ML)	Cumulative Subsurface Drainage (ML)	Cumulative Direct Runoff (ML)
1	150	30.777	0.249	30.528	30.8	0.2	30.5
2	90	18.888	0.571	18.317	49.7	0.8	48.8
3	68	14.956	1.116	13.839	64.6	1.9	62.7
4	0	1.058	1.058	0.000	65.7	3.0	62.7
5	0	1.006	1.006	0.000	66.7	4.0	62.7
6	0	0.958	0.958	0.000	67.6	5.0	62.7
7	0	0.915	0.915	0.000	68.6	5.9	62.7
8	0	0.876	0.876	0.000	69.4	6.8	62.7
9	0	0.840	0.840	0.000	70.3	7.6	62.7
10	0	0.807	0.807	0.000	71.1	8.4	62.7
11	0	0.776	0.776	0.000	71.9	9.2	62.7
12	0	0.748	0.748	0.000	72.6	9.9	62.7
13	0	0.722	0.722	0.000	73.3	10.6	62.7
14	0	0.697	0.697	0.000	74.0	11.3	62.7
15	0	0.674	0.674	0.000	74.7	12.0	62.7
16	0	0.653	0.653	0.000	75.4	12.7	62.7
17	0	0.633	0.633	0.000	76.0	13.3	62.7
18	0	0.614	0.614	0.000	76.6	13.9	62.7
19	0	0.596	0.596	0.000	77.2	14.5	62.7
20	0	0.579	0.579	0.000	77.8	15.1	62.7
21	0	0.563	0.563	0.000	78.3	15.7	62.7
22	0	0.548	0.548	0.000	78.9	16.2	62.7
23	0	0.534	0.534	0.000	79.4	16.7	62.7
24	0	0.521	0.521	0.000	79.9	17.3	62.7
25	0	0.508	0.508	0.000	80.4	17.8	62.7
26	0	0.496	0.496	0.000	80.9	18.3	62.7
27	0	0.484	0.484	0.000	81.4	18.7	62.7
28	0	0.473	0.473	0.000	81.9	19.2	62.7
29	0	0.462	0.462	0.000	82.4	19.7	62.7
30	0	0.452	0.452	0.000	82.8	20.1	62.7
31	0	0.443	0.443	0.000	83.3	20.6	62.7
32	0	0.433	0.433	0.000	83.7	21.0	62.7
33	0	0.424	0.424	0.000	84.1	21.4	62.7
34	0	0.416	0.416	0.000	84.5	21.8	62.7
35	0	0.408	0.408	0.000	84.9	22.3	62.7
36	0	0.400	0.400	0.000	85.3	22.7	62.7
37	0	0.392	0.392	0.000	85.7	23.0	62.7
38	0	0.385	0.385	0.000	86.1	23.4	62.7
39	0	0.378	0.378	0.000	86.5	23.8	62.7
40	0	0.371	0.371	0.000	86.9	24.2	62.7
41	0	0.364	0.364	0.000	87.2	24.5	62.7
42	0	0.358	0.358	0.000	87.6	24.9	62.7
43	0	0.352	0.352	0.000	87.9	25.3	62.7
44	0	0.346	0.346	0.000	88.3	25.6	62.7

45	0	0.341	0.341	0.000	88.6	25.9	62.7
46	0	0.335	0.335	0.000	89.0	26.3	62.7
46	0	0.330	0.330	0.000	89.3	26.6	62.7
47	0	0.325	0.325	0.000	89.6	26.9	62.7
48	0	0.319	0.319	0.000	89.9	27.3	62.7
49	0	0.315	0.315	0.000	90.2	27.6	62.7
50	0	0.310	0.310	0.000	90.6	27.9	62.7
51	0	0.305	0.305	0.000	90.9	28.2	62.7
52	0	0.301	0.301	0.000	91.2	28.5	62.7
53	0	0.297	0.297	0.000	91.5	28.8	62.7
54	0	0.292	0.292	0.000	91.8	29.1	62.7
55	0	0.288	0.288	0.000	92.0	29.4	62.7
56	0	0.284	0.284	0.000	92.3	29.6	62.7
57	0	0.281	0.281	0.000	92.6	29.9	62.7
58	0	0.277	0.277	0.000	92.9	30.2	62.7
59	0	0.273	0.273	0.000	93.2	30.5	62.7
60	0	0.270	0.270	0.000	93.4	30.7	62.7
61	0	0.266	0.266	0.000	93.7	31.0	62.7
62	0	0.263	0.263	0.000	94.0	31.3	62.7
63	0	0.260	0.260	0.000	94.2	31.5	62.7
64	0	0.256	0.256	0.000	94.5	31.8	62.7
65	0	0.253	0.253	0.000	94.7	32.0	62.7
66	0	0.250	0.250	0.000	95.0	32.3	62.7
67	0	0.247	0.247	0.000	95.2	32.5	62.7
68	0	0.244	0.244	0.000	95.5	32.8	62.7
69	0	0.241	0.241	0.000	95.7	33.0	62.7
70	0	0.239	0.239	0.000	95.9	33.3	62.7
71	0	0.236	0.236	0.000	96.2	33.5	62.7
72	0	0.233	0.233	0.000	96.4	33.7	62.7
73	0	0.231	0.231	0.000	96.6	34.0	62.7
74	0	0.228	0.228	0.000	96.9	34.2	62.7
75	0	0.226	0.226	0.000	97.1	34.4	62.7
76	0	0.223	0.223	0.000	97.3	34.6	62.7
77	0	0.221	0.221	0.000	97.5	34.9	62.7
78	0	0.219	0.219	0.000	97.8	35.1	62.7
79	0	0.216	0.216	0.000	98.0	35.3	62.7
80	0	0.214	0.214	0.000	98.2	35.5	62.7
81	0	0.212	0.212	0.000	98.4	35.7	62.7
82	0	0.210	0.210	0.000	98.6	35.9	62.7
83	0	0.208	0.208	0.000	98.8	36.1	62.7
84	0	0.206	0.206	0.000	99.0	36.3	62.7
85	0	0.204	0.204	0.000	99.2	36.5	62.7
86	0	0.202	0.202	0.000	99.4	36.7	62.7
87	0	0.200	0.200	0.000	99.6	36.9	62.7
88	0	0.198	0.198	0.000	99.8	37.1	62.7
89	0	0.196	0.196	0.000	100.0	37.3	62.7
90	0	0.194	0.194	0.000	100.2	37.5	62.7
91	0	0.192	0.192	0.000	100.4	37.7	62.7
92	0	0.190	0.190	0.000	100.6	37.9	62.7

93	0	0.189	0.189	0.000	100.8	38.1	62.7
94	0	0.187	0.187	0.000	101.0	38.3	62.7
95	0	0.185	0.185	0.000	101.2	38.5	62.7
96	0	0.184	0.184	0.000	101.3	38.7	62.7
97	0	0.182	0.182	0.000	101.5	38.8	62.7
98	0	0.181	0.181	0.000	101.7	39.0	62.7
99	0	0.179	0.179	0.000	101.9	39.2	62.7
100	0	0.177	0.177	0.000	102.1	39.4	62.7
101	0	0.176	0.176	0.000	102.2	39.6	62.7
102	0	0.174	0.174	0.000	102.4	39.7	62.7
103	0	0.173	0.173	0.000	102.6	39.9	62.7
104	0	0.172	0.172	0.000	102.8	40.1	62.7
105	0	0.170	0.170	0.000	102.9	40.2	62.7
106	0	0.169	0.169	0.000	103.1	40.4	62.7
107	0	0.167	0.167	0.000	103.3	40.6	62.7
108	0	0.166	0.166	0.000	103.4	40.8	62.7
109	0	0.165	0.165	0.000	103.6	40.9	62.7
110	0	0.164	0.164	0.000	103.8	41.1	62.7
111	0	0.162	0.162	0.000	103.9	41.2	62.7
112	0	0.161	0.161	0.000	104.1	41.4	62.7
113	0	0.160	0.160	0.000	104.2	41.6	62.7
114	0	0.159	0.159	0.000	104.4	41.7	62.7
115	0	0.157	0.157	0.000	104.6	41.9	62.7
116	0	0.156	0.156	0.000	104.7	42.0	62.7
117	0	0.155	0.155	0.000	104.9	42.2	62.7
118	0	0.154	0.154	0.000	105.0	42.3	62.7
119	0	0.153	0.153	0.000	105.2	42.5	62.7
120	0	0.152	0.152	0.000	105.3	42.6	62.7
121	0	0.150	0.150	0.000	105.5	42.8	62.7
122	0	0.149	0.149	0.000	105.6	42.9	62.7
123	0	0.148	0.148	0.000	105.8	43.1	62.7
124	0	0.147	0.147	0.000	105.9	43.2	62.7
125	0	0.146	0.146	0.000	106.1	43.4	62.7
126	0	0.145	0.145	0.000	106.2	43.5	62.7
127	0	0.144	0.144	0.000	106.4	43.7	62.7
128	0	0.143	0.143	0.000	106.5	43.8	62.7
129	0	0.142	0.142	0.000	106.6	44.0	62.7
130	0	0.141	0.141	0.000	106.8	44.1	62.7
131	0	0.140	0.140	0.000	106.9	44.2	62.7
132	0	0.139	0.139	0.000	107.1	44.4	62.7
133	0	0.138	0.138	0.000	107.2	44.5	62.7
134	0	0.138	0.138	0.000	107.3	44.7	62.7
135	0	0.137	0.137	0.000	107.5	44.8	62.7
136	0	0.136	0.136	0.000	107.6	44.9	62.7
137	0	0.135	0.135	0.000	107.8	45.1	62.7
138	0	0.134	0.134	0.000	107.9	45.2	62.7
139	0	0.133	0.133	0.000	108.0	45.3	62.7
140	0	0.132	0.132	0.000	108.2	45.5	62.7
141	0	0.131	0.131	0.000	108.3	45.6	62.7

142	0	0.131	0.131	0.000	108.4	45.7	62.7
143	0	0.130	0.130	0.000	108.5	45.9	62.7
144	0	0.129	0.129	0.000	108.7	46.0	62.7
145	0	0.128	0.128	0.000	108.8	46.1	62.7
146	0	0.127	0.127	0.000	108.9	46.2	62.7
147	0	0.127	0.127	0.000	109.1	46.4	62.7
148	0	0.126	0.126	0.000	109.2	46.5	62.7
149	0	0.125	0.125	0.000	109.3	46.6	62.7
150	0	0.124	0.124	0.000	109.4	46.7	62.7
151	0	0.124	0.124	0.000	109.6	46.9	62.7
152	0	0.123	0.123	0.000	109.7	47.0	62.7
153	0	0.122	0.122	0.000	109.8	47.1	62.7
154	0	0.121	0.121	0.000	109.9	47.2	62.7
155	0	0.121	0.121	0.000	110.0	47.4	62.7
156	0	0.120	0.120	0.000	110.2	47.5	62.7
157	0	0.119	0.119	0.000	110.3	47.6	62.7
158	0	0.119	0.119	0.000	110.4	47.7	62.7
159	0	0.118	0.118	0.000	110.5	47.8	62.7
160	0	0.117	0.117	0.000	110.6	48.0	62.7
161	0	0.117	0.117	0.000	110.8	48.1	62.7
162	0	0.116	0.116	0.000	110.9	48.2	62.7
163	0	0.115	0.115	0.000	111.0	48.3	62.7
164	0	0.115	0.115	0.000	111.1	48.4	62.7
165	0	0.114	0.114	0.000	111.2	48.5	62.7
166	0	0.114	0.114	0.000	111.3	48.6	62.7
167	0	0.113	0.113	0.000	111.4	48.8	62.7
168	0	0.112	0.112	0.000	111.6	48.9	62.7
169	0	0.112	0.112	0.000	111.7	49.0	62.7
170	0	0.111	0.111	0.000	111.8	49.1	62.7
171	0	0.111	0.111	0.000	111.9	49.2	62.7
172	0	0.110	0.110	0.000	112.0	49.3	62.7
173	0	0.109	0.109	0.000	112.1	49.4	62.7
174	0	0.109	0.109	0.000	112.2	49.5	62.7
175	0	0.108	0.108	0.000	112.3	49.6	62.7
176	0	0.108	0.108	0.000	112.4	49.7	62.7
177	0	0.107	0.107	0.000	112.5	49.9	62.7
178	0	0.107	0.107	0.000	112.6	50.0	62.7
179	0	0.106	0.106	0.000	112.7	50.1	62.7
180	0	0.105	0.105	0.000	112.9	50.2	62.7
181	0	0.105	0.105	0.000	113.0	50.3	62.7
182	0	0.104	0.104	0.000	113.1	50.4	62.7
183	308	113.063	50.379	62.684			

APPENDIX D

EMPLACEMENT WATER QUALITY MANAGEMENT AND MONITORING PLAN (VERSION 1)

D STAGE 3 EMPLACEMENT WATER QUALITY MANAGEMENT AND MONITORING PLAN (DRAFT)

D.1 CORE MANAGEMENT PRINCIPLES

As the Emplacement expands down Brennans Creek valley, only the area of rehabilitated land and land undergoing rehabilitation will increase in size, It is presumed that this area will continue to have all direct surface runoff diverted to clean water diversion drains down the western and eastern sides of Stage 3 in accord with the established paradigm for Stages 1 and 2.

Thus the progressively expanding area of rehabilitated land and land undergoing rehabilitation will only generate infiltration into the underlying coal wash to report to the northern end of the emplacement and be managed appropriately but the daily and cumulative volumes of the direct runoff component of total outflows form the emplacement will essentially remains the same (for any identical antecedent rainfall event).

In our view, the key principle of direct runoff equivalence but subsurface drainage progressive expansion should guide the design and operation of the water management system for the entire emplacement including the future phases of development of the proposed Stage 3.

It should be clearly understood and accepted by West Cliff management that arbitrarily increasing the active coal wash filling area does have:

1. an acute effect on both the volumetric generation rate <u>and</u> timescales of direct runoff throughout significant storm events; and
2. will increase the demands on the water management system; and
3. will increase the probability of uncontrolled transfer of dirty water into BCD, with all the consequent potential environmental and operational impacts listed at the end of **Section 2.1** above.

Therefore, we recommend that:

1. the active area of the emplacement <u>should be restricted to a maximum size</u> of (say) 18 ha plus 15% i.e. 20.7 ha any one time during filling of Stage 3; and
2. improved methods of drainage of the active area which are designed to slow down the rate of runoff from the active area and increase the rate of infiltration into the subsurface drainage system should be investigated, identified and then implemented wherever and however possible

D.2 PROPOSED CATCH PONDS DESIGN AND OPERATION

Our hydrologic model of the existing Emplacement used a value of 20.5 ha for the area of active filling, some 14% greater that the BHPBIC-declared likely average for the area of active emplacement at any one time.

This implies that direct runoff rates for the design maximum storm as described in **Section 2.3** and **Appendix 2** have a built in factor of safety of 14% if the active fill area is kept closely to the stated design average of 18.0 ha.

We have assumed that the active working area of emplacement will always be at least 18 ha at any one time and will not exceed (say) an area 15% larger (20.7 ha).

Therefore, on the basis of the model described in **Section 2.2** above, the modelling of an adopted 10 year ARI, 72 hour design maximum storm as described in **Section 2.3** modelling it is proposed that the following water management principles should be adopted for the Stage 3 Emplacement Water Quality Management Plan.

1. There is no need, and indeed it is unwise, to restrict total dirty runoff collection to a single catch pond. However, the minimum pond size downstream of the emplacement of each catch pond should be sized to capture and treat the first flush of direct runoff i.e. the first days runoff from the design maximum storm having a Hydraulic Residence Time (HRT) of at least 24 hours to contain the 1^{st} days runoff, to allow passive settling of coarse coal wash and to allow for 10% live capacity loss due to prior sludge buildup. In accord with standard practice the aspect ratio (length/width) of the catch pond should be at least 3 (Goldman et al. 1986).
2. Each phase of Stage 3 should be served by two sequential catch ponds sited down Brennans Creek valley. The 1^{st} two such catch ponds could be designated EP1 and EP2 for example. As each phase approached completion, and filling of the first catch pond is imminent, a new catch pond would need to be constructed, designated EP3 and so on.
3. It would be preferable to keep the upstream of each pair of catch ponds for 1st flush detention/passive settling of the 1^{st} days runoff of up to a design maximum 10 year ARI 72 hour storm, providing decantation via floating offtake up to a maximum design rate of 20 ML/day (0.22 m^3/s) to a 2^{nd} pond while dosing a cationic coagulant up to that maximum design dosing rate. Decantation in this manner is a practical proposition and could be achieved with (say) a 20 m length (L) of 250 mm internal diameter small bore PVC or reinforced concrete pipe through the catch pond wall. Taking in account frictional losses, under those conditions flow rates from a floating off take should range from about 6000 m^3/day (6 ML/day) for a head (H/L) of 0.01 (H = 0.2 m water depth in catch pond over pipe intake) up to about 37000 m^3/day (37 ML/day) for a head of 0.23 (H = 4.6 m water depth in catch pond over pipe intake), thus averaging just over 20 ML/day throughout a one day duration decant (Hannan, 1995).
4. Experience with coal wash and coal fines management indicates that the fine particle settling rate in the presence of a cationic coagulant dosed at the appropriate concentration would be at least 1 mm/s or 86 m/day. Allowing for a factor of safety 10 – 15 for turbulence effects this would ensure a clean water column depth developing at a rate of at least 5.7 m/day.
5. Coagulant dosing may be achieved by fitting a Parshall flume or similar flow measuring device to the inlet to the 2^{nd} pond (EP2 etc), generating a flow rate signal (covering at least the 2 – 20 ML/day range) to control a mobile, bank-mounted dosing plant at the inlet to the 2^{nd} catch pond.
6. In order to keep the 1^{st} pond as dry as possible over the long term, all subsurface drainage should be routed to either the 2^{nd} pond with an option to close that off and route to a point downstream of the 2nd pond. In the first few days of a much increased subsurface drainage rate the subsurface drainage is sometimes black but it quickly clears over 2 - 3 days. This means that there should be a facility to treat, in the 2^{nd} pond, the first 5 ML or so of

subsurface drainage. Therefore, the routed subsurface drainage line past the 1st pond should have a restricted T connection (fitted with a non-return valve) to allow a 1st flush of subsurface drainage to be manually directed into the 2nd pond.

7. The minimum total water treatment pond volume downstream of the emplacement should always be maintained to contain a 10 year ARI 72 hour storm and allow for approximately 3 – 5 ML of loss of live storage volume due to accumulated sludge, at any one time.
8. Both catch ponds should be fitted with staff level gauges and volume calibration curves established for each by analysis of AUTOCAD survey data.
9. There would need to be provision for access to each catch pond by an excavator or front end loader for regular de-sludging during dry weather periods.

D.3 MINIMUM WATER MANAGEMENT MONITORING REQUIREMENTS

D.3.1 Monitoring of Subsurface Drain Discharges into Perimeter Diversion Drains

A cumulative flow meter should be installed on the outlet from the Emplacement Subsurface Drain. This meter should preferably be of the magflow rather than impeller type.

Manual or automatic recording of cumulative daily flows through this meter should be made and if manually, regularly recorded daily between 6 and 9 am.

Manual field monitoring of the subsurface drainage stream should occur for pH, EC and Turbidity at least twice weekly,

Monthly samples should be collected, around the middle of each month, for analysis for the parameter set listed in **Table 1.1, Section 1.2** as for existing WMS monitoring POINTS 0, 9, 13, 14 and 15.

D.3.2 Chemical Monitoring of Direct Runoff into First Catch Pond.

At least twice weekly during visually significant flows (>1 L/s) manual field monitoring of direct runoff from the emplacement active area should occur for pH, EC and Turbidity.

When possible i.e. when flows are > 1 L/s, monthly samples should be collected, around the middle of each month, for analysis for the parameter set listed in **Table 1.1, Section 1.2** as for existing WMS monitoring POINTS 0, 9, 13, 14 and 15.

D.3.3 Hydraulic Monitoring of Decant from 1st to 2nd Catch Ponds

A data logger should be installed on the Parshall Flume-based inlet to the 2nd catch pond (e.g. EP2). Data on cumulative flow through the decant system to the 2nd catch pond should be downloaded daily.

At least twice weekly during decants from the 1st catch pond, manual field monitoring of the decant stream should occur for pH, EC and Turbidity.

D.3.4 Chemical Monitoring of Clarified Water from 2nd Catch Pond

At least twice weekly during visually significant decants (>1 L/s) field monitoring of clarified water decants from the 2nd catch pond (e.g. EP2) should occur for pH, EC and Turbidity.

When possible, monthly samples should be collected at this site, around the middle of each month, for analysis for the parameter set listed in **Table 1.1, Section 1.2** as for existing WMS monitoring POINTS 0, 9, 13, 14 and 15.

D.4 DAILY EMPLACEMENT WATER MONITORING REGIME

With respect to manual emplacement water management monitoring, it is proposed a competent operator(s) would carry out a daily monitoring regime. The timing of monitoring detailed here is approximate only and indicates the intent of information gathering. The programme should include as a minimum the following activities:

1. Record Subsurface Drain cumulative flow over the previous 24 hours at some fixed time between 6 and 9 am.
2. Record cumulative flow in the previous 24 hours of the 1st catch pond (e.g. EP1) decant to the 2nd catch pond (e.g. EP2) at some fixed time between 6 and 9 am.
3. Record the two catch pond (e.g. EP1 and EP2) level gauge readings at some fixed time between 6 and 9 am.

D.5 METHODOLOGY OF CHEMICAL MONITORING REGIME

Monitoring of the water levels in the 1st and 2nd catch ponds (EP1 and EP2 etc) should be made by manual recording of the level gauges installed in them.

Monitoring of daily rainfall would preferably be made by download of control room data from a new automatic West Cliff pluviometric monitoring station.

Monitoring of Temperature, pH and EC would be conducted at each designated water-monitoring site in accord with best practice and with NSW EPA guidelines. This means that:

1. Temperature should be monitored with a solid-state sensor and meter that had been recalibrated against a high precision certified thermometer at the beginning of each year of monitoring.
2. pH should be monitored with a probe and meter that had been freshly calibrated with a two-point calibration using pH 7.00 and 9.20 buffers at the start of each day of monitoring.

EC should be monitored with a Kappa = 10 probe and meter that had been freshly calibrated by a single point calibration using an EC = 2760 µS/cm (at 25 deg. C) standard electrolyte at the start of each day of monitoring.