GHD

Yallourn Energy Pty Ltd

Yallourn Mine Rehabilitation Concept Review

Report

January 2005

Executive Summary

Yallourn Energy Pty. Ltd. (YE) has prepared a Rehabilitation Master Plan for its Open Cut Coal mine (YE, 2001) (RMP) that will result in flooding of the mine forming two large lakes to a level of +38mRL, divided by the Morwell River diversion flowing in a canal. The lakes are to be filled by diversion of river flows from the adjacent Morwell and Latrobe Rivers. This report is a review of this RMP and the possible impacts on final water balance, water quality and costs of rehabilitation if no river diversion was to occur and all water was sourced from within the current Power Station and mine licence boundary.

On the basis of the assumptions made in this review, the lake surface level at water balance, based on no river diversions, was found to be +32mRL, which is 6m below the design level in the RMP of +38mRL. With no river diversion, the time to reach 99% of the final lake surface level was approximately 100 years after the mine closure.

Based on current dollar value of rehabilitation this review found the increase in rehabilitation construction costs due to the lower final lake level is approximately $320 000 (about 10-15% above current costs for the areas affected). These costs do not allow for rehabilitation scheduling and costs of "shore beaching" and batter shaping incurred due to exposure of coal batters. They also do not allow for the likely substantial issues that a much longer term filling regime presents in terms of safety, environmental, security and maintenance aspects.

Although it is noted that the lakes may not discharge to the local Rivers, and thereby may not be required to comply with the State Environment Protection Policy for the Waters of the Latrobe and Thompson River and Merriman Creek catchments S122 (1996), these lakes will be important water bodies for the region with potential value as important recreational and environmental resource, and it may be in the interests of YE to consider the social and community implications of not complying with the SEPP in the spirit of YE's environmental commitments.

Additional aspects of this review were:

- The effect of retaining Power Station discharge water for a period before closure of the mine to reduce the fill time of the lakes. This reduced the time to fill by approximately 5 years.
- The change to costs for rehabilitation for areas of coal batters and overburden dump that remained exposed due to the lower lake surface level. The additional rehabilitation required for the lower final lake level was found to increase costs by approximately 10-15% (additional area of exposed overburden dumps to be rehabilitated).
- Sensitivity of the water balance model to groundwater discharge and climactic data. Final water level was found be relatively insensitive to groundwater discharge rate however time to fill was much more sensitive.
- The consequences of sourcing all water from within the licence boundary on water quality. The result indicated salinity would continue to increase while the lakes were operated as a closed system.
- Acid mine drainage from internal overburden dumps and the perimeter overburden batters could reduce lake pH to around 5 during filling if no buffering or neutralisation process occurred.

- The effect on water quality of diverting 10 ML/day of river flow through the lake system was found to stabilise lake salinity however this was not sufficient to bring pH within the range specified in the SEPP for this site. This option would not adversely affect total river flows except for the section of river between water diversion into the lakes and the balancing outflow from the lake however salinity and acidity in the river downstream of the discharge would be affected.

This report is a review of the rehabilitation concept if no diversions from the Morwell or Latrobe Rivers occur and we make the following recommendations for further investigations:

Sources of Water

1. Further investigation of the groundwater run-off, in particular from the north-west section of the overburden layer, to better calibrate the model. Investigation of water sources of the drainage ponds would complement this study.
2. Quantify flow rate and water quality of overburden batter groundwater discharge to improve filling model and water quality model.
3. Design of local catchment management system to maximise water run-off within the mining licence boundary into the mine.
4. Investigate the potential and practicality to permanently divert a mean annual volume of 10 ML/day (3.7 GL/year) from Morwell and Latrobe River flow through the lake system for stabilising lake water quality.
5. Study of the hydraulic connectivity between the base of mine and underlying aquifers, particularly for undeveloped areas of East Field and the Maryvale mine to assess potential groundwater recharge from the lake system.

Coal Batter stability and Mine access

1. Analyse potential for coal batter instability from slower rate of filling and relatively longer period during which the batters will be less than 40% covered.
2. Potential implications and costs to control access to areas of coal batters during filling.

Costs of Rehabilitation

1. Detail design and costing of rehabilitation of Coal Batters; including need for regrading profile and re-shaping.

Water Quality – Salinity

1. Investigate potential approval of diversion of approximately 10 ML/day of surface waters through lake system.
2. Study of the hydraulic connectivity between the base of mine and underlying aquifers to assess potential groundwater recharge from the lake system.

Water Quality - Acidity

1. Management of acid mine drainage from overburden batters and capping material should address both the treatment of collected water and means for reducing acid production. Methods have been presented in the Earth Systems report (Draft, 2003) and interim rehabilitation plans for the need to consider rehabilitation of the overburden dumps to reduce infiltration and neutralise seepage.

2. Ash Management plan should ensure Power Station Ash is not located in areas of the mine where seepage from overburden batters and dumps can mobilise potentially toxic soluble in the ash.
3. Investigate need (if any) for additional interim rehabilitation of overburden capping layers and batters to reduce infiltration and stabilise capping material.
4. Investigate options for treatment of lake water to maintain pH ideally within SEPP Guidelines.
5. Study of the hydraulic connectivity between the base of mine and underlying aquifers to assess impacts of acidity on potential groundwater contamination from the lake system.

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1. Introduction

Yallourn Energy Pty. Ltd. (YE) has prepared a Rehabilitation Master Plan for its Open Cut Coal mine (YE, 2001) (RMP) that will form two large lakes with a surface at +38mRL, divided by the Morwell River diversion (MRD) flowing in a canal. The lakes are to be filled by diversion of river flows from the adjacent Morwell and Latrobe Rivers. Flooding is proposed to begin following the closure of the mine in 2032. The lakes and the original Open Cut mine are identified in this review as the "Township Field" (consisting of a number of connected sections of mine to the west of the MRD) and the "East Field/Maryvale Field", which includes the East Field extension section, which are to the east of the MRD.

The proposed source of water for flooding is primarily by diversion of up to 10% of flow from the adjacent Morwell and Latrobe rivers over a 10-year period.

This report provides a basic review of the plan and considers the consequences on the final water balance, water quality and costs of rehabilitation if no river diversion to flood the Mine occurred and all water was sourced from rainfall and groundwater catchment within the current Power Station and mining licence boundary through catchment management and groundwater seepage at the Mine batters. The provisional water balance is based on best estimates of rainfall, evaporation, groundwater infiltration and rainfall. A number of assumptions have been made in order to do this and to provide a broad view of the effects on the rehabilitation of the mine to allow management to determine further investigations.

1.1 Relevant Regulatory criteria

Surface waters in this area are protected by the State Environment Protection Policy for the Waters of the Latrobe and Thompson River and Merriman Creek catchments S122 (1996), (the SEPP, see Appendix C).

The lakes do not connect to surface waters and may not be subject to the SEPP. Groundwater is unlikely to be impacted due to the low permeability of coal seams and underlying interseams, which limit infiltration significantly and contamination of groundwater is considered negligible.

The current RMP does discuss the possibility of surface water through-flow as a component to maintaining water balance and water quality, in which case the SEPP will need to be considered. Other relevant statutory requirements are detailed in the RMP and should be referred to as necessary.

2. Rehabilitation Plan Review

YE has prepared a Mine Rehabilitation Master Plan (Dec 2001) (RMP) to manage ongoing operations of the open cut pits and to establish a sustainable long-term land use following mine closure. The open cut pits are to be flooded to +38mRL to create two large lakes, with the re-aligned Morwell River flowing through the middle in a canal formed in a large levee bank (known as the Morwell River Diversion – MRD). These lakes are in the Township Field including the Southern and Midfield overburden dumps to the west and the East Field and Maryvale Fields pits existing and planned to the east of the MRD. The water to fill the lakes comes from the proposed diversion of up 10% of the Latrobe River flow for 10 years. Progressive rehabilitation of the pits before flooding begins and during in filling will allow interim management of the site and prepare for eventual flooding.

The RMP was prepared in order to provide "*a guiding vision for the progressive repair or rehabilitation of its disturbed mining areas through to mine closure*". It recognises that with planned mining operations continuing for another 30 years, community expectations, government policy and mining and rehabilitation techniques may change and the RMP was designed for maximum flexibility while providing guidance to ensure a responsible, progressive implementation.

HRL (2000) estimated the final Township and Eastfield/Maryvale lake surface level if filling was solely due to local runoff and evaporation would be 29m below the lowest crest height (about +10mRL) and the deepest section of the lake would be 61m deep. This assumed there are no large shallow areas due to overburden distribution.

This report provides a review of these data if no diversion of river flows for flooding purposes is possible and includes an assessment of possible implications on:

- Filling time and final surface level,
- Rehabilitation planning and costs, and
- Lake water quality.

2.1 Operation of Mine and Review assumptions

As far as possible, current and planned operations have been incorporated into the review. As far as possible likely mining operations and final mine surfaces are based on extrapolation of current data or from discussions with Yallourn Energy and GHD's experience in the region.

Major Assumptions:

- Operations in the mine will continue as planned to finish in 2032 and filling can begin shortly thereafter. This implies overburden dumping will progress in Township Field to the final level as planned, and then be transferred to the East Field. Development of the Maryvale Field will progress with overburden deposited in the East Field pit.
- Conveyors carrying coal from the mine to the power station coalbunkers are assumed to remain in place until mine closure in 2032 and represent a maximum flood level of the mine during its operational phase. At its lowest level, this equipment is approximately at +11mRL, and this was used as the maximum flood level in the Township mine during mine operations.

- It is assumed as part of the YE planning strategy that the fire services and flocculation ponds presently located in the Township Field will be relocated to the East Field mine when overburden dumping operations cease in the Township Field.
- It is assumed the Mining Licence boundary can be used to define the catchment boundary for diversion of surface runoff to the lakes. Management of this catchment area beyond the cessation of mine operations and the filling period will be necessary to maintain the long term water balance of the lakes.
- For Scenario 2 (refer next page for description of scenarios), diversion of up to the entire current discharge licence volume (subject to approval by relevant regulatory and statutory authorities) into the Township Field could begin as soon as the overburden level within this mine has reached its final levels and infrastructure for the overburden distribution system and pumps for the existing ponds have been removed.

3. Water Balance

The water balance uses two scenarios to determine the time to reach equilibrium water depth. The catchment area of the mine based on the Licence boundary was 2500Ha.

Scenario 1

Filling the Mine beginning in 2032 following mine closure, using only catchment of water within the mining licence boundary. It is assumed capture of water run-off within the present mine-lease boundary is maximised using appropriate earthworks and drainage and all runoff is directed to the Mine.

Scenario 2

As an alternative to Scenario 1 flooding the Township Field mine while mining operations continue in the East Field/Maryvale Field by retaining water currently discharged from the fire service dam to the Morwell River. It was thought this may allow a faster filling schedule by capturing available water flows before the closure of the mine and reduce the time to reach final water level.

Water Balance

The boundary of the mining licence area was used as the catchment area for diversion of all surface flows (other than the riparian area of the sections of the Latrobe and Morwell Rivers that flow through the Mining Licence) into the mine.

The relationship between water volume, surface level and surface area is necessary to account for water volume, water depth and evaporation. Appendix A provides information on the development of the mine surface contours.

Balancing of the water levels between the western and eastern areas of the mine is assumed to be instantaneous once the level of both lakes have risen above the lowest tunnel level (approximately +11mRL) between the Township and Eastfield/Maryvale Fields beneath the Morwell River Diversion channel (MRD).

Groundwater

Yallourn Mine sits within the Gippsland Land Basin close to the northwestern margin of the basin. Coal is won from the Yallourn coal seam, which in this area is covered by a thin veneer of overburden.

Groundwater discharge occurs as seepage from overburden exposed at the batters and in the overburden dump at the base of the mine in the Township Field. Seepage may also occur from the internal overburden dump in the East Field pit when the Maryvale Mine is in full operation. Seepage from the overburden layer is due to infiltration of groundwater into permeable surface layers and the relative impermeability of the coal seam underlying the overburden resulting in discharge from the overburden layer at the edges of the mine.

The mine voids were divided into 11 separate sections and groundwater monitoring data for each section was used to define seepage. Two spreadsheets were used, one for seepage through the overburden and one for seepage through the coal.

The base of the mine is in the Yallourn Coal Seam, which typically has a hydraulic conductivity of 0.00085m/day. This is significantly lower than the overburden and underlying aquifer (k = 0.5-3 m/day), and it is assumed the Yallourn Coal measures underlying the site and forming the major batters to the sides of the mine act as aquitards.

The Coal Seam in this area does not contain extensive faulting. Although jointing does exist in the East Field, the connectivity with the underlying aquifer is unknown but is not considered significant. For the purposes of this study, the leakage from the lake into the underlying aquifer is negligible.

The interseam underlying the coal consists is of low permeability and considered an aquitard. The internal overburden dumps sits within the Yallourn Coal Seam. Discharge into the underlying aquifer is not considered significant.

The low conductivity interseam mentioned previously limits groundwater infiltration from the underlying aquifer and groundwater recharge from the water in the Mine pits. As such the groundwater is considered to discharge from the overburden on the pit margins, and infiltration of surface and rainfall through the overburden dumps. Groundwater discharge and recharge through the base and sides of the pit is considered negligible.

The seepage from overburden batters is not dependant on water levels in the void. It assumes that the coal measure underlying the overburden is basically an aquitard and the seepage face is controlled by the elevation of the base of the overburden. This is based on the observed seepage in the old mine which is typically seen at the base of the overburden (Bill Wood, pers. comm.). To define the base of the overburden which varies significantly over some sections, an average value of the top of batter elevation was determined from several points from each section and standard overburden thickness used to calculate elevation of base of the overburden. The average overburden thicknesses used were between 12 m and 20 m with 20 m used for Maryvale Field and 12 m for the Township Field and East field with the exceptions of East Field W and Township-E where 15 m was used. These values were estimated from the geological model.

The seepage from the coal is dependent on water levels in the void but overall is less due to lower permeability of the coal. Seepage values were incorporated into the water balance model.

The groundwater data was obtained from Bill Wood (YE) and the following bores were used:

- Overburden bores 13740, 13741 and 13766 for the southern section of Maryvale Field. This assumes the current distance to mine voids is applied to future mine void to take into account the dewatering which will occur due to mining of the Maryvale Field.
- Overburden bore 13704 for east section of Maryvale Field with an allowance made for the greater elevation to the east.
- Bores 31694 and 25216 used for northern section of East Field.
- Bores 24645, 24646 and 24741 for Township NW.
- Bore 24388 and 23994 and 25216 for Township N.
- Historical data from regional bore Narracan 4651 used for southern section of Township Field.
- Estimates of the river elevations were used for the river diversion sections.

Assumptions

- Yallourn Coal permeability is from "Science of Victorian Brown Coal" RA Durie, 1991, page 223.

- Higher permeability is used for the section of the Morwell River Diversion that is believed to be more fractured.
- Overburden permeability is from Pratt (GHD, pers. comm.) plus regional data.
- Water level in Yallourn Coal and overburden similar at distance from mine. This was assumed due to lack of data to verify otherwise.

Note that these estimates are preliminary. The main areas of uncertainty are the groundwater levels away from the mine in the areas not yet mined and nature of interaction between water levels in the coal and overburden close to the mine (i.e. is it valid to assume overburden seepage occurs along OB coal interface). The base of the overburden is well known from the geological model but varies significantly over some sections. The issue of how much seepage water is evaporated from the face is not addressed. Other issues such as the dumping of overburden against the batters in the Township Field were not taken into consideration as the internal dump was assumed to not extend to the overburden batters and seepage from coal is only minor input.

The groundwater contribution is a major source of water inflow into the pit (approximately 55% on average). Average seepage flow for the Township and East/Maryvale Fields are:

Township	9047 m^3/day
East/Maryvale	1377 m^3/day

The predominant source of groundwater flow into the Township Field is from the north west batters, where a relatively steep hydraulic gradient exists. Observation of the seepage from this area indicates the water volume is no more significant than other section of the mine.

A sensitivity analysis for the model using a reduction in total groundwater contribution to water balance by reduction of groundwater discharge by 50% and 100% was performed in order to assess the impact of groundwater on filling time and final surface level.

3.1 Yallourn Mine Water Balance

Description

A water balance assessment was undertaken to assist with costing of options for mine rehabilitation. The assessment was based on the following:

- Rainfall data from BoM station Morwell – Mail Centre (085062) was used for this assessment. The data was sourced from SILO, which included infilling (by extrapolation) for the period 1900 – 2004. This station was selected because it had the longest record period of actual data;
- SILO pan evaporation from the abovementioned station (085062) was also used for this assessment;
- Elevation/Volume/Surface Area obtained from mine survey data, which included in part estimated surfaces for mine completion levels.
- Groundwater seepage into each mine was estimated to be 275 ML/month into the Township Field and 30 ML/month into the East/Maryvale Fields (refer hydrogeological notes above).

Water Balance Modelling

The REALM water resources model was used to simulate water levels in the proposed lakes. The model was configured as follows:

- A monthly time step was used for the modelling;
- Inflow from surface runoff was estimated from rainfall and catchment area, and adopting a runoff co-efficient of 30%. The catchment area was calculated as the total area (constant) minus the surface area of the lake/s (variable).
- The net loss/gain due to rainfall and evaporation directly on the lakes was calculated using a pan co-efficient of 0.7. This corrects the ideal pan evaporation rate to typical evaporation rates for surface waters of lakes.
- Two simulation runs were undertaken. The first run was a 104-year simulation comprising a repeat of the full period of climatic record. The second simulation involved multiple year replicates. Using the 104 years of climate records, 70 time series with a duration of 30 years each were set up using different combinations of the climate data. This dataset provided 70 storage projections in which statistics can be obtained. This provides a range of lake depths at time following closure of the mine based on likely climate data.

3.1.1 Scenario Details

Scenario 1 - Filling from Surface Runoff

Assumptions:

- Inflows to the mine comes from surface runoff and groundwater seepage only,
- All Water loss from the lakes is from evaporation only,
- Water ponding above +11mRL in the Township Field is transferred to the East Field until the East Field reaches +11mRL
- The lakes are connected at +11mRL via Tunnels

3.1.2 Scenario 2 - Filling from Surface Runoff and River Retained River Diversions

- As above, with the retention of up to 50 ML/day (18 GL/annum) of discharge water presently pumped to the River by storage in the Township Field for the period up to 2032, up to a surface level of +11mRL (this level is constrained by the established coal conveyors).

Results

Scenario 1 (Surface Runoff and groundwater seepage): Figure 1 and Figure 2 show plots presented in terms of volume and elevation vs. time. These charts show that the Township Field fills to an elevation of +11mRL within 10 years. The Eastfield/Maryvale Field Mines takes an additional 37 years to reach + 11mRL. The graphs show that the storage level reaches an RL of +32mRL after the 104-year simulation period (based on the climatic and groundwater seepage data for the period 1900 and 2004), which is approximately water balance level.

The drawing in Appendix B shows the resultant final outline of the lake system for this scenario. In addition the interim area of the Township Field that is flooded during the equilibration period (below +11mRL) is shown shaded in purple, and the area of the East/Maryvale Field exposed above

-10mRL is shaded in blue. This is to provide an estimate of exposed surface approximately 35 years after mine closure as a guide to interim rehabilitation requirements.

The current RMP intends to rehabilitate the base of mine area for the period to 2020 as an interim rehabilitation for the Township Field Overburden capping layer and areas of the East Field, and that in general no additional rehabilitation is necessary for the exposed areas at base of mine.

Figure 1 Storage Volume (ML) in lakes following beginning of flooding in 2032

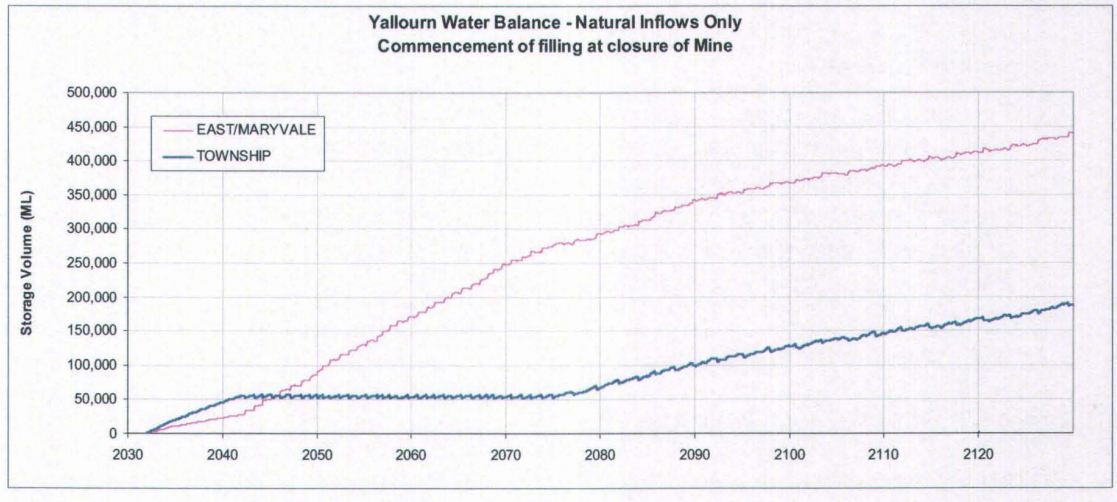
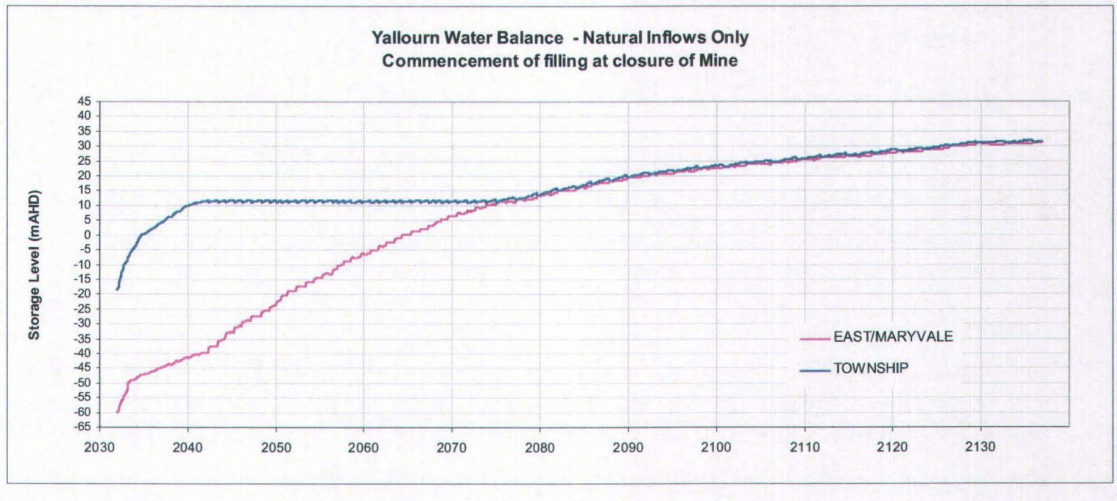


Figure 2 Surface Level (mAHD) in lakes following beginning of flooding in 2032



Scenario 2 (Surface Runoff + 18GL/year discharge from Power Station): The Township Field fills to an elevation of +11mRL within 5 years. No further filling of the Township Field nor East/Maryvale Field lakes can occur until the Power Station closes down due to conveyor infrastructure remaining in the Township pit. Equilibration of the two lakes occurs approximately 40 years after the Power Station closes.

An option that may be more acceptable for storage of discharge water while maintaining approximately normal river environmental flows would be to retain up to a maximum percentage of the Mine discharge flow so that filling of the Township field below +11mRL grade can occur over a longer period. This assumes the filling of Township Field below +11mRL grade can be extended over a (nominal) 20 year period,

This scenario would need re-configuration of the pumping operations planned for the mine. The Fire Service Pond (and any treatment facility for the future discharge of water) would need to be relocated east of the Morwell River Diversion to permit inundation of the Township Field to commence.

Sensitivity study

As the estimate of groundwater seepage was subject to greater level of uncertainty than the surface water flow, the sensitivity of the model to reduced groundwater inflow contribution to the filling of the Open Cut pits was investigated. In addition sensitivity of the water balance to variability in climactic data was investigated by determining the likelihood of achieving water balance levels during infilling.

Groundwater Sensitivity

Two models were run of the water balance model with groundwater flow reduced to 50% and 0% used for Scenario 1. Results are summarised in Table 1. The final lake level will be between +30mRL and +27mRL respectively. Time reach 99% of final level increases to 178 years with no groundwater contribution.

Table 1 Filling of Lakes based on percentage groundwater flow from design level

Groundwater Inflow	100 year Level	Time to equilibrate	Time to 99%	Final level
100% of Scenario 1	+31 mRL	42 years	100 years	+32 mRL
50% of Scenario 1	+22.6 mRL	64 years	N/A	+30 mRL
0% of Scenario 1	+14.5 mRL	85 years	178 years	+27 mRL

Depending on the groundwater contribution, the lakes will fill to between +27mRL and +32m RL. This range is considered relatively minor on the basis of the original design level of +38mRL, although the time to fill is increased by up to 78%, which may be significant. On this basis, the final lake level for the model is considered relatively insensitive to groundwater inflow.

Climactic Sensitivity

The water balance model was used to predict a range of possible future storage levels. The existing climate data provides 100 years of continuous records, which can be used to produce 1 storage projection with a duration of 100 years. From this data, another 70 climate sequences (with a duration of 30 years) were then produced using different combinations of the existing data. This is a simplified technique to produce multiple climate datasets, which represent the possible range of

climate conditions that may be experienced in this catchment. More sophisticated techniques for producing synthetic climate sequences were not considered warranted at this stage. The water balance model was then run another 70 times to produce 70 independent storage projections.

Using the 70 different storage projections for Scenario 1, a statistical assessment (to provide confidence limits) was then undertaken to determine the probability of achieving a certain storage level, over a specified (30 year) period of time. Table 2 shows the results of this assessment.

Table 2 Assessment of likelihood to fill based on climatic variability.

Water level (mAHD)	2037	2042	2047	2052	2057	2062
NATURAL INFLOW ONLY						
TOWNSHIP						
99%	**5.0**	**11.0**	**11.0**	**11.0**	**11.0**	**11.2**
90%	**5.2**	**11.1**	**11.2**	**11.1**	**11.1**	**11.2**
50%	**5.9**	**11.7**	**11.5**	**11.4**	**11.4**	**11.6**
10%	**6.4**	**11.8**	**11.9**	**11.7**	**11.8**	**11.8**
1%	**6.8**	**11.9**	**11.9**	**11.8**	**11.9**	**11.9**
EAST/MARYVALE						
99%	**-48.4**	**-40.5**	**-29.4**	**-19.9**	**-12.5**	**-4.7**
90%	**-48.1**	**-40.1**	**-28.0**	**-19.6**	**-11.3**	**-4.4**
50%	**-47.3**	**-37.9**	**-27.1**	**-17.8**	**-10.5**	**-3.7**
10%	**-46.7**	**-36.1**	**-25.7**	**-17.4**	**-9.2**	**-2.4**
1%	**-46.2**	**-35.8**	**-25.2**	**-16.2**	**-9.0**	**-2.2**

4. Progressive Rehabilitation Plan

Present plans for the rehabilitation of the site are based on flooding the pits to +38mRL level, which results in flooding up to the top of Coal Seam batters and benching with exposure generally of only the overburden batters. Scenario 1 estimates the mine floods to +32mRL, and the areas exposed above this level to +38mRL would require permanent rehabilitation.

The areas subject to either permanent inundation or areas for which interim rehabilitation have been proposed in the RMP have been altered by the effects of slower filling and lower level of final water balance.

Table 3 provides information on the significant rehabilitation changes required due to changes in the final surface level exposing areas of the mine between +38mRL and + 32mRL. Changes to costs due to area change have been estimated *pro rata* and where an area is exposed that requires a change in the nature of rehabilitation, the generic rate for rehabilitation as Open Woodland ($3675/Ha) has been applied. No additional costs for interim rehabilitation have been applied as these cost are considered built into the current cost model. Costs have been based on rates estimated in the most current Whole of Life Rehabilitation Provision (GHD, (draft) 2004) prepared for YE in September 2004.

Table 3 Costs change for affected rehabilitation work - Filling to +32mRL

Area*	RMP Planned End Use	Areas of Rehabilitation (+38 mRL)		Areas of Rehabilitation (+32 mRL)			
				Inundated		Woodland	
		Ha	Cost	Ha	Cost	Ha	Cost
1	Inundation	232	$ 249,189.86	165	$ 177,225.55	67	$ 246,225.00
4	Inundation	371	$ 790,660.81	361	$ 769,349.19	10	$ 36,750.00
6	Inundation	193	$ 19,523.83	160	$ 16,185.56	33	$ 121,275.00
12	Open woodland, some forest	58	$ 859,348.08			58	$ 859,348.08
14	Mixed woodland	32	$ 204,708.77			32	$ 204,708.77
	Sub Total				$ 962,760.31		$1,468,306.85
	Total		**$ 2,123,431.35**				**$2,431,067.15**
	Cost Increase						**13%**

* Areas are identified in the "Whole of Life Rehabilitation Provision – 2004 Review of Liability"

Batter Stability

Without diversion of river flows, the lakes take longer to fill (as noted above), and coal and overburden batters will also be exposed for a longer period. Geo-Eng (1995) noted the submerged coal batters are considered stable once submerged to 40-50% of final depth. This implies a slight increase in risk from extended exposure of batters less than 40% submerged during the filling process.

Shore "Beaching"

Costs for the RMP final rehabilitation plan with flooding to +38mRL included an allowance for a "shoreline" at approximately +38mRL to protect batters, especially on overburden dump areas, from erosion due to wave action. This was based on inundation of the worked out mine occurring over a relatively short period of time.

The revised inundation plan to +32mRL and over a considerably longer period will require a review of this design philosophy. This aspect has not been considered in any detail in this report and would be the subject of future work. The lower level of filling would reduce the overall perimeter length to be treated, however the vertical range over which beaching would be required would increase.

5. Water Quality

While the site is within the area identified as Segment E of the SEPP for Waters of the Latrobe and Thomson River basins and Merriman Creek catchment, relevant water quality guidelines for this segment are not necessarily applicable to this review. The SEPP is only triggered by the discharge of water to the catchment, which requires either:

- Surface discharge to the Morwell or Latrobe Rivers: or,
- Hydrogeological connection to an aquifer that discharges to catchments identified in the SEPP.

While the lakes are filling, discharge to surface waters is highly unlikely, and the impermeability of the underlying formation and coal batters will prevent recharge of water exceeding the SEPP to adjacent aquifers. As the final water level is below the overburden layer, impacts of lake water potentially exceeding the SEPP are highly unlikely.

The SEPP (Appendix C) for surface waters specifies TDS must be less than 700 mg/L, the annual 90^{th} percentile of TDS must be less than 500 mg/L, and pH must be within the range of 6 to 8.5.

These will be used as guideline values for the lake system, although no discharge of lake water to surface waters is possible for a closed system and therefore the lakes are not required to meet the current SEPP. Water infiltration into the ground is limited by the relatively impermeable coal seam underlying the site. Fracturing of coal and the underlying interseam is limited and is not thought to increase infiltration significantly.

5.1 Salinity

Surface water run-off from areas with ground cover will typically have low salinity and sediment load, however internal catchment may result in sheet flow over overburden capping layers and exposed coal and ash dumps that may leach salts, acid mine water and trace metals (HRL, 1998).

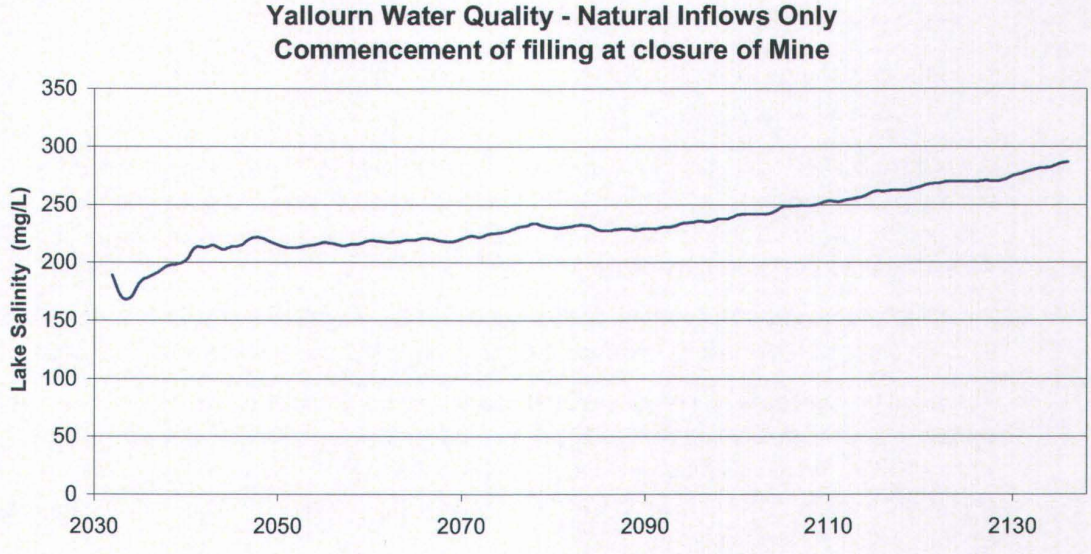
Groundwater discharge to the mine will occur primarily as seepage from the exposed overburden layer around the perimeter of the mine. The Yallourn coal measures, though thicker, have hydraulic conductivity orders of magnitude smaller and acts as an aquitard. Similarly, infiltration into the internal overburden dumps will generally discharge into the lowest point of the mine above the remaining coal seam underlying the base of mine.

Water chemistry data provided by YE (K Brown, pers comm.) for the drainage ponds in Township Field and East Field between June 2001 and July 2003 indicate average salinities of 450 mg/L and 710 mg/L respectively for water pumped from the ponds.

A water chemistry balance model was developed using annual water balance data for Scenario 1 and average groundwater water quality of 450 mg/L for Township Field and 710 mg/L for East/Maryvale Fields. The lake salinity during filling is shown in Figure 3 and shows a steady increase of salinity for the lakes. The modelling indicates the lakes will not exceed the 90^{th} percentile concentration specified in the SEPP (TDS > 500 mg/L) until around 2230. As noted in the Introduction, while the lakes remain isolated from the Latrobe and Morwell River catchments and groundwater aquifers, the lakes may not need to meet the relevant SEPP guideline values.

The model assumes the water quality of the groundwater remains constant, complete mixing of the lake water (i.e. no stratification), no interaction of dissolved solids with sediments or biological activity and no changes to water quality for the period under investigation.

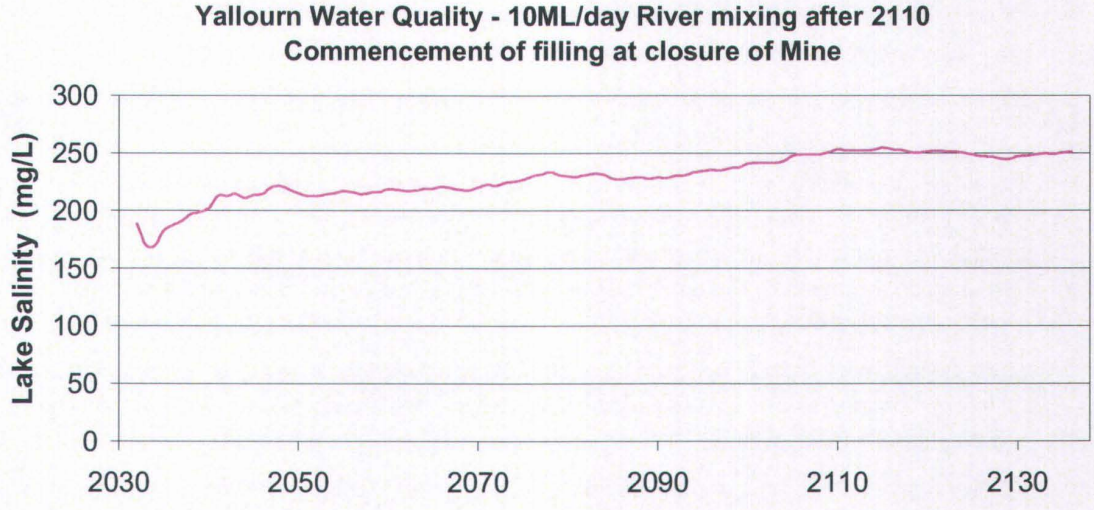
Figure 3 Water Quality for lakes system during period of infilling



The model was then modified to see the effects on lake water quality from diversion of 10 ML/day from the Morwell River (with subsequent pumping from the lake of the same amount of water to maintain river flows) from about 2110. Using this process, the lake salinity stabilises at around 250 mg/L (Figure 4) after river diversion begins.

A model provided by HRL (2000) indicated water quality in the Yallourn lakes would exceed 700 mg/L within 500 years with a daily inflow from the river limited to 5 ML/day (1825 GL/year). The present review broadly supports that conclusion.

Figure 4 **Water Quality for lakes system during period of infilling with diversion of 10 ML/day from river from 2110**



This design concept requires further work outside the scope of this study. Potential problems exist with release of lake water to the river due to the potential acidity of the lakes as noted in the section below. Changes to the requirements of the SEPP for this area cannot be foreshadowed at this stage.

5.2 AMD/acidity

The internal overburden dump in the Township Field has been identified as a source of acid mine drainage, with additional contribution from the overburden batters, which is attributed to the presence of pyrite in the overburden (HRL, 1998). Drainage water with pH as low as 3.49 has been pumped from the Township Field section of the mine (K. Brown, pers comm.).

A draft study of the acid production potential of the overburden dumps (Earth Systems, 2003) indicates approximately 250 tonnes of sulphuric acid was produced annually although no appreciable loss of water quality was noted in the water discharged from the site. The acid production was determined by the decrease in alkalinity between the Latrobe River supply water and water discharged from the site, which effectively consumed 189 tonnes of $Ca(OH)_2$ a year and is buffering the acid production in the mine.

Submergence of the overburden dumps will eventually halt acid production and discharge from the overburden capping layer as the hydraulic gradient and potential for oxidation through the internal dumps is reduced, although discharge of acidic groundwater may continue from the overburden batters. Figure 2 shows the flooding of the internal overburden dumps does not occur for a minimum of 40 years from the end of mine operations. During this time potential discharge of acid may occur into the lake system which will impact on the lake chemistry unless other actions are taken to neutralise or halt acid drainage production.

For the water model developed, and assuming:

- All the acid produced from the existing overburden dumps remains in solution,
- Complete mixing of the water, and
- No other reactions occur,

then the approximate pH of the water will be between 5 and 6. This does not comply with the SEPP values for the adjacent surface water segment (Segment E).

Currently the acidity of groundwater discharged into the Mine is buffered by the alkalinity of water from the Latrobe River used by the Power Station and discharged to the mine. Following closure of the power station, this will no longer occur and ongoing buffering of this acidity (eg due to sediment interaction) is limited by the organic acids present in exposed coal faces, and the slightly acidic nature of rainwater.

Diversion of river flows of approximately 10 ML/day through the lake system would reduce acidity through dilution, however the water discharged to the river would require treatment until lake water quality met SEPP criteria.

This length of time would depend on lake stratification and buffering reactions available in the river water. The possible acid-sediment interactions and buffering capacity of the system requires further investigations. The potential for early filling of the Township Field and ongoing buffering of acid mine water drained from the overburden by mixing with Power Station discharge water may maintain pH levels of the lake system during flooding. These studies are outside of the scope of this review but are recommended for further investigation.

5.3 Stratification

HRL (1998) concluded the Township and East/Maryvale Field lakes would most likely exhibit stratification. This produces gradients in temperature and chemistry between the near surface and deeper lake. Warmer water, lower salinity and higher oxygen concentrations would be found at depths above 5 to 12 metres and a distinct reduction in temperature and increase in salinity would be found below this. The transition may be abrupt as found in the Yallourn North Extension Open Cut (YNEOC) lakes (HRL, 1998). This would appear during summer, but surface cooling in winter may be sufficient to promote turnover of the water allowing mixing of lakes waters on an annual basis.

Low oxygen concentration would be likely to occur at depth while the lakes were stratified, which may inhibit biological activity at depth. If turnover occurred during winter, low oxygen concentrations could adversely affect biological activity at the surface.

Until the lakes are established, it is hard to predict exactly the nature of the stratification and the likelihood and effects of annual turnover. Stratification could have important implications for lake water quality by quarantining salinity at deeper levels where sediment interactions may alter water chemistry. This study is outside of the scope of this review but is recommended for further investigation.

5.4 Impacts on beneficial uses

The models developed for this review indicate that using local catchment for supply of water to flood the mine may result in non-compliance of water quality in the lake system with the SEPP. While the

lakes remain isolated from surface waters, they may not need to comply with the SEPP, but acidity may exceed SEPP guidelines within the filling period of the lakes.

Further work is recommended to assess the flow rate and salinity of groundwater seepage from the overburden batters, and the potential acid production capacity of the overburden dumps in the mine. Water treatment may be required as an interim measure during lake filling, particularly while acid release from internal overburden dumps continues.

As a general consideration it is noted these lakes will be important water bodies for the region, and it may be worthwhile to consider the social and community implications of not complying with the SEPP in the spirit of the stated environmental commitments when setting guideline values for lake water quality during further development of the rehabilitation plan.

6. Conclusions

Equilibrium Depth and Filling Time

The Rehabilitation Management Plan prepared by Yallourn Energy (YE, 2001) was reviewed and the filling time and water balance for the Township and East/Maryvale Field pits using water capture only from the within the licence boundary including groundwater discharge from overburden batters around the perimeter of the mine was determined.

Based on the model developed for this review, the time to fill to 99% of the final level was found to be approximately 100 years from the start of filling (approximately 2132).

The final water level was determined to be +32mRL, which is 6 metres below the RMP design level of +38mRL.

Diversion of water presently discharged from the site by retention in the Township Field reduces the time to fill by 5 years.

The sensitivity of the model was investigated by reducing the groundwater seepage to 50% and 0% of modelled volumes. The equilibrium lake surface level was found to be +30mRL and +27mRL respectively. The time for the lake to approach 99% of water balance increased to 178 years for the zero-groundwater model. It was therefore concluded that the final surface level was relatively insensitive to groundwater inflow but filling time was more sensitive.

Rehabilitation costs

Based on current dollar value of rehabilitation this review found the increase in rehabilitation costs due to the lower final lake level is approximately $320 000 (about 10-15% above current costs for the areas affected). These costs do not allow for rehabilitation scheduling and changed costs of "shore beaching" and batter shaping incurred due to longer filling time and exposure of coal batters.

Water Quality - Salinity

The model developed for this review indicates there is potential for salinity of the lake system to exceed the SEPP 90th percentile value of 500 mg/L by 2260.

The model found that diverting approximately 10 ML/day through the lakes system beginning in 2110 would stabilise salinity of the lakes below 250 mg/L.

Water Quality - Acidity

The model developed for this review indicates the potential for acidity in the lake system to exceed the range prescribed in the SEPP of 6 to 8.5 during and after filling. The model developed for this review indicated a pH of about 5 was possible about 40 years after filling began. As the internal overburden capping layer remains exposed longer, acid mine drainage may continue for longer and therefore reduce water quality.

The review found the acidity of the lakes would be affected by the lack of ongoing mixing of the Township and East/Maryvale Field lakes with surface waters, particularly after the mine has filled. Diversion of approximately 10 ML/day through the lake system would reduce acidity, however the water discharged to the river would require treatment until lake water quality met SEPP criteria. This

length of time would depend on lake stratification and buffering reactions available in the river water, which is outside the scope of this review.

Water Quality - Stratification

Stratification would most likely occur in the lakes resulting in reduced salinity at the surface and decreased temperatures at depth. It was not possible given limited present knowledge to predict whether or not turnover (or de-stratification) would occur during winter.

7. Recommendations

Sources of Water

1. Further investigation of the groundwater discharge, in particular from the north-west section of the overburden layer, to better calibrate the model. Investigation of water sources of the drainage ponds would complement this study.
2. Quantify flow rate and water quality of overburden batter groundwater discharge to improve filling model and water quality model.
3. Design of local catchment management system to maximise water run-off within the mining licence area into the mine.
4. Investigate the potential and practicality to permanently divert a mean annual volume of 10ML/day (3.7 GL/year) from Morwell and Latrobe River flow through the lake system for stabilising lake water quality.
5. Study of the hydraulic connectivity between the base of mine and underlying aquifers, particularly for undeveloped areas of East Field and the Maryvale Field to assess potential groundwater recharge from the lake system.

Coal Batter Stability and Mine Access

1. Analyse potential for coal batter instability from slower rate of filling and relatively longer period during which the batters will be less than 40% covered.
2. Potential implications and costs to control access to areas of coal batters during filling.

Costs of Rehabilitation

1. Detail design and costing of rehabilitation of coal batters; including need for regrading profile and re-shaping.

Water Quality – Salinity

1. Investigate potential approval of diversion of approximately 10 ML/day of surface waters through lake system.
2. Study of the hydraulic connectivity between the base of mine and underlying aquifers to assess potential groundwater recharge from the lake system.

Water Quality - Acidity

1. Management of acid mine drainage from overburden batters and capping material should address both the treatment of collected water and means for reducing acid production. Methods have been presented in the Earth Systems report (Draft, 2003) and interim rehabilitation plans for the need to consider rehabilitation of the overburden dumps to reduce infiltration and neutralise seepage.
2. Ash management plan should ensure power station ash is not located in areas of the mine where seepage from overburden batters and dumps can mobilise potentially toxic soluble in the ash.
3. Investigate need (if any) for additional interim rehabilitation of overburden capping layers and batters to reduce infiltration and stabilise capping material.

4. Investigate options for treatment of lake water to maintain pH ideally within SEPP Guidelines.
5. Study of the hydraulic connectivity between the base of mine and underlying aquifers to assess impacts of acidity on potential groundwater contamination from the lake system.

8. Limitations

This Yallourn Mine Remediation Concept Review has been prepared in accordance with the scope of works provided by GHD in our letter of 25 June 2004. The report is based on information obtained from previous works and from Yallourn Energy Pty Ltd. GHD has accepted this information in good faith.

Estimates of water balance, rehabilitation costs and water chemistry are based on information provided by Yallourn Energy and third parties. GHD does not accept responsibility for the consequences of significant variations in the information.

This report should not be altered, amended or abbreviated, issued in part or issued in any way incomplete without prior checking and approval by GHD.

GHD accepts no responsibility for any circumstances that arise from the issue of the report that has been modified in any way as outlined above.

9. References

Australian and New Zealand Environmental and Conservation Council, Australian Water Quality Guidelines for Fresh and Marine Waters, 2000.

Deed, R, Expected Quality of Water in Flooded Latrobe Valley Open Cuts, SEC, Report 314, 1975.

Durie, RA (Ed). 'The Science of Victorian Brown Coal', Oxford, 1991.

Earth Systems, Quantifying the Impact of Acid Mine Drainage and Developing Management and Treatment Options (Draft Report), April 2003.

EPAV, Schedule F5, State Environment Protection Policy for the Waters of the Latrobe and Thompson River and Merriman Creek catchments, S122, Victorian Government, 1996.

Geo-Eng, Assessment of Mine Batter Stability during proposed flooding to +38mRL , June 1995.

Geo-Eng, Review of Provision for Site Restoration, December 1995.

GHD, Whole of Life Rehabilitation Provision – 2004 Review of Liability (Draft Report), September, 2004

HRL, Factors affecting water quality in a flooded brown coalmine, August 1998.

HRL, Prediction of Water Quality in Flooded Open Cut Brown Coal Mines in Victoria, July 2000.

SKM, Maryvale Project Morwell River Diversion: Functional design, Geotechnical investigation and Design, Environmental Effects Statement, Maryvale Coal Field Development, AGC-Woodward Clyde, Supplementary Reports, Vol. 2, 1999.

Yallourn Energy Pty. Ltd., Mine Rehabilitation Master Plan, December 2001.

YOC Rehabilitation Master Plan Geotechnical and Groundwater Considerations, 1992.

YOC Mine Rehabilitation Assessment of Open Cut Stability, 1993.

Appendix A

Surface of Mine at End of Operations

3D Surface Creation Methodology

In order to determine the water balance and determine the outline for the final lake system, the relationship between the final surface contours of the base of mine and internal overburden dumps, pit volume at each elevation was established.

A combination of:

- Existing topographic survey information (including worked out mine surfaces),
- Design surfaces for overburden dumps in Township, East and Maryvale Fields,
- Design surfaces for the final worked out East and Maryvale Fields, including "Bottom of Coal" information,

was used to create a single 3D file for the final mine shape.

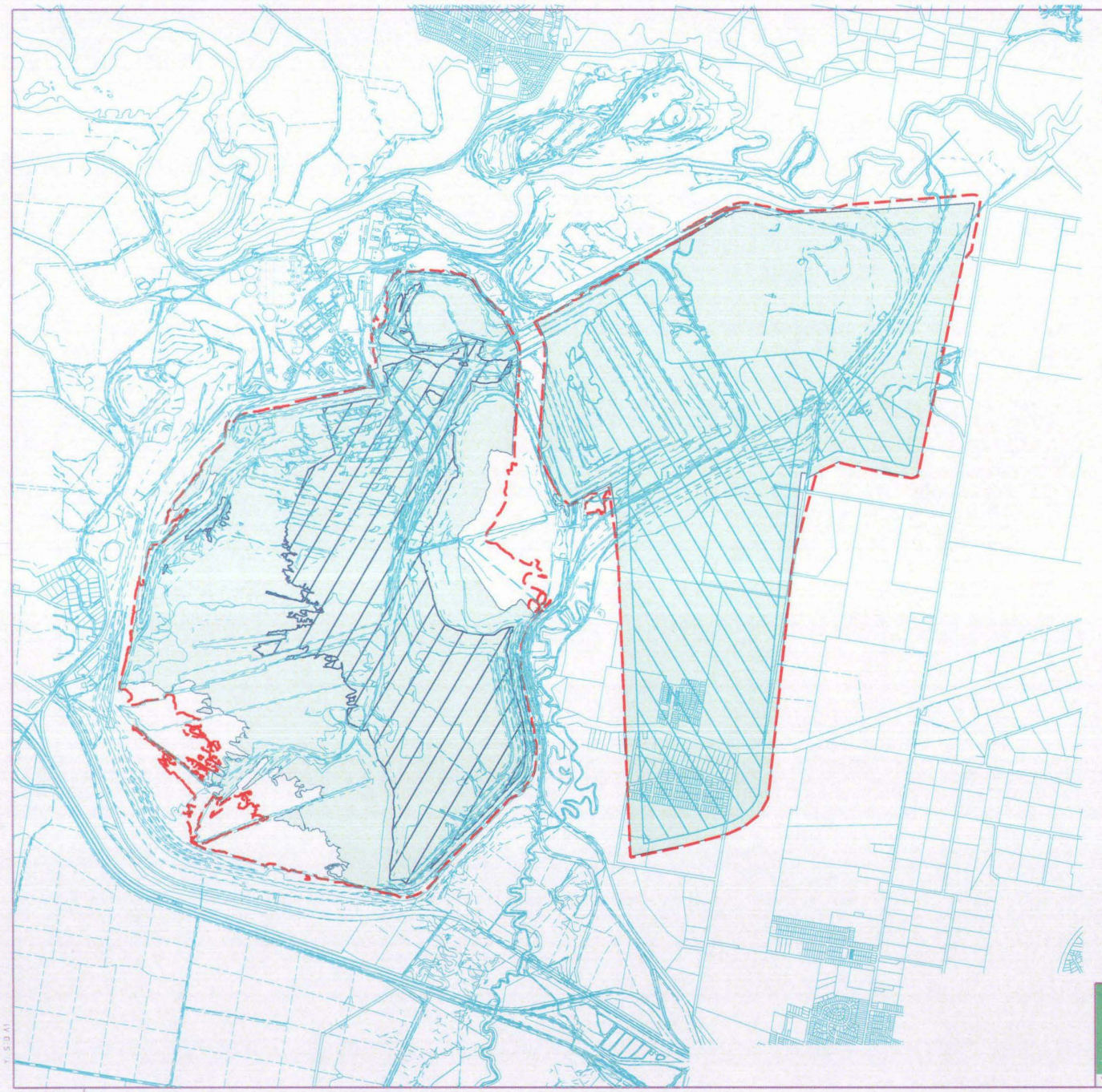
This information was supplied by Yallourn Mine Alliance (YMA) in Microstation format, some specifically for this job, and some already in hand from previous work. Manipulation of this data to create a single surface was performed by GHD.

It should be noted that design of the overburden dumps, especially in East and Maryvale Fields is subject to change, and that the final inundated surface at a given level may change from that shown in this report. This is important to note that in the situation where a nominal change in dump height may significantly change the plan area of inundation, that there will be a corresponding change in total evaporation.

Levels at the inverts of conveyor tunnels through the Morwell River Diversion were supplied by YMA, while approximate dimensions of the tunnel cross-sections were supplied by the MRD group of RTL.

Appendix B

Lake Outlines for Scenario 1



500 250 0 500 1000 2000

SCALE

N

LEGEND

INUNDATION TO RL –10
IN MARYVALE FIELD

INUNDATION TO RL 11
IN TOWNSHIP FIELD

INUNDATION TO RL 32
IN BOTH TOWNSHIP & MARYVALE
FIELDS

INUNDATION TO RL 38
IN BOTH TOWNSHIP & MARYVALE
FIELDS

YALLOURN
Yallourn Energy Pty Ltd

Yallourn Energy Pty Ltd
Mine Rehabilitation

Drg No
31 15555 C001 A 23-8-04

Approved

Date
11-01-05

YALLOURN MINE
REHABILITATION CONCEPT REVIEW
WATER BALANCE AREAS

G:\31 1484904\drawings\yef 31 15555 c001

565 x 807mm

Appendix C

State Environment Protection Policy (Waters of Victoria)

Schedule F5 - Waters of the Latrobe and Thomson River Basins and Merrimans Creek Catchment

State Environment Protection Policy for Surface Waters in the Latrobe Valley

The Victorian Government issued a State Environment Protection Policy for the Waters of the Latrobe and Thompson River Basins and Merriman Creek catchment, No S122 (EPA, 1996) (the SEPP). The Latrobe and Morwell rivers in the area of the Open Cuts and downstream to coordinate 470 000E are in Segment E of the Catchment and require protection of the following Beneficial Uses:

1	Maintenance of natural aquatic ecosystems	Modified ecosystem with some habitat values	Excluding Avon river downstream of Redbank, Morwell River downstream of Eel Hole creek and Bennetts Creek
		Highly modified ecosystem with some habitat values	Morwell River downstream of Eel Hole creek and Bennetts Creek
3	Recreation	Primary Contact (eg. swimming, water skiing) Secondary Contact (eg. boating and fishing) Aesthetic enjoyment (eg. walking by waters)	
4	Agricultural Water Supply		
5	Fishing and Aquaculture	Stock watering	
		Irrigation	Excluding estuarine areas
6	Industrial Water use		
7	Aquifer Recharge		

Water Quality to be maintained for this catchment are specified in the Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC, 2000), subject to sub-clause 8.3 of the SEPP which specifies in-stream Water Quality indicators and objectives for particular segments identified in the Catchment. For Segment E these are provided in Table 1 below:

Table 1 Water Quality indicators and objectives and acceptable variations for Segment E

Indicator		Criterion	Acceptable variation	
pH (pH units)	Acceptable range	6.0-8.5	Variation from N[a]	<1
Dissolved Oxygen (mg/L or % saturation)	Min concentration	<5.0		
	Min saturation	<55%		
Toxicants (formula)	Max	<T[b]		
Salinity (mg/L)	90th percentile	<500 except Latrobe River upstream of Glengarry Rd in which <350 shall apply	% increase	<10%
	Max	<700 except Latrobe River upstream of Glengarry Rd in which <400 shall apply	% increase	<10%
Suspended Solids (mg/L)	50th percentile	<50 except Latrobe River upstream of Glengarry Rd in which <35 shall apply		-
	90th percentile	<90 except Latrobe River upstream of Glengarry Rd in which <70 shall apply		
Turbidity (NTU)	50th percentile	<25	% increase	-
	90th percentile	<50		
Colour (Pt. Co units)	50th percentile	<60	% increase	<20%
	90th percentile	<100		
Total Phosphorus (mg/L)	50th percentile	<0.060		
	90th percentile	<0.1		
Total Nitrogen (mg/L)	50th percentile	<0.90		
	90th percentile	<1.60		
E coli (organisms/100mL)	42 day geometric mean	<200		

Temperature (°C) Range from **N**[a]	Refer to Acceptable Variation	90th percentile	<1.5 except industries existing at 1 January 1996 and discharging to Taralgon Ck where <3.0 shall apply from Dec to March and industries existing as at 1 January 1996 and discharging to Morwell River where <3.0 shall apply Dec to March
		Max	<2.0 except industries existing at 1 January 1996 and discharging to Taralgon Ck where 3.5 shall apply from Dec to March and <4.0 shall apply from April to Nov and industries existing as at 1 January 1996 and discharging to Morwell River where <4.0 shall apply from Dec to March and <6.0 shall apply from April to Nov
		Rate of change	<1 in 30 minutes except industries existing at 1 January 1996 and discharging to Taralgon Ck where <2.0 in 30 minutes shall apply and industries existing as at 1 January 1996 and discharging to Morwell River where <2.0 in 30 minutes shall apply

(a) N indicates an objective that there is no variation from background level.

(b) T is the national guideline concentration for toxicants in waters specified for the protection of aquatic ecosystems in the Australia Water Quality Guidelines for Fresh and Marine waters (ANZECC, 2000).

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