



MONASH University
Engineering



Department of
Primary Industries

Water Balance at Coal Mine Closure: A Conceptual Model for the Latrobe Valley

Prepared By:

Ms. Adele Carpenter

Academic Supervisor: Mr. Dilip Nag

Industry Supervisors: Mr. Paul Barrand and Mr. Mark Pratt

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Executive Summary

The Latrobe Valley is located approximately 150km east of Melbourne, Victoria and meets 85% of the state's electricity demand via combustion of brown coal. The coal used for power generation is mined locally via open cut methods from extensive reserves. Currently there are three open cut mines in the region, located at Yallourn, Hazelwood and Loy Yang, which have been operating for close to 85, 50 and 30 years respectively. The coal to overburden ratio at these sites is high at up to 5:1. The combination of the high strip ratio and extensive lives means that the mines have grown quite big since their inception. Their vast size means that rehabilitation of the mines after closure so that they can be returned to the community is a large task.

- o The approved Rehabilitation Plans for each mine cite mine flooding to crest level as the preferred final concept. However, a continuing drought and increasing public awareness of environmental issues means that there is increasing doubt over whether this will be possible.
- o The purpose of this study was to determine the steady state water level and the length of time to reach this level for a hypothetical mine which is representative of those currently operating in the Latrobe Valley. The relative importance of the input parameters in determining the steady state water level and filling rate was also determined by conducting a sensitivity analysis.

The method used to achieve these objectives was the construction of an analytical water balance model. The model used as the base of the study was the Comprehensive Realistic Yearly Transient Infilling Code as presented by Fontaine, Davis and Fennemore in 2003. The model uses a modified aquifer rebound equation in order to determine the groundwater inflow to the pit, in addition to external fluxes such as precipitation, runoff, evaporation and surface water diversion. The chief groundwater parameters considered are transmissivity and storativity.

The steady state water level of a hypothetical mine 120m deep with a surface area at crest of 21km² and 18.4° (3:1) batters was determined to be 75m if the only hydrologic components acting were precipitation, runoff, evaporation and groundwater influx. It was found that it would take 244 years to reach this level. If surface water is diverted into the pit at a rate of 20GL/yr for the first 50 years after closure the long term results are the same, however the lake depth will peak at 80m after 50 years.

Due to the type of model chosen and the number of assumptions made with respect to the hydrogeology of the site, the results of the study are approximate and should be used with care. Having said this, the results of this study are considered useful in supporting the strategic mine planning role of Clean Coal Victoria. However, it is recommended that site specific numerical modelling is undertaken for each mine as they approach closure. It is further recommended that other rehabilitation options for the Latrobe Valley be thoroughly investigated.

Chapter 1

Introduction

1.1 Background and Setting

1.1.1 Coal Mining in the Latrobe Valley

The Latrobe Valley is located approximately 150km east of Melbourne, Victoria. It is a diverse region, particularly in industry, with activities such as agriculture, manufacturing and power generation contributing significantly to the local economy by making the most of the region's natural resources (LCC, 2010).

One of the richest resources in the region is one of the world's largest brown coal (lignite) reserves, which make up the Latrobe Valley Depression. 112 billion tonnes of coal is thought to exist in the Depression, with 53 billion tonnes estimated as economically winnable (GHD, 2005). The Latrobe Valley provides 85% of Victoria's electricity needs, extracting 60 million tonnes annually from the region's open cut mines (GHD, 2005). Latrobe Valley coal is characterised by thick seams, with the strip ratio being as high as 5:1 (coal to overburden). This makes the area suitable for relatively cheap coal extraction via open cut methods.

Currently, three open cut brown coal mines operate within the Latrobe Valley. These are located at Yallourn, Hazelwood and Loy Yang, as shown in Figure 1-1.

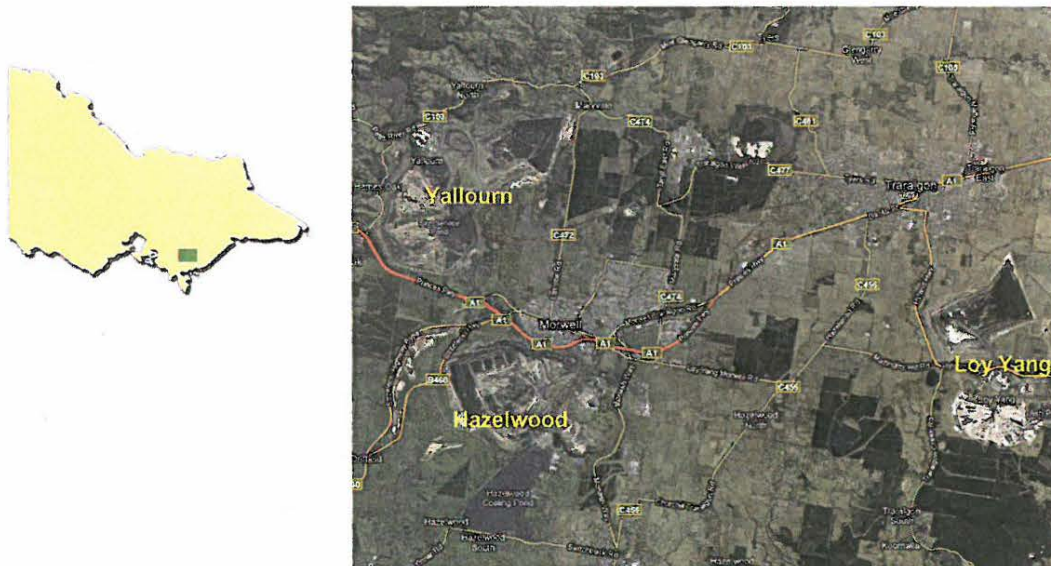


Figure 1-1: Location of existing Latrobe Valley mines at Yallourn, Hazelwood and Loy Yang

Loy Yang, Hazelwood and Yallourn and have been operating for close to 30, 50 and 85 years respectively. Their extensive lives and the increasing demand for electricity means that the mines have grown quite large since their inception. Loy Yang Mine currently covers a surface area of 6.5 km² at mine crest, Hazelwood mine an area of 8km², and Yallourn an area of 10km²,

including the exhausted Township field. The size of the pits and the high strip ratio makes rehabilitation a particular challenge for environmental mine managers.

1.1.2 Rehabilitation in the Latrobe Valley

In 1990, the Victorian Government passed the *Mineral Resources Development Act* which requires those who hold exploration or mining licenses rehabilitate all disturbed areas. Rehabilitation is the process of returning land disturbed by mining to its former use or a use of equal utility to the community (GHD, 2009). Two of the most common rehabilitation options for large pits include back-filling with overburden or waste material or flooding the mine with water. In the Latrobe Valley, the high strip ratio makes total backfilling virtually impossible due to the relatively low amount of overburden. Hence, mine flooding to form a pit lake has long been considered a viable option for the Latrobe Valley. On a global scale, pit lakes are increasingly common, with notable examples including Lake Senftenberg of Germany's Lusatian district and Berkely Pit Lake of Montana, USA. The chief advantages of mine flooding are its relatively low cost (compared to extensive earth works), aesthetics, and potential use as a recreational or industrial area (Castendyk & Eary, 2009). The main disadvantage is the potential for poor water quality and associated impact on the environment.

Mine flooding is currently the preferred final rehabilitation concept for Yallourn, Hazelwood and Loy Yang as set out in their Rehabilitation Master Plans. While these plans have been approved by the DPI, the potential effects of climate change and the increasing focus on water scarcity are bringing into question whether flooding of these voids to crest level is possible, and in what timeframe. There is also community concern on where the water to fill the mines will come from and whether this is the most effective use of this precious resource.

1.1.3 Latrobe Valley Aquifers

The Gippsland Basin of Victoria is one of the world's major fossil fuel zones. The basin covers an area of 56,000km², with approximately two thirds of it located off shore (Holdgate, 1996). Within the Gippsland Basin, recoverable groundwater is stored in both confined and unconfined aquifers, which occur locally and as regional systems. Recoverable groundwater can be found in sand and gravel deposits, at fracture zones within basalt or basement rocks, or in cavities and fractures within limestone or coal seams (Schaeffer, 2008).

Three regional aquifer systems have been identified within the Gippsland basin. The Haunted Hills formation is unconfined, while the Morwell Formation Aquifer System (MFAS) and Traralgon Formation Aquifer System (TFAS) are confined. Sandy interseam sediments represent confined aquifers beneath the Latrobe Valley Mines. Local aquifers consist of the Yallourn, Morwell 1A, M1B, M2A, M2B, M2C, and Traralgon 1 aquifers. Whether confined or unconfined, aquifers intersecting the Latrobe Valley coal mines need to be appropriately managed (dewatered) so that coal mining can be carried out safely without the risk of floor heave or batter movement. The aquifers at each Latrobe Valley mine are briefly discussed below.

At Yallourn Mine, unconsolidated sand and gravel of the Haunted Hill Formation comprise an unconfined aquifer, which requires dewatering. The M2A also occurs beneath Yallourn Mine, and consists of interbedded sand, clay, silt and basalt (Schaeffer, 2008). Another significant aquifer is the M1A, which intersects at Yallourn East Field, and also requires depressurisation.

The M1B interseam is a regionally extensive stratigraphic layer, and is the major aquifer beneath the Hazelwood Mine requiring depressurisation (Schaeffer, 2008). The M1B interseam overlies the M2 aquifer which also undergoes dewatering. The M2 Aquifer represents the M2A, M2B and M2C aquifers that occur elsewhere in the Latrobe Valley.

The M2B and M2C aquifers are the main layers requiring depressurisation at Loy Yang Mine. These overlay the T1 Aquifer which is the deepest of the major aquifers beneath the Loy Yang Mine, which also undergoes dewatering (Schaeffer, 2008). While the T1 aquifer extends across much of the Gippsland Basin, it reaches thicknesses in excess of 100m east of the Loy Yang Mine. M1A and M1B interseam silts and clay and the M2A aquifer become sandier and more significant to the east of Loy Yang mine.

1.1.4 Role of Government

The Department of Primary Industries is responsible for approving mine Work Plans and mine Rehabilitation Master Plans. As mentioned, the approved Rehabilitation plans for Yallourn, Hazelwood and Loy Yang, cite mine flooding as the preferred mine closure concept. Despite increasing concerns about water scarcity and climate change, the government is apprehensive in forcing changes to approved plans which may increase the financial burden of rehabilitation on mine operators.

In 2009, Clean Coal Victoria was formed. CCV is a branch of the DPI and was formed with the aim of maximising the value of Victoria's coal resources in order to best deliver the economic, social and environmental objectives for the state. CCV's main tasks include strategic mine planning including a drilling program as well as working with the community. There is room in the strategic planning of future mines to consider the requirements for effective rehabilitation. In the case of mine flooding, having a general understanding of the steady state water level and filling time of a typical Latrobe Valley mine may ultimately assist with future mine planning and eventually changes to legislation. CCV may also use this information to work cooperatively with existing mine operators to review current rehabilitation plans.

1.2 Problem Statement

Mine Rehabilitation Plans assume that water will be a major part of the post mining landscape. However, there has been little work undertaken by government to determine the steady state water level that will be reached in each Latrobe Valley coal mine after closure and how long after closure this level will be reached given the current reduced water budget from a changing climate.

This study will attempt to fill this knowledge gap by constructing an analytical water balance model for a hypothetical Latrobe Valley mine which is representative of those currently operating in the region, based on a more recent understanding of potential future climatic trends.

1.3 Objectives

The objectives of the study are:

- To construct and calibrate an analytical water balance model for a typical Latrobe Valley brown coal mine

- To use the model to determine the steady state water level in the typical mine and the time required to reach this level, assuming groundwater, precipitation and runoff as the primary inflow sources
- To use the model to construct three filling scenarios, including the diversion of surface water, to determine the effect on final water level and filling time.
- To use the model to iteratively determine the relative importance of each parameter used in the model on final water level and filling time

1.4 Deliverables

There are a number of outputs from this study. These include

- Final water level if groundwater, precipitation and runoff are the only inflow sources
- Relative importance of parameters in determining steady state water level
- Final Water level and time taken to fill for three different filling scenarios
- Spreadsheet model – with inbuilt flexibility to be easily modified for local mines

1.5 Limitations

The study was carried out with the following limitations

- The quality of the data available, for example transmissivity and storativity of overburden, coal and aquifers
- The need to choose a set of climatic data which will be assumed to be representative of future climate
- The assumption that the aquifer depressurisation systems used to maintain mine stability during operations are shutdown at the close of mining
- The assumption that recovery in aquifer pressures below the mine do not result in any pit floor instability so that groundwater inflows do not occur vertically to the pit
- Timeline for completion: the study has to carried out and reported within a 13 week period

1.6 Definitions of Terms

Batter	The wall of the mine void
Coal	In this report, the term coal refers to lignite (brown coal)
Hydraulic conductivity	The rate with which water can move through a permeable medium, such as overburden or coal
Interseam	Layers between coal seams, mainly comprising sands, silts and clays

Lignite	Otherwise known as brown coal. Lignite seams in the Latrobe Valley range between 7 and 45 million years old. These deposits were formed by the coalification of ancient plant debris which became overlain with water and sediment millions of years ago
Pit Lake	The body of water formed in an open cut mine after closure. Also referred to as Mine Lake.
Overburden	Material overlaying the coal seams, mainly comprising sands silts and clays
Rehabilitation	The restoration of land disturbed by mining to its former use, or a use of equal or better utility to the community
Steady state water level	The equilibrium water level reached in a flooded mine void where water inflows and outflows balance each other
Storativity	The volume of water released from storage in a confined aquifer per unit area of the aquifer per unit decline in hydraulic head
Transmissivity	The product of hydraulic conductivity and aquifer thickness; a measure of a volume of water to move through an aquifer
Water balance	The flow of water into and out of a system

Chapter 2

Literature Review

2.1 Open Cut Coal Mine Rehabilitation

In Australia, the term rehabilitation is used to describe the process of repairing land disturbed by mining. Rehabilitation can be defined as the process of returning land disturbed by mining to its former use or a use of equal utility to the community (GHD, 2009). Rehabilitation is generally thought of as consisting of two phases: final concept planning and progressive rehabilitation.

The final concept of a mine is the overall vision of what the site will look like when rehabilitation is complete and the site is handed back to the community. Ideally, the final concept will detail the land form and the proposed land use of the site after closure (GHD, 2009). The optimum land form design would be the one that achieves erosion stability for minimum cost of earthworks and other treatments (Evans et al, 1997) and blends in with the other landforms in the locality (Simon-Coinçon et al, 2003). The land use would be of equal value to the community as the pre-mining land use, and would be in line with community needs and expectations.

Progressive rehabilitation is undertaken at all open cut coal mines within the Latrobe Valley. The principle aims of progressive rehabilitation are to stabilise disturbed areas – particularly slopes – to improve safety, limit fugitive dust, reduce wind and water erosion, and minimise visual impact on the surrounding environment (Missen, 2010; Brown, 2010; Jones, 2010). Progressive rehabilitation also has the added benefit of reducing the liability for rehabilitation works after decommissioning, and provides opportunity for mine managers to trial different rehabilitation options so that rehabilitation practices may improve over time (DITR, 2006). Commonly, progressive rehabilitation efforts focus on improving slope stability and minimising erosion by establishing vegetation (Brown, 2010; Jones, 2010).

In Victoria, the final concept is detailed in a Mine Rehabilitation Plan, which must be approved by the DPI before mining commences. Currently, the approved Rehabilitation Plans for Yallourn, Hazelwood and Loy Yang cite mine flooding to crest level as the preferred final concept. However, emerging concern over the potential impacts of climate change and water scarcity bring the feasibility of these plans into question. Hence other rehabilitation options are being considered, one of which is a lowered landscape. In a lowered landscape, slopes may be reworked so that they are sufficiently stable and covered with native vegetation or made available for grazing and other agricultural activities (GHD, 2009).

Despite the increasing water quantity concerns relating to mine lakes, it is generally accepted by environmental mine managers and government that a water body of some form will feature in the Latrobe Valley's post-mining landscape (Missen, 2010). Even in a lowered landscape, groundwater infiltration and surface runoff would contribute to the formation of a lake; however, the water level would be significantly lower than the mine crest. Depending on how the landscape is constructed and managed, potential land uses could include agriculture, forestry, native flora and fauna areas, aquaculture, and industry (LYP, 2007).

2.2 Mine Lakes

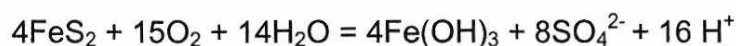
As previously mentioned, the approved Rehabilitation Master Plans of Yallourn, Hazelwood and Loy Yang cite mine flooding as the preferred closure option for the mine void. This is consistent with mines of similar size overseas, for example the Senftenberg and Hambacher lignite mines of Germany and the Berkeley Copper mine of the United States of America (see Schultze et al, 2009; Klapper & Geller, 2001; Werner et al, 2001 and Castendyk & Eary, 2009). While mine lakes have many potential benefits such as water-based recreational areas, opportunities for industry and agriculture as well as habitat for local wildlife (McCullough, 2008), there are many complex issues that need to be resolved before the mines can be allowed to fill. Broadly, these can be separated into two types of issues – water quantity issues and water quality issues

2.2.1 Water Quantity Issues

The main sources of water for mine void filling include influx of groundwater, precipitation and surface water diversion (see Schultze, 2009; Bowell, 2002; McCullough, 2008). In a net-evaporative climate (such as the Latrobe Valley), surface water diversion has the advantage of limiting the effects of acid mine drainage and achieving neutralisation (Schultze, 2009). One of the reasons this occurs is that the quickly rising, neutral surface water causes the surrounding underground to become anoxic which inhibits sulphidic metals from entering the lake (Mudroch et al, 2002). Accelerated filling with surface water may also improve the stability of slopes during filling, compared to the slopes of a void inundated with groundwater (Mudroch et al, 2002). An option for surface water diversion into Latrobe Valley mines may be the transfer of current power station surface water allocations to mine filling for a period after power station closure. Full details on power station water allocations are given in section 3.5.2. Another option may be to divert flood waters from near by rivers during extreme rainfall events. This may have the added benefit of the reducing the risk of flood in residential areas, particularly in Traralgon, and may make it possible to re-zone floodplains for urban or industrial development.

2.2.2 Water Quality Issues

Those planning for mine flooding (partial or total) upon closure must also consider issues related to pit lake quality. One of the main issues is acid mine drainage (see McCullough, 2008; Schultze et al, 2005; Johnson & Hallberg, 2005). Acid mine drainage is a multi-stage chemical process. In the first stage, pyrite (FeS_2) decomposition releases ferrous ions (Fe^{2+}) which are rapidly oxidized to ferric ions (Fe^{3+}) at pH greater than 3. As the pH falls below 3, the solubility of ferric ions increases and these ions act as an oxidant with the pyrite, which accelerates acidification via production of sulphuric acid (Bigham & Gagliano, 2006). The overall reaction can be expressed as:



$\text{Fe}(\text{OH})_3$, or Iron (III) hydroxide is commonly known as “Yellow Boy” and is responsible for the reddish-yellow colour that appears in waters affected by acid drainage (Khalequzzaman, 2010). In the Latrobe Valley, subsoils contain not only pyrite but also elevated concentrations of

other metal sulphides (GHD, 2005). These compounds can also result in the formation of sulphuric acid when exposed to oxygen and water.

The effects of acid drainage can be mitigated by pre-filling (preventative) strategies or post-filling strategies. Pre-filling strategies include faster filling (to reduce incidence of pyrite oxidation from exposure to air), improved catchment and shoreline stability and removal or capping of reactive materials (McCullough, 2008). Post filling strategies include in situ manipulation of groundwater (for example, microbial sulphate reduction), diversion of river water and flushing, and the addition of alkaline solutions and carbon dioxide (Schultze et al, 2009). Land form design may also have an impact on water quality, with deep, steep sided lakes with low shore development contributing to lake water quality which is suitable for drinking, water recreation or aquaculture (Mudroch et al, 2002).

While this study does not look in detail at water quality over time the results of the inflow scenarios may be useful in considering the possible water quality outcomes with differing pit water levels.

2.3 Analytical and Numerical Groundwater Modelling

The most common approach to modelling pit lake filling is by constructing a water balance. A water balance considers all the inflows and outflows of a system. For pit lakes, the most important inflow is usually groundwater (Niccoli, 2009). The groundwater influx into a pit can be modelled using analytical or numerical methods.

Numerical models are based on the principles of finite difference. They are a popular method of modeling groundwater flows as they can account for complex geology near the pit, assess the impact of active pit dewatering and predict the long-term impacts of post-mining groundwater flow into the pit (Naugle & Atkinson, 1993). While traditionally, models based on finite difference could be difficult to construct, the emergence of software packages such as MODFLOW has made the development of numerical groundwater models quicker and simpler (SSG, 2010). Despite these advantages, numerical models do have limitations. The chief limitation is the reliance of the model on detailed field data in order to yield accurate results (Fontaine et al, 2003). While the complexity of numerical models allows more possible scenarios to be considered and limits the need for simplifying assumptions, the absence of detailed field data can severely reduce the model's reliability and validity (Niccoli, 2009). Where the necessary field data is not available, or where there are time constraints, analytical modelling may be more appropriate.

Analytical models use simplifying assumptions and known relationships between common parameters to calculate the desired model outputs. In the case of groundwater modelling for pit lake formation, analytical models are usually based on well recharge equations (Marinelli & Niccoli, 2000). Analytical models usually begin with the development of a conceptual model or diagram which clearly shows the flows within the system (Niccoli, 2009). The accuracy of an analytical model depends largely on the number and type of assumptions made, as these determine how closely the model reflects reality (Praveena et al, 1993). The advantage of making sound assumptions is that often an answer can be found easily with reasonable confidence, especially in the absence of detailed field data (Fontaine et al, 2003).

Chapter 4

Results

Table 4-1, below summarises the steady state fill level and time to reach this level for Scenarios 1, 2 and 3. Scenario 1 assumed no surface water diversion, Scenario 2 assumed 20GL/yr surface water diversion using existing power station water allocations for the first 50 years of filling and Scenario 3 assumed flood water diversion for ARI > 5 at 1.3GL/yr.

Table 4-1: Steady state water level and filling time for Scenarios 1, 2 and 3

	Scenario 1 No surface water diversion	Scenario 2 20GL/yr for first 50 years	Scenario 3 1.3GL/yr
Steady state water level (lake depth)	74.45 metres	*74.45 metres	78.85 metres
Time to reach steady state water level	244 years	244 years	244 years
Time to reach steady state water level for Scenario 1	-	40 years	185 years

* The water level peaks at 81m after 51 years, then declines to steady state level

From the table, it can be seen that the steady state time period for all scenarios is the same at 244 years, with the highest steady state water level achieved by Scenario 3 at 79m lake depth. However, Scenario 2 has the highest peak water level at 81m depth after 51 years of filling, just after surface water diversion ceases. This suggests that utilising existing power station water entitlements for a period after closure may be a good option for pit filling in the Latrobe Valley, as it reduces the time to reach the steady state level. This method has the added advantage of potentially improving lake water quality, and improving slope stability during inundation.

As the time step that had to be used was one day, the time period over which the pit filling could be modelled was limited by the number of Excel cell rows available (65536). This resulted in a total modelled time period of 180 years. In all scenarios the steady state water level was not quite reached in this time. To determine the steady state level, the water level for years 170 to 180 were used to form a linear trendline using Excel for Scenario 1 and Scenario 2. It was assumed that the steady state water level would be the same for both scenarios (this occurred early in the modelling process when a higher transmissivity was initially used which resulted in steady state being reached). The intersection of the two lines was then calculated by solving the simultaneous trendline equations provided by Excel. Figure 4-1, below shows how the steady state was calculated for Scenarios 1 and 2. The steady state water level for Scenario 3 was calculated as the steady state water level for Scenario 1 plus the difference between Scenario 1

and Scenario 3 at $t = 180$ years. The time for Scenario 3 to reach its steady state was assumed to be the same as Scenario 1 due to the similar shape of their respective filling graphs.

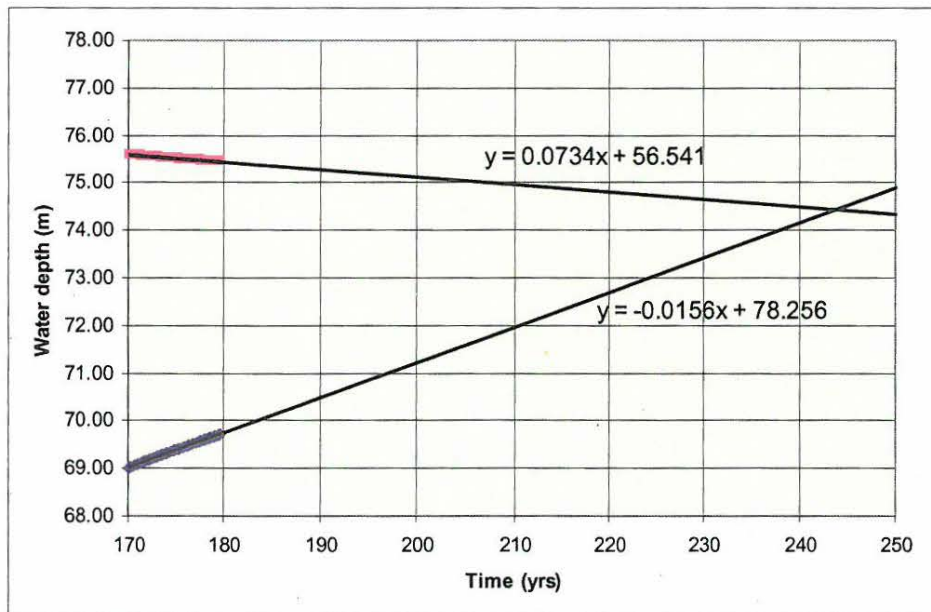


Figure 4-1: Determination of steady state water level for Scenario 1 and 2

The model produced a graph showing water level below crest vs time. This allowed the filling rate and steady state water level to be easily seen. Figure 4-2, below shows the water level below crest vs time graph for each scenario on the same axes.

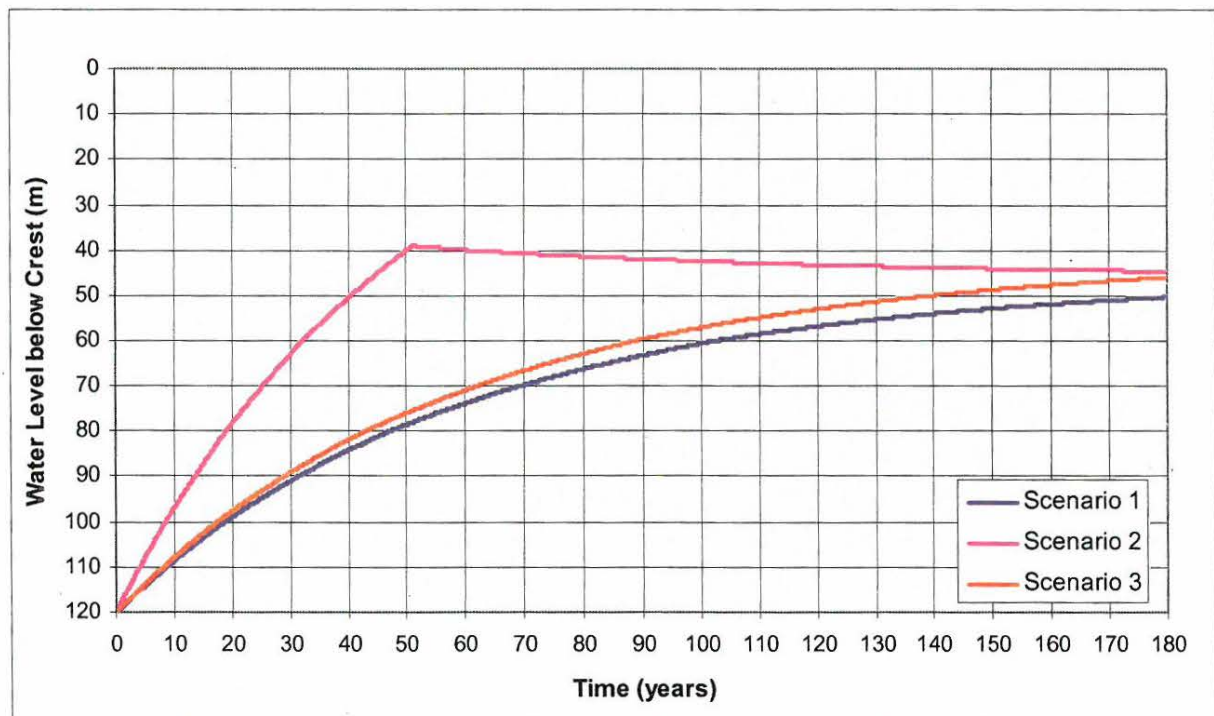


Figure 4-2: Pit Lake water level below crest vs time for Scenarios 1, 2 and 3

It is not expected that DPI will carry out numerical pit lake modelling for specific sites in the Latrobe Valley. Rather, modelling would be carried out by individual mine operators or by an engineering consultancy experienced in this field.

5.3.2 Investigation of other Rehabilitation Options

It is important to conclude this chapter by emphasising the importance to both government and industry of thoroughly investigating rehabilitation options other than pit inundation. As previously mentioned in this report, the issues of water scarcity and changing community expectations are two reasons why simply “filling the mine with water” may not be a viable rehabilitation option into the future. Other options, such as a lowered landscape have already been put forward by GHD in the report *Mine Rehabilitation Options and Scenarios for the Latrobe Valley – Developing a Rehabilitation Framework*. The report also highlighted the importance of considering land form and land use when investigating potential post mining landscapes.

While it is generally accepted that water will feature in the post mining landscape, its extent and its interactions with the surrounding environment need to be carefully considered. By investigating land uses that are of benefit to the community, government and industry may be better equipped to work together in the future to develop a post mining landscape that has economic, social and environmental benefits.

The first stage of this investigation in other rehabilitation options for the Latrobe Valley will be carried out by the author on behalf of the DPI from June to November 2010.

Chapter 6

Conclusions

The primary aims of this study were to determine the relative importance of each of the modelling parameters in calculating the steady state water level and filling rate of a hypothetical Latrobe Valley mine; to present CCV with a possible range of water levels achievable; and to specify the time period over which these levels are likely to be reached in order to support CCV's functions in strategic mine planning.

The most important parameters in determining the steady state water level and filling rate were transmissivity and storativity, as determined by the sensitivity analysis. An order of magnitude change in transmissivity and storativity resulted in a 24% and 22% increase in steady state water level respectively. Additionally, an order of magnitude change in transmissivity and storativity resulted in a 133% and 119% increase in the filling rate in the first 30 years. Also crucial to the calculation of the steady state water level were static water elevation, evaporation factor and precipitation rate.

The steady state water level when the only hydrologic parameters acting are groundwater, precipitation and evaporation was determined to be a depth of 75m, which is 45m below crest level of the hypothetical mine. It was estimated that it would take 244 years to reach this level, with a lake depth of 40m being reached in 50 years.

If 20GL/year of existing power station surface water allocation is diverted to the mine for the first 50 years after closure, the steady state water level and time to reach this level are the same as in the first scenario; however, the lake depth will peak at 80m after only 50 years of filling. Faster filling has the advantage of reducing the effects of acid drainage and improving slope stability.

In the third scenario where flood waters of Traralgon Creek in events greater than ARI 5 (1.3GL/year) are permanently diverted into the mine, the filling rate is left largely unchanged; however, the steady state water level increases by 4m to give a steady state water level of 79m after 244 years.

The results suggest that while increased inflows of surface water increase the initial filling rate, which may have advantages for water quality management, in the longer term pit water levels fall to a common steady state level in the order of 45m below the crest.

While single values have been presented for the steady state water level and time to reach this level, these values are considered only approximate due to the type of model used, the assumptions made and the consequent limitations. The chief limitations are the determination of transmissivity and storativity based on little field data, the use of average daily values for precipitation and evaporation, the assumption that the aquifers are homogenous with only horizontal flow, and the inability of the CRYPTIC model to consider complex pit geometry and the influence of nearby features such as pumping wells and water storages.

Despite the limitation of the model, it is considered that the results of this study can be used with some confidence for planning purposes and as a starting point for further investigations

into mine rehabilitation by CCV. It has been recommended that a site specific numerical model be constructed for each of Loy Yang, Hazelwood and Yallourn Mines as they approach closure, and that a thorough investigation into other mine rehabilitation options such as a lowered landscape, be carried out.