



AGS VICTORIA 2016 SYMPOSIUM
Excavations and slope stability
in Melbourne geology:
experiences and recent developments

Wednesday, 16 November 2016, 12:00pm – 7:00pm
Engineers Australia, 600 Bourke Street, Melbourne



AUSTRALIAN GEOMECHANICS SOCIETY
VICTORIA CHAPTER

WELCOME

The Victorian chapter of the Australian Geomechanics Society (AGS) is pleased to welcome you to this half-day symposium titled "Excavations and slope stability in Melbourne geology: experiences and recent developments".

Since the publication of the "Engineering Geology of Melbourne" in 1992, both the geotechnical profession and Melbourne has undergone significant change. Urban sprawl over the past few decades has seen increasing development in the hillside areas in the Dandenong and Mornington Peninsula regions. This coupled with changes to the regulatory environment and the introduction of the Landslide Risk Management Framework by the AGS in 2007 has changed the way in which local and state government as well as geotechnical practitioners manage and assess slope stability.

In addition to development in hillside areas, significant development in the inner parts of Melbourne has posed many challenges for excavations not just in the soft soils of the Yarra Delta but also the weak rock of the Melbourne Formation.

This symposium seeks to bring together practitioners from consulting, construction and academia to share and discuss their experiences on the separate, but related, topics of excavation and slope stability. Best practices, case histories and innovative solutions for dealing with these challenges will be presented and discussed, with a particular emphasis on local geotechnical issues.

ORGANISING COMMITTEE*

Daniel King (Chair)

Clare Bridgeman (Co-chair)

Mahdi Disfani

Jie Li

Jeremy Barber

Rob Day

Richard Kaser

*a sub-committee of the AGS Victoria committee

TECHNICAL REVIEWERS

Mahdi Disfani (Technical Chair)

Chris Boyd

Stuart Colls

Chris Coulson

David Glover

Richard Kaser

Steven Lankshear

Bing Lee

Ramtin Tajeddin

THE EVOLUTION OF GEOLOGICAL MODELS AS AN AID TO GEOTECHNICAL STABILITY ANALYSIS, LATROBE VALLEY

Ben Jansen¹, Principal Geologist, GHD and Slavko Kacavenda², Principal Geotechnical Engineer, GHD.

¹GHD, 5 Church Street, Traralgon, Vic 3844; PH (03) 5136-5800; FAX (03) 5136-5888; email: ben.jansen@ghd.com

²GHD, 5 Church Street, Traralgon, Vic 3844; PH (03) 5136-5800; FAX (03) 5136-5888; email: slavko.kacavenda@ghd.com

ABSTRACT

Lignite Mining in the Latrobe Valley commenced in the late 19th Century (Drucker, 1984) and three world scale large open pits continue to operate today. Extensive coal exploration, hydrogeological and geotechnical investigation drilling for over a century, enabled the establishment of desktop geological models. Up until the 1980s these models required extensive manual input and updates were onerous. Due to the extensive data available, as well as a team of State Electricity Commission of Victoria (SECV) geologists, the models were considered reliable and carried a reasonable degree of accuracy, including in areas of geotechnical stability interest.

To facilitate potential expansions in the use of lignite, in 2002 a government led initiative resulted in the creation of the digital Latrobe Valley Regional Coal model (Jansen et. al., 2003). This model relied on data from some 8,000 drillholes including the SECV's stratigraphic interpretations and coal quality results. This model has since grown in extent to cover the Stradbroke area (in 2008) and the Moe Swamp Basin and Seaspray Depression (2011). Of note is the coarse scale of these models with respect to the lignite seams which required seam definition rules to define the extent of the seams which tend to split at basin margins.

Each of the operating mines has a more sophisticated subset of the model and include hydrogeological and additional structural detail. Such detail is required in areas both within the operational and non-operational areas of the mine, where geotechnical stability carries significant importance. The models allow rapid sectional work providing slope angles of coal seams for geotechnical studies as required. Such studies are valuable in the planning for various conceptual mining and infrastructure projects.

Keywords: geology, lignite, model, mine, batter, stability.

1 INTRODUCTION

The digital model of the Latrobe Valley coal resource is a 3D computer generated model that captures and replicates knowledge previously acquired (Gloe 1980) and presented in written format. Prior to this the bulk of the knowledge related to the Latrobe Valley coal measures were within the SECV with some information available in the Geology of Victoria (Douglas and Ferguson 1988).

In the early 1990's the Victorian Government decided to privatise the SECV which resulted in a 10 year moratorium on exploration in a defined restricted area that surrounded each of the three privatised lignite operations. With the end of the moratorium nigh, the prospect of encouraging new interested parties to explore and utilise the vast resources outside of the three mines was an economic imperative.

The relevant Department's initiated a process to develop a digital geological model of the Latrobe Valley coal resource. The aim of the task was to use the model for coal utilisation and land use planning. The model was to

provide seamless comprehensive information on the geology and resource. It should be able to be interrogated for resource information against a variety of parameters. Development of the model was a two stage process:

- First ensure that the stratigraphic and coal quality information in the Latrobe Valley bore database and other sources is 'clean'.
- Build the digital model.

2 DESCRIPTION

The data review and cleansing phase of the digital model was an essential pre-requisite. Outside of the existing mines, the bore information in the bore database, including coal quality, had not been rigorously checked as there was no imperative to do so. Potential mines outside of Yallourn, Loy Yang and Hazelwood were proposed on the basis of the database information but these were all conceptual. Three major obstacles to address were:

- The placement of the base of the overlying Haunted Hills Formation.
- The conversion of textual lithological logs to coded logs.
- The splitting of seams into multiple sub-seams in many areas.

The model was enhanced by the incorporation of all available coal quality information that can now be readily presented on screen in a clear and unambiguous manner. The ability to combine both stratigraphic and coal quality information, and the production of GIS outputs and generic modelling outputs further enhance the usefulness of the product beyond specialised software.

Coal modelling geologists utilised Minescape software to construct the model which was then scrutinised by an experienced exploration and research geologist having detailed local knowledge of both the resource and the methods used to collect the basic data. Additional specialists were used in the production of ARCVIEW and Mapinfo GIS packages, and also for the production of a 3-D fly-through of the model's surfaces.

Since the original model build in 2003, the model was expanded in 2008 to cover the Stradbroke-Longford area to the east and further in 2011 to cover the Yarram-Gelliondale area.

The presence of the model to assist in geotechnical studies including mine batter stability assessments has been an important facet for exploration companies looking at the coal resource outside of the existing three mines. The model was particularly useful in this regard for the Flynn Field, to the east of Loy Yang Mine.

2.1 Features and Innovations

Around nine thousand bore holes have been used to build a digital three-dimensional model showing the distribution and quality of the Cainozoic brown coal in a 1100 square kilometre area between Moe and Rosedale in the Latrobe Valley—including Victoria's vital electricity generating resources.

2.1.1 The Area

The project area is located in the Gippsland Basin, southeast Victoria and the study area covers resources in and surrounding the Latrobe Valley Depression.

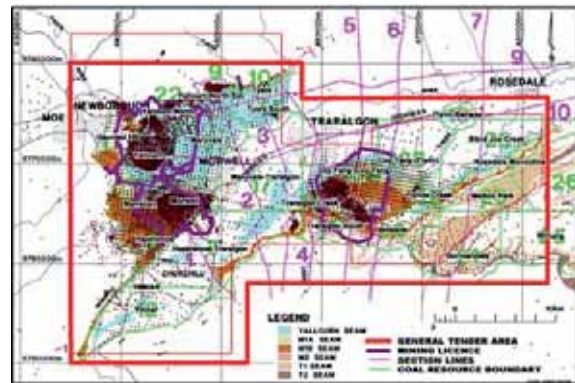


Figure 1. Latrobe Valley Coal Resource Model tender area. Bores in the Latrobe Valley bore database are shown as red points.

2.1.2 Landsat Images

One of the features of the GIS outputs provided is the use of landsat imagery, which provides an alternative plan view to the area. Subject to software upgrades these images can also be incorporated into the 3D model. Figure 2 shows an example of the output provided in 2D format.

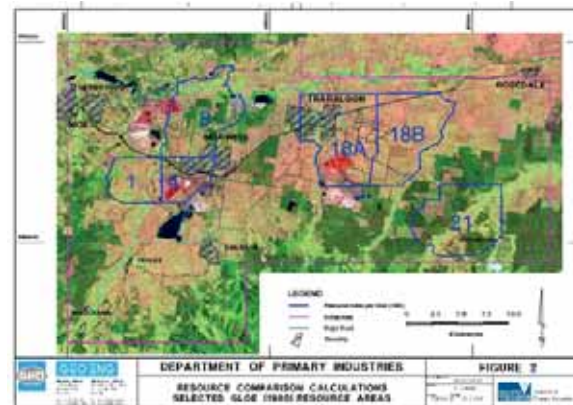


Figure 2. Latrobe Valley Coal Resource Model tender area – utilisation of landsat imagery.

2.1.3 GIS Imaging & fly-through

The use of this sort of imagery in 2D applications is “standard” in relation to the use of reference files. However, it is the utilisation of the image in a 3D sense in GIS packages such as ArcView that is innovative practice in the project. Arcview, Mapinfo and Mincom mine modelling software were utilised to develop 2 and 3 dimensional data models that are accessible to the simplest of GIS systems, but still informative and powerful enough to produce sophisticated flythrough models of coal seam position and thickness. These were then combined with surface digital terrain models and Landsat Imagery to produce a comprehensive overview of the regional resource that could simultaneously be used to

assess the resource on a detailed scale. Figure 3 below is an example of this output and was captured from the fly-through product. Software utilised for the fly-through was the 3D-Analyst extension to ArcView.

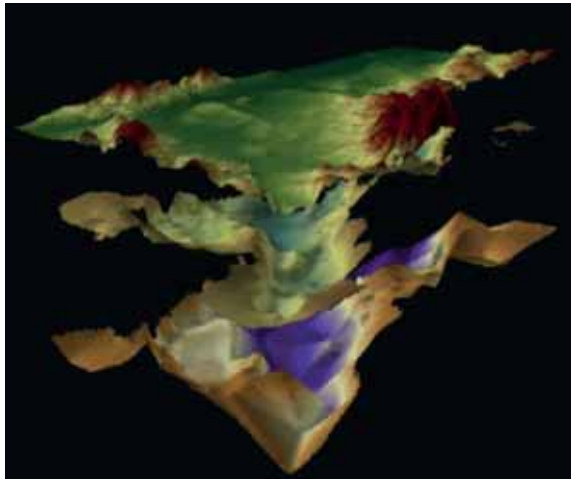


Figure 3. Looking northeast along the Latrobe Syncline at terrane, Morwell1b coal seam roof and Strzelecki Group basement roof modelled surfaces.

2.1.4 Coal Quality Block Model

Due to the extensive nature of drilling and coal quality testing undertaken over some 60 years by the former SECV, the area covered by the block model is perhaps one of the largest in Australia. Again, due to the foresight of the SECV to record and subsequently capture a wealth of coal quality information, the content of the block model comprises 17 different attributes.

Any of these attributes can be quickly interrogated along user defined sections, and the software allows for fence sections as well straight linear sections. An example of this is presented in Figure 4.

A requirement of the project was to ensure that the confidential information present within each of the three current Mining Licence holders (the MINs) was not compromised. Coal quality values within the MINs have been averaged to protect this confidential information. The polygon update form in Minescape was used to find and replace interpolated values with published average values for each seam and each MIN.

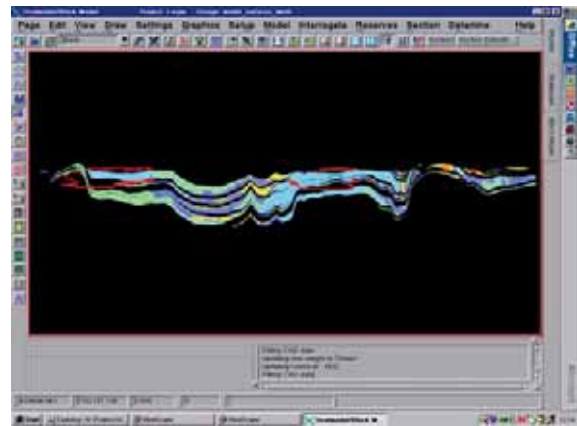


Figure 4. A coal quality section from the block model.

2.1.5 Resources – Land Use Planning considerations

In situ coal resources have been calculated directly from the model. The in situ resource figures are an estimate of the contained coal and do not meet JORC reporting requirements.

The strength of the model is that it can quickly calculate resources for many different criteria. Whilst some attempt has been made to calculate in situ resources using the criteria of Stanley (1986) and Gloe (1980), this was not a major objective of the project because these are strongly dependant on the method of coal extraction and end-use. For example, whilst early resource estimates were limited to 200 m depth (eg. Gloe, 1980), later estimates were limited to 300 m (eg. Stanley, 1986) reflecting improvements in open pit technology. The potential for extraction of coal seam methane using wells pushes this 'depth of interest' even further.

Table 2 lists in situ resources calculated directly from the model against a variety of criteria. The criteria are arbitrary and illustrate the versatility of the model.

Table 2: In situ resource as at 2002

Area	Criteria	In situ resource coal (Mt)	
		A	B
Latrobe Valley model area only	Coal contains less than 30% ash (coal and inferior coal)	A	129,000
	Coal contains less than 10% ash (coal) Seams are greater than 3 m thick	B	118,000
	Coal contains less than 10% ash (coal)	C	86,000
Coal available for utilisation. Model area excluding MINs and selected current local government planning exclusion zones.	Seams are greater than 3 m thick Greater than 1:2 coal: waste ratio Less than 300 m depth	D	53,000

The 9% difference between resources A and B means that inferior coal, that is coal containing between 10–30% ash, makes up only a small proportion of the <30% ash resource. The criteria used to calculate resources C and D are the same as used by Stanley (1986) and “have taken into account coal winning technology applicable to the present and foreseeable future”.

Resources A, B and C include coal within the MINs that may already have been mined.

Resource D is coal available for utilisation and excludes coal within the MINs and areas where coal mining is prohibited under Local Government planning schemes (Fig. 6.1, Table 6.1). Planning scheme information was derived from Latrobe, Wellington and Baw Baw Local Government data dated 1999–2002. The excluded areas were in part flagged with an Environmental Significance Overlay (ESO) in this data.



Figure 5. Current local government planning scheme exclusion zones taken into consideration in the calculation of available coal resource.

2.2 The Stradbroke Extension 2008

In 2008, a Victorian Government initiative saw the extension of the digital model to the east of the original model (Figure 6). A further 290 bores were added to the model.

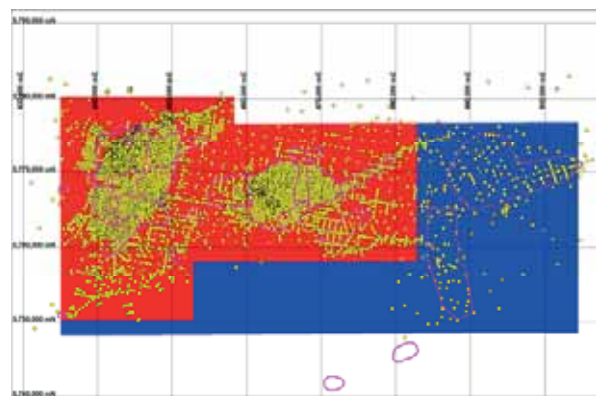


Figure 6. The eastward extension of the digital coal model of Victoria

The major requirements were to:

- Include seams to no less than six metres thick.
- Maximum of six metres within a seam that is > 30% ash d.b.

Of note in the Stradbroke area, is the visualisation of the structure and thickness of the Traralgon seams, along with their coal quality trends, which are seams not mined in any of the existing lignite mines. Again, the model facilitates geotechnical design of potential mines.

2.3 The Seaspray Depression and Moe Swamp Extension 2011

A final extension to the model was undertaken in 2011 with the addition of 650 bores. This extension essentially completed the digitisation of the SECV knowledge of the lignite resource in Victoria.

This extension covered the lignite deposits in the Moe Swamp Basin as well as the Gelliondale and Alberton Fields (Figure 7).



Figure 7. Model extents, 2011

3 GEOTECHNICAL MODELS

The 3-D regional geological model is suitable for planning of future mines including preliminary mine batter stability assessments (e.g. the Flynn Field to the east of Loy Yang). Selection of any potential future mine site is primarily based on the coal resource and includes its geological setting as well as favourable geotechnical and hydrogeological conditions. It should be noted that potential mining induced ground movements and their impact on structures and infrastructure are another key consideration in siting of future mines. This all assumes that regulatory, stakeholder and community requirements are also satisfied.

Geotechnical models for the preliminary stability assessments of proposed lignite mines are then established from the regional geological models and incorporate the stratigraphy, including overburden, coal seam(s), interseams, aquifers, geological structures such as faults as well as nominal mine batter profiles. Geotechnical parameters and hydrogeological conditions adopted in these models are based on historical data base for the Latrobe Valley coal mines and include any site specific data.

This high level analysis is aimed at assessing the likely mine stability conditions and identifying any significant issues and potential modifications that may be required to the design in order to address them. At this stage the primary issues being addressed are overall

stability (block sliding) and floor heave, although local stability including structure controlled failure as well as ground movements are also considered.

The above assessment is undertaken in light of the typical potential modes of failure at the Latrobe Valley coal mines as presented in Section 4.1 below. These serve the existing active mines well, where the coal seams are relatively flat or at worst have a relatively gentle dip, say up to 11°. However, in some locations, such as monoclines and faults where dips in strata are much higher or faults truncate the deposit, specific stability models, such as "Overall Stability" need to be established and utilised.

4.1 Mine Stability Issues

- Design and performance of permanent mine batters
- Stability of coal faces during excavation
- Stability of the overburden faces during excavation
- Stability of the overburden dump during placement and long term
- Stability of the mine floor under influence of artesian aquifer pressure

4.2 Significant Batter Failures

- 1950: Yallourn North Open Cut Northern Batter (230,000 m³).
- 1962: Hazelwood Mine BW3 Coal Operating Batter (600 m³).
- 1991: Hazelwood Mine Overburden Operating Batter (80,000 m³).
- 2007: Yallourn East Field Northern Batter (6,000,000 m³).

4.3 Potential Failure Mechanisms

Some key aspects of mine batter stability are unique to Latrobe Valley Brown Coal Mines. This is primarily due to the light weight nature of coal that makes up the majority of the mine batter profiles and its sensitivity to groundwater pressures in its joint system.

The following are typical potential failure mechanisms:

- Block sliding.
- Circular slip.
- Floor heave.
- Structure controlled failure.

Each of the above failures can occur on small and large scale.

4.3.1 Block Sliding

- Sliding of coal on interseam.
- Driven by water pressure in coal joints.

Factor of Safety (FoS) = Resisting Force / Driving Force
 Where Resisting Force = $(W \cos \alpha + P \sin \alpha - U) \tan \phi + C$, X, L and Driving Force = $W \sin \alpha + P \cos \alpha$
 (Note: C = Cohesion and ϕ = Friction)
 (Note: Based on unit length of batter)

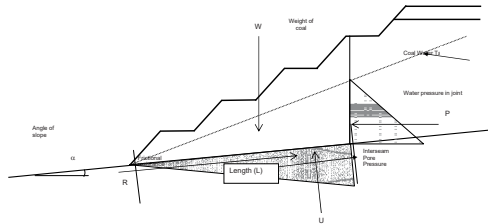


Figure 6. Mine batter Block Sliding Mechanism

4.3.2 Circular Slip

Typical risks to instability in Overburden and Overburden Dump Batter

- Weak materials (Fireholes).
- Over-steepening.
- Saturated sands.



Figure 7. Circular slip in weaker overburden materials

4.3.3 Floor Heave

Mine floor heave will occur when artesian aquifer pressure exceeds weight of material above it.

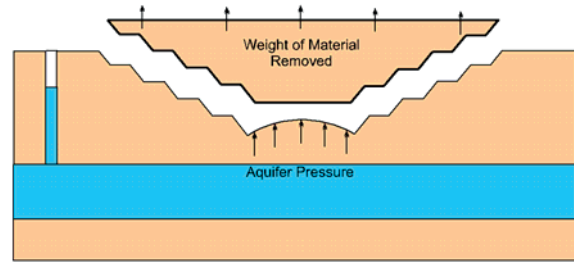


Figure 8. Mine floor heave due to excessive aquifer pressures

4.3.4 Structure Controlled Failure

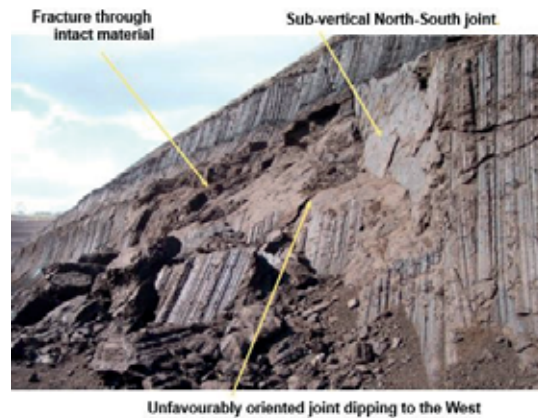


Figure 9. Failure in a coal operating batter

4 SUMMARY

Around eight thousand bore holes have been used to build a digital three-dimensional model showing the distribution and quality of the Cainozoic brown coal in a 1100 square kilometre area between Moe and Rosedale in the Latrobe Valley—including Victoria’s vital electricity generating resources. The model facilitates fast and versatile assessments of this resource. It also captures and safely archives 90 years of knowledge accumulated by the State Electricity Commission of Victoria and other workers that, until now, was accessible only as paper records. The model has applications in resource utilisation planning, land use planning and assessments of groundwater and subsidence.

The project was funded by the Victorian Department of Innovation, Industry and Regional Development as an outcome of the Latrobe Valley Ministerial Taskforce. Modelling was undertaken by GHD Pty Ltd for the Victorian Department of Primary Industries.

This area covers the Latrobe Valley Depression that contains coal resources of 129,000 million tonnes and is one of the world’s largest, and lowest cost, energy sources. Most of the State’s

electricity is generated utilising coal from the Loy Yang, Hazelwood and Yallourn mines. In addition to these massive operations, significant additional coal resources are available and unallocated at this time. Opportunities exist for the continued utilisation of these resources for electricity production, gasification, liquefaction and other coal conversion processes; as well as solid fuel for industrial, domestic and other uses. The seams were last modelled, and resources, calculated in the 1980s, but parameters affecting coal economics have changed. One of the model strengths is versatility. It readily takes account of changes to parameters as fundamental as "what is coal?".

Roofs and floors have been created for the sixteen thickest brown coal seams and splits off main parent seams. Importantly, **some intraseam occurs within seams**, particularly away from the mines. This has not been modelled although it has been taken account of during resource calculations. Smaller seams and splits were either incorporated with these sixteen or not modelled. This intraseam and coal is recorded in bore lithologies. Surfaces for the floor of the Haunted Hills Formation cover sequence and roof of Strzelecki Group (and Palaeozoic) basement have also been estimated. Surfaces are based on a 200 m grid spacing with grid values interpolated from bores drilled on a nominal 400 m grid.

Seventeen coal quality parameters have been incorporated into a block model. The 160 x 160 x 12 m blocks can be queried and should assist with the matching of brown coal to development opportunities.

The 3-D geological model forms the basis for development of geotechnical models that are particularly associated with the current and potential future mining and associated developments in Latrobe Valley.

Regional geological model is suitable planning of future mines including preliminary mine batter stability assessments. Mine site specific, detailed geological models, nested within the regional model, have been developed for the detailed analyses of mine stability. The potentially hazardous nature of open pit mining requires adequate management of geotechnical and related ground risks.

REFERENCES

Abele C, et.al, 1988, *Tertiary*, in Douglas, J. G., & Ferguson, J. A. (eds), *Geology of Victoria. Victn . Div. geol. Soc. Aust.* Pp. 251-350.

Drucker, G. C., 1984, *A History of Victorian brown coal developments and their impact on the economy*, in "Victoria's Brown Coal – A Huge Fortune in Chancery (ed. J.T. Woodcock).

Jansen, B. L., Say P., & Maher S., 2003, *Digital Geological Model of the Latrobe Valley Resource*. Unpublished Geological Survey of Victoria Report no. 2003/2.

Gloe, C. S., *The economically winnable brown coal reserves in the Latrobe Valley*. Unpublished State Electricity Commission of Victoria Report No. 26.

AGS VICTORIA 2016 SYMPOSIUM
**Excavations and slope stability
in Melbourne geology:
experiences and recent developments**



**AUSTRALIAN GEOMECHANICS SOCIETY
VICTORIA CHAPTER**