Ashurst Australia

HAZELWOOD MINE FIRE INQUIRY
Expert Report on Rehabilitation Relevant to Loy Yang Mine

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1 INTRODUCTION

1 My full name is Timothy Daniel Sullivan and I was born on 23rd October 1951.

2 I have been engaged by Ashurst Australia (Ashurst) on behalf of AGL Loy Yang Pty Ltd (AGL Loy Yang) to prepare a statement of expert evidence and to appear as an expert witness at the Hazelwood Mine Fire Inquiry (HMFI).

3 My overall brief is in relation to the HMFI Terms of Reference (TOR) 8, 9 and 10, and specifically:

> *"To prepare a statement which sets out the key steps in the process to developing a rehabilitation solution that represents a stable landform, and reviews comments on the current AGL Loy Yang process and rehabilitation options*."

4 It is important when assessing rehabilitation to understand there are two scales of stability, geotechnical stability and erosional stability. Geotechnical stability is large scale stability of the overall land form, while erosional stability is more related to local instability of the land surface itself. In some instances in the various regulatory and guideline documents the words stable and stability have not been well defined and often it is unclear which element is being referred to.

5 Mine rehabilitation covers a very wide range of technical issues. This report is largely focused on geotechnical stability, namely the broader scale issues around establishing a landform that assists in stabilizing the mine void to a level commensurate with the planned final land use. Based on my experience this is the key element for successful rehabilitation within the Latrobe Valley.

6 Consequently this report does not deal with all elements of rehabilitation. There is a large body of expertise and experience covering erosional stability, including the basic aspects of rehabilitation such as earthworks, soil handling, re-vegetation, soil nutrients, maintenance, material characteristics, etc. Hence these aspects are not dealt with or covered in detail.

7 The approach I have used in answering the Brief and the structure of this report is focused on the AGL Loy Yang situation and follows the following process:

a) Identifying the key clauses and or conditions in the Regulations and Mining Licence.

b) Assessing how these should be interpreted using Department Guidelines.

c) Assessing the appropriate approaches to and principles for rehabilitation, contained within well accepted government and industry guidelines.

d) Reviewing the rehabilitation plans described in the various Work Plans and Work Plan Variations.

e) Reviewing and evaluating the results of rehabilitation to date at AGL Loy Yang in the light of the regulations, guidelines, approaches and principles.

f) Answering the specific questions contained in the Brief based on all of the above.

8 The information I have relied on in making this report is listed in Appendix C.

2 QUALIFICATIONS

2.1 Qualifications and Experience

9 My Tertiary qualifications comprise:

- Bachelor Degree, majoring in Geology from Macquarie University in Sydney,
- Master of Science from the University of London and
- Diploma from the Imperial College of Science and Technology, London.

10 I am a Chartered Professional Engineer, a Chartered Professional (Mining), A Registered Professional Engineer of Queensland, a Fellow of the Institution of Engineers and a Fellow of the Australasian Institute of Mining and Metallurgy.

11 I am also currently an Adjunct Professor in the School of Civil and Environmental Engineering at University of NSW (UNSW).

12 In addition to my practical experience, for more than 25 years I have been teaching a course on stability for mines. In addition for the last 13 years I have been teaching a course on geological and geotechnical models. Both of these courses are part of the UNSW Masters Programs in the Schools of Civil and Environmental, and Mining Engineering.

13 I am a Principal of Pells Sullivan Meynink, a firm I founded in partnership in 1993. Prior to that period I was with Coffey Partners for 19 years, of which for the last 10 years I was a Director.

2.2 Experience

14 My relevant work and employment history comprises:

a) 1974 to 1993 - Coffey & Partners Pty. Ltd., Sydney,

b) 1979 to 1980 - Post Graduate Studies in United Kingdom,

c) 1983 to 1993 - Director, Coffey Partners International Pty. Ltd., Sydney,

d) 1992 to 1993 - Visiting Professor, University of NSW,

e) 1997 to 2000 - Coroner's Adviser on Thredbo Landslide,

f) 2008 - Mining Warden - Yallourn Mine Batter Collapse Inquiry, Victorian Government,

g) 2009 to 2011 - Chairman of Technical Review Board for Victorian Government,

h) 2002 to Present - Adjunct Professor in School of Civil and Environmental Engineering, UNSW, and

i) 1993 to Present - Principal, Pells Sullivan Meynink Pty Ltd, Sydney.

15 I have included my curriculum vitae as Attachment A.

2.3 Expertise to make this Report

16 I have worked as a consultant to the mining industry for more than 40 years. I specialise in open cut mine stability and land stability in general and have worked on more than 400 land and mine stability projects throughout Australia, Asia the Pacific; and also in Africa and South America.

17 During that time I have also worked either as a government advisor or government appointed representative in the following roles:

a) Thredbo Landslide (1997) - Coroners Advisor,

b) Latrobe River Collapse Inquiry (2007) – Mining Warden; and

c) Chairman of the Technical Review Board (TRB) for Victorian Government (2009 to 2011).

18 My first major involvement in the Latrobe Valley was in 2007, I was appointed a Mining Warden to undertake the Yallourn Mine Collapse Inquiry.

19 A principal recommendation arising from that Inquiry was for the formation of a Technical Review Board (TRB). One of the Terms of Reference for the TRB was to focus on reducing the risks to the natural and man-made environment associated with mining in the Latrobe Valley.

20 The Yallourn Mine Batter Collapse came as a surprise to the Victorian Government mainly because it occurred after a period of some decades without major adverse stability events in the Latrobe Valley Mines. However it is now evident from the work of the TRB, from the detailed mine stability reviews I have undertaken on behalf of the Victorian Government and from the number of more recent stability incidents and failures; that there are many underlying stability risk issues associated with the open cut mining in the Latrobe Valley. Understanding and addressing those land stability risk issues is fundamental to any rehabilitation option for the Latrobe Valley Mines.

21 In addition to the Yallourn Inquiry I have also completed the following land stability studies in the Latrobe Valley:

- Detailed geotechnical review of Hazelwood Mine,
- Detailed geotechnical review of Yallourn Mine,
- Detailed geotechnical review of Loy Yang Mine,
- Detailed study of the Northern Batter Movements at Hazelwood Mine that threatened the Princes Freeway and Morwell Township;
- Advised the government about the Morwell River Diversion collapse at Yallourn Mine and
- Review of the Latrobe Road Movement and Cracking at Yallourn Mine.

22 In 2014/15 I completed a Draft Guideline titled Managing Ground Control Risks associated with open cut mining in the Latrobe Valley. This Guideline was developed under the initiative of the Victorian Government and one major aim was to increase understanding and awareness in order to decrease the incidence of adverse stability incidents.

23 In early 2014 I was part of the “expert panel” advising the Fire Services Commissioner on the Hazelwood Mine Fire.

24 In addition to the above from 2002 to 2005, I assisted the Sydney Catchment Authority with studies to evaluate and predict the effects of mining on a critical component of the Sydney water supply infrastructure. This included prediction of the mining impacts on a number of hand excavated tunnels, canals and bridges; and development of monitoring and mitigation strategies.

25 Since 1995 I have also been responsible for evaluating mining related impacts on the Waihi Township in New Zealand, which has a large open cut mine located within the town itself. These studies have focused in large part on mine closure, stability post closure, rehabilitation and associated risks.

3 BRIEF

26 I have been asked to prepare a statement that sets out the key steps for developing a rehabilitation solution that result in a stable landform. I have also been asked to review the AGL Loy Yang rehabilitation options and the process adopted by the mine.

27 In addressing these overall questions, I have been provided with the following scope of work:

a) *Prepare a report that sets out the key principles and processes that should in your opinion be used in developing a rehabilitation strategy for an open cut coal mine, regardless of its location and particular characteristics.*

b) *Explain the technical constraints that apply to the Loy Yang Mine arising from its particular geotechnical and hydrogeological context, and the broader Latrobe Valley context.*

c) *Describe some of the key events and anomalies that have occurred in the Latrobe Valley, and in broad terms discuss any implications for the development of a rehabilitation strategy at Loy Yang Mine.*

d) *Consider whether the general principles for developing a rehabilitation strategy noted in (1), might require adaption to the Loy Yang Mine context.*

e) *Review of the proposed Work Plan Variation and rehabilitation plans for Loy Yang Mine, and comment on whether these plans align with the general principles and processes that should in your opinion be used in developing a rehabilitation strategy for the Loy Yang mine.*

f) *Explain how fire risks are ordinarily considered in relation to:*

i. *the carrying out of progressive rehabilitation; and*

ii. *developing longer term rehabilitation options for coal mines in Australia.*

4 REGULATORY CONTEXT

4.1 Mineral Legislative Context

28 I consider it is essential as part of any rehabilitation solution to firstly consider the legislative context. This is contained in three documents:

a) Mineral Resources (Sustainable Development) Act 1990 No. 92 of 1990 (MRSDA 1990),

b) Mineral Resources (Sustainable Development) (Mineral Industries) Regulations 2013 S.R. No. 126/2013 (MRSDA 2013), and

c) Mining License No. 5189 (Approved 06/05/1997) (Mining License).

29 I note the MRSDA 1990 in Part 7 Rehabilitation states:

*"**Licensee must rehabilitate land***

(1) The holder of a mining licence or prospecting licence must rehabilitate land in accordance with the rehabilitation plan approved by the Department Head.

(2) The holder of an exploration licence or retention licence must rehabilitate land in accordance with the conditions in the licence."

AND

*"**Rehabilitation Plan***

*A rehabilitation plan **must** –*

(a) take into account –

*(i) **any special characteristics of the land**; and*

*(ii) the **surrounding environment;** and*

*(iii) the need to **stabilise the land*** (bold added for emphasis); *and*

(iv) the desirability or otherwise of returning agricultural land to a state that is as close as is reasonably possible to its state before the mining licence or extractive industry work authority was granted; and

(v) any potential long term degradation of the environment; ….."

30 I note the MRSDA 2013 in Schedule 15 Part 6 states:

"A rehabilitation plan that –

(a) addresses concepts for the end utilisation of the site; and

(b) *includes a proposal for the progressive rehabilitation and* ***stabilisation of extraction areas,*** (bold added for emphasis) *road cuttings and waste dumps, including re-vegetation species; and*

(c) *includes proposals for the end rehabilitation of the site, including the final security of the site and the removal of plant and equipment."*

31 I note the Mining License includes the following Conditions 15 and 16 in regard to rehabilitation:

"PROGRESSIVE REHABILITATION

Progressive reclamation will be conducted as per the rehabilitation plan. In addition, any further rehabilitation work will be carried out at the direction of an Inspector."

"FINAL REHABILITATION

Final reclamation will be in accordance with the rehabilitation plan and additional requirements as directed by an Inspector."

32 I note the Mining License also includes the following under Condition 8 Erosion:

"The licensee shall undertake all necessary works to ensure that the potential for erosion of land affected by mining is minimised"

Should erosion occur, the licensee shall take all practical steps to minimise the erosion to the satisfaction of an Inspector."

33 In summary I conclude the various regulatory documents provide the following points:

a) Direct the licensee to rehabilitate the land in accordance with the Rehabilitation Plan that has been submitted and approved.

b) The rehabilitation should be progressive and in accordance with the Rehabilitation Plan.

c) The areas must be stabilised.

d) Erosion must be minimised.

e) The Rehabilitation Plan must take into account any special characteristics of the land and the surrounding environment.

34 I interpret this last point e) to mean the Setting of the mine. The Setting of the mine is fundamental to most aspects of rehabilitation. I consider it is the most important question to be addressed at the start of any planning for final land use and final landform. The particular mine Setting then determines the process and approach required to achieve a safe and stable final landform, which is commensurate with the final land use.

35 To illustrate the importance of the mine setting I have included a number of examples in the Figures:

a) Figure 1, a small scale open cut mine in a remote arid setting.

b) Figure 2, a medium scale open cut mine located within a town, which clearly will require a completely different approach to achieving a safe and stable final landform than the example in Figure1.

c) Figure 3, the Loy Yang Mine, which is in a rural setting without adjacent man-made or natural infrastructure.

d) Figure 4, portion of the Hazelwood Mine, which is similar to the example in Figure 2

36 The Setting of Loy Yang is relatively benign, comprising a rural environment well away from any significant developments, as described in the Work Plan Variation, Figure 3, (Reference 2):

"The Loy Yang Mine is located in a rural agricultural landscape which is predominantly for grazing and forestry. Traralgon is located to the northwest of the mine…" (approximately 1.4 km away).

37 This rehabilitation setting is completely different to the case if the mine was adjacent to significant man-made or natural infrastructure, Figures 2 and 4.

4.2 Other Conditions

38 Given the very long time frames involved in future mining and then mine closure/ rehabilitation, I also note there are some other important clauses in the Legislative Documents to be considered as part of a rehabilitation solution.

39 The MRDA under Condition 7, Groundwater, Sections 7.3 and 7.4 states:

"In the event that the monitoring program in 7.2 indicates material adverse impacts beyond those evident at the date of issue of the license which are attributable to the dewatering/depressurization by the licensee after the date of issuing the license then the licensee must institute such reasonable remedial action as may be required by the Inspector and the responsible Minister under the water Act 1989 or his delegate to ameliorate these effects, proportionate to the licensee's contribution."

"For the purposes of 7.3 material adverse impacts comprise effects on aquifers in the Latrobe Valley such that the interests of other users are materially prejudiced or subsidence on a significant scale occurs as a direct result of ground water extraction which materially adversely affects private property or public lands."

40 I further note the Licence was amended on 20th January 2015 the conditions were amended to include a new Condition 1A – Risk Management. That clause includes the following:

"The Risk Assessment and Management Plan shall:

(a) *assess the risk (likelihood and consequence) to the environment and public safety from the work done or* ***proposed to be done*** (bold added for emphasis) *under the licence, including but not limited to the prevention, mitigation and suppression of fire entering or breaking out in the licenced area;*

(b) *review the following licensees' documents in effect when preparing the Risk Assessment and Management Plan;-*
   (i) *the 'Mine Fire Service Policy and Code of Practice'*
   (ii) *any mine emergency plan;*
   (iii) *any crisis management and communication strategy;*
   (iv) *any ground control plan; and*
   (v) *any other relevant policy, code or plan.*

(c) *detail quantifiable risk control standards to be achieved so as to protect the environment and public safety;*

(d) *identify the most reasonably practicable effective actions to manage the risk(s) identified under condition 1A.4(a) as well as the requirements of condition 4.5 and condition 15 so as to protect the environment and public safety, to the standards listed under condition 1A.4(c); and*

(e) *set milestones for completing the actions identified in condition 1A.4(d)."*

41 I note a guidance document "Requirements for Compliance with Risk Management Conditions" was issued by Department of Economic Development, Jobs, Transport and Resources (DEDJTR) on 7th May 2015. This note states:

"… the information must be reviewed and the documents update (if appropriate) ***to reflect*** *the current state of the mine, the current level of risk appreciation and the past, present and* ***future operations****."* (bold added for emphasis).

AND

"Environment – Particular attention is to be given to identifying environmental receptors that may be harmed from a single event or gradually over a period of time as a result of the mining operation."

AND

"Public Safety – Public safety includes the health of individuals and communities. Harm caused by a single event or gradually over time must be considered."

AND

"Risk – <u>All</u> risks to the environment and public safety as a result of the operation of the mine are to be identified, and their management described, …"

AND

"Hazards associated with the work that has been done must be identified. This includes the hazards associated with working areas of the mine, worked out areas of the mine …"

AND

"Hazards associated with work that is yet to be done…"

AND

"The hazards identified are to include, but not necessarily be limited to the following categories: ground stability, fire, noise, dust, terrorism, earthquake and flood."

AND

"Once hazards are identified, their likelihood and consequence must be assessed to determine the risk."

42 I interpret these conditions to mean that in regard to rehabilitation, where there are any uncertainties or where current understanding or analysis indicates a significant possibility that there may be questions over meeting some of the regulatory conditions with the rehabilitation plans, then this should be incorporated into risk management plans. I also interpret the clauses to mean that future subsidence is possibly a significant issue. Given the uncertainties associated with the very long time frames for future mining and rehabilitation activities this aspect should be captured in the risk management plans.

4.3 Environmental Legislative Context

4.3.1 Licence - Environmental Protection Act

43 The Licence - Environmental Protection Act 1970 Section 20 (EPA) includes two clauses potentially relevant:

"LI_DW2 Discharge of waste to surface waters must be in accordance with the 'Discharge to Water' Table". This table sets the discharge limits and the discharge measurement locations.

AND

"LI_DL1 You must not contaminate land or groundwater".

4.3.2 State Environment Protection Policies (Waters of Victoria)

44 I note the State Environment Protection Policy (Waters of Victoria) 23/2/1988, No.S13, Gazette 26/2/1988, (SEPPs) is aimed at securing "*a sustainable future for Victorians*" by "*continuously reduce our impact on surface water environments, by using land and water resources within their capabilities*". The policy purpose "..*is to help achieve sustainable surface waters*" and the basis of the policy is contained in a series of principles which should be used to guide decisions.

45 The strong focus of the principles is on the future sustainability, stewardship, conservation and protection of water resources and the environment for future generations. However I also note the principles recognise the need to integrate economic, social and environmental considerations in decisions, including

appropriate valuations and pricing. Thus the economic value of any decision is an appropriate consideration.

46 I note where there are competing environmental demands the principle of integrated environmental management applies in order to achieve "…*the best possible environmental outcome*."

47 In regards to final land-use planning decisions and approvals the SEPPs requires municipal councils to ensure that "*stormwater … management is improved*" which leads the way for harvesting of peak stormwater flows for void filling.

48 The overall implications of the policy need to be understood within the context of the decisions around rehabilitation and the planned water filled void, which appears to present some significant challenges, including:

- The current AGL Loy Yang rehabilitation assumes some surface water will be available for supplementing the void filling;
- This decision will be implemented some decades into the future and
- There will also potentially be some competing surface water demands from other mines.

49 In summary there is a strong focus in the SEPP on preservation of natural resources for future generations. This presents some challenges and opportunities including:

a) Given the importance of this aspect to final rehabilitation planning and discussions with the relevant stakeholders should commence as soon as practicable.

b) An overall social, economic and environmental appraisal may allow some harvesting of surface waters to supplement void filling.

c) Treating the water filled final void as a no release private structure and dealing with any water quality issues if they arise.

d) Opportunities exist with environmental management of Traralgon Creek to use the mine void to manage peak flood flows and assist Traralgon township.

4.3.3 State Environment Protection Policy (Groundwaters of Victoria)

50 I note goal of the State Environment Protection Policy (Groundwaters of Victoria), No.S160, Gazette 17/12/1997, is to maintain and improve groundwater quality to protect existing users and potential uses of groundwater.

51 The focus of the policy principles is on protection of groundwater, which is an undervalued resource, fundamental to the environment of surface waters and it is the responsibility of all to protect this resource from serious or irreversible damage from human activities.

5 REHABILITATION STANDARDS AND GUIDANCE DOCUMENTS

5.1 Guidelines for Environmental Management Plans

52 Although the Guidelines for Environmental Management Plans, DEDJTR, Victoria is only an advisory document it is aimed at providing "*assistance to mining licensees under the MRSDA 1990*." The Guideline advises licensees to carefully assess which matters are relevant to their particular operation and address these in their Work Plan.

53 Within the context of the Brief and focus of this report, I note the following matters of relevance to AGL Loy Yang:

a) The Act identifies four important components for the Rehabilitation Plan one of which is *"the need to stabilise the land".*

b) The Guideline recognises that long lived operations may require further consideration, planning and approval in the future, which I understand to mean the details of the Rehabilitation Plan may evolve over time.

c) However the final land use, which should be established early in the operational life, concept plan should be *"practical and currently achievable."*

d) Leave a final landform compatible with the surrounding natural landscapes and *"ensure that the land is stable and will not erode."*

e) The *"recommended slopes are 1V:3H or shallower".*

f) *"Site safety and security. Mining…sites must be left in a condition that ensures the safety of the public. The Rehabilitation Plan should cover the security of the site and public safety, following the cessation of operations. This may require limiting public access by fencing and barring of vehicular access tracks. Where applicable, the safety and stability of the pit faces,…and safety of water bodies should be addressed."*

g) *The Work Plan should detail drainage and erosion control measures, including dams, drains and sediment traps. As a general guide, drains and sediment traps should be designed for a one in 100 year flood event."*

h) *"As a general rule, if no discharge is proposed, dams should be designed to contain rainfall of a one in 10 year rainfall regime."*

54 Under the heading of Open Pits I note the following matters of relevance to AGL Loy Yang:

a) *"Open cuts most often change the land form permanently….back filling of deeper pits is generally not practical due to cost or lack of available fill material."*

b) *"Where voids are left the following matters should be addressed in the rehabilitation Plan:*

   i. The final pit slope geometry should ensure that the pit walls are structurally stable and allow for the placement and long term stability of the rock fill (overburden) and soil required for revegetation.

> ii. *Where possible, final pit walls and floors should be progressively rehabilitated.*
>
> iii. *Where open cuts intersect the water table, a permanent water body will be created unless the pit is back filled to a level above the water table. Information on the depth of the water table and groundwater quality will be required…If a water body is proposed, the regional water authority and DEWLP may also require studies of the impact of the open cut on aquifer systems, recharge areas, groundwater users and local rivers and streams.*
>
> iv. *Pit safety and security should have high priority as the risk to public safety can be high. Measures should be included to limit public access to open cut sites. Design of final pit faces, especially upper faces, and water bodies should minimise risk to public."*

55 In summary I conclude this Guidance document provides the following key points:

a) Recognises that for operations such as Loy Yang, which are very long lived, the Rehabilitation Plan may evolve over time.

b) The final land use should be practicable and achievable and the final land form should be compatible with the surrounding areas.

c) The open pit void should be stable.

d) The mine post closure should be left in a condition that ensures public safety.

e) Where a lake is planned for the mine void, studies of the impact on surface water and aquifer systems may be required.

5.2 Leading Practice Sustainable Development Program - Rehabilitation

56 The emphasis in the Leading Practice Sustainable Development Program for the Mining Industry, Mine Rehabilitation document is on landform design and revegetation. Both of these are important aspects of rehabilitation and generally applicable to most mining situations. However in the context of the challenges for the Latrobe Valley Mines I consider these are not the most important elements to be addressed.

57 Nevertheless the document does seek to provide some over-riding principles that can be used to guide leading practice in achieving site-specific sustainable planning for rehabilitation.

58 The document sets out a number of key principal guidance elements to be undertaken as part mine rehabilitation, comprising:

(a) Rehabilitate the land in accordance with appropriate post-mining land uses.

(b) Consult stakeholders and develop a closure plan that clearly defines the post-closure land use.

(c) Agree success criteria with stakeholders.

(d) Rehabilitate progressively.

(e) Undertake research into the land and water aspects.

(f) Use appropriate technologies to reduce negative impacts.

(g) Use appropriate standards.

(h) Monitor and report on performance.

59 Some of the important elements outlined in the document, which may be relevant to the AGL Loy Yang situation and the Latrobe Valley Mines in general are:

(a) The long term objective of rehabilitation is to convert the area to *"…a safe and stable condition…"*

(b) The emphasis on safety for any final void appears to be around construction of barriers and or fencing that exclude entry and on adequate warnings. This solution appears to be more suited to the mine setting illustrated in Figure 1, than to the Loy Yang setting, Figure 3.

(c) The document recognises two scales of stability, *"geotechnical stability*" that and *"erosional stability",* that is large scale stability of the overall land form and more local instability of the land surface itself.

(d) The need to incorporate all relevant stakeholders into final land use planning. This will often require a careful balancing of competing demands from different groups.

(e) The physical attributes of the site place ultimate constraints on what can be achieved with rehabilitation.

(f) Developing and creating appropriate landforms which will behave in a predictable manner.

(g) Absolute standards for stability are not set out rather there is recognition that because stability can be impacted by many elements including the site constraints, it is important to agree on the objectives for the landform associated with the final land use, including stability aspects.

5.3 Mine Rehabilitation Handbook MCA

60 This handbook from the Minerals Council of Australia lays out the broad principles and practices that should be used for rehabilitation; where rehabilitation and decommissioning is one of nine principles of an overall environmental management code for mining. However this handbook is also focussed more narrowly on landform design and revegetation, which are set out as the two main steps in the process.

61 Notwithstanding this I note the handbook includes the following relevant sections:

a) The main principle of rehabilitation is stated as *"Ensuring the decommissioned sites are rehabilitated and left in a* ***safe and stable condition****, after taking into account beneficial uses of the site and surrounding land."*

b) The objective(s) of the rehabilitation should be:

i. Clearly defined,

ii. Established in consultation with all the stakeholders, and
iii. In accord with the planned final land-use.

c) In all cases the first objective is to ensure the safety and health of people in the areas surrounding the mine are protected.

d) The need to be aware of the statutory requirements and to ensure they are met.

e) The need for well-defined rehabilitation plans, with ongoing monitoring and review of performance.

f) A program of progressive rehabilitation commensurate with the rate of excavation and the nature of the operation.

g) The Handbook refers extensively to the requirement to achieve a *"safe and stable" or a "safe, stable and non-erodible"* condition or *"made safe" or "reconstruction of a stable land surface".*

h) Making the site safe, referring to the void itself, is addressed by removing tracks and roads so as to limit public access.

i) *"Unless slopes are stable, the effectiveness of subsequent topsoiling and re-vegetation is greatly reduced and maintenance will be prolonged."*

j) *"…it is common for an open pit to remain at the end of mining…It is essential that final voids be left in a safe condition where backfilling is not reasonably feasible. The location and nature of the pit mainly determines available options for post mining land-use.*

k) In relation to final voids developed as water storage bodies:

i. *"Sufficient catchment should be provided to fill the pit within a reasonable time…"* and
ii. The quality of the stored water will be a determining factor and it may be necessary to *"flush the pit storage periodically to prevent the stored water becoming saline".*

6 AGL DOCUMENTS

6.1 Work Plan 1996

62 The Work Plan Submission in 1996 (Reference 1) includes a number of statements regarding rehabilitation and the initial long term strategy:

"Part 1:

The preferred long term option for rehabilitation of the mine is flooding to the stable groundwater level. A study is currently in progress to determine the environmental and engineering requirements of this option."

AND:

"*Part 2:*

It is currently proposed the mine be gradually flooded at the end of operations to form a lake for community recreational purposes. The overburden dump would be reverted to grazing land and recreational areas."

63 The progressive rehabilitation comprised:

"Part 1:

The Loy Yang Mine policy for land rehabilitation is to progressively and at the earliest opportunity appropriately shape, landscape, revegetate and return disturbed land to appropriate uses such as agricultural or silvicultural. Design is undertaken within the parameters of a Rehabilitation Master Plan (refer Part 2)."

AND:

"Progressive rehabilitation began on the overburden dump after permanent batters were established. In the mine permanent batters are progressively being rehabilitated. The total area rehabilitated to date is approximately 220 Ha. A further 15 Ha per year (approximately) is programmed."

64 I note that while initially all waste materials were to be placed in an external dump this has now changed.

6.2 Work Plan Variation

65 In May 2015 a Work Plan Variation was submitted by AGL (Reference 2) that included the following statements:

"Revised mine development plans, including a program for the transfer of the final coal system into Stage B, and for completion of the bottom of mine development in Stage A."

AND:

"An overburden dump development strategy that includes internal dumping, consequently reducing the overall planned height of the external overburden dump."

AND:

"During Stage C, the first tripper stacker (TS4) will be relocated from the external dump to the internal dump site and the conveyor system to the internal dump will be installed."

AND:

"Internal dumping within the mine will commence during Stage C in approximately 2017."

AND:

"Internal dumping will commence in the floor of the Stage B area north of the trunk conveyors and advance eastwards as the mine operating faces advance. TS4 will develop the initial two levels of the internal overburden dump in an easterly direction. TS5 will place overburden over the dump levels developed by TS4. The internal dump will fill across from the southern permanent batters to the northern permanent batter, with an access slot developed on the southern permanent batters."

AND:

"The internal dump will be progressively rehabilitated in stages as the dump is completed to height and as stages are completed as the dump develops to the east."

66 In regards to the establishment of permanent mine batters (for rehabilitation) the Work Plan Variation (Reference 2) notes:

"Stage B is the open cut development at the time of this work plan variation."

AND

"Stage C. This stage will see the development of the permanent batter on the north side of the mining licence boundary at an overall slope of 1:3 (V:H) (as measured from top of mine crest to the Base of Mine toe)."

AND

"Stage D. This stage will see the development of the permanent batter on the east side of the mining licence boundary at an overall slope of 1:3 (V:H)."

AND

"Stage E. This stage will see the development of the permanent batter on the south side of the mining licence boundary at an overall slope of 1:3 (V:H).

67 Stage B was completed in 2014 and the status is:

"Stage B (Figure 12) has seen the development of some 6,500 metres of permanent batters in the south western, western and northern batters."

"Thus, the permanent batters developed up to Stage B are at overall slopes of 1:3 or flatter, as measured from top of mine crest to the toe at the Base of Mine (BoM), except for one (900 metre long) section on the north permanent batter where they are 1:2.7 (V:H) or flatter, ….."

68 As noted in the Work Plan Variation (Reference 2) the basis for the design of the permanent batter slopes of 1:3 (H:V) is:

"The geometry of the permanent batters is generally designed in the Strategic Mine Plan to address geotechnical and operational matters. (AGL Loy Yang's mine design process is described in Figure 24). Geotechnical considerations include the major known defects, joint sets, faults and bedding planes. Operational requirements influence bench width and batter slopes, for example."

AND

"The design of the permanent batters will achieve the objective of an overall slope of 1:3 (H:V) (as measured from top of mine crest to the toe at the Base of Mine), or flatter, for all permanent batters in Stages C, D and E. In these mine development stages, the permanent batter rehabilitation design will be informed by the findings of the rehabilitation trials and geotechnical assessments. In these mine development stages, operating batters will use the current mine operating batter design of 45°."

69 The design of the final inpit landform comprises, Work Plan Variation (Reference 2):

"At the mine closure and final rehabilitation the slopes can be divided into three domains – above the final lake water level, below the final lake water level and at the final lake water level.

Above the final lake water level the interseam material will not be re-saturated, although some increase in moisture can be expected to occur due to material covering the final slope preventing water evaporation from the interseam. Therefor it is expected that there will be no adverse impacts on stability.

Below the final lake water level the interseam will be saturated, but as noted above, the batter slopes have been designed for this condition. Therefore no significant impact is expected.

Around the final lake water level there will be some variation in the water level due to seasonal impacts plus wave action. It is expected that protection of the sandy interseam will be required. It is considered that at some locations the interseam will need to be covered with geotextile and rock beaching (rip rap). However, alternative protection measures are possible where the interseam is located high up in the bench scale batter. Trials of potential protection measures will be undertaken when the lake level is well below the final lake water level. These trial areas will be flooded as the lake level increases. Therefore the extent and size of the works at the final lake water level will be gauged during progressive lake water level increase after mine closure. In addition, it is expected that if any instability issue occurs within the interseam, it will only be local/small and would not cause significant slope stability concerns."

6.3 Work Plan Variation Cover Letter

70 Some of these statements are also reiterated in a letter from AGL Loy Yang on 1st June 2015 (Reference 11), which although dated later than the WPV is a cover letter to that document:

*"**Rehabilitation of permanent batter slopes***

The Work Plan Variation now contains a clear commitment to achieve an overall permanent batter slope of 1:3 (V:H) (as measured from the top of mine crest to the toe at the "Base of Mine"), or flatter. As per the discussion at the 19 May 2015 meeting, we understand that interslopes may be steeper or flatter so long as:

- *the overall slope angle of 1:3 (V:H) is maintained;*
- *long term exposed coal is protected (so as to reduce fire risk); and*
- *the final landform is stable from a geotechnical perspective, and provides safe access for maintenance and end-use purposes.*

We confirm that the "Base of Mine" will be taken to be the original "Base of Mine" even though this may not ultimately be the lowest point of the rehabilitated pit after overburden back fill.

71 The letter also includes some notes of caution:

Rehabilitation experience, proposed trials and future research

AGL Loy Yang's rehabilitation, geotechnical and mining experience to date shows that there can be competing technical issues with respect to the rehabilitation objectives, and a holistic approach is required to manage the permanent batters over the longer term.

This experience demonstrates that a rehabilitation design that involves all overall slopes being set at 1:3 (V:H) and covered with overburden may not mitigate competing risks. In particular, AGL Loy Yang's rehabilitation experience demonstrates that while such a design would decrease coal fire risks, it may increase long term stability risks. A steeper slope may be better from a stability perspective."

6.4 HMFI Submission on Rehabilitation

72 The AGL Loy Yang Submission to the HMFI on rehabilitation includes further detail and discussion on a number of aspects of the planned rehabilitation.

73 In regards to the final landform this document concludes:

":….. there is basically only one landform option".

> *"Thus, at closure the landform will be a partially water-filled lowered landform".*

74 In regards to achieving a stable final landform there are a number of statements of intent, including:

“Instability in the long term in the created landforms may undermine future land use options”.

“…. AGL Loy Yang Mine’s rehabilitation principals:

- *Create a safe and stable landform”.*

“Create a geotechnical stable landform”.

“Sustainability and land use principles:

“Final landforms will need to be geotechnically and geochemically stable, compatible with the surrounding landscape and able to support designated post closure land uses”.

“Rehabilitation (progressive and final) requires a stable landform both before and after rehabilitation”.

75 In regards to mine sub-floor aquifers and aquifer recovery post mining the aim of the in-pit waste dump is:

“Overburden must be placed to a depth in the pit that counteracts hydrostatic pressures for long term stability. With the limited volume of overburden available this depth can only be achieved in the western half of the pit, leaving the eastern half an open void ….. this area becomes a lake and be filled to a level that assists with recovering hydrostatic pressures / modelled to achieve weight balance (-22.5 RL)”.

“On this basis the whole area of the pit will have long term stability from groundwater pressures”.

76 The rehabilitation will require careful management of the existing mine dewatering systems and AGL Loy Yang intend to undertake the following:

“… dewatering will have to be continued until a final groundwater pressure balance is achieved through lake filling. Once that balance / weight balance has been modelled at -22.5 mRL is achieved, a stable condition will exist and the groundwater pump can be de-commissioned”.

“Pit slope dewatering, through horizontal drains is a critical component to maintain slope stability and these systems must be extended and maintained as the mine develops. The systems and areas they cover are required to be in place until cessation of mining and until closure”.

77 The importance of surface drainage control is recognized:

“Surface drainage systems are a critical component to maintain slope stability and these systems must remain in place during the operating life of the mine”.

78 In regards to timing of rehabilitation works:

“Complete the majority of the rehabilitation works with 15 years of closure; with a subsequent period of monitoring and maintenance as required.”

79 The demolition materials will be re-used as part of the rehabilitation:

"Materials available at the site from demolition activities, where appropriate, will be used re-utilised in the rehabilitation process to improve long-term stability and weathering. A good example is concrete materials from demolition that could be utilised to buffer wave action at the intersection between rehabilitated surfaces and any lake development."

80 The role of future trials is also set out:

"…. there are competing issues still to be resolved in determining the design for progressive coal slope rehabilitation …..".

"The trials will assist in determining the first rehabilitation ……. (inter-slope angle, clay and topsoil coverage) for the existing slopes and maintenance requirements".

7 ASSESSMENT OF CURRENT REHABILITATION AT AGL LOY YANG

7.1 Rehabilitation

81 Loy Yang have undertaken extensive rehabilitation of the upper soil and weathered coal slopes, mainly outside the active mining area, along, Figure 5:

- Southwest,
- West and
- Along the Northern Batter.

82 In addition a small rehabilitation trial of the upper coal batter slopes was carried out in 2006 towards the northern end of Western Batter, Figure 6.

83 The rehabilitation, including the trial, comprises two different base preparation conditions:

(a) Along the western half of the Northern Batter the upper existing cut slope in in-situ soil was regraded to a uniform slope then covered with clay and topsoil, Figure 7.

(b) Along the eastern half of the Northern Batter and in the trial area the rehabilitation has entailed cut and filling of the original benched mine profile to a uniform slope then covering with clay and topsoil. This was to achieve a balanced cut/fill excavation profile, Figure 8.

84 The technical details for the rehabilitation used thus far comprise:

- Overall slopes of 3:1 (H:V) or 18.4°,
- Although locally it is understood some sections of the Northern Batter approach 2.5:1 or 21.8°;
- Other areas around the mine where the existing mine slopes are flatter approach a slope of 4:1 or 14°;
- The trial was placed at an angle of 2.9:1 or 19°.

- The cover comprises 0.5 to 0.6 m of “clay” and 0.1 to 0.2 m of topsoil;
- No compaction was used except for tracking with the dozer used to spread the cover;
- There are no specific surface drainage measures except for a small berm in the upper third of the slope in the higher parts of the Northern Batters; and
- Slope heights and down slope lengths range from:
  - Northern Batters west – 25 to 45 m high and 65 to 110 m long;
  - Northern Batters east – 30 m high and 85 m long; and
  - Trial – 55 m high and 170 m long.

85 The trial area is now approaching 10 years and on the Northern Batters the rehabilitation is from 5 to 20 years old.

7.2 Discussion of the Results

86 Although it is understood there was minimal design and engineering preparation used for both the general rehabilitation and the trial area, the overall result is quite reasonable and no major problems were evident. This is considered to be positive for the success of future rehabilitation at AGL Loy Yang. However notwithstanding this the following issues have either been identified by AGL Loy Yang or were evident on inspection:

(a) Remediation and maintenance requirements are understood to have been higher than expected.

(b) Thicker cover appears to yield better results, compare Figures 7 (approximately 600 mm to 700 mm) and 8 (variable thickness).

(c) The trial area gave problems in the second year which was attributed to higher than normal rainfall.

(d) The trial area has shown some slumping/movement of the “filled” sections in the cut/fill profile.

(e) The trial area continues to have rill channels formed on the lower section of the slope caused by rainfall runoff due to the long slope length and surface gradient.

(f) The “clay” material available for cover is dispersive and prone to erosion if cracked or disturbed and or if there are concentrated water flows, Figure 9.

(g) The cut area in the west of the Northern Batter shows, Figure 9:

   a) Widespread minor sinkhole development, caused by the combination of dispersive cover and open cracks in the underlying coal; and

   b) Some cracking and erosion.

87 The design of the cover layer for the coal is a complex question, of which the thickness is only one, probably smaller component. The answer will require detailed design and trials in order to resolve.

88 Overall the cut and fill slope at the eastern end of the Northern Batters appears in better condition than the cut slope to the west. However this could merely be a manifestation of the more limited exposure time and the fact that the western end of the pit has had larger historic movements. Further movements in the east are expected as mining continues and this could change the situation.

7.3 Groundwater and Rainfall Runoff Implications

89 Review of all available groundwater data for all of the rehabilitation areas, including the trial area, has shown very positive results with no obvious adverse impacts on either:

- Groundwater levels or
- Rainfall responses within the slopes.

90 Given the current design life of these areas I would have expected based on experience that if adverse impacts were associated with the rehabilitation they would have been manifested at least to some extent by now. However this finding needs to be judged within the context of the following factors:

- The life of these areas,
- The limited slope heights and down slope lengths;
- The short length in plan of the trial area,
- The general lack of shallow piezometers in these rehabilitated areas and
- The lack of piezometers in general directly under the rehabilitated areas.

7.4 Current Hydrogeological Regime

91 A new hydrogeological regime has developed in the mine batters as a result of the combined impacts of all the mining related activities at AGL Loy Yang. The components of the site that have contributed to this situation comprises:

- Exposed mine faces,
- That have undergone large movements, with
- Joints exposed,
- Horizontal drains and
- Aquifer pumping.

92 This hydrogeological regime has largely stabilized. Overall this new stabilized regime is positive, however because of the metres of movement that have occurred over time there are partial hydraulic connections over hundreds of metres between some geological units.

8 DISCUSSION OF THE REGULATORY AND GUIDANCE CONDITIONS

8.1 Main Conditions in the Regulations and Guidance Documents

93 Although the various regulatory and guidance documents differ considerably in their individual applicability, emphasis and detail, there is broad agreement about many of the main conditions and requirements in regards to mine rehabilitation.

94 In summary the various regulatory documents and the DEDJTR guideline dictate the following requirements:

(a) The licensee to rehabilitate the land in accordance with the Rehabilitation Plan that has been submitted and approved.

(b) The rehabilitation should be progressive and in accordance with the Rehabilitation Plan.

(c) The areas must be stabilised.

(d) Safety is a high priority and post closure the mine should be left in a condition that ensures public safety.

(e) Erosion must be minimised.

(f) The Rehabilitation Plan must take into account any special characteristics of the land and the surrounding environment, which I interpret as the Setting.

(g) Recognise that for long lived operations such as AGL Loy Yang the Rehabilitation Plan may need to evolve over time.

(h) The final land use should be practical and achievable and the final landform should be compatible with the surrounding areas.

95 In addition to these elements recent additions to the regulatory documents, require a risk based approach. In regards to rehabilitation I interpret these conditions to also apply to rehabilitation. For example there are still considerable uncertainties with the rehabilitation plans and hence this should be incorporated into risk management plans. Given the uncertainties associated with the very long timeframes for future mining and rehabilitation activities future subsidence is possibly an important issue. I also interpret the clauses to mean subsidence should be captured in the risk management plans.

96 In summary there is a strong focus in the SEPPs on preservation of natural resources for future generations. The overall implications of the policy need to be understood within the context of the decisions around rehabilitation and the planned water filled void, which appears to present some significant challenges. However a balanced overall approach seems possible with the principles recognising the need to integrate economic, social and environmental considerations in decisions, including appropriate valuations and pricing. The principle of integrated environmental management also applies in order to achieve the best possible environmental outcome.

97 Therefore it is considered that opportunities may exist within the SEPP for a number of measures including:

a) Given the importance of this aspect to final rehabilitation, planning and discussions with relevant stakeholders should commence as soon as practicable.

b) An overall social, economic and environmental appraisal may allow some harvesting of surface waters to supplement void filling.

c) Treating the water filled final void as a no release private structure and dealing with any water quality issues if they arise.

d) Opportunities exist with environmental management of Traralgon Creek to use the mine void to manage peak flood flows and assist Traralgon township.

98 The key principles and objectives for rehabilitation set out in the government and industry guidance documents relevant to the AGL Loy Yang situation and the Latrobe Valley Mines in general are:

(a) Ensure the statutory requirements are met.

(b) The long term objective of rehabilitation is to convert the area to a safe and stable condition.

(c) Recognition that the physical attributes of the site place ultimate constraints on what can be achieved with rehabilitation.

(d) Absolute standards for stability are not set out rather there is recognition that because stability can be impacted by many elements including the site constraints (including the Setting), it is important to agree on the objectives for the landform associated with the final land use, including stability aspects.

(e) Rehabilitate the land in accordance with appropriate post-mining land uses.

(f) Develop well-defined rehabilitation plans.

(g) Consult stakeholders and develop a closure plan that clearly defines the post-closure land use.

(h) Developing and creating appropriate landforms which will behave in a predictable manner.

(i) Agree success criteria with stakeholders.

(j) Rehabilitate progressively, but commensurate with the rate of mining and the nature of the mining operation.

(k) Undertake research into the land and water aspects.

(l) Use appropriate technologies to reduce negative impacts.

(m) Use appropriate standards.

(n) Monitor, review and report on performance.

99 I note that neither document clearly sets out the importance of the mine setting as a fundamental initial assessment. However the concept is included within many of the objectives and principles as subsidiary clauses or qualifiers.

8.2 "Safe and Stable" a Discussion

8.2.1 Slope Design Criteria

100 Quantification of stability is normal practice in engineering. Where the stresses promoting stability are equal to the stresses promoting instability the factor of safety (FOS) = 1 and in normal engineering usage this case is described as Marginally Stable. Where FOS <1 the slope is termed unstable. Where FOS >1 the slope is termed stable.

101 Some normally accepted ranges of FOS for slopes in various settings are:

- A civil engineering slope – FOS = 1.3 to 1.5;
- A mine slope – FOS = 1.2 to 1.3;
- The minimum FOS for a slope under earthquake loading = 1.0 to 1.1; and
- A long term rehabilitated mine slope – FOS = 1.5.

102 However, there is no such thing as absolute stability only increasing probabilities of stability as the FOS becomes larger. The margin of the FOS above 1.0 is often taken as a measure of the relative stability of a slope. So one accepted measure of stable is in terms of the FOS of the slope. However this simple view is not comprehensive enough for the Latrobe Valley conditions. This is because under loading events, or with flattening of coal batters or pit flooding, even with a high starting FOS, the FOS can reduce to less than 1.0.

8.2.2 The Meaning of Safe and Stable

103 In geotechnical engineering there is no definition of either "Safe" or "Stable". Often these can be personal value judgements. Hence in terms of the Regulatory and Licence Conditions the questions to be answered are:

- What is the practical definition of these two terms? and
- How may they be applied in practice at a particular mine?

104 It is important to note that neither term is defined in the regulations or guidance documents described in Sections 4 and 5. Some definitions that could possibly be used for guidance are contained in the following sources:

1. Queensland Mining Council, 2001, "Guidelines for Mine Closure Planning in Queensland".
2. Australian and New Zealand Minerals and Energy Council (ANZMEC) and Minerals Council of Australia (MCA), 2000, "Strategic Framework for Mine Closure".
3. The Oxford English and the Oxford Advanced Learner's Dictionaries.
4. Websters dictionary.

105 The definitions of safe contained in these documents are:

"A condition where the risk of adverse effects to people, livestock, other fauna and the environment in general has been reduced to an acceptable level." (1)

"A condition where the risk of adverse effects to people, livestock, other fauna and the environment in general has been reduced to a level acceptable to all stakeholders." (2)

"Protected from danger or risk"; "not causing or leading to harm or injury"; "not involving much or any risk". (3)

"Free from risk"; "unthreatened by danger"; "Free from danger and risk of harm". (4)

106 The definitions of stable contained in these documents are:

"A condition where the rates of change of specified parameters meet agreed criteria." (1 and 2)

"Not likely to change or fail". (3)

"Remaining or able to remain unchanged in form, structure, character,"; "able to return to its original condition or recover its equilibrium after being slightly displaced"; "permanent", "enduring".(4)

107 Of note is the Oxford Dictionary which also recognises; "Metastable": (of a state of equilibrium) *"stable provided it is only subjected to small forces; theoretically unstable but are so long-lived as to be stable for practical purposes."* (3)

108 In geomorphology (science of natural slopes) it is recognised that slopes can have acceptable FOS but still be subject to movement and subsidence. In the context of natural slopes, in a non-critical mine setting, this is referred to as "Conditional Stability".

109 Overall these definitions cannot be used in a practical sense. However the concepts of acceptance criteria and stakeholders are introduced. These are included in the following phases *"acceptable level"* and *"meet agreed criteria"* and *"acceptable to stakeholders".*

8.2.3 Proposed Acceptance Criteria and Safe and Stable

110 In Section 4.1 I introduced the concept of the mine setting and illustrated it with reference to a number of actual examples, Figures 1 to 4.

111 The Setting of the mine is fundamental to most aspects of rehabilitation. It is the most important question to be addressed at the start of any planning for achievable final landform(s). It is also essential for considerations of the final land use(s).

112 It should be apparent from comparison of the mines in Figures 1 and 2 that the particular mine Setting must determine the process and approach required to

achieve a safe and stable final landform. In the first case (Figure 1) safe and stable could be readily achieved by fencing, placing a bund around the open pit and removal of tracks and roads. This is what is actually done in practice.

113 However in the second case (Figure 2) this approach to “safe and stable” is insufficient. This is because the engineering studies to satisfy a criteria of safe and stable also need to include aspects such as:

- Higher FOS,
- Design earthquake loading for the mine slopes in the very long term,
- Design rainfall loading for the slopes in the very long term,
- Probabilities of failure of the slopes,
- Potential for landslide waves in the mine lake if failure occurs (Seiche analysis),
- Public amenity,
- Access to the area by the public,
- Risk based studies to assess the individual risk of significant injury or death; and
- Comparison of these risks with societal norms.

114 The Setting of AGL Loy Yang is a rural environment well away from significant natural or man-made infrastructure. As noted in the AGL Loy Yang submission to the HMFI (Reference 4) because the total waste available is only 20% of the total mined volume and because of the hydrogeology there is basically only one landform option for Loy Yang Mine, a partially backfilled and partially water-filled lowered landform.

115 For the Setting of the Loy Yang Mine and understanding the stability challenges posed by the geotechnical conditions it is proposed that rather than “safe and stable” that the following definition is more appropriate:

> “Safe, sustainable and stable within the context of the final landform and land use”.

116 Using that overall definition, with the principles set out in the various guidelines described above and in accordance with the latest Guideline on Open Pit Slope Design (Reference 12) the key steps in developing a rehabilitation solution for Loy Yang Mine are:

(a) Understanding the setting of Loy Yang Mine and hence the implications of a low intensity land use built largely around agricultural type activities means. Defining what this landform and land use means in terms of safe, sustainable and stable.

(b) Acceptance of the final landform and land use.

(c) AGL Loy Yang then needs to formulate their own acceptance criteria.

(d) These criteria then need to be accepted by the Stakeholders.

(e) The acceptance criteria should be based on multiple criteria including:

i. FOS, which addresses stable;

ii. Stable under base conditions, which addresses stable;

iii. Derivation of the appropriate design loading events for rainfall and earthquake, which addresses sustainable, safe and stable;

iv. Assessment of deformations under the design earthquake loading, which addresses sustainable and stable;

v. Monitoring data, which addresses sustainable and stable;

vi. Quantified risk and consequence studies, which addresses safe;

vii. Control of catchment sizes and design of cover layers, and

viii. Completion of the planned rehabilitation and ongoing management, which addresses sustainable, safe and stable;

9 ANSWERS TO THE BRIEF

117 **Question 1**

"Prepare a report that sets out the key principles and processes that should in your opinion be used in developing a rehabilitation strategy for an open cut coal mine, regardless of its location and particular characteristics."

118 I have addressed many of the key principles and processes in the discussions contained in the preceeding sections. In the following paragraphs I have summarized the key elements of that process.

119 All mine rehabilitation is in effect a process. In theory that process is aimed at repairing the impacts caused by mining on the environment. Ideally that repair would approach the conditions that existed prior to mining.

120 However in practice the aims have to vary from mine site to mine site because of particular site characteristics and may vary from:

- Fully restoring the pre-mining conditions,
- To simply establishing the "safe and stable" condition.

121 Leading practice in mine rehabilitation then simply entails employing a process that is the best method for carrying out that process at the particular mine site.

122 However as for all mining, flexibility is a key element to success and hence the strategy and processes should incorporate a flexible approach (Reference 9):

*"As new challenges emerge and new solutions are developed, or better solutions are devised for existing issues, **it is important that leading practice be flexible and innovative in developing solutions that match site-specific requirements**. Although there are underpinning principles, leading practice is as much about approach and attitude as it is about a fixed set of practices or a*

particular technology. Leading practice also involves the concept of 'adaptive management', a process of constant review and 'learning by doing' through applying the best of scientific principles." (bold added for emphasis).

123 Mine rehabilitation then usually comprises (Reference 9):

- Developing appropriate landform designs commensurate with the post-mining land-use;
- The landforms should behave in a predictable manner in keeping with the design principles; and
- Establishing appropriate sustainable ecosystems.

124 These are important parts of the process, however a rehabilitation strategy for an open cut coal mine regardless of its location and characteristics should also include consideration of the following aspects:

- Establishing any particular site conditions which may constrain the rehabilitation;
- Clearly define the mine setting, including any important man-made or natural infrastructure potentially at risk from the mine is identified and included in the strategy and process;
- Evaluating the climatic regime,
- Evaluating the geomorphological setting,
- Establish the appropriate post-mining land-use;
- Establishing the appropriate land-use for the final void;
- Establishing appropriate sustainable ecosystems,
- Undertaking rehabilitation progressively over the life of the mine; and
- Implementing an effective monitoring and maintenance program.

125 The end land-use is usually determined in consultation with all the stakeholders including community, government departments, local government, traditional owners and private landholders. However it should be an outcome of the process and cannot be predetermined or preordained except perhaps in concept.

126 The particular site conditions may place constraints on either the final landform, end land-use or other aspects of the rehabilitation. Where this is the case these particular conditions should be established very early in the process.

127 I have reviewed all the objectives and principles set out in the various regulations and guidelines and together with my own understanding and experience compiled the following list, which I consider appropriate for an open cut coal mine regardless of its location and particular characteristics:

(a) Ensure the statutory requirements are met.

(b) The long term objective of rehabilitation is to convert the area to a safe and stable condition.

(c) Safety is a high priority and post closure the mine should be left in a condition that ensures public safety.

(d) Erosion must be minimised.

(e) Recognition that the physical attributes of the site place ultimate constraints on what can be achieved with rehabilitation.

(f) Absolute standards for stability are not set out rather there is recognition that because stability can be impacted by many elements including the site constraints (including the Setting), it is important to agree on the objectives for the landform associated with the final land use, including stability aspects.

(g) Rehabilitate the land in accordance with appropriate post-mining land uses.

(h) The final land use should be practical and achievable and the final landform should be compatible with the surrounding areas.

(i) Develop well-defined rehabilitation plans.

(j) Develop and create appropriate landforms, which will behave in a predictable manner.

(k) Consult stakeholders and develop a closure plan that clearly defines the post-closure land use.

(l) Agree success criteria with stakeholders.

(m) Rehabilitate progressively, but commensurate with the rate of mining and the nature of the mining operation.

(n) Undertake research into the land and water aspects.

(o) Use appropriate technologies to reduce negative impacts.

(p) Use appropriate standards.

(q) Monitor, review and report on performance.

128 **Question 2**

"Explain the technical constraints that apply to the Loy Yang Mine arising from its particular geotechnical and hydrogeological context, and the broader Latrobe Valley context."

129 Because of the low density of the coal, 1.1 t/m^3, compared to water at 1.0 t/m^3, the stability of the mine batter slopes is very sensitive to water pressures. This basic situation is exacerbated by three other factors, the thick coal seams, the continuous joints in the coal and the very large stress related movements that have occurred and are continuing around all the mines. This means it is easy for groundwater pressures to build up under rainfall runoff events and to destabilize the mine batters. This also means it is easy for water to cause uplift pressures on the coal seams, basically because the coal almost floats in water.

130 These water pressures can have adverse impacts on stability under various conditions when the water is located anywhere in relation to the mine batter, including:

- A water body (mine lake) at the toe of the batter, or
- A water body at the top of the mine above the mine batter, either a natural lake, river or wetlands; or
- Within the mine batter itself or
- Below the mine floor.

131 Hence under certain conditions simply filling the mine void with water may destabilize the mine batters. The critical condition for stability is probably during filling with water but in some geological circumstances even a largely water filled mine void may have a lower FOS than an empty mine void. This is quite unusual in an open cut mining situation.

132 In addition a partial waste backfill at the toe of a mine batter may be insufficient to control stability if adverse groundwater conditions develop in the slope over time or as a result of a rainfall loading event. This is unlike almost all other mine situations where even small amounts of waste placed at the toe of a mine batter are able to stabilize the batter and result in high FOS.

133 The low coal density means a high sensitivity to water. However this same factor also means the mine batters are also very sensitive to earthquake loading. The degree of the sensitivity is also quite unusual in an open cut mining situation.

134 In the long term, post rehabilitation the mine void slopes will be required to be able to withstand adverse loading events for peak rainfall events and earthquakes. Under some geological situations these adverse loading events are sufficient to reduce the FOS to much less than 1.0 (that is to cause the slopes to be unstable). This is despite a high conventional static FOS, greater than 1.5, for the static situation.

135 The origin of the 3H:1V slopes is uncertain and references to it are contained both within AGL Loy Yang and regulatory documents. This would appear to be a slope angle largely derived from precedent practice with mining in the Latrobe Valley. I have not sighted any scientific evidence to support this angle as a preferred long term slope for rehabilitated mine slopes in the Latrobe Valley. Recent rehabilitation studies by AGL Loy Yang have also shown that flattening the existing mine batters reduces the FOS and hence makes the slopes less stable.

136 The geotechnical characteristics of the geological profiles in the Latrobe Valley are also unlike most other mine situations. In general flattening a slope to allow mine rehabilitation improves the overall stability. However in the Latrobe Valley Mines re-grading the mine batters to flatter overall slopes to allow clay and topsoil covering may actually reduce the stability.

137 During normal mining operations all the slopes within the mines require the following to ensure stability:

- Depressurisation of aquifers under the mine floor,
- Horizontal drains in the mine batters to depressurise the slopes and control infiltration from rainfall;

- Control of surface water on the mine batters to limit infiltration and limit surface water concentrations;
- Active continuous ongoing management of these factors and
- Overall management of the whole stability situation.

138 After some decades of mining quasi-equilibrium conditions become established in the mine batters under the combined impacts of all these factors. This situation has resulted in "stable" slopes at least under average conditions. At AGL Loy Yang this equilibrium condition is now established below most of the older mine batters. However notwithstanding this situation many slopes are still showing ongoing creep movements. Hence one of the challenges facing rehabilitation in the Latrobe Valley Mines in general is how to maintain this hydrogeological situation when there will be significant changes to many factors, including:

- Partial backfill against the mine slopes with waste,
- Covering some of the horizontal drains,
- Turning off the pumps and
- Partially filling the mine void over the medium to long term with water.

139 A number of mine batters within the Latrobe Valley are showing ongoing creep movements decades after mining has ceased. This ongoing movement has the capacity to change the hydrogeological regime, either positively or negatively. In addition ongoing movement increases the potential for hydromechanical coupling events with rainfall runoff causing adverse batter movements or instability. Ongoing movements could also lead to further opening of coal joints exacerbating erosion potential and sinkhole development.

140 In the preceeding paragraphs I have highlighted the special characteristics of the materials and also the technical constraints and challenges posed by these characteristics. It is precisely because of these factors that careful consideration of the mine setting is fundamental to mine rehabilitation. At AGL Loy Yang based on the geotechnical characteristics, the hydrogeology and the quantity of available waste materials there is only one landform option and that is the one adopted by Loy Yang.

141 This is not the case universally within the Latrobe Valley and in other cases entirely different settings apply to particular domains of various mines, for example Figure 3. Each setting and domain will require a specific process and acceptance criteria to be developed. Until the appropriate engineering, studies have been carried out and acceptance gained from the Stakeholders it is difficult to see how a landform and rehabilitation approach can be set out other than in broad concept.

142 **Question 3**

"Describe some of the key events and anomalies that have occurred in the Latrobe Valley, and in broad terms discuss any implications for the development of a rehabilitation strategy at Loy Yang Mine."

143 Mining of brown coal for power generation in the Latrobe Valley commenced in the early 1920's. Initially the scientific understanding was poor and mines were developed close to infrastructure and towns. After some decades it became apparent that surface movements, both inside and outside the mines had occurred ever since excavation commenced. As the size and depth of the mines increased the surface movements both inside and around the mines became increasingly significant.

144 Since 2007 there have been a number of significant adverse stability incidents affecting both natural and man-made infrastructure both inside and well outside the mines. The history shows periods of relative stability followed by adverse stability incidents, which occurred both inside and outside the mining licences. On each occasion these incidents have generally led to an increase in the knowledge and understanding of the technical issues, hazards and risks associated with such large mines and mining related activities.

145 The collapse of the Latrobe River Batter in Yallourn Mine in November 2007 was the first major catastrophic failure for many decades. However, over the past 10 to 15 years there appears to have been an increase in the number of stability incidents including:

1. 2007 - Yallourn Latrobe River Batter Failure.
2. 2009 - Hazelwood Mine - Sinkholes discovered in the Morwell Main Drain.
3. 2011 - Hazelwood Mine, Northern Batter Movement, sinkholes, cracking and closure of Princes Freeway.
4. 2010 and 2011 - Yallourn Mine, re-initiation of movements on the western batters of old Township Mining Field, extending outside the mine and across public roads.
5. 2014 - Hazelwood Mine, ground movement occurred in conjunction with the Hazelwood Mine Fire.
6. 2014 - Yallourn Mine, Latrobe Road cracking and sinkholes.

146 In addition to these incidents the dewatering and depressurization is causing regional subsidence, which is ongoing, Figure 11. This subsidence is not entirely uniform and anomalies (concentrations of subsidence) are evident in at least two areas, north of Hazelwood Mine and north of Loy Yang Mine, Figure 12. This subsidence, both general and the anomalies, leads to ongoing creep movements of the mine batters, both vertical and horizontal.

147 The anomaly north of Hazelwood Mine contributed to:

- Sinkhole development discovered in the Morwell Mine Drain in 2009; and
- Northern Batter movement in 2011.

148 The Northern Batter movement occurred in an area where, Figure 4:

- Mining had ceased in the 1960's and 70's;

- The lower sections of the mine batters had been buttressed by a dam and dry ash pond (HARE); and
- The lower mine batters had been rehabilitated.

149 This example illustrates the points described in the answers to Question 2 above. The important point is that mine batters may still become unstable even with a substantial toe weight, which is analogous to an in-pit dump as part of rehabilitation plan.

150 The Hazelwood Mine Fire also resulted in movement of the northern mine batters over a very large area. The movement was associated with increases in pond levels at the toe of the batters and water infiltration into the batters from fire suppression watering activities. This example relates to the potential adverse stability impacts that can occur due to rising mine lake levels and intense rainfall runoff events.

151 The Area of Influence is the zone outside the mine crest that has undergone significant movement in the past and or is subject to significant ongoing movements into the future as a result of mining related activities. There is an Area of Influence surrounding each of the mines.

152 The Latrobe Valley and the mines are impacted by two main mining related effects:

1. Movements caused by relief of the in-situ horizontal stress relief.
2. The much larger area, Latrobe Valley wide, affected by regional dewatering and depressurisation of the aquifers.
3. These two effects are superimposed onto each other.
4. However both processes are continuing, hence the areas impacted are not fixed and are changing over time.

153 Substantial movements have occurred historically in and around all three mines in the Latrobe Valley and these movements are continuing as mining progresses.

154 Historically it was thought that once the stresses had been relieved, the movements would largely cease and the batter was then stable. Hence this was generally considered to be of no consequence and just part of the normal “benign” behavior pattern. However the Latrobe Road Incident in 2014 has highlighted that not all the risks associated with ground movements are yet fully understood or appreciated.

155 The rehabilitation strategy for Loy Yang Mine in order to be successful has to be cognisant of all these events, their controls, timing and consequences. At the primary level this goes back to the mine setting. Many of these events and consequences would probably be manageable within the context of the planned final landform and land use at Loy Yang. Hence it is considered that in the Loy Yang Mine rehabilitated landforms above the mine lake level can probably be developed that are safe, sustainable and stable but only within the context of a low intensity land use built largely around agricultural type activities. However that may not be the case in other mine settings in the Latrobe Valley.

156 The other aspect that requires careful consideration is the potential interaction of progressive rehabilitation of the mine batters with areas continuing to be affected by movements. Ideally most mine rehabilitation commences with an underlying substrate that has largely ceased movements and then cover layers, surface drainage control measures and vegetation are established. This is not to say that if creep movements are occurring that rehabilitation cannot be accomplished early, rather that some questions and challenges will remain.

157 **Question 4**

"Consider whether the general principles for developing a rehabilitation strategy noted in (1), might require adaption to the Loy Yang Mine context."

158 I consider the objectives and principles I have set out in the answer to Question 1 above all apply to Loy Yang Mine. However all have to be assessed or modified in degree and emphasis to lesser and greater extents in order to achieve successful rehabilitation of Loy Yang Mine.

159 By way of example I refer to the discussion on "safe and stable" in Section 8.2. This example illustrates, perhaps to the greater extent, how one of the principles and objectives needs to be addressed in order to achieve a satisfactory rehabilitation outcome for Loy Yang Mine.

160 **Question 5**

"Review of the proposed Work Plan Variation and rehabilitation plans for Loy Yang Mine, and comment on whether these plans align with the general principles and processes that should in your opinion be used in developing a rehabilitation strategy for the Loy Yang mine."

161 In principle based on the geotechnical characteristics, the hydrogeology and the quantities of available waste materials there is only one landform option and that is what has been adopted by AGL Loy Yang. This then necessitates a low intensity land use built largely around agricultural type activities. I agree with this proposal by AGL Loy Yang.

162 Overall on review it is evident that conceptual planning for rehabilitation of Loy Yang Mine, that is to flood the mine void and rehabilitate within an overall rural setting has been relatively fixed since 1996 (Reference 1). However it is also evident that the essential underlying scientific studies to underpin many aspects have only recently commenced. Similarly research on rehabilitation has also only recently been planned.

163 However the science supporting many of the details around that overall concept are in progress and many are yet to be determined.

164 I have reviewed all the objectives and principles set out in the various regulations and guidelines and together with my own understanding and experience compiled the following list, which I consider appropriate for Loy Yang Mine:

(a) Ensure the statutory requirements are met.

(b) The long term objective of rehabilitation is to convert the area to a safe and stable condition.

(c) Safety is a high priority and post closure the mine should be left in a condition that ensures public safety.

(d) Erosion must be minimised.

(e) Recognition that the physical attributes of the site place ultimate constraints on what can be achieved with rehabilitation.

(f) Absolute standards for stability are not set out rather there is recognition that because stability can be impacted by many elements including the site constraints (including the Setting), it is important to agree on the objectives for the landform associated with the final land use, including stability aspects.

(g) Rehabilitate the land in accordance with appropriate post-mining land uses.

(h) The final land use should be practical and achievable and the final landform should be compatible with the surrounding areas.

(i) Develop well-defined rehabilitation plans.

(j) Develop and create appropriate landforms, which will behave in a predictable manner.

(k) Consult stakeholders and develop a closure plan that clearly defines the post-closure land use.

(l) Agree success criteria with stakeholders.

(m) Rehabilitate progressively, but commensurate with the rate of mining and the nature of the mining operation.

(n) Undertake research into the land and water aspects.

(o) Use appropriate technologies to reduce negative impacts.

(p) Use appropriate standards.

(q) Monitor, review and report on performance.

(r) Recognise that for long lived operations such as AGL Loy Yang the Rehabilitation Plan may need to evolve over time.

165 I note that the approach adopted by AGL Loy Yang is in general accord with many of these elements. However, as I have discussed in the answers to the preceeding discussions, rehabilitation of the mine is a complex task, involving many factors. While AGL Loy Yang have commenced studies and assessments of many of these objectives and principles, the approaches still need to evolve over time. As more understanding develops, additional challenges and issues will become apparent. Thus far AGL Loy Yang have shown a strong corporate commitment to addressing these issues and challenges.

166 The extent of the progressive rehabilitation carried out to date at Loy Yang Mine and the extent of the exposed coal batters are obvious questions for the HMFI. I have reviewed this question in relation to Loy Yang Mine and overall consider there are two important aspects to be understood:

- Firstly the coal batter angles, which are much steeper than the 3H:1V rehabilitation slopes; and
- Secondly the nature and physical attributes of the mining operation, which places significant constraints on progressive rehabilitation.

167 In regards to the first question I note the earlier discussion around the impact on stability of flattening the slopes. However if this is not undertaken a question remains about simply covering the batters with soil to reduce fire hazards. Based on the slope geometries and the factors around the mining operation set out below it is not clear to me that this covering is a simple solution that may be successfully undertaken as a widespread solution without careful assessment and review.

168 In regards to the second aspect the Latrobe Valley Mines contain more infrastructure located both within the mine void and surrounding the void, than most other open cut mines in the world. The mining systems employed are also very inflexible and require planning and implementation time periods measured in years to 10's of years. In addition the mine stability management systems entail substantial in-pit equipment installations and also require ready access to the insitu materials to allow ongoing inspection and monitoring.

169 Because of the nature of the mining systems and the geotechnical and hydrogeological constraints, this situation is even more intensive for Loy Yang than the other two Latrobe Valley Mines.

170 In addition to the infrastructure and instrumentation substantial access roadways are also required on all mine batters and the mine floor. Access to all areas is also required for mine fire control activities.

171 I consider all these factors place significant limits on progressive rehabilitation of coal batters during mining at Loy Yang Mine.

172 I consider the very long time frames involved in future mining and achieving a final rehabilitated situation are very important considerations for rehabilitation, which must of their very nature entail significant uncertainties. In Appendix B I have set out a list of uncertainties related to future outcomes from studies and trials. The principal uncertainties are set out in Table 1 against the HMFI time frames. While the outcomes of many aspects will be known within the short timeframe many outcomes will not be fully known till the medium to long term.

173 Based on this I have assessed the general rehabilitation concepts planned for Loy Yang Mine. Figure 10 illustrates in diagrammatic format this concept. This was undertaken in order to understand the current state of understanding, the likelihoods of success and the timeframes involved. The aim was to assist with formulating strategy and direction for studies as well as understanding the controls.

174 I have divided the slope into four slope components, Figure 13. Figures 13 to 17 show different segments of a rehabilitated slope for the northern batters. The major uncertainty is around the final pit lake level and this will have the longest timeframe before it is fully resolved, Figure 17. Hence the strategy for Loy Yang

should be aimed at increasing the flexibility of rehabilitation final slope design in slope component 2, Figure 15.

175 Based on my current understanding of the main technical issues and constraints, together with the performance of the rehabilitation to date the recommended approach to rehabilitation comprises:

(a) Area 1:

   i. Increase the cover thickness using mixed layers, although much of the detail including the layer thickness is yet to be determined;

   ii. Ensure the underlying coal surface is scarified or tyned prior to covering; and

   iii. Limit the down slope lengths to less than 100 m and include surface drainage.

(b) Area 2:

   i. Do not flatten the coal batters to the 3H : 1 V slope;

   ii. Maintain the benched profile and

   iii. Investigate onsite materials for buttressing and covering, including recycled concrete.

(c) Area 3:

   i. Investigate the potential for a more staggered dump profile against the batters; and

   ii. Reduced dump height in the centre of the mine away from the batters.

(d) Area 4:

   i. The major current uncertainty and the factor in rehabilitation with the longest timeframe is the water and the final water level;

   ii. Hence the rehabilitation plans need to incorporate flexibility in design to cover the range of uncertainty, which should continue to be refined moving forward.

176 **TABLE 1**
MAIN TECHNICAL ISSUES FOR REHABILITATION AND TIMEFRAMES FOR UNDERSTANDING OUTCOMES

REHAB SLOPE COMPONENTS	APPROX. TIME ORDER	MAIN ISSUES	TIME WHEN YOU KNOW OUTCOMES (HMFI DEFINITION)		
			SHORT	MEDIUM	LONG
UPPER SLOPE	1	Rehabilitation trials	●		
	2	Capping materials	●		
	3	3:1 rehabilitation slopes	●		
	4	Design rainfall (long term)	●		
	5	Long term groundwater levels in batters	●	●	
OVERALL SLOPE	1	In-pit dumping	●		
	2	Availability of other water sources	●		
	3	Other mines and mining	●	●	
	4	Creep movements of slope		●	●
	5	Aquifer depressurisation		●	
	6	Aquifer recovery		●	●
		Time			●

177 **Question 6**

"Explain how fire risks are ordinarily considered in relation to:

i. the carrying out of progressive rehabilitation; and

ii. developing longer term rehabilitation options for coal mines in Australia."

178 I am not an expert on fire risks and hence I can only answer this question from a general mining experience standpoint. In general mining situations fire risks and rehabilitation, either progressive or longer term solutions, are not normally considered together. The high cost of rehabilitation means that most mines have to ensure that whatever rehabilitation is carried out progressively fits within the longer term final rehabilitation solution for the site. Most mine rehabilitation is only done once, and to a level such that it meets the long term landform and landuse objectives.

179 If a fire risk exists and a solution is adopted to cover the area affected this is not usually part of rehabilitation. In the Loy Yang Mine example, if this solution was adopted for an area identified as a potential fire risk then it would be essential

that the geotechnical and groundwater implications were also carefully assessed to be sure no adverse stability outcomes were generated. The fire risk may also generate a requirement for a risk assessment process, which could also identify alternate solutions to address the fire risk instead of the covering solution.

For and on behalf of
PELLS SULLIVAN MEYNINK

TIM SULLIVAN

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October 1996

2. AGL
Loy Yang Work Plan Variation
Mining Licence 5189
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3. AGL
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Submission of AGL Loy Yang Pty Ltd
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10th August 2015

4. AGL
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Mine Rehabilitation Terms of Reference
25th August 2015

5. GHD
AGL Loy Yang
Loy Yang Mine Rehabilitation
Mine Lake Water Balance Modelling
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6. GHD
AGL Loy Yang
Groundwater Modelling
Long Term Mine Plan
31/11584/15 March 2015

7. GHD
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Regional Groundwater Management Committee
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5 Year Review
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9. Australian Government, Department of Industry Tourism and Resources
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Leading Practice Sustainable Development Program For The Mining Industry
October 2006

10. Department of Primary Industries, Victoria
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11. AGL Loy Yang
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1st June 2015

12. Stacey and Read (2009)
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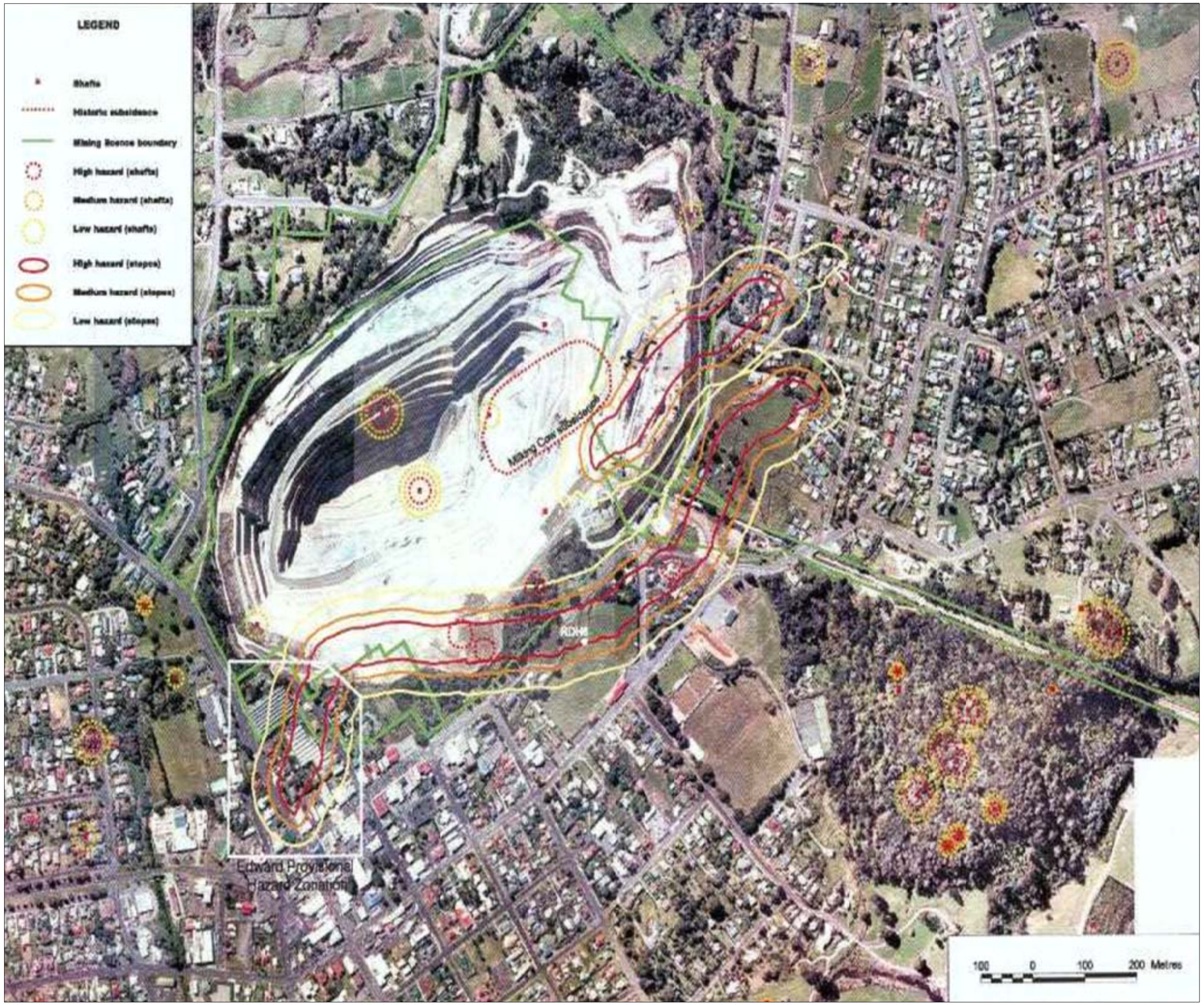
TYPICAL SMALL OPEN CUT MINE IN A REMOTE ARID REGION

Pells Sullivan Meynink

PSM 2801-003R	Figure 1



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OPEN CUT MINE
SITUATED WITHIN A TOWN

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PSM 2801-003R	Figure 2

Mainly rural, nearest urban development ~ 1.4km &
no Significant natural infrastructure

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LOY YANG SETTING

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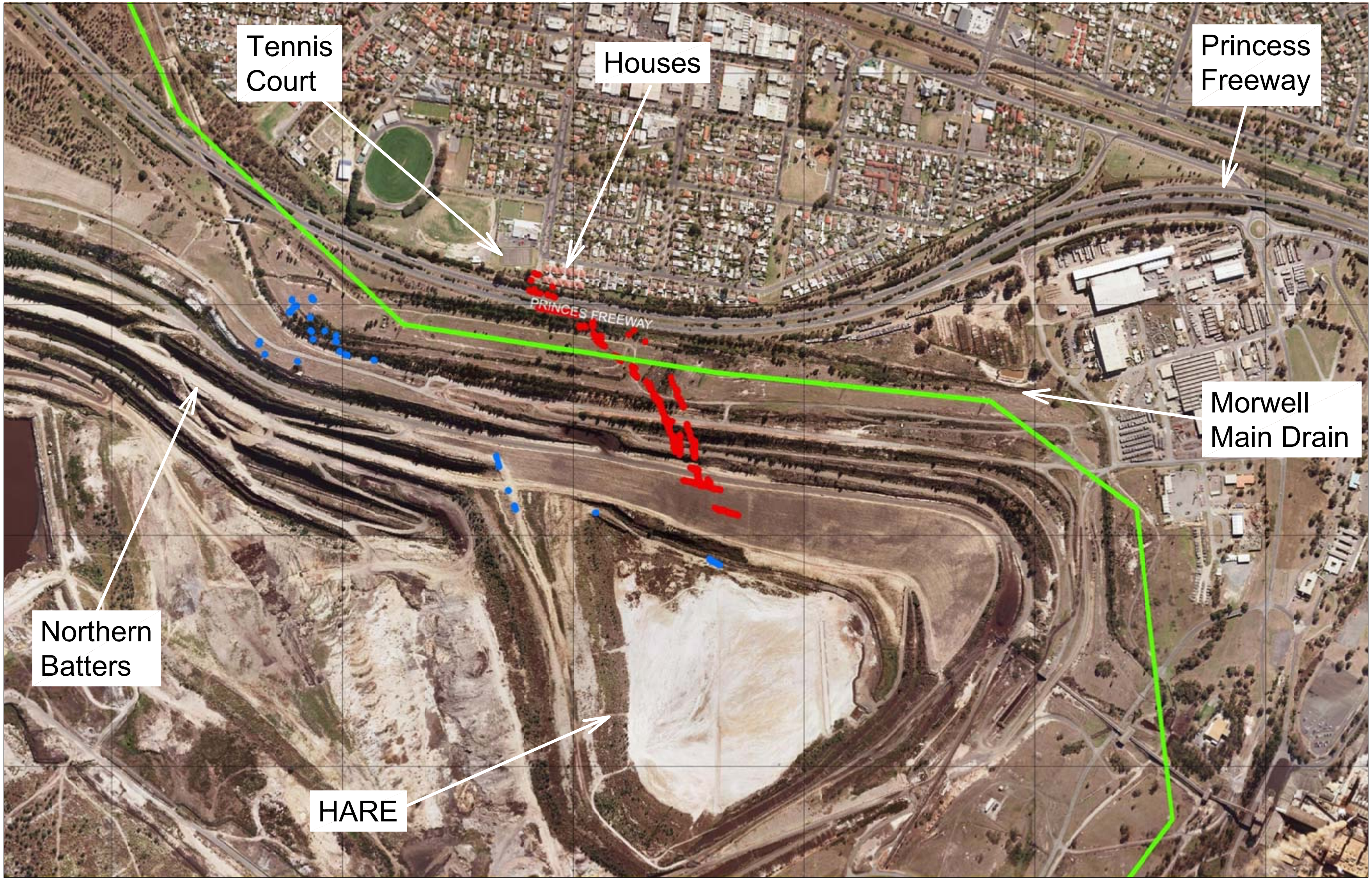
PSM 2801-003R | Figure 3



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PART OF HAZELWOOD MINE
SHOWING THE SETTING

PSM 2801-003R	Figure 4

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LOY YANG MINE NORTHERN BATTERS
OVERVIEW OF REHABILITATION &
GEOMETRIC CONSTRAINTS

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PSM 2801-003R	Figure 5

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LOY YANG MINE WESTERN BATTERS
TRIAL REHABILITATION AREA

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PSM 2801-003R	Figure 6

GENERALLY STABLE CONDITIONS

SMALL SLUMP

SINK HOLES

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LOY YANG MINE NORTHERN BATTERS WESTERN END GENERAL PERFORMANCE OF UPPER REHABILITATED SLOPE

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PSM 2801-003R	Figure 7

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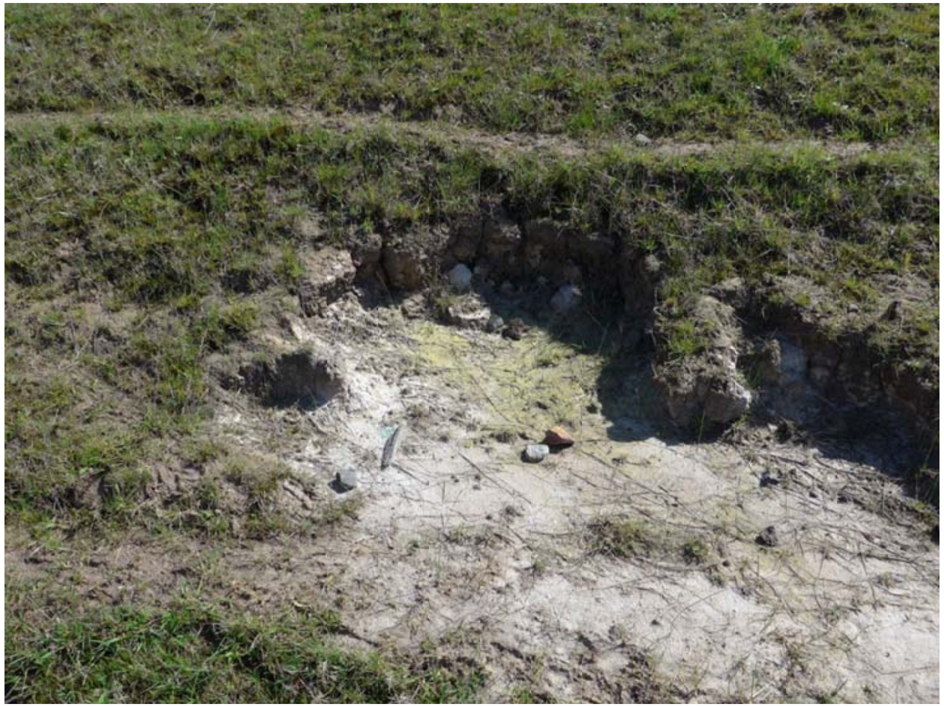
LOY YANG MINE NORTHERN BATTERS EASTERN END GENERAL PERFORMANCE OF UPPER REHABILITATED SLOPE

PSM

Pells Sullivan Meynink

PSM 2801-003R	Figure 8



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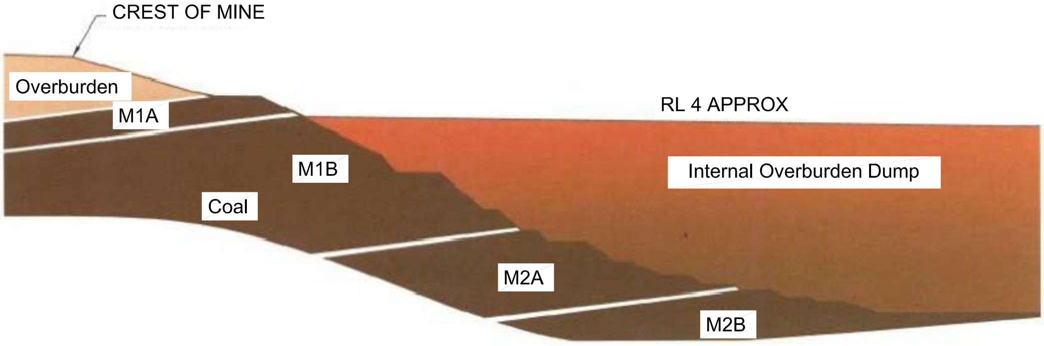
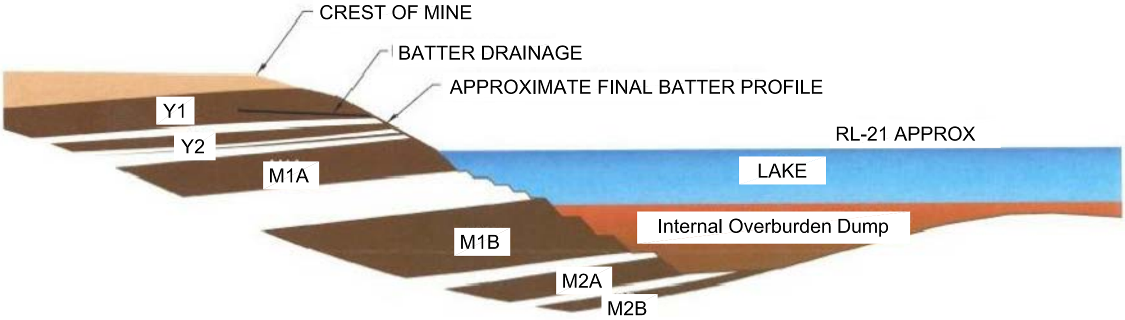
LOY YANG MINE
MATERIAL CHARACTER & BEHAVIOUR
LOCAL SINK HOLE & EROSION

Pells Sullivan Meynink

PSM 2801-003R	Figure 9



Northern Batters & Internal Dump



Northern Batters at Lake

Southern Batters

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LOY YANG MINE
GENERAL ILLUSTRATION OF THE FINAL
PLANNED REHABILITATION

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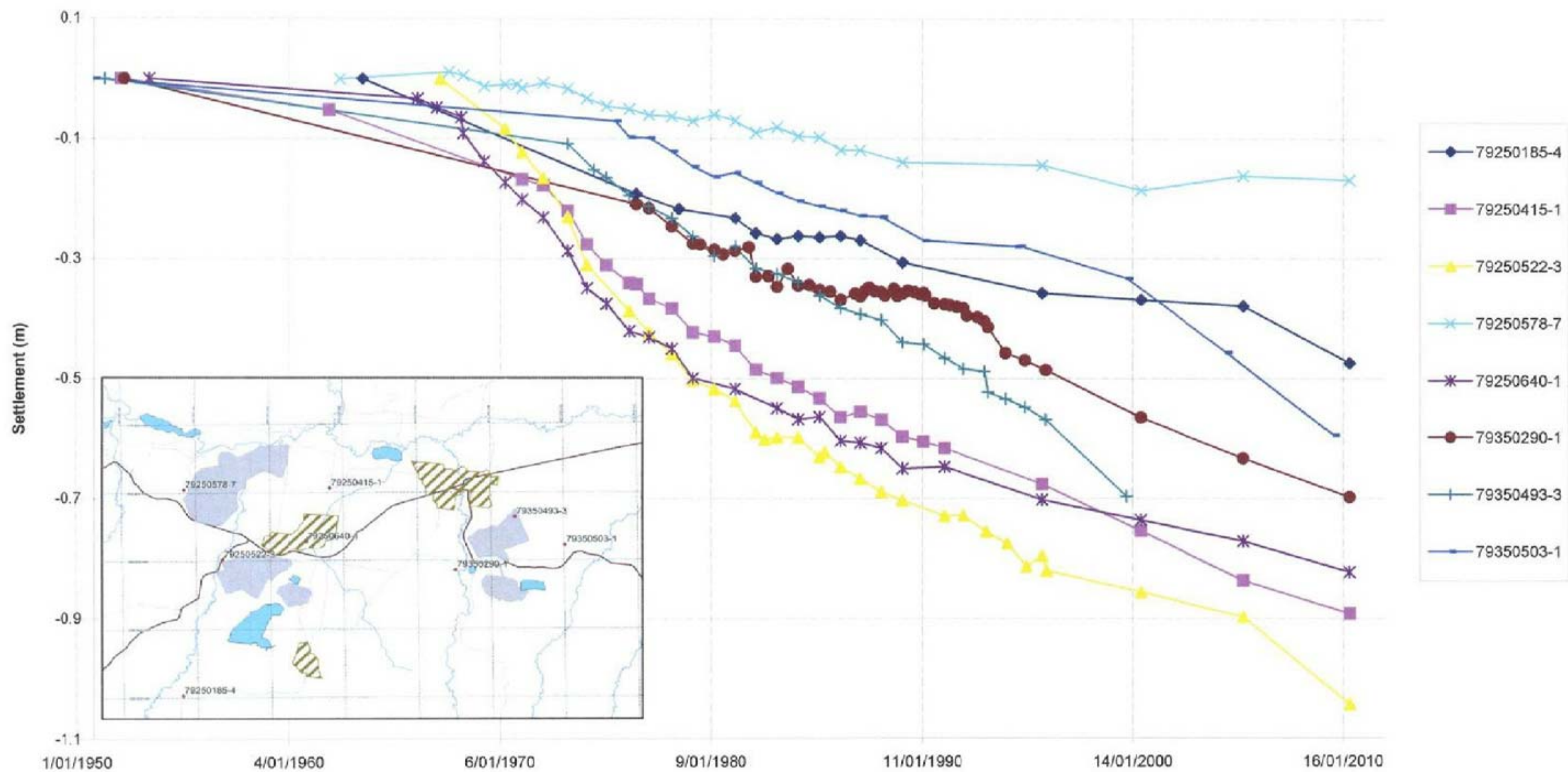
PSM 2801-003R	Figure 10



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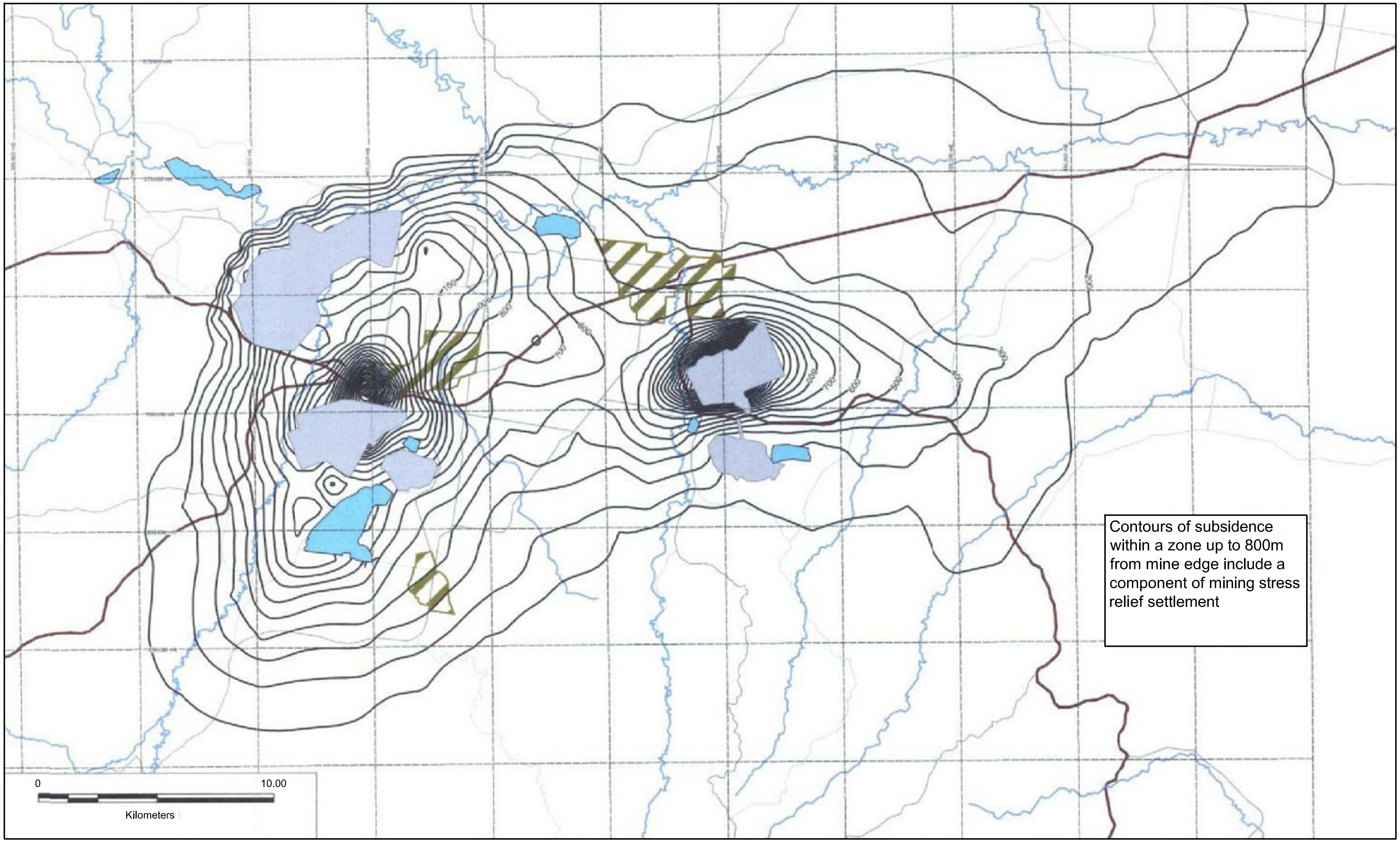
REGIONAL SUBSIDENCE PROFILES
5 YEAR REGIONAL MONITORING REVIEW
2010

Pells Sullivan Meynink

PSM 2801-003R | Figure 11



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PREDICTED SUBSIDENCE IN 2015
5 YEAR REGIONAL MONITORING REVIEW
2010

PSM

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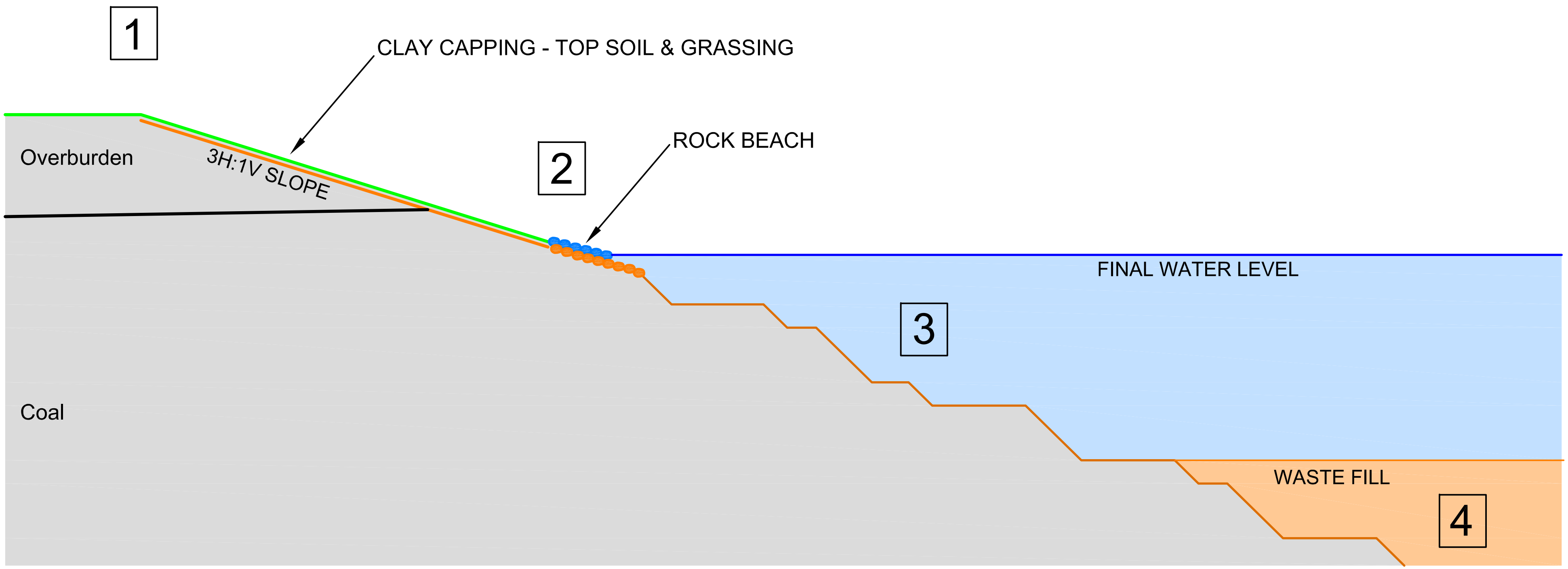
PSM 2801-003R | Figure 12



Note: Areas 1 to 4 are described in Figures 14 to 17

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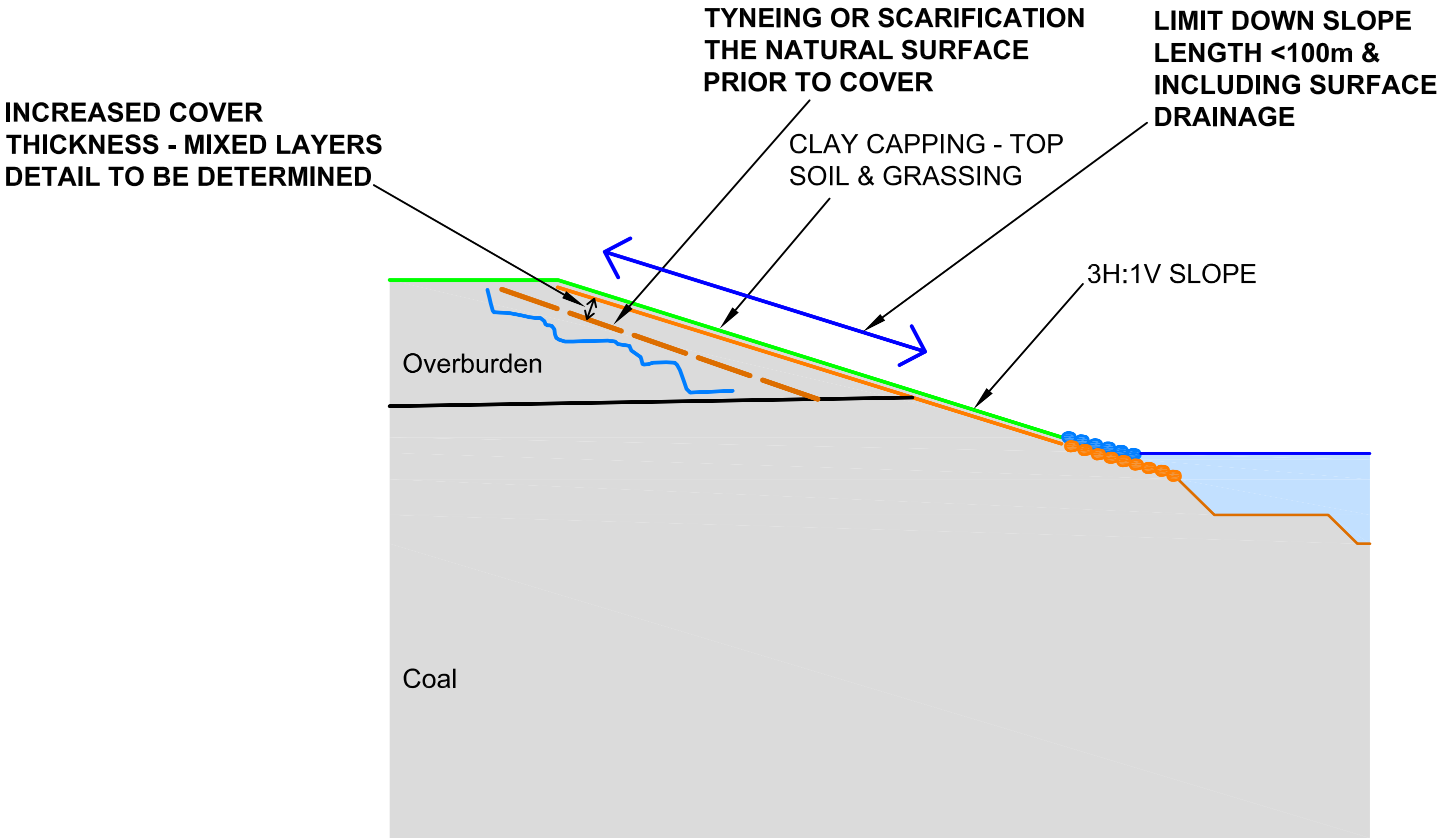
Ashurst Australia Hazelwood Mine Fire Inquiry Expert Report on Rehabilitation to Loy Yang Mine SECTION OF NORTHERN BATTERS ILLUSTRATING THE MAIN COMPONENTS OF PLANNED REHABILITATION	
PSM 2801-003R	Figure 13



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AREA 1
UPPER "OVERBURDEN"

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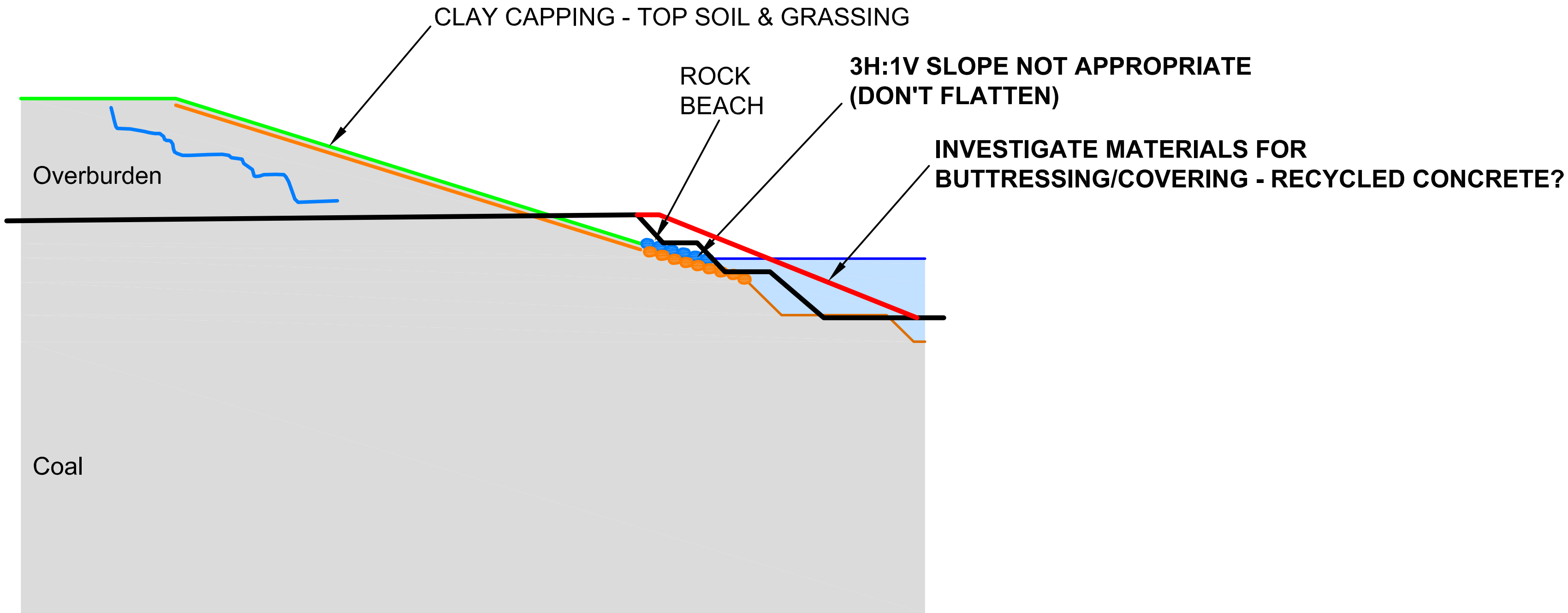
PSM 2801-003R | Figure 14



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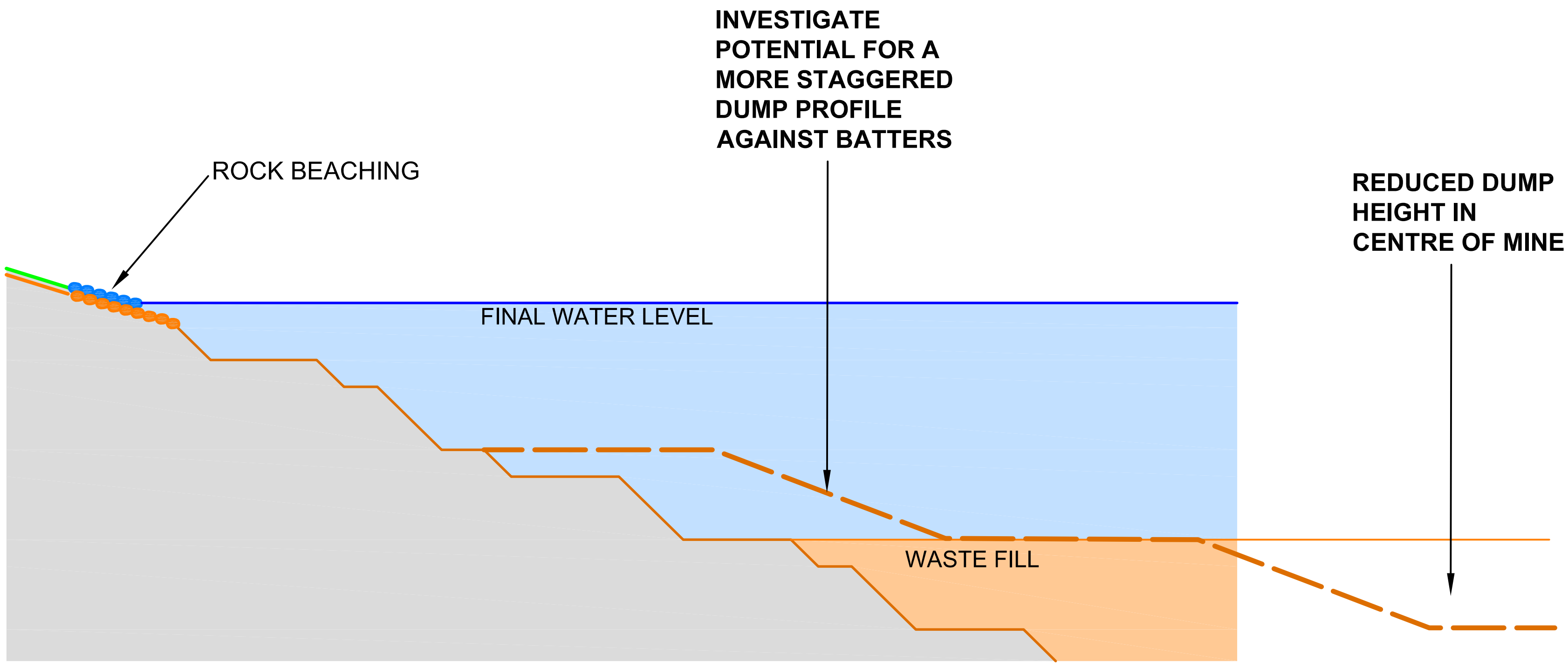
Expert Report on Rehabilitation to Loy Yang Mine

AREA 2
COAL SLOPE ABOVE THE WATER LEVEL

PSM 2801-003R | Figure 15



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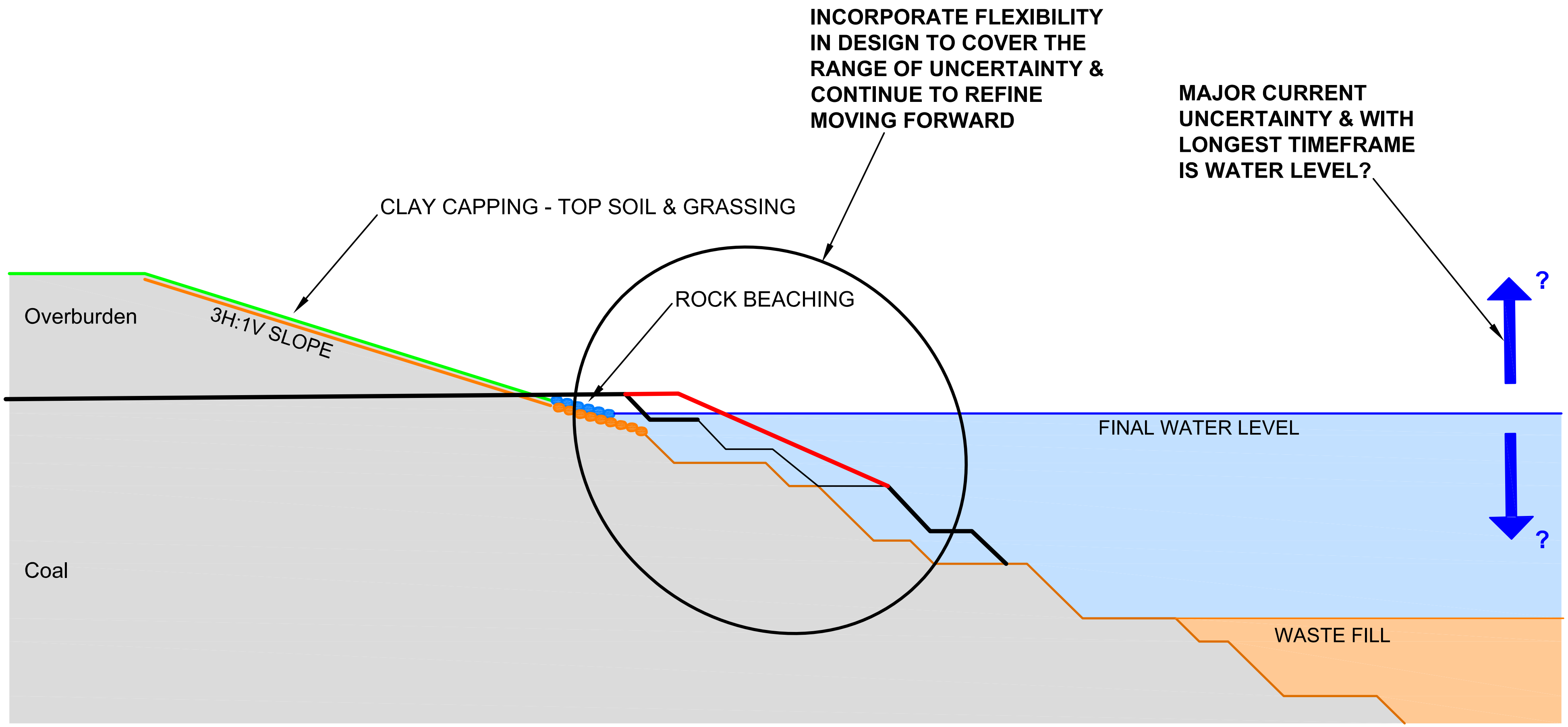
AREA 3
IN-PIT WASTE DUMP

PSM 2801-003R

Figure 16



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Ashurst Australia Hazelwood Mine Fire Inquiry Expert Report on Rehabilitation to Loy Yang Mine AREA 4 IN-PIT LAKE	
PSM 2801-003R	Figure 17

APPENDIX A

CV

PSM

TIM SULLIVAN

BA MSc DIC CPEng FIEAust FAusIMM CPMin MMICA RPEQ
Mining

Country Of Citizenship:	Australia
Educational Qualifications:	BA (Geol), Macquarie University, Sydney 1973 Diploma of the Imperial College, 1980 Master of Science (with Distinction), University of London, 1980 2012 Adjunct Professor (UNSW)
Professional Affiliations:	Fellow, Australasian Institute of Mining and Metallurgy Fellow, Institution of Engineers, Australia Chartered Professional Engineer Chartered Professional (Mining) Member, Mineral Industry Consultants Association Member, Geological Society of Australia Member, Australian Geomechanics Society Registered Professional Engineer Queensland
Professional Activities:	1987 SA Engineering Excellence Awards Project Director, Lochiel Trial Pit 2007 Keynote Lecture, Slope Stability 2007, Perth 2007 Mitsubishi Lecture 2008 Victorian Government Mining Warden, Yallourn Inquiry 2009 Chairman Victorian Government Technical Review Board 2010 13th Kenneth Finlay Memorial Lecture 2010 Keynote Lecture 11th IAEG Congress 2013 Keynote lecture Int. Symposium on Slope Stability in Open Pit and Civil Engineering 2014 Keynote Lecture Australian Earth Science Convention

FIELDS OF SPECIAL COMPETENCE:

Mine Development Studies

- Open pit rock mechanics
- Slope stability and stabilisation
- Mine dewatering and drainage
- Material excavation and handling characteristics
- Underground rock mechanics
- Dam embankment engineering

Mr. Sullivan graduated from Macquarie University in 1973 with a degree majoring in geology. He joined Coffey's in 1974 and was employed with them till 1993. While at Coffey's Mr Sullivan was a Director of the firm and established the Mining Geotechnics Group. In 1979-80 Mr Sullivan undertook postgraduate studies in London and was awarded an MSc from the University of London and a DIC from the Imperial College of Science and Technology. From 1992-1993, he was a Visiting Professor at the School of Mines, University of New South Wales. He is currently Adjunct Professor of Geotechnical Engineering, University of New South Wales. From 1997 to 2000 Mr Sullivan was also the NSW Coroner's adviser on the Thredbo Landslide. In 1993 Mr Sullivan established his own firm Pells Sullivan Meynink.

Mr Sullivan has been a geotechnical consultant for some of the world's largest mining operations and companies; including BHP Billiton, Rio Tinto, Xstrata, Newmont, Anglo Gold, Pilbara Iron and Newcrest. In addition to all the states and mainland territories of Australia, major projects have been located in India, Papua New Guinea, Indonesia, Thailand, Africa, Philippines, Mexico, New Zealand and Fiji. Mr Sullivan has worked on over 400 mining projects at all stages from planning to operating.

PSM

TIM SULLIVAN

BA MSc DIC CPEng FIEAust FAusIMM CPMin MMICA RPEQ
Mining

EXPERIENCE:

1993 - Present	Principal, Pells Sullivan Meynink, Sydney
2002 - Present	Adjunct Professor of Civil Engineering, University of NSW
2009 - 2011	Chairman Victorian Government Technical Review Board
2008	Mining Warden – Victorian Government. Yallourn Mine Collapse Inquiry
1997 - 2000	Coroner's Adviser on Thredbo Landslide
1992 - 1993	Visiting Professor, University of NSW
1983 - 1993	Director, Coffey Partners International Pty. Ltd., Sydney
1979 - 1980	Post Graduate Studies in United Kingdom
1974 - 1993	Coffey & Partners Pty. Ltd., Sydney

GEOTECHNICAL AUDIT AND REVIEW ASSIGNMENTS

Thalanga Copper Mine, QLD	Review of failure impact on highway.
Boral Resources	Dunmore Quarry Review.
Department of Primary Industries, VIC	Audit Latrobe Valley Mines.
Department of Primary Industries, VIC	Audit Victorian Mines.
Muara Tiga Coal, Sumatra, Indonesia	Geotechnical review.
Burton Downs Coal, QLD	Review and revised slope design.
Mt Leyshon Gold Mine, QLD	Review and redesign of slope design for 400m deep pit.
Masaboni Copper Mines, India	Geotechnical review of four underground mines.
Mae Moh Lignite, Thailand	Geotechnical and groundwater review.
Leigh Creek Coal, SA	Review, investigation, monitoring and analysis of low wall depressurisation due to unloading.
Lihir Gold Mine, Papua New Guinea	Geotechnical review.
Telfer Gold Mine, WA	Geotechnical review and audit for 450mm deep open cut mine.
Goonyella Riverside Coal Mine, QLD	Geotechnical review.
Condor Oil Shale Project, QLD	Geotechnical review.
Lindsay Coal Project, QLD	Geotechnical review.
Mt Newman Iron Ore Mine, WA	Geotechnical review.
Mt Owen Coal Mine, NSW	Geotechnical review.
Liddell Coal Mine, NSW	Geotechnical review.
Waihi Gold Mine, New Zealand	Geotechnical review.
Tarmoola Gold Mine, WA	Geotechnical review.
Boddington Gold Mine, WA	Geotechnical review for 400m deep open cut mine.
Ernest Henry Copper Gold Mine, QLD	Geotechnical review for 500m deep open cut mine.
Highway Reward Copper Mine, QLD	Geotechnical review.
Tai Lam Highway Cutting, Hong Kong	Geotechnical review.
Kelian Gold Mine River Diversion, Indonesia	Review of geotechnical studies and design.
Gold Cross Tailings Dam, New Zealand	Geotechnical review.
McArthur River Mines, N.T.	Geotechnical review.
Mt Isa Mines, QLD	Geotechnical review, Blackstar Open Cut
Mt Isa Mines, QLD	Geotechnical review, Large Open Pit

GEOTECHNICAL AUDIT AND REVIEW ASSIGNMENTS

Ensham Coal Mine, QLD	Geotechnical review.
Eildon Dam, VIC	Geotechnical review.
North Parkes Mines, NSW	Geotechnical review.
Rolleston Coal, QLD	Geotechnical review.
Newlands Coal, QLD	Geotechnical review.

MAJOR OPEN CUT MINES
Hard Rock

Oxiana, Prominent Hill, SA	Prefeasibility Mining Study.
Cadia Copper/Gold, NSW	Feasibility studies for 250m deep pit.
Woodsreef Asbestos Mine, NSW	Advise on landslide stabilisation.
Haveluck Gold Mine, WA	Advice on monitoring and stabilisation.
Woodlawn Lead Zinc, NSW	Slope design, slide stabilisation, monitoring and cable bolting.
Browns Creek Gold Mine, NSW	Slope design and slide stabilisation.
Phar Lap Gold Mine, WA	Slope design, cable bolting and monitoring.
Wiluna Gold Mine, WA	Slope design.
Rand Gold Mine, WA	Advice on pit instability.
Rotokaua Sulphur, NZ	Design geotechnical studies for dredging and open cut mining.
Fenian Gold Mine, WA	Slope design.
Mt Weld Phosphate and Rare Earth, WA	Design geotechnical studies.
PT Kelian Gold Mine, Kalimantan, Indonesia	Preliminary and design studies for 300m deep open cut mine including cable bolting.
Hidden Valley Gold, PNG	Preliminary and design studies for 400m deep open cut mines.
Cork Tree Well Gold Mine, WA	Advice on pit stability.
Gibralta Gold Mine, WA	Slope design, haul road layout and cable bolting.
Super Pit, Kalgoorlie, WA	Slope design for 400m deep pit.
Blue Funnel Gold Mine, WA	Slope design and cable support assessment.
Croesus Gold Mine, WA	Advice on slope stability beneath crusher
Mt Morgans Gold Mine, WA	Pit slope design and monitoring.
Chapri Copper Mine, India	Slope design.
Barrytown Mineral Sand, NZ	Geotechnical study.
Jubilee Gold Mine, WA	Pit slope design and cable support.
Reefton Gold Mine, NZ	Geotechnical study for open cut mining.
Tom Price Iron Ore Mine, WA	Redesign of slopes in BIF and shale to 350m high.
Paraburdoo Iron Mine, WA	Slope design.
Brockman Iron Ore Mine, WA	Advice on slope stability.
Channar Iron Ore Mine, WA	Design geotechnical studies.
Marandoo Iron Ore Mine, WA	Design geotechnical studies.

MAJOR OPEN CUT MINES
Hard Rock

Mt. Keith Nickel Project, WA	Design stage studies for 400m deep mine.
Throssel River Copper, WA	Preliminary studies.
Gabanintha Gold Mine, WA	Geotechnical design for four pits.
Nathans Deep South Gold Mine, WA	Slope design.
Labouchere Gold Mine, WA	Slope design.
Bannockburn Gold Mine, WA	Slope design.
Trough Tank Copper Gold, QLD	Preliminary assessment.
Grants Gold Mine, WA	Slope design.
Cosmo Howley Gold Mine, NT	Review and slope design.
Woolwonga Gold Mine, NT	Slope design.
Mickey Doolan Gold Mine, WA	Slope design.
Marmont Gold Mine, WA	Slope design.
Globe Gold Mine, WA	Advice on stability.
Commodore - St. Francis Gold Mine, WA	Slope design.
Red Spider Gold Mine, WA	Slope design.
Halcyon/Democrat Gold Mine, WA	Slope design.
Yackabindie Nickel, WA	Review and slope design for two pits to 350m.
Macraes Gold Mine, NZ	Design of pit slopes.
Wafi Copper/Gold, PNG	Preliminary geotechnical studies.
Kidston Gold Mine, QLD	Slope design, cable bolting and monitoring.
Lorne Hill Lead Zinc, QLD	Preliminary design.
Kanowna Belle Gold Mine, WA	Design stage studies.
Waihi Gold Mine, NZ	Analysis and design for 250m deep pit.
Coeur Gold Mine, NZ	Analysis and design pit and tailings.
Kelian Gold Mine, Indonesia	Feasibility and operating design studies.
Honeymoon Well, Nickel, WA	Preliminary and feasibility studies for 250m deep open cut mine.
Union Reefs Gold Mine, NT	Feasibility and operating studies for 200m deep open cut mine.
Orlando Gold Mine, NT	Design and operating studies.
Cleo Gold Prospect, WA	Open cut studies for 200m deep pit.
Golden Delicious Gold Mine, WA	Open cut studies for 130m deep pit.

MAJOR OPEN CUT MINES
Hard Rock

Perseverance Nickel Mine, WA	Advice on slope stabilisation.
McKinnons Gold Mine, NSW	Design of open pit.
Lake Cowal Gold Mine, NSW	Design of 300m deep open pit.
Kidston Gold Mine, QLD	Design for Eldridge pit 250m deep.
Mt Edon Gold Mine, WA	Design for 220m deep open cut mine.
Lynas Fine Gold Mine, WA	Design for two small gold pits.
Boddington Gold Mine, WA	Geotechnical review.
Savage River, TAS	Advice on stability.
Gosowong Gold Mine, Indonesia	Review and redesign.
Highway Reward, Charters Towers, QLD	Geotechnical review of open pit.
Wallgrove Quarry, NSW	Advice on quarry failure.
Draggages, Hong Kong	Geotechnical review of 80m high highway cutting.
Cadia Hill Gold Mine, NSW	Geotechnical studies for 750m deep pit.
Cadia Hill Quarry, NSW	Geotechnical investigations.
Cadia East, NSW	Geotechnical study.
Cadia Hill Gold Mine (Cadiangullong Creek Diversion), NSW	Geotechnical review.
Ernest Henry Mine, QLD	Geotechnical review of 'life of mine'.
Kelian Gold Mine (River Diversion), Indonesia	Geotechnical review.
Telfer Gold Mine, WA	Geotechnical Review for 400m deep open cut mine.
Batu Hijau Mine, Indonesia	Geotechnical advice and guidance in the technical program for 1000m deep open pit.
Mt. Prominent, SA	Design for 500m deep open pit to Bankable Feasibility Study level.
Geita Gold Mine, Tanzania	Assistance with Mine Risk Study.
Bolnisi Gold, Mexico	Feasibility Design for 300m deep open cut mine.
North Parkes Mine, NSW	Design and ongoing advice for 190m deep open pit, E27.
North Parkes Mines, NSW	Investigation and design for 200m deep open pit, E22.
Olympic Dam , SA	Pre-feasibility and feasibility studies for 1500m deep open cut mine.
Batu Hijau, Indonesia	Design studies for 900m deep open cut mine.
Lihir Gold Mine, PNG	Ongoing assistance with design and operation.
Tampakan Gold Project, Philippines	Pre-feasibility slope designs.

MAJOR OPEN CUT MINES
Coal and Oil Shale

Curragh Coal Mine, QLD	Feasibility geotechnical studies.
Mt. Sugarloaf Collieries, NSW	Feasibility geotechnical studies.
Wolfang Coal deposit, QLD	Geotechnical studies for 300m open cut mine.
Boggabri, NSW	Appraisal of conditions for strip mine.
Oaklands, NSW	Preliminary, feasibility and design studies for strip mining.
Rosedale Brown Coal, VIC	Appraisal.
Yaamba Oil Shale, QLD	Feasibility studies for 600m deep mine.
Bulga Coal Mine, NSW	Geotechnical assessment and assessment of spoil pile stability in steeply dipping seams.
Leigh Creek Coal Mine, SA	Summary of geotechnical investigations.
Wintinna Coalfield, SA	Feasibility geotechnical study.
Lochiel Lignite, SA	Feasibility and design studies for strip mine in soils.
Wambo Coal Mine, NSW	Study for pit extension.
Lindsay Coal, QLD	Geotechnical audit.
Millmerram Coal, QLD	Geotechnical appraisal.
Charleston Coalfield, NZ	Design studies.
Gretley Colliery, NSW	Slope stability.
Banko Barat Coal, Sumatra, Indonesia	Design studies.
Chatham Islands Peat, NZ	Feasibility studies for open cut mining and dredging.
Whaitewhena Coalfield, NZ	Preliminary appraisal of open cut mining.
P.T. Kaltim Prima Coal, Kalimantan, Indonesia	Preliminary and feasibility studies for open cut mining and dump design studies.
Lochiel Lignite, SA	Investigation, analysis and design for trial pit.
Stuart Oil Shale, QLD	Geotechnical study for box cut excavation.
P.T. Berau Coal Mine, Kalimantan, Indonesia	Geotechnical studies for open cut mining.
Hill River Coal, WA	Design studies for open cut mining.
Stuart Oil Shale, QLD	Design geotechnical studies.
Ulan Coal Mine, NSW	Advice on dragline failure, spoil pile failure, and general slope design.
Muja Coal Mine, WA	Cable bolt design, monitoring, dump design, stabilisation.

MAJOR OPEN CUT MINES
Coal and Oil Shale

Mae Moh Lignite Mine, Thailand	Geotechnical audit and advice.
Griffin Coal, WA	Slope design, detailed monitoring instrumentation.
Western Collieries, Muja North, WA	Slope design.
Cumnock No. 1 Colliery, NSW	Geotechnical studies for open cut coal mining.
Mt Owen Mine, NSW	Geotechnical review.
Liddell Coal Mine, NSW	Geotechnical review.
Ensham Coal Mine, QLD	Geotechnical designs and guidance.

MAJOR UNDERGROUND PROJECTS
(including) Tunnels, Shafts and Declines

BHP Billiton, Illawarra Coal, NSW	Devines Tunnel Review.
BHP Billiton, Illawarra Coal, NSW	Dendrobium Mine water inflow and grouting.
Xstrata Coal, Tahmoor Colliery, Singleton, NSW	Subsidence Reviews.
Mines Subsidence Board, Lithgow, NSW	House Damage.
Yonki, Papua New Guinea	Geotechnical investigations.
Tickhole Tunnel, Newcastle, NSW	Widening of tunnel and portal landslide stabilisation.
Buchanan Borehole Colliery, NSW	Stability of 65m high tunnel portal.
Z.C. Mine, Broken Hill, NSW	8m diameter 900m raisebore shaft. 400m decline. 330m raisebore shaft.
Peak Gold Mine, Cobar, NSW	500m raisebore shaft. 400m decline
Sydney Harbour Tunnel, NSW	Stability of southern interface.
Wintinna Coalfield, SA	Investigation and design for 200 to 300m deep coal mine.
Northside Storage Tunnel, NSW	Review of geotechnical conditions and tunnel support for tender.
Eastern Distributor, NSW	Specialist advice concerning difficult ground conditions and ground support.
Wintinna Coalfield, SA	Investigation and design of 200 to 400m deep coal mine.
Vickery Coal Project, NSW	Investigation and design for 200 to 300m deep coal mine.
Wambo Colliery, NSW	Investigation for extension to existing mine.
Whaitewhena Coal, New Zealand	Appraisal of underground conditions.
Rakha Copper Mine, India	Investigation, analysis and design.
Kendadih Copper Mine, India	Investigation, analysis and design.
West Cliff Colliery, NSW	Geotechnical investigation for mine extension.
Admiral Copper, WA	Preliminary appraisal.
Wafi Copper/Gold, PNG	Preliminary assessment of underground mining.
Waihi Gold Mine, New Zealand	Investigation of collapses and old underground mines.
Perseverance Nickel Mine WA	Investigation and remediation of slope movements into old stopes.

MINE DEWATERING AND SLOPE DEPRESSURISATION
Dewatering

Kaltim Prima Coal Mine, Indonesia	Investigations and mine dewatering study.
Westland Ilmenite, New Zealand	Water management study.
Channar Iron Ore Mine, WA	Dewatering for 150m deep pit in colluvial deposits.
Stuart South Oil Shale, QLD	Cut-off through marine sediments and pit dewatering.
Stuart South Oil Shale, QLD	Pit dewatering.
Waisoi Copper Project, Fiji	Dewatering for two 400m deep open cut mines.
Wolfang Coal, QLD	Dewatering for 300m deep open cut.
Oaklands Coal, NSW	Investigation analysis and design for one of the world's largest mine dewatering and reinjection projects.
Yaamba Oil Shale, QLD	Dewatering of tertiary overburden.
Lochiel Trial Pit, SA	Dewatering for 40m deep trial mine.
Lochiel Coal, SA	Dewatering studies for strip mining. Overburden dewatering and basal depressurisation.
Charleston Coal, New Zealand	Mine dewatering studies.
Rotokaua Sulphur, New Zealand	Dewatering for open cut mining of sulphur in hot springs area.
Kunwarara Magnesite Mine, QLD	Dewatering and reinjection studies.
Wintinna Coalfield, SA	Mine dewatering and reinjection studies.
Goonyella Coal Mine, QLD	Stabilisation of spoil pile slide with horizontal drains.
Nathans Deep South Gold Mine, WA	Stabilisation of toppling failure with horizontal drains.
Cosmo Howley Gold Mine, NT	Stabilisation of large scale toppling failure with horizontal drains.
Kidston Gold Mine, QLD	Slope depressurisation with horizontal drains.
Woodlawn Mine, NSW	Slope depressurisation and landslide stabilisation with horizontal drains.
Lochiel Trial Pit, SA	Pre-drainage ahead of mining using vertical pressure relief wells.
Democrat Gold Mine, WA	Stabilisation of large failure with horizontal drains.
Mt Keith Nickel, WA	Slope depressurisation for pit wall steepening.
Gibralta Gold Mine, WA	Slope depressurisation for pit wall steepening.
Prohibition Gold Mine, WA	Slope depressurisation.
Kelian Gold Mine, Indonesia	Slope depressurisation.

EXCAVATION ASSESSMENTS

Oaklands Coal, NSW	BWE.
Yaamba Oil Shale, QLD	BWE.
Lochiel Lignite, SA	BWE and Wirtgen miner.
Muara Tiga Coal, Sumatra, Indonesia	BWE.
WIM 150 Mineral Sands, VIC	BWE excavation of cemented sands.
Rotokaua Sulphur, NZ	Dredge excavation.
Hill River Coal, WA	BWE.
Kunwarara Magnesite Mine, QLD	Excavation assessment and dredging.
Marandoo Iron Ore Mine, WA	Excavation assessment, BWE continuous miners. Blasting.
Mt. Keith Nickel, WA	Drilling, blasting and crushing.
Kelian Gold Mine, Indonesia	Crushing.
Kanowna Belle Gold Mine, WA	Drilling and blasting.
Yakabindie Nickel, WA	Crushing and blasting.
Newrybar Mineral Sands, NSW	Excavation assessment.
Kiama Bypass, NSW	Expert witness assessment of excavation characteristics.
Coppabella Coal Mines, QLD	Expert witness assessment of excavation and mining conditions.

WATER SUPPLY DAMS, AND TAILINGS DAMS

NSW Department of Commerce, Tillegra Dam, NSW	Review of reservoir and abutment stability.
GHD Pty Ltd, Eildon Dam, VIC	Rock Slope Stability Review
Allens Arthur Robinson, Indonesia	Kelian Dam Quarry construction claim.
Ranger Uranium Mines, NT	Geotechnical investigations, retention ponds 1 and 2.
Jabiluka Uranium Project, NT	Investigation and design, tailings dam site one.
Jabiluka Uranium Project, NT	Investigation and design, tailings dam site two.
Public Works Department, NSW	Investigation and design, feasibility and design stages Mangrove Creek dam.
Public Works Department, NSW	Assessment of foundation geology and strength, Hume weir.
Minatome Aust., QLD.	Investigation and design, Uranium tailings dam.
Coeur Gold, NZ	Investigation and advice on stability, tailings dam.
Coeur Gold, NZ	Investigation and advice on stability, Union Silt dam.
GH & D, VIC	Investigation of dam foundations, Euroa dam.
Kelian Gold, Indonesia	Safety inspection, tailings dam.
Waihi Gold Mining Co Ltd, NZ	Advice on surface instability and rehabilitation, tailings dam/waste embankment.
Dept Public Works, PNG	Foundation investigation, diversion tunnel and rip rap search. Yonki water supply dam.

HYDROGEOLOGICAL STUDIES

Hill River Coal, WA	Open cut mining to 140m.
Curragh Coal Mine, QLD	For strip mining.
Oaklands Coal, NSW	Regional hydrogeological studies covering 5000km2.
P.T. Berau Coal Indonesia	Hydrogeological investigations for mining.
Lochiel Deposit, SA	Regional studies covering 100km2.
Millmeran Coal, QLD	Groundwater investigations.
Westland Ilmenite, NZ	Hydrogeology of 15km of coastal marine flats.
Chatham Islands Peat, NZ	Island wide hydrogeological appraisal.
Stuart South Oil Shale, QLD	Detailed hydrogeological investigations.
Kunwarara Magnesite Mine, QLD	Review.
Kelian Gold Mine, Indonesia	Hydrogeological Investigations.
Hidden Valley Gold, PNG	Hydrogeological Investigations.
Kaltim Prima Coal Mine, Indonesia	Detailed investigations for pit wall depressurisation/ dewatering.
Horsham Minerals Sand, VIC	Regional hydrogeological studies.
Lake Lindsay, QLD	Review.
Condor Oil Shale, QLD	Review of dewatering studies.
Vickery Coal, NSW	Hydrogeological study.

NATURAL AND CIVIL ENGINEERING LANDSLIDES

Bogong Creek, NSW	Geotechnical review.
Spears Point, NSW	Investigation into block slide landslip in coal measure rocks adjacent to Lake Macquarie NSW.
Golden Cross, New Zealand	Assessment of movements in a hillside supporting a tailings dam and interpretation that these represented a half kilometre wide by one and a half kilometre landslide with a volume of about 50 million m^3. Recommendations for and implementation of major drainage remedial measures.
Thredbo, NSW	Principal investigator on behalf of the NSW Coroner into the causes of the 1997 Thredbo Landslide.
Tuen Mun, Hong Kong	Assessment of slope stability in 90m deep cutting in weathered and fresh granite for access to new Hong Kong airport.

LEGAL

Mines Subsidence Board, NSW	Lithgow. Damage to Residence
DLA Phillips Fox, Perth, WA	Expert Opinion on Highwall Collapse and Rockfall.
Moray and Agnew, WA	Roche Mining vs WMC. Property loss recovery claim.
Clayton Utz, Muswellbrook, NSW	Muswellbrook Colliery. Expert Opinion on Highwall failure.
Clayton Utz, Mackay, QLD	Coppabella Coal Mine. Latent conditions claim due to groundwater.
Clayton Utz, Perth, WA	Esperance Lignite Project. Expert Witness.
Baker & McKenzie	Bogong Creek Landslide. Expert Witness.
Allens Arthur Robinson	Latent Condition Claim Nakan Dam Indonesia
Dickson Fisher & Macansh	Latent Conditions Claim - Tahmoor
Henry Davis York, Kiama, NSW	Latent Conditions Claim. Kiama Bypass.
Workcover Authority of NSW	Cross City Tunnel Collapse – assistance with project recovery.
Great Barrier Reef Marine Park, QLD	Review of boulder stability
DLA Philips Fox	Expert Witness. Pamela French. Personal injury claim due to rockfall.
DLA Philips Fox, WA	Expert Witness. Personal injury claim for rockfall at Sally Malay Mine.
Collins and Thompson	Assistance in Interpretation of Reports & Aerial Photographs for Land and Environment Proceedings.
NSW Police Department, Thredbo, NSW	Thredbo Landslide Inquiry
Department of Primary Industries, VIC	Yallourn Mine Batter Failure – Mining Warden Inquiry.
Minter Ellison Lawyers	Victorian Comprehensive Cancer Centre Project (VCCC).
Warringah Shire Council	Bungan Head. Expert witness cliffline stability.

PUBLICATIONS

Sullivan T.D. (1982). The Origin and Characteristics of Defects in Oil Shale. Coal Resources Symp., Melbourne 1982.

Sullivan T.D. and Burman B.C. (1985), Geological and Geotechnical Aspects of small basins and their effects on mining. Asian Mining Conf. Manila 1985, pp. 321-335.

Burman B.C. and Sullivan T.D. (1985). Dewatering and depressurisation studies for development of the Lochiel open pit mine South Australia. Proc. 2nd Int. Mine Water Congress Granada 1985. pp. 307-324.

Sullivan T.D. (1986). Mine and Monitor - An approach to coping with unstable pit walls. 13th CMMI Conf., Singapore.

Sullivan T.D. and Burman B.C. (1986). The Lochiel Project - A case study of geotechnical engineering studies in a difficult environment. Singapore 1986. 13th CMMI Congress.

Fell R., Sullivan T.D., Parker C. (1987). The Speers Point Landslide Proceedings Soil Slope Instability and Stabilisation. Walker and Bell, Balkema.

O'Brien M.D. and Sullivan T.D. (1988). The Lochiel Trial Pit - Design and Excavation. Conf. Minerals at the Crossroads, AusIMM, Sydney 1988, pp. 127-133.

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Sullivan T.D., Duran A. and Eggers M.J. (1992). The Use and Abuse of Oriented Core in Open Pit Mine Design. Third Large Open Pit Mining Conf., Mackay 1992, pp. 387-395.

Sullivan T.D. (1993). Understanding Pit Slope Movements. Geotechnical Instrumentation and Monitoring in Open Pit and Underground. Proc. Aust. Conf. June 1993 Kalgoorlie. pp. 435-446.

Sullivan T.D. (1993). Mine Geology from a Geotechnical Perspective Int. Mining Geology Conference. Kalgoorlie WA. July 1993. pp. 255 to 262.

Sullivan T.D. (1994). Mine Slope Design - The chances of getting the answer right and the risk of getting it wrong. Fourth Large Open Pit Mining Conference Perth 1994.

Eggers M., Mostyn, G. and Sullivan, T.D. (1999). Probabilistic Stability Assessment of a High Rock Slope in Variable Strength Rocks. Proceeding 8th ANZ Conference on Geomechanics.

Mostyn G. and Sullivan T. (2002). Quantitative risk assessment of the Thredbo landslide, Australian Geomechanics, V 37 No 2, May, pp 169-181.

Sullivan T.D. (2006) Pit Slope Design and Risk – A view of the current state of the art. Proceedings Symposium S44, Stability of rock slopes in open pit mining and civil engineering situations. S.A. Institute of Mining and Metallurgy, Cape Town 2006

Sullivan T.D. (2007) Highwalls, Stockpiles and Dangers: Safety and Productivity.
2007 UNSW/Mitsubishi Lecture

Sullivan T.D. (2007) Hydromechanical Coupling and Pit Slope Movements.
Keynote Lecture proceedings, International Symposium on Rock Slope Stability in Open Pit Mining and Civil Engineering, Perth. September 2007.

Sullivan T.D. (2010) The Geological Model. Keynote Lecture preceding 11th Congress of International Association for Engineering Geology and the Environment. Auckland, 2010.

Sullivan T.D. (2013) Global Slope Performance Index. Keynote lecture, International Symposium on the Slope Stability in Open Pit Mining and Civil Engineering, Brisbane, September 2013.

Sullivan T.D. (2013) The Influence of Geotechnical and Groundwater Factors on Ore Reserve Estimation, AUSIMM, Monograph 2, 2nd Ed, 2013.

APPENDIX B

FUTURE UNCERTAINTIES IN REHABILITATION

QUESTIONS

There are a number of possible fundamental questions that frame the problem or issues and all may be applicable.

(a) Will the planned rehabilitation be successful?

(b) Will the planned rehabilitation produce a safe and stable landform in accord with the final landuse?

(c) Can the rehabilitation be achieved?

(d) Will the final landform concept be suitable for the range of land use options being considered?

(e) Will the 3:1 upper slope produce a safe, stable and sustainable landform in the long term?

SOURCES OF UNCERTAINTY IN THE PROBLEM

There are a significant number of decisions to be made, associated with the current planned rehabilitation of Loy Yang Mine. Many of these decisions will be made and/or confirmed a long time into the future. Because of this there are significant uncertainties and hence some risk.

(a) Implications for regional subsidence of aquifer depressurisation until mine closure 2048.

(a) Implications for regional subsidence of aquifer depressurisation from mine closure until aquifer depressurisation is stopped, 2048 to 2063 or 2138.

(b) Subsidence becomes a problem and limits dewatering into future?

(c) Ability to access water for lake filling from aquifer depressurisation post mine closure, 2048 to 2063 or 2138.

(d) Ability to access surface water for lake filling post mine closure 2048 to 2063 or 2138.

(e) Lake level -22.5 mRL for stability.

(f) Time to achieve stable and final lake levels.

(g) Reduction in mine dewatering associated with in-pit dumping causes rises in batter water levels.

(h) Possible new mines.

(i) Time – what happens between start of filling and completion of filling with regards to stability? How long is this period?

(j) Flooding options to include continued pumping post mining.

(k) Each mine is operating in isolation regarding water sources for rehabilitation. As silos!

(l) How long will movement of batters continue?

(m) Will movement of the batters stop at the end of mining?

(n) Will movement of the batters continue while aquifer depressurisation continues?

(o) In-pit dump stops movements of batters.

(p) Water level stopes movements of batters.

(q) Rebound after depressurisation ceases.

(r) Rate of internal dump rise.

(s) Are the rehabilitated slopes, 3:1 (H:V) in coal appropriate?

(t) Impacts of peak rainfalls due to longer design life.

(u) What is the design rainfall, should it be like earthquakes, that is Maximum Credible?

(v) Stability of soil covering layer and impacts on :

- Surface drainage and
- Subsurface drainage.

(w) Erosion of cover into coal because of long term opening of coal joints.

(x) Existing rehabilitation – what are the lessons?

(y) Are the aquifers completely or partially connected?

(z) Groundwater levels in the batters post mining.

(aa) Post mining aquifer(s) recovery levels long term.

(bb) There are perched water tables relative to the base of the open pit;

What happens long term?

What happens after covering?

What happens after backfilling?

(cc) Impact of in-pit dump on horizontal drains.

(dd) Impact of in-pit dump on natural joint drainage (hydraulic characteristics).

(ee) Aquifer recovery – final levels and time.

(ff) Future mining, in particular the other Latrobe Valley mines, their design life and long term dewatering?

TABLE A.1
SOURCES OF UNCERTAINTY

MAIN ISSUE	RESULTANT OR RELATED ISSUES
Aquifer Depressurisation	Subsidence impacts. Availability of water for mine filling. Recovery levels (post mining) are substantially different to modelling prediction. Time to achieve final lake level is substantially longer than modelled. Reduction in mine dewatering associated with in-pit dumping causes rises in batter water levels.
Aquifer Recovery	Are aquifers partially or completely connected now? Could aquifers become connected in future due to ongoing creep or subsidence movements? Mixing or interactions between different aquifers on recovery.
In-pit Dumping	Alters coal joint characteristics. Cuts off horizontal drains. Increases coal water levels. Is it in the right area and to the requisite level? Locations and levels.
Capping materials	Materials on site are not suitable. Insufficient quantity available. Construction details are unknown.
3:1 slopes above final lake level	Is too steep to allow safe and stable landform. Will this slope be stable in perpetuity? Impact of 200 to 240 m long uniform slopes on surface runoff. Impacts of 200 to 240 m long uniform slopes on capping layer stability. Impact of 200 to 240 long uniform slopes on erosion. Capping layer is unstable. Final lake levels are much lower and upper slopes are significantly longer. Capping layer cannot be achieved due to erosion and stability issues. Capping layer proves ineffectual in covering coal. Capping layer changes to the recharge to coal from surface rainfall/runoff. Capping layer cannot be effectively keyed into the underlying coal. What is the long term stable slope angle?

MAIN ISSUE	RESULTANT OR RELATED ISSUES
Creep movements of coal batters	Stopped by in-pit dumping in area of dump. Stopped by lake filling. Stopped by cessation of mining. Continue with subsidence. Continue due to other causes. Increase with ongoing mining and aquifer depressurisation effects. Lead to adverse cracking in coal and or the capping layer. Allows erosion of capping layer with sinkhole formation. Unable to achieve a safe and stable landform. Are the slopes safe and stable if creep movements are occurring?
Long term groundwater levels in batters	Stabilise. Don't stabilise. Fluctuate wildly due to rainfall because capping is inadequate. Increase due to long term ongoing subsidence effects.
Rainfall	What is the design rainfall in perpetuity?
Other mining	Closure of other mines, Yallourn and Hazelwood: – Increases Loy Yang depressurisation requirements, and – causes additional local adverse subsidence around Loy Yang. Opening of additional mines results in: – Increased groundwater extraction, – Increased demand for surface water resources, and – Additional adverse subsidence effects.
Rehabilitation trials	Unsuccessful. Unable to resolve all technical questions.
Availability of other water sources	
Time	

APPENDIX C

INFORMATION RELIED ON

Loy Yang Mine Documents

1. Letter of Engagement, 20 July 2015.
2. Terms of Reference for the Hazelwood Mine Fire Inquiry, 26 May 2015.
3. Mining Licence No. 5189, first issued on 6 May 1997, varied in 2015.
4. Mining Licence Application – Work Plan Submission, 30 October 1996.
5. Work Plan Variation cover letter, 1 June 2015.
6. Work Plan Variation Vol 1: Main text and figures, 29 May 2015
7. Work Plan Variation Vol 2: Appendices, 29 May 2015
8. Work Plan Variation Figures, 29 May 2015
9. Strategic Framework for Rehabilitation and Closure Planning – Main Report (Earth Systems and GHD), August 2003.
10. Strategic Framework for Rehabilitation and Closure Planning – Appendices (Earth Systems and GHD), August 2003.
11. Land Rehabilitation Manual, 19 June 2015.
12. Loy Yang Mine Rehabilitation Mine Lake Water Balance Modelling, March 2015.
13. Environmental Licence 11149, 22 May 2014

Legislation and Regulations

14. Mineral Resources (Sustainable) Development Act, 1990.
15. Mineral Resources (Sustainable Development) (Mineral Industries) Regulations, 2013.
16. Extract of definitions from Environment Protection Act, 1970.
17. SEPP (Groundwaters of Victoria).
18. SEPP (Waters of Victoria).

Rehabilitation Standards and Guidelines

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