Appendix 4 – Technical References (continued)

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Appendix 4 – Technical References (continued)

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GHD CLIENTS | PEOPLE | PERFORMANCE

09 April 2009

Mr Jon Missen
Loy Yang Power
PO Box 1799
TRARALGON EAST VIC 3844

Our ref: 31/11466/09/164426
Your ref:

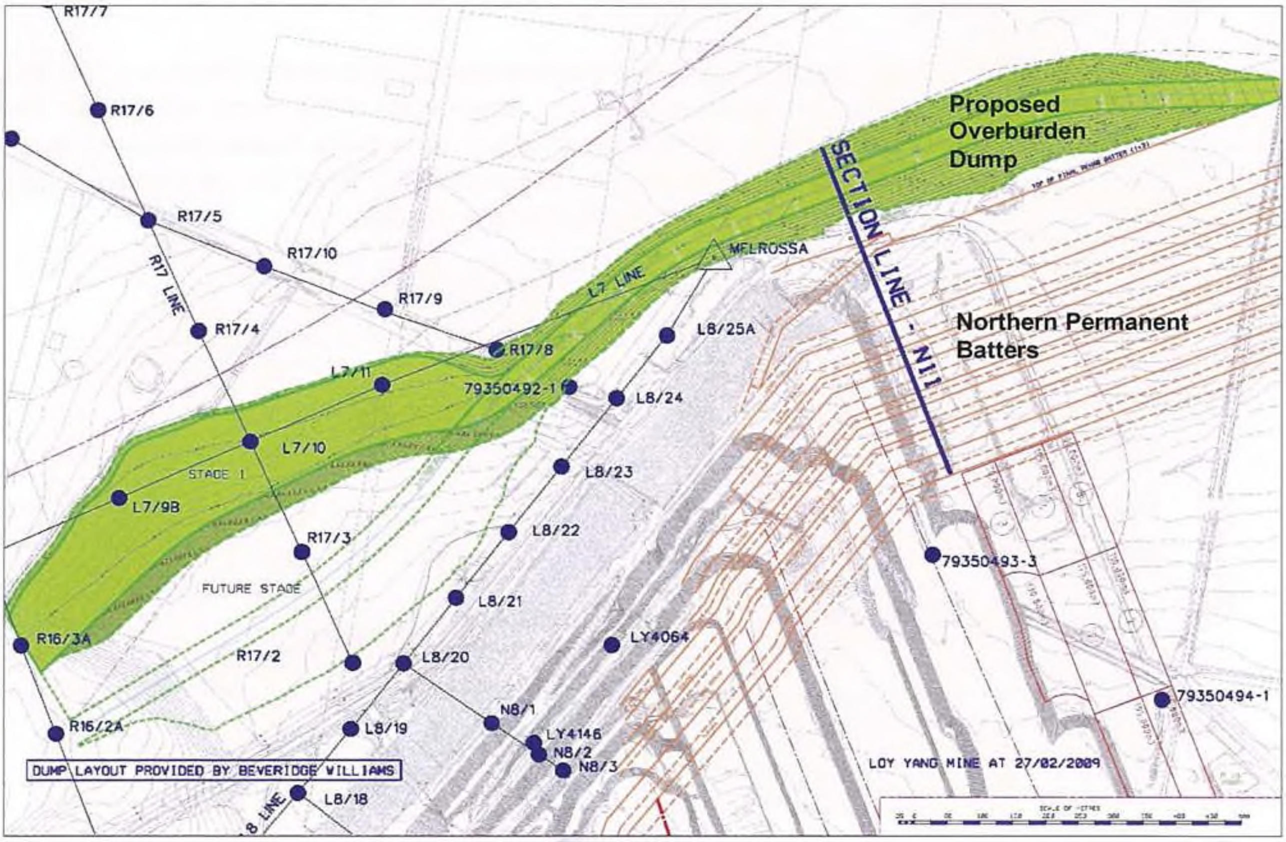
Dear Jon

Northern Batters Waste Dump Construction
Geotechnical Assessment

1 Introduction

GHD was requested by Stewart Cluning, Civil Engineer at Loy Yang Power on 20 March 2009 to assess the geotechnical implications of constructing a minor overburden dump near the crest of the Loy Yang Mine Northern Batters. The dump materials will be originating from the Loy Yang Mine overburden strip and will be dumped on either side of the Old Hyland Highway. The overburden material will be predominantly Haunted Hill Formation. The location of the proposed dump in relation to the Loy Yang Northern Batters is shown in Plate 1.

Plate 1 Location Plan of Proposed Overburden Dump



GHD Pty Ltd ABN 39 008 488 373 Level 8, 180 Lonsdale Street Melbourne VIC 3000 Australia
T 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com.au **W** www.ghd.com.au

2 Batter Stability Assessment

2.1 General

The most critical section (N11) was selected for stability analyses on the Northern Batters with the section location as shown in Plate 1. The main selection criterion was the proximity of the 7m high overburden dump to the planned mine crest. Mr Jon Becker (Senior Engineer at Beveridge Williams & Co) provided the overburden dump design on 23 March 2009.

The phreatic surface was assumed to be 10m below the natural surface. The overburden dump material parameters were adopted from previous studies on the Loy Yang External Overburden Dump Level 3 West (GHD Ref: 31/11466/09/160908.doc). The insitu overburden material parameters were adopted from the October 2002, Loy Yang High Level Storage Dam, Design Review, Geo-Eng (Ref No: 31/11779/40). The material parameters are summarised in Table 1.

Table 1 Material Strength Parameters

Material	Unit Weight (kN/m^3)	c' (kPa)	Φ' (°)
Overburden (Insitu)	19	16	25
Dump Material	17	10	22

2.2 Local Stability

Slope stability analyses were conducted on a comparative basis to assess the influence of the proposed overburden dump on stability. The results indicate that construction of the dump reduces the Factor of Safety (FoS) from 5.26 to 4.14 as shown in Plate 2 and Plate 3 respectively. This is still above the minimum design criteria for Slope Category 3 as outlined in the March 2009 Loy Yang Ground Control Management Plan that requires a minimum design FoS of 1.3 for the Northern Batters.

Plate 2 Base Stability Conditions Without Proposed Overburden Dump

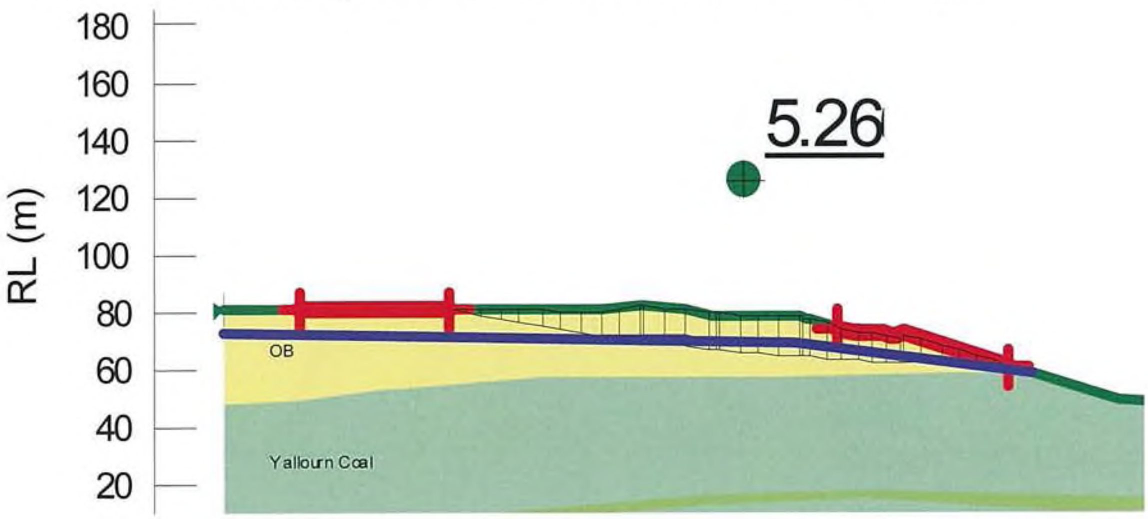
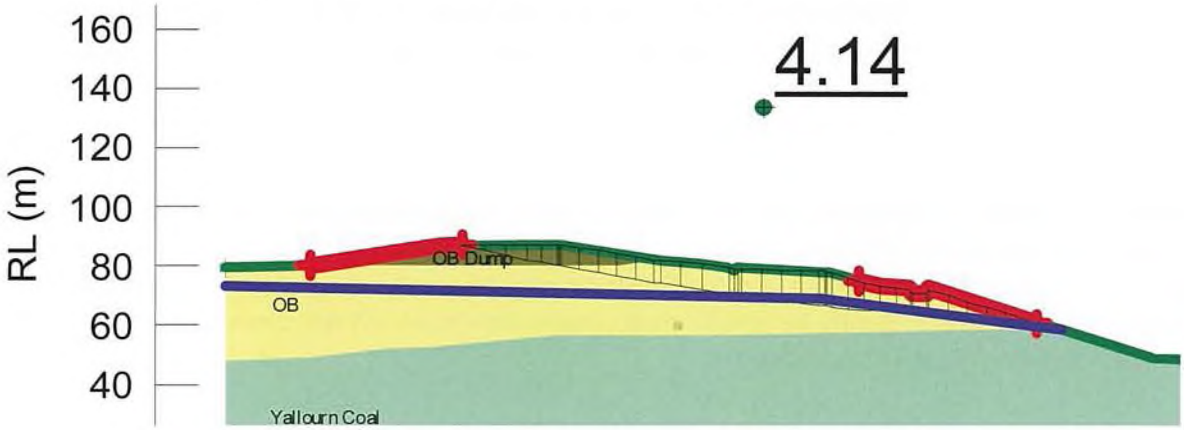


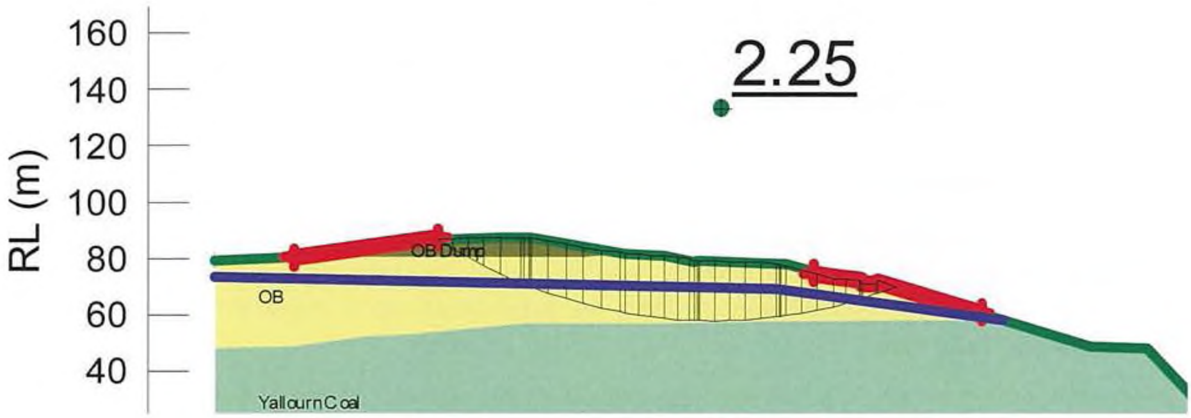
Plate 3 Stability Conditions With Overburden Dump Loading



2.3 Earthquake Loading

For seismic analysis a horizontal acceleration coefficient of 0.1 was adopted to assess the slope stability implications of a potential earthquake. Stability analysis conducted on this slope (with the proposed overburden dump) obtained a FoS = 2.25 as shown in Plate 4. For pseudo static conditions a minimum FoS = 1.15 be considered appropriate for slope design purposes (Li et al 2008).

Plate 4 Stability Conditions With Seismic Loading



2.4 Overall Stability

Deeper-seated large block failures mechanisms sliding on interseam material were also analysed as part of this assessment and the FoS was found to exceed the minimum design FoS of 1.3 even with proposed dump construction.

2.5 Survey Network

There are a number of survey pins in the proposed dump construction area that will be buried by the proposed dump as shown in Plate 1. These pins are located on the L7 and R17 survey lines and include L7/9B, L7/10 and L7/11. In addition a number of other survey pins and survey stations could be affected by construction. Consideration should be given during construction to protect and maintaining R16/3A, R17/8, 79350492-1 and the MELROSSA station.

3 Conclusions

Localised slope stability analyses were conducted on a comparative basis to assess the affect of the proposed overburden dump on the stability of the Northern Batters. The results indicate that construction of the dump reduces the Factor of Safety (FoS) from 5.26 to 4.14 as shown in Plate 2 and Plate 3 respectively. This is above the minimum design criteria for Slope Category 3 as outlined in the March 2009 Loy Yang Ground Control Management Plan that requires a minimum design FoS = 1.3 for the Northern Batters.

Localised pseudo static analysis conducted on the Loy Yang Northern Batters and proposed overburden dump obtained a FoS = 2.25. For pseudo static conditions a minimum FoS = 1.15 may be considered appropriate for slope design purposes. Earthquake loading will therefore not have an adverse effect on localised stability of the proposed overburden dump area.

Overall deeper-seated block failures mechanisms were also analysed as part of this assessment and the FoS was found to exceed the minimum design FoS of 1.3 even with proposed dump construction.

It can therefore be concluded that the construction of a 7m high overburden dump on the Northern Batters will not adversely affect overall slope stability.

4 Recommendations

Consideration should be given in the dump design to ensure adequate surface drainage during and after dump construction. This is to limit surface water ponding behind the dump area and then seeping into the Northern Batters. This is of geotechnical concern as groundwater is a major driving factor for slope instability at the Loy Yang Mine.

The proposed overburden dump should be inspected during the routine fortnightly geotechnical inspections for indications of cracking or instability. These inspections should be conducted during and after the overburden dump construction. Other triggers for inspections should be inclement weather as outlined in the Loy Yang Ground Control Management Plan.

The geotechnical impacts of this overburden dump on overall slope stability will have to be monitored as future groundwater and slope movement data becomes available. The stability conditions will also have to be re-assessed with any major dump redesign or dimension increase, or uncharacteristic movements or signs of instability are detected.

There is no need to re-instate L7/9B, L7/10 and L7/11 on the L7 and R17 survey lines. It is recommended to protect and maintaining R16/3A, R17/8, 79350492-1 and the MELROSSA station. It is also recommended to increase the survey frequency of MELROSSA, 79350492-1, R17/8, L8/25A, L8/24 and L8/23 in this area for surveying and slope monitoring purposes. The survey frequency should be monthly during the dump construction process.

5 Reference

Li, A.J., Lyamin, A.V., Merifield, R.S. (2008). Seismic rock slope stability charts based on limit analysis methods. Computers and Geotechnics, Doi:10.1016/j. compgeo.2008.01.004.

Yours sincerely

Marthinus Sonnekus
Principal Geotechnical Engineer
61 3 8687 8763

Copy to: Michael Laird
Barry Wood
John Kienhuis
Stewart Cluning

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Appendix 4 – Technical References (continued)

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From: Paul Barrand (Loy Yang)
Sent: Tuesday, 10 December 2013 8:18 AM
To: Anne.Bignell@dpi.vic.gov.au
Cc: John Kienhuis (Loy Yang)
Subject: FW: Ash dredging trial- AGL Loy Yang

Good morning Anne,

As discussed last week. The attached letter and following emails (to be sent shortly) show the correspondence to the EPA regarding our planned ash dredging activities to the overburden dump. As previously discussed this is the precursor to positioning ash into the mining void in future years.

Regards

Paul

Energy in action.™
AGL

Paul Barrand
Infrastructure, Civil and Environmental (ICE) Manager, AGL Loy Yang

AGL Loy Yang
Bartons Lane
Traralgon VIC 3844
PO Box 1799
Traralgon VIC 3844

T: 03 5173 2553
F: 03 5173 3298
M: 0427 536 267
E: pbarrand@agl.com.au
www.agl.com.au

From: Kapila Bogoda [mailto:Kapila.Bogoda@epa.vic.gov.au]
Sent: Friday, 27 September 2013 8:23 AM
To: Paul Barrand
Cc: Justin Vanderzalm
Subject: RE: Ash dredging trial- AGL Loy Yang

Good morning Barrand
Thank you for your email.
Yes, only a letter. However, it appears that the second page has not been scanned (not sure why). I am attaching a copy of the letter again to this email.
The original signed letter is in the mail. My apologies if this has caused any confusion.
Regards
Kapila

Kapila Bogoda
Lead Assessor Waste Management
EPA Victoria
Kapila.Bogoda@epa.vic.gov.au

From: Paul Barrand [mailto:pbarrand@loyyangpower.com.au]
Sent: Friday, 27 September 2013 7:35 AM
To: Kapila Bogoda
Subject: RE: Ash dredging trial- AGL Loy Yang

Thanks Kapila,

This is much appreciated and timely! Was there more than just the one page attachment though?

Cheers

Energy in action.™

AGL

Paul Barrand
Infrastructure, Civil and Environmental (ICE) Manager, AGL Loy Yang

AGL Loy Yang
Bartons Lane
Traralgon VIC 3844
PO Box 1799
Traralgon VIC 3844

T: 03 5173 2553
F: 03 5173 3298
M: 0427 536 267
E: pbarrand@loyyangpower.com.au
www.agl.com.au

From: Kapila Bogoda [mailto:Kapila.Bogoda@epa.vic.gov.au]
Sent: Thursday, 26 September 2013 3:12 PM
To: Justin Vanderzalm
Cc: Tim Eaton; David Guy; Paul Barrand; Jon Missen
Subject: RE: Ash dredging trial- AGL Loy Yang

Dear Justin
Please find the attached letter for the proposed trail. The original letter is in the mail.
Regards
Kapila

Kapila Bogoda
Lead Assessor Waste Management
EPA Victoria
Kapila.Bogoda@epa.vic.gov.au

From: Justin Vanderzalm [mailto:jvanderz@loyyangpower.com.au]
Sent: Tuesday, 24 September 2013 11:49 AM
To: Kapila Bogoda
Cc: Tim Eaton; David Guy; Paul Barrand; Jon Missen
Subject: RE: Ash dredging trial- AGL Loy Yang

Kapila

Please find attached a copy of the independent audit report prepared by David Telford.

A copy of this report was sent to EPA (Dave Guy) when it was completed.

regards

Justin van der Zalm
Environment Manager AGL Loy Yang

AGL LoyYang
Hyland Hwy
Traralgon VIC 3844
PO Box 1799
Traralgon VIC 3844

M: 0438 082 846
T: 03 5173 2524
F: 03 5173 2038
E: jvanderz@loyyangpower.com.au
agl.com.au

From: Kapila Bogoda [mailto:Kapila.Bogoda@epa.vic.gov.au]
Sent: Tuesday, 24 September 2013 9:41 AM
To: Justin Vanderzalm
Cc: Tim Eaton
Subject: RE: Ash dredging trial- AGL Loy Yang

Hi Justin
Thank you for submitting further information, and I am currently reviewing them.

You have stated that

- On 2 July 2012 Mr Telford issued an Independent Audit Report, this audit report included a letter of certification, stating the following, "I certify that the applicant (Loy Yang Power) has an Environmental Management System in place which is capable of sustaining a level of environmental performance appropriate for granting accreditation as an Accredited licensee".

However, our Audit Unit tells me that they not received an audit report from Mr David Telford that you referred to.

Can you please re-confirm this, to continue with the assessment.
Regards
Kapila
Kapila

Kapila Bogoda
Lead Assessor Waste Management
EPA Victoria
Kapila.Bogoda@epa.vic.gov.au

From: Justin Vanderzalm [mailto:jvanderz@loyyangpower.com.au]
Sent: Thursday, 12 September 2013 9:54 AM
To: Kapila Bogoda
Cc: Paul Barrand; Jon Missen; 'Jo Stone'
Subject: RE: Ash dredging trial- AGL Loy Yang

Kapila

Thank you for your email regarding our proposed leached ash dredging trial.

In response to your comments modifications to the EIP have been made including changes to the monitoring program. This program has now also been assessed by an Environmental Auditor from SKM. A revised EIP (main document) is attached along with an amended Appendix C. The other appendices have not been changed, however for completeness I will send these in a separate email.

I have provided below an overview as to how we have addressed each of your comments:

1. **Monitoring:** Monitoring program needs to be improved and assessed by an environmental auditor (The site monitoring program has already been assessed by an Auditor (Peter Ramsey), and all additional monitoring proposed for this trial has now been assessed by SKM auditor Richard Wolfe (Confirmation of this assessment is attached) .

The monitoring should include and improve for the testing of the following:

- ash both before and after dewatering. (Detailed analysis of the ash in the ash ponds has already been completed (see appendix A to be sent as a separate email), and analysis of the ash remaining in the trial area will be undertaken, this detail is now included in the monitoring section of the EIP and is also included now in Table 1 , Summary of Monitoring of leachate ash trial).
- water that is drained from ash (if it is discharged outside of leachate ponds) (all water drained from the ash will be returned to the ash ponds via the leachate collection ponds. No water will be drained outside of the leachate ponds); and
- groundwater (in the vicinity of the trial area) (Additional groundwater monitoring in and around the Trial area was already proposed as outlined in the 'Monitoring' section of the EIP, as follows: "In addition to the existing network of groundwater bores an additional 4 shallow bores will be constructed around the trial area to monitor changes in groundwater quality associated with the trail. These bores will be monitored once per month during the trial period. Groundwater quality parameters that will be monitored include, but are not limited to Total Dissolved Solids (TDS), pH and major cations (calcium, magnesium, sodium and potassium). A selection of existing bores will also be included in the trial monitoring program and monitoring frequency of these bores will be increased to monthly in line with the trial monitoring schedule. A revised GHD report detailing the monitoring program proposed is attached as Appendix C while a plan showing the siting of groundwater bores is detailed in Appendix D." This detail was also shown in Table 1 , Summary of Monitoring of leachate ash trial).

In addition the results of all monitoring will be assessed by an Environmental Auditor. This has been detailed in the Reporting section of the EIP as follows: "An independent Environmental Auditor will be engaged to assess the trial, which will include review of all monitoring results and reports. The auditor assessment will be appended to the final report."

2. **Maintaining accreditation:** Please submit adequate information to demonstrate that the accredited licensee status has been maintained.

Please find below details of information which demonstrate that AGL Loy Yang have maintained the requirements of licence accreditation.

<u>Annual Public Reporting of Environmental Performance</u>

- AGL Loy Yang prepares quarterly reports detailing the environmental performance of the site. This performance is made available to the public via the Environmental Review Committee. This committee meets quarterly and is made up of interested community representatives and neighbours as well as stakeholders from EPA and other regulators.
- AGL Loy Yang also details results of environmental performance in our Annual Sustainability report. Copies of this report are available to the public on line via the AGL website.
- AGL Loy Yang holds regular Public Forums. These forums are designed to discuss current issues affecting the region and include summary details of AGL Loy Yang's environmental performance. The last public forum was held on the 6 December 2012.

<u>Review of accreditation</u>

- In 2012 AGL Loy Yang Pty Ltd (formally Loy Yang Power Management Pty Ltd) engaged the services of EPA environmental auditor, David Telford, to assess the LYP EMS for its suitability as part of the LYP accredited Licensee system for licence EM31241 held by Loy Yang Power Management Pty Ltd.
- On 2 July 2012 Mr Telford issued an Independent Audit Report, this audit report included a letter of certification, stating the following, "I certify that the applicant (Loy Yang Power) has an Environmental Management System in place which is capable of sustaining a level of environmental performance appropriate for granting accreditation as an Accredited licensee".

- On 4 July 2012 EPA were made aware that an Audit report and verification of our EMS had been received.

Please let me know if this information is now sufficient for EPA to provide approval of the proposed Ash Dredging Trial?

Regards

Justin van der Zalm
Environment Manager AGL Loy Yang

AGL LoyYang
Hyland Hwy
Traralgon VIC 3844
PO Box 1799
Traralgon VIC 3844

M: 0438 082 846
T: 03 5173 2524
F: 03 5173 2038
E: jvanderz@loyyangpower.com.au
agl.com.au

From: Kapila Bogoda [mailto:Kapila.Bogoda@epa.vic.gov.au]
Sent: Friday, 9 August 2013 3:38 PM
To: Justin Vanderzalm
Cc: Tim Eaton; Helen Corry; Stefan VanRhyn; Shahbaz Aftab
Subject: Ash dredging trial- AGL Loy Yang

Dear Justin
Thank you for your call. Further to our discussion this afternoon, I can confirm the following:

EPA has no objection (in principal) to the proposed trail submitted in your EIP document. However, the EIP should address the following in more detail:

1. **Monitoring:** Monitoring program needs to be improved and assessed by an environmental auditor. The monitoring should include and improve for the testing of the following:
   - ash both before and after dewatering;
   - water that is drained from ash (if it is discharged outside of leachate ponds); and
   - groundwater (in the vicinity of the trial area).

2. **Maintaining accreditation:** Please submit adequate information to demonstrate that the accredited licensee status has been maintained.

Your request to undertake work without a Works Approval or a RD& D approval is because of the accredited licensee status. Please note the following paragraph about maintaining accreditation (refer to EPA Publication 424.8 – *Accredited Licensee system- Guidelines for Applicants*, for more details).

MAINTAINING ACCREDITATION

Accreditation is granted to a licensee subject to maintaining the requirements of accreditation. A number of checks and balances are integrated into the system to ensure performance is maintained. These include annual public reporting of environmental performance and five yearly reviews of accreditation. In addition, where EPA finds a licensee is performing poorly or is failing to maintain their EMS, environmental audit program, EIP or community consultation programs, accreditation may be reviewed.

Please submit a revised EIP addressing the above. If you have any further queries on the above please call me to discuss.
Regards
Kapila

Kapila Bogoda, MEM, MSc, BSc(Hon), CEng
Lead Assessor Waste Management
Development Assessments
EPA Victoria

EPA VICTORIA Victoria

200 Victoria Street, Carlton VIC 3053 | GPO Box 4395, Melbourne VIC 3001 | DX 210082
☎ 03 9695 2889 | ☎ 03 8710 5577 ☎ 0488316485
kapila.bogoda@epa.vic.gov.au | www.epa.vic.gov.au

A healthy environment that supports a liveable and prosperous Victoria.

From: Justin Vanderzalm [mailto:jvanderz@loyyangpower.com.au]
Sent: Friday, 9 August 2013 2:19 PM
To: Kapila Bogoda
Subject: email address

Kapila

As discussed please send me some points which outline EPA's feedback on our EIP for a proposed ash dredging trial.

regards

Justin van der Zalm
Environment Manager AGL Loy Yang

AGL LoyYang
Hyland Hwy
Traralgon VIC 3844
PO Box 1799
Traralgon VIC 3844

M: 0438 082 846
T: 03 5173 2524
F: 03 5173 2038
E: jvanderz@loyyangpower.com.au
agl.com.au

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Appendix 4 – Technical References (continued)

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West Gippsland
Catchment Management Authority

www.wgcma.vic.gov.au
☎: 1300 094 262 **Fax:** (03) 5175 7899

Works on Waterways Application Form

Application for a permit is required under the West and East Gippsland Catchment Management Authority's Waterways Protection By-law No. 1 Pursuant to sections 160, 161 and 219 of the Water Act, 1989.

EAST GIPPSLAND CATCHMENT MANAGEMENT AUTHORITY

www.egcma.com.au
☎: (03) 5152 0600 **Fax:** (03) 5150 3555

The applicant must complete all details on this form, attach all required details, and ensure that the indemnity clause is signed. Before completing this application, please ensure you read the ***Guidelines for Applying for a Works on Waterways Permit*** and the specific notes for the proposed work type that you wish to undertake. These documents are available from our website.

1. NAME OF APPLICANT May be a person representing the owner

Full Name: Mr/Mrs/Ms: Jon Missen – Env & Earth Science Superintendent

Company Name (if applicable): Loy Yang Power Management Pty Ltd

Postal Address: PO Box 1799, TRARALGON

Postcode: 3844

Daytime Phone No: 03 5173 3484 After Hours Phone No:.................. Mobile Phone No: 0429 880106

Fax No: 03 5173 3298 Email: jmissen@loyyangpower.com.au

2. NAME OF LAND OWNER (if different from applicant) The permit will be issued to this party

Full Name: Mr/Mrs/Ms:..................

Company Name (if applicable):..................

Postal Address:.................. Postcode:..................

Daytime Phone No:.................. After Hours Phone No:.................. Mobile Phone No:..................

Fax No:.................. Email:..................

3. NAME OF WATERWAY DETAILS – Please consult the DSE's Catchment Information Mapper and provide a print out if possible. See Page 4 for web link

Name of Waterway: Sheepwash Creek

Tributary of: Latrobe River

4. PROPERTY DESCRIPTION WHERE THE WORKS ARE PROPOSED

Property Address *(e.g. 3 Kurrajong Road, Homesview)*	Must include **ONE** of the following (refer to your Title): **Crown Allotment and Parish Name** *(e.g. CA 12, Section D, Parish of Home)*	**Lot Number of Plan of Subdivision (PS) or Lodge Plan Number (LP), *etc.*** *(e.g. Lot 4 of PS144333)*
....	CA 5R, Parish of Loy Yang	....

Are the works on Crown land or Private land? ☐ Crown land ☒ Private land

If you ticked Crown land, DSE will be advised of your proposed works

Name of Nearest Town: Traralgon..................

Any further useful details: Within ML5189 – east of Loy Yang Mine current operational area
Previous Reference WG-W-2008-0004..................

....

Co-ordinates (if available): Easting: .... Northing: ....

Have you had a pre-application meeting or contact with a CMA staff member? ☒ Yes ☐ No

If Yes, who with? Adam Dunn – Land Planning Manager

Locality Maps MUST be supplied with this Application.

5. GENERAL DESCRIPTION OF THE PROPOSED WORKS

- ☐ Access Crossing - Bridge
- ☐ Access Crossing - Culvert
- ☐ Access Crossing - Ford
- ☐ Sand and Gravel Extraction
- ☐ Vegetation Removal
- ☐ Pipeline
- ☐ Stabilisation (erosion control)
- ☒ ***Retention Embankment***
- ☒ **Waterway Deviation**
- ☐ Jetty
- ☐ Stormwater Outlet

5A. Proposed use and description of works

Describe the land use (*e.g.* grazing, cropping, residential, *etc.*) adjacent to the proposed works site:

Open Farmland – mostly grazing use, some fodder crops (within Mining Licence area)

Proposed Use / Purpose of Works:

The diversion and retention embankment are to divert flows along the Sheepwash Ck watercourse outside of the mine operational area and provide flood protection in extreme rainfall events

Brief description of works

The proposed work involves a retention embankment that would cut off up stream flows which would be diverted outside the mine operating area via a new channel and flood protection embankment. This would then discharge to a downstream tributary of Sheepwash Ck.

See accompanying report for more detail.

5B. Waterway Dimensions

How wide is the waterway?

Distance between top of waterway banks.......................................metres

Distance across waterway bed...metres

The stream is a poorly defined ephemeral watercourse – see accompanying assessment for more detail

Please attach a sketch of the waterway cross section

5C. Describe any erosion and vegetation details

Is there evidence of erosion in the bed and banks of the waterway? ☐ Yes ☒ No

Please Comment:

The watercourse follows a path of gentle grades and is well vegetated. There are areas of silt retention / settlement.

Describe the type and extent of existing vegetation on the bed and banks of the waterway at the proposed site.

Bed: the vegetation in the bed is dominated by exotic pasture grasses and areas of riparian tussocks, grasses and sedges.

Banks: there is very little vegetation along the stream other than exotic pasture grasses and isolated remnant trees. There is a significant stand of trees at the old Hyland Hwy bridge site but this will not be impacted by these works

See accompanying report for further information

5D. Describe the soil type of the bed and banks

BED of the waterway: Please tick appropriate box

☒ Clay ☐ Loam ☐ Sand ☐ Gravel ☐ Rock ☐ Other: ....

BANKS of the waterway: Please tick appropriate box

☒ Clay ☐ Loam ☐ Sand ☐ Gravel ☐ Rock ☐ Other: ....

6. Please fill out the relevant section below if applicable

Bridge Crossing

Proposed Bridge Dimensions:

Total Length:...metres

Bridge Width:..metres

Number of Spans: ☐ Single Span ☐ Two Spans ☐ Three Spans ☐ Four Spans ☐ Other:.......................

Proposed Material:

☐ Concrete ☐ Steel ☐ Timber ☐ Other (please specify):...

Pipe and Box Culvert Crossing

Proposed Culvert Dimensions:

Culvert Type: ☒ Box Culvert ☐ Pipe Culvert

Size of box or pipe diameter: 5 x 1.2 x 0.75 metres

Width of crossing (measured from upstream to downstream): 12 metres

Length of crossing (measured from bank to bank): 8 metres

Number of parallel culverts: 5

Height of crossing above waterway bed level: 1.5 metres

Proposed Material:

☒ Concrete ☐ Steel ☐ Other (please specify):...

Ford Crossing

Total Width of ford crossing (measured from upstream to downstream): 12 metres

Total Length of ford crossing (measured from bank to bank): 8 metres

Height of crossing above waterway bed level: 1.5 metres

Proposed Material:

☐ Concrete Slab ☒ Rock ☐ Other: ....

7. ANCILLARY WORKS

Do the proposed works involve stream alignment? ☐ Yes ☒ No

Are there any proposed bed and/or bank protection works? ☐ Yes ☒ No

If you ticked **YES** to either of the above questions, please attach sketch with dimensions of the works

8. NATIVE VEGETATION REMOVAL ASSOCIATED WITH THE PROPOSAL

Will any native vegetation be removed? (includes trees, shrubs, grasses)

☒ Yes ☐ No If **YES**, please specify the type and amount/area of vegetation to be removed. You should also contact your local Council to determine whether a planning permit is required.

Some minor areas of riparian grasses and sedges

Have you considered other alternative work sites to minimise native vegetation removal? ☐ Yes ☒ No

If **NO**, please explain reason: minimal disturbance to stream and offset plantings proposed

9. FLOOD LEVEL INFORMATION (WHERE APPLICABLE AND KNOWN)

Please provide any available information on frequency of floods and previous flood levels at the proposed crossing site, *e.g.* how often is the site inundated by flooding.

Description:..

....

Source of Information:..

Please show any flood level information, including date (*i.e.* year) at the works locality plan

10. PROVIDE SKETCHES OF PROPOSED WORKS

- Provide plans and drawings of the proposed works if available.
- Please consult the DSE's Catchment Information Mapper using the link below and provide a print out if possible. http://www.dse.vic.gov.au/DSE/dsencor.nsf/LinkView/836EE128E54D861FCA256DA200208B945FD09CE028D6AA58CA256DAC0029FA1A
- If possible, please provide a photograph of the site

Land Locality Plan Where is the land? Show in relation to roads and nearest intersections.

See Attachments

Works Locality Plan Where on the land will the works be? Show the waterway and location of the works in relation to boundaries, roads, buildings etc. Give distances.

See Attachments

Sketch a cross section of the waterway and the proposed works, including dimensions.

See Attachments

11. INDEMNITY CLAUSE

This indemnity must be signed by the owner of the property, or if an organisation, someone authorised to do so. Where works are sited on Crown land, the owner of the works must sign the indemnity.

I acknowledge that the West or East Gippsland Catchment Management Authority may issue a permit for the construction of the works on a waterway but that West or East Gippsland Catchment Management Authority shall not be responsible for any claims, suits or actions, arising from injury, loss, damage or death, to any person or property which may arise from the construction, maintenance, existence or use of the works.

I hereby indemnify the West or East Gippsland Catchment Management Authority and its officers against all claims, suits or actions arising from injury, loss, damage or death, to any person or property which may arise from the construction, maintenance, existence or use of the works described in this application.

Signed:.. Date:..

Print name in CAPITALS:..

12. CMA MAILING DETAILS: All correspondence for both CMA's is administered by West Gippsland CMA	
Postal Address: West Gippsland Catchment Management Authority PO Box 1374 Traralgon VIC 3844 **Email:** planning@wgcma.vic.gov.au	**Telephone No:** 1300 094 262 **Fax No:** (03) 5175 7899

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Appendix 4 – Technical References (continued)

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26/11/08

SMEC Urban: Michael Jones, Jennie Jones, Gary Harle.
Latrobe City: Carole Jeffs, Swee Lim
Loy Yang - Power Jon Missen

1/ Sheepwash Creek.
Jon summarised project, effemeral stream, SMU
Investigated enviro qualities,
- looking at flood protection for mine.
- diversion to decrease flows
- options of where to relocate.
- stakeholders: CMA discussion, need more detailed proposal, provision offsets,
Southern Rural Water: no great interest, will give background to project + proposal
- need permit to do works on Water ways
- offsets will be around Tributary 3 - longer term
Monash Energy resource - no buffer between mines

- Mining Licence: Minerals Petroleum Act
- EES - required - approval now given.
- offsets - vegetation - replicate water treatm benefits.
- water flow will be reduced.

Project: Exempt from Planning Permit requirement due to Exploration.
- Water Act - no quality change.
- CMA - LCC
- Cultural Heritage.
- Will offset veg but no permit required
Melaluca swamp - being removed.
- DPI - will be consulted - works plan.
Invited Latrobe City - to be on steering committee

Works program - March 09 ish? - 3 year program 2011

Consultative group.

26/11/08

SMEC Urban
Latrobe City

Hollydale: - Mike explained background, design concept.
- Water - GW discussions - satisfactory solution available to service property with pump station.

- Latrobe City - Corridor.

Growth areas in Traralgon including corridor
* 6 mths. - mid 09.
Process

Request indicative support. - key Council staff
- Councillors.
- Airport Master Plan.
Interim - Airport - Overlay - height
- Double Glazing -

Adjoining owners - concerns.

Risk - ? Commercial Development.

DDO + DPO - Proposed for precinct.

VicRoads - upgrading Crinigans Rd intersection
- Harvey Anelli. - Meeting.

Bulky Goods Review

smec urban
consulting group

sm urban pty ltd - traralgon
abn 99 124 206 819 acn 124 206 819
trading as smec urban
t +61 3 3 5173 0100 f +61 3 5174 0088
18 breed street traralgon vic 3844 australia
www.smu.com.au

16 April 2009

cc
enc **Alluvium Report and Drawing**
project no. 3420300E
doc no. SRWater_01

Mr Vince Lopardi
Southern Rural Water
88 Johnson Street
Maffra Vic 3860

Dear Vince,

Re: Loy Yang Power – Open Cut Mine, Traralgon South
Proposed Deviation of Sheepwash Creek

With reference to the above and further to a phone conversation with you earlier in the year, I would like to confirm the proposal to deviate the waterway known as Sheepwash Creek.

I would like to firstly advise that we are involved with this project through our engagement by Loy Yang Power (LYP) to investigate the realignment of Sheepwash Creek to accommodate the future expansion of the Loy Yang Open Cut Mine.

The proposal is to realign the existing Sheepwash Creek around the future mine expansion Refer to the following attachments:

1. Drawing reference number 3420202E Rev A for the concept realignment
2. A Preliminary Background Assessment Report by Alluvium for the Sheepwash Creek Diversion

The key points in regards to the proposal are:

- The realignment is to follow a contour line commencing un the vicinity of the creek location on the immediate north side of the Hyland Highway and extend in an northerly and north-easterly direction, reconnecting back to the creek via an existing tributary in the vicinity of Ingles Road ((Connection point noted on drawing as 'north-eastern most waterway' an existing tributary to Sheepwash Creek)
- The realignment may be carried out in two stages. This is dependent upon the final proposal by LYP as to their mine expansion direction and speed
- The works are tentatively programmed to commence in 2010

To date we have held discussions with other authorities in regards to the development. These are:

- Latrobe City Council in regards to planning issues and as a matter if informing them of the proposal
- West Gippsland CMA. We are still working with the WGCMA in regards to approvals for the work

We are currently in the process of providing flora and fauna and archaeological due diligence investigation and reporting.

The purpose of contacting Southern Rural Water was to advise of the proposal and to seek any comments or inputs the Authority may have into the proposed waterway deviation. It is taken from our last discussion that SRW will have no input or requirements in regards to the proposed deviation.

The purpose of following up our phone discussion was to provide SRW with some background on the proposal.

Could you please confirm in writing that SRW has no formal interest in the proposed waterway deviation and if you would like to be kept informed of the progress of the approvals process and timeline for works.

If you have any questions or require further information, please contact me on 5173 0116 or gary.harle@smu.com.au

Yours faithfully
SMEC Urban

Gary Harle
Engineering Manager - Gippsland

d +61 3 5173 0116
f +61 3 5174 0088
m 0427 536 018
e gary.harle@smu.com.au

Harle, Gary

From: Harle, Gary
Sent: Friday, 17 April 2009 7:20 AM
To: 'srw@srw.com.au'
Cc: Jones, Michael
Subject: Loy Yang Power - Mine Expansion adn Prpoposed Relocation of Sheepwash Creek
Attachments: SR Water_01.pdf; Dwg 3420202E Rev A.pdf; P108029_R01_V3 _Sheepwash_Ck_background.pdf

Attention Vince Lopardi

Vince,

I am following up on my phone call to you earlier in the year regarding the above proposal. Loy Yang Power wish to proceed with the planning and approvals for the relocation of Sheepwash Creek to allow for the mine expansion.

Please find attached my covering letter regarding the proposal. I have also included:

- A report by Alluvium – Background Assessment – Sheepwash creek Diversion at Loy Yang
- A plan of the area showing the proposed deviation of Sheepwash Creek (Dwg 3420202E Rev A)

As per our phone discussion I am providing this information as background material on the proposal.

To date we have held discussion with:

- Latrobe City as the planning authority and for their information; and
- West Gippsland CMA

We will be applying to the WGCMA for their comments on the proposal as it is developed.

As per our phone discussion, you advised that you would expect that SRW would have no input into the proposal. Could you please confirm in writing that SRW has no formal interest in the proposed waterway deviation. Could you also advise if you would like to be kept informed of the progress of the approvals process and timeline for works. .

I am going on annual leave as of the 20/4 until the 11/5/2009. If you have any questions could you please contact Michael Jones of this office on 5173 0100 or michael.jones@smu.com.au

Regards

Gary

Gary Harle
Engineering Manager - Gippsland

d +61 3 5173 0116 **f** +61 3 5174 0088
m 0427 536 018
e gary.harle@smu.com.au

smec urban
18 Breed Street, Traralgon, vic 3844
p +61 3 5173 0100 | **f** +61 3 5174 0088 | www.smu.com.au

RECEIVED
19 MAY 2008

West Gippsland
Catchment Management Authority

Application Number: WG-W-2008-0004
Document Number: 1
WGCMA ID: 34311
Date: 14 May 2008

Gary Harle
SM Urban Pty Ltd
18 Breed Street
Traralgon, VIC 3844

Dear Gary,

Application Number: **WG-W-2008-0004**

Location:
Cadastral: **Lot 1, PS449976, Parish of Loy Yang (Loy Yang Mine)**

Waterway:
Name: **Sheepwash Creek (Tributary of Flynn's Creek)**

I refer to your correspondence dated 22 January 2008, received at the West Gippsland Catchment Management Authority on 24 January 2008.

Below is the Authority's understanding of the application

The applicant(s), Gary Harle
SM Urban Pty Ltd
of 18 Breed Street Traralgon, VIC 3844

propose the following

Works Category: Stream Deviation
Works Type: Deviation without Access Crossing
Works Description: Proposed realignment of Sheepwash Creek for mine expansion.

Although the permit has not been issued at this stage, attached is a list of typical conditions, for your reference, which should be considered when applying for works of this nature. This list may change once further information regarding the proposed works has been received.

In light of the above information and pursuant to *Sections 160, 161 & 219* of the *Water Act 1989*, the Authority advises the following:

- The diversion channel should be constructed with batter of a gentle gradient to avoid erosion. It should be topsoiled and grassed for further protection.
- The confluence of the diversion and creek will need to be angled to prevent erosion of the creek
- There will be a need to monitor for the impact of increased flows on the creek as a result of the diversion. Works to negate any impact may result.

Offset Requirements

1. Any clearing of native vegetation associated with the project must be consistent with the net gain offsets principles stated under the Native Vegetation Framework.
2. The types, extent and condition of vegetation and habitat areas will need to be defined for all areas that will be either cleared, excised or retained within the project area.
3. Similar to the net gain offset principles, vegetation and habitat areas excised from the waterway will need to be offset with 'like for like' vegetation or habitats at the nearest location to the impacted reach and must be connected to a waterway.
4. Enhancement of similar habitats within and adjacent to the project area will be required to maintain connectivity with existing vegetation and to improve biodiversity values.
5. Impacts to threatened flora and flora species will need to be identified and addressed.

Please note, this document contains advice only and does not constitute a Permit Issue for any works at this location.

A formal application for this proposed works will need to be lodged with the West Gippsland Catchment Management Authority before a permit will be issued. An application form is attached.

Should you have any queries, please do not hesitate to contact the John Crosby on 1300 094 262. To assist the Authority in handling any enquiries please quote **WG-W-2008-0004** in your correspondence with us.

Yours sincerely

Adam Dunn
Land Planning Manager

Permit Conditions for Temporary Deviation

1. The deviation shall be constructed in accordance with the plan/s attached.

2. The side slopes of the banks of the deviated section of the waterway shall be no steeper than 2 horizontal to 1 vertical. All bank areas of the deviated section of the waterway shall be top soiled and planted with locally occurring native grasses.

3. Stream flows shall not be diverted into the deviated section of the waterway (by breaching the area at the commencement of the deviation) until a reasonable grass cover has established on the bank areas of the deviation.

4. Disturbance of the bed and banks of the waterway and the use of construction plant and equipment is to be kept to a minimum during construction. Removal, destruction or lopping of native vegetation is also to be kept to a minimum. Suitable conservation measures are to be implemented to prevent vegetation, silt, chemicals and spillage from construction activities either entering the waterway or moving downstream. No discharge/dumping of wastewater or other materials into the waterway is permitted, unless specifically authorised by the Authority.

5. All disturbed bank areas shall be graded to remove humps and hollows and top soiled and planted with locally occurring native species of grasses and shrubs.

6. Vegetation that has been cleared for construction purposes and any heaps of excavated soil remaining after the completion of the works shall be removed from site. No material of any sort shall be pushed into the waterway or left in a manner where it can slip or be moved by floodwaters, into the waterway.

7. Any works in the bed of the waterway should be designed and constructed so as not to impede fish passage.

8. Logs and boulders removed from the waterway as a result of construction activity should be returned to the waterway and randomly distributed.

9. Within the first twelve months following construction, the person issued with this permit shall inspect the deviation and any grade reducing structures constructed in it, at a minimum of three monthly intervals and after significant flow events. Any damage to the deviation and structures shall be promptly restored.

   Note: Any erosion of the bed of the deviation is likely to progress upstream and cause extensive damage to the stream system.

10. The deviation shall always be maintained in good order.

11. It is the responsibility of the person issued with this permit to obtain the necessary approval of the works before their commencement:

    (a) from the relevant planning authority

    (b) from the Department of Sustainability and Environment in relation to the Land Act 1958, Forests Act 1958, the Flora and Fauna Guarantee Act 1988, the Conservation, Forests and Land Act 1987 and the Catchment, Land Protection Act 1994 and the Native Title Act 1993 (the later being applicable to Crown Land only)

    (c) from Aboriginal Affairs Victoria (AAV) in relation to the *Aboriginal Heritage Act 2007*

Permit Conditions for Permanent Deviation

1. The deviation shall be constructed in accordance with the plan/s attached.

2. The side slopes of the banks of the deviated section of the waterway shall be no steeper than 2 horizontal to 1 vertical. All bank areas of the deviated section of the waterway shall be top soiled and planted with locally occurring native grasses.

3. Stream flows shall not be diverted into the deviated section of the waterway (by breaching the area at the commencement of the deviation) until a reasonable grass cover has established on the bank areas of the deviation.

4. Disturbance of the bed and banks of the waterway and the use of construction plant and equipment is to be kept to a minimum during construction. Removal, destruction or lopping of native vegetation is also to be kept to a minimum. Suitable conservation measures are to be implemented to prevent vegetation, silt, chemicals and spillage from construction activities either entering the waterway or moving downstream. No discharge/dumping of wastewater or other materials into the waterway is permitted, unless specifically authorised by the Authority.

5. All disturbed bank areas shall be graded to remove humps and hollows and top soiled and planted with locally occurring native species of grasses and shrubs.

6. Vegetation that has been cleared for construction purposes and any heaps of excavated soil remaining after the completion of the works shall be removed from site. No material of any sort shall be pushed into the waterway or left in a manner where it can slip or be moved by floodwaters, into the waterway.

7. Any works in the bed of the waterway should be designed and constructed so as not to impede fish passage.

8. Logs and boulders removed from the waterway as a result of construction activity should be returned to the waterway and randomly distributed.

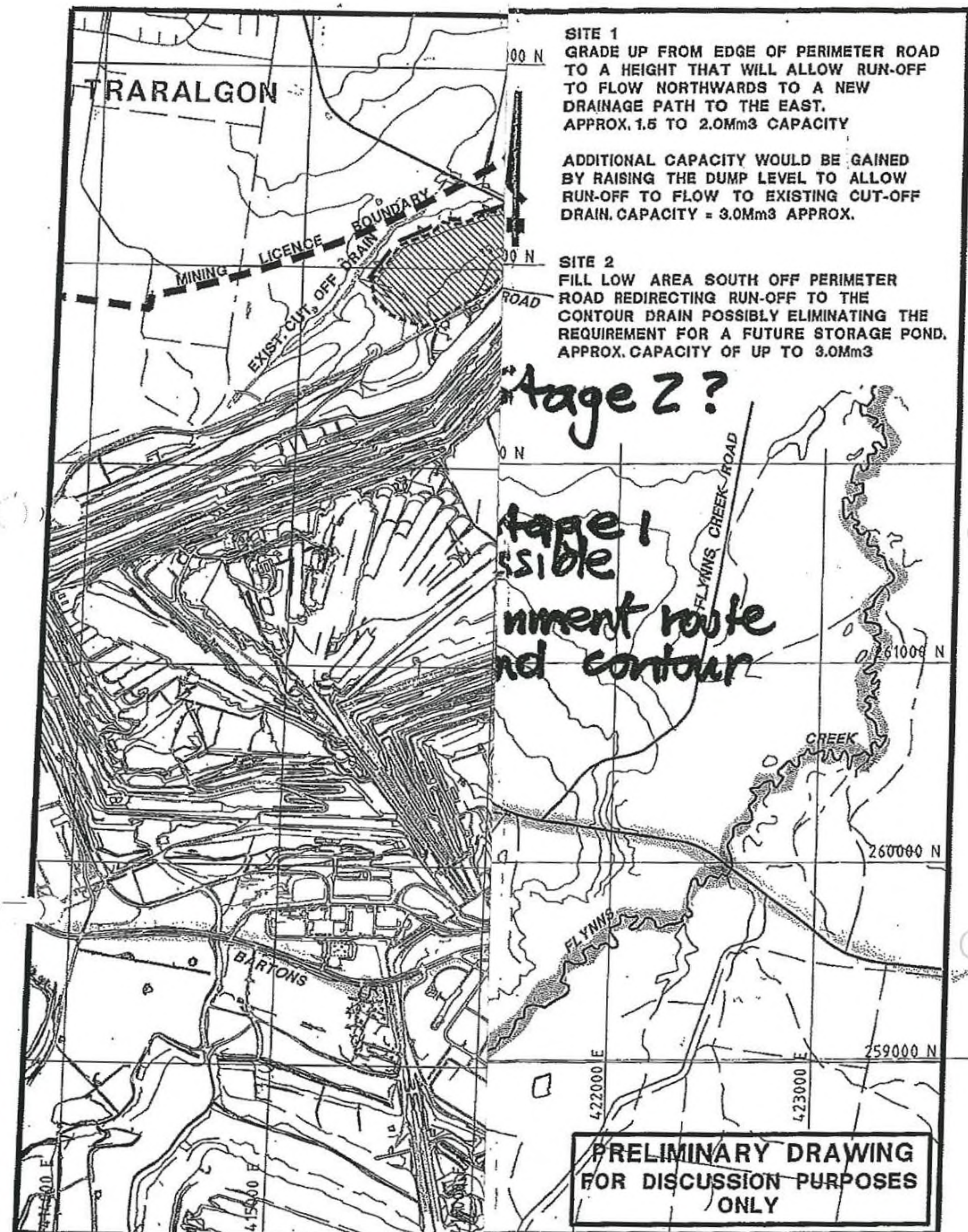
9. Within the first twelve months following construction, the person issued with this permit shall inspect the deviation and any grade reducing structures constructed in it, at a minimum of three monthly intervals and after significant flow events. Any damage to the deviation and structures shall be promptly restored.

   Note: Any erosion of the bed of the deviation is likely to progress upstream and cause extensive damage to the stream system.

10. The deviation shall always be maintained in good order.

It is the responsibility of the person issued with this permit to obtain the necessary approval of the works before their commencement:

- (a) from the relevant planning authority
- (b) from the Department of Sustainability and Environment in relation to the Land Act 1958, Forests Act 1958, the Flora and Fauna Guarantee Act 1988, the Conservation, Forests and Land Act 1987 and the Catchment, Land Protection Act 1994 and the Native Title Act 1993 (the later being applicable to Crown Land only)
- (c) from Aboriginal Affairs Victoria (AAV) in relation to the *Aboriginal Heritage Act 2007*



30/8/07	A	BACKGROUND UPDATED	POWER LTD
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REVISION

LOY YANG

Appendix 4 – Technical References (continued)

175 SUPPORTING THE COMMUNITY AGL

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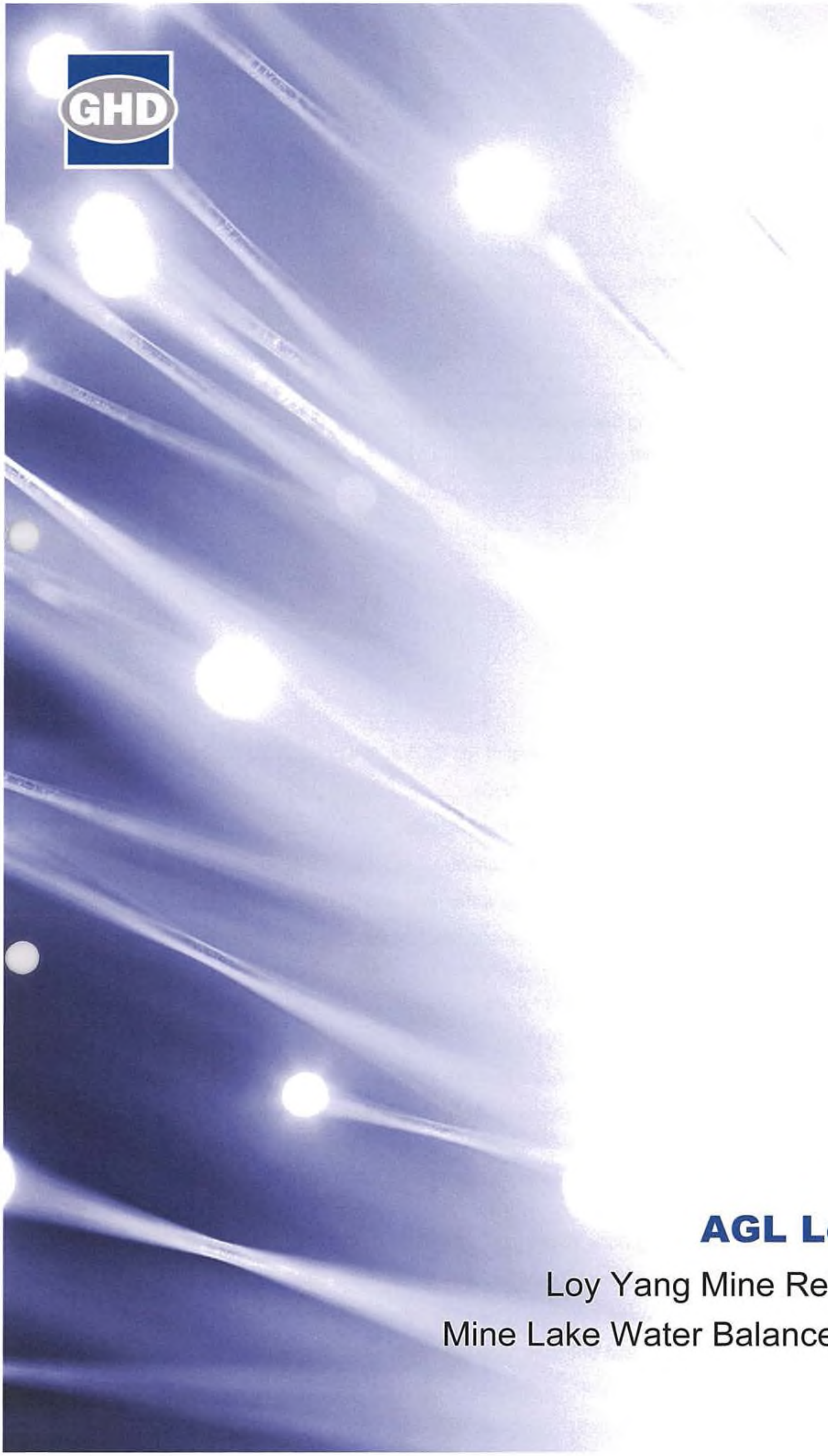

AGL Loy Yang

Loy Yang Mine Rehabilitation
Mine Lake Water Balance Modelling

March 2015

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Table index

Figure index

Appendices

1. Introduction

1.1 Background

A water balance assessment of the Loy Yang Mine final mine void has been undertaken to estimate the time required to fill the void, and at what level the lake would stabilise in the long term currently modelled at 200 years after mine closure. This study builds on the water balance assessments undertaken in 2011, 2006 and 2004 as part of the Loy Yang Mine Rehabilitation Plan (GHD 2011; GHD 2006; GHD, 2004).

The filling rate of the lake impacts on the post mining aquifer depressurisation requirements as aquifer pressures need to be maintained below weight balances as the lake fills. A lake level of RL-22.5 m AHD is estimated to be the highest level at the key bore locations required to achieve a weight balance pressures of RL+20m which is considered to represent the long term TR aquifer recovery level. At lake levels above RL-22.5m AHD, the risk of floor heave is considered low and active groundwater management is not likely to be required. The maximum lake level of RL-22.5 is based on the Whole of Life (WOL) mine development plan and recent internal dump plan modifications including placement of additional material for fire protection against the northern batters in the Minniedale Dome area as discussed in *Long term Aquifer Depressurisation Assessment* (GHD 2015a).

One limitation of the long term depressurisation assessment is that has been completed at key bores rather than spatially. Key bores which extend to the Traralgon aquifer were used so there is good geological control and a high level of confidence in the weight balance level estimates at these locations. The bores have been selected to provide good coverage across the mine area including the critical deeper mine areas and structural highs and are considered to be representative of the range of 2059 weight balance and floor stability lake levels. However to improve the confidence in the results, further modelling of these levels spatially across the mine area could be considered in future studies.

2. Model Setup

A number of REALM (Resource Allocation Model) models have been configured to simulate the mine lake water balance for a combination of inflow scenarios and climatic conditions to provide an indication of the variation in the lake water level over time. The models were configured with a monthly time step for a 200 year simulation period post mine closure (2060 – 2260).

The Stochastic Climate Library was used to generate a 200 year monthly rainfall and evaporation time-series, derived from the gauge Morwell Mail Centre (85062).

The water balance modelling was assessed using the final mine void shape from the *"Revised Whole of Life Mine Plan – 2011"*, with the internal dump shape from the *"August 2014 option for maximising dumping against the northern batters"*.

See Appendix A and Appendix B for further details on REALM model inputs and configuration.

2.1 Contributions to inflows

Contributions to inflow to the mine lake are discussed below.

Runoff from maximised catchment

Rainfall runoff from the catchment that naturally drains towards the mine void above the mine lake surface area (maximised catchment), calculated using the equation below:

$$Runoff = (Maximised\ Catchment\ Area - Surface\ Area\ of\ Lake) \times Rainfall\ \times Runoff\ Coefficient\ \times Climate\ Coefficient$$

Assuming a maximised catchment area of 3687 Ha, a runoff coefficient of 0.3 and the corresponding climate coefficient for rainfall (refer to Table 9 in Appendix A). Maximising the catchment would be achieved capturing flows from Sheepwash Creek and other waterways which naturally flow towards the mine void. It

Runoff from minimised catchment

Rainfall runoff from a catchment limited to the area of the mine void (minimised catchment) above the mine lake surface area, calculated using the equation below:

$$Runoff = (Minimised\ Catchment\ Area - Surface\ Area\ of\ Lake) \times Rainfall\ \times Runoff\ Coefficient\ \times Climate\ Coefficient$$

Assuming a minimised catchment area of 2115 Ha, a runoff coefficient of 0.3 and the corresponding climate coefficient for rainfall (refer to Table 9 in Appendix A). Minimising the catchment would be achieved by diverting flows from Sheepwash Creek and other waterways within the mining licence area, and flood flows from Traralgon Creek, away from the mine void.

Traralgon Creek flood flows

Traralgon Creek flood flows diverted to the mine void, assuming a flow of 4 GL/year (10% of the mean annual flow) uniformly distributed at a monthly time-step, using the equation below:

$$Traralgon\ Creek\ Flood\ Flows\ = {}^{4}/_{12} \times Climate\ Coefficient$$

For the corresponding climate coefficient for streamflow (refer to Table 9 in Appendix A).

9.8 GL/yr Groundwater extraction for 10 years

Groundwater extractions at a rate of 9.8 GL/yr over the first ten years post mine closure, uniformly distributed at a monthly time-step. This groundwater extraction scenario was selected as it is simulated in the WOL post-closure mine recovery model documented in *Loy Yang Groundwater Modelling – Long Term Mine Plan* (GHD, 2015) and is considered a reasonable estimate of post mining pumping requirements as discussed in Section 4.1.4.

15 GL/yr groundwater extractions

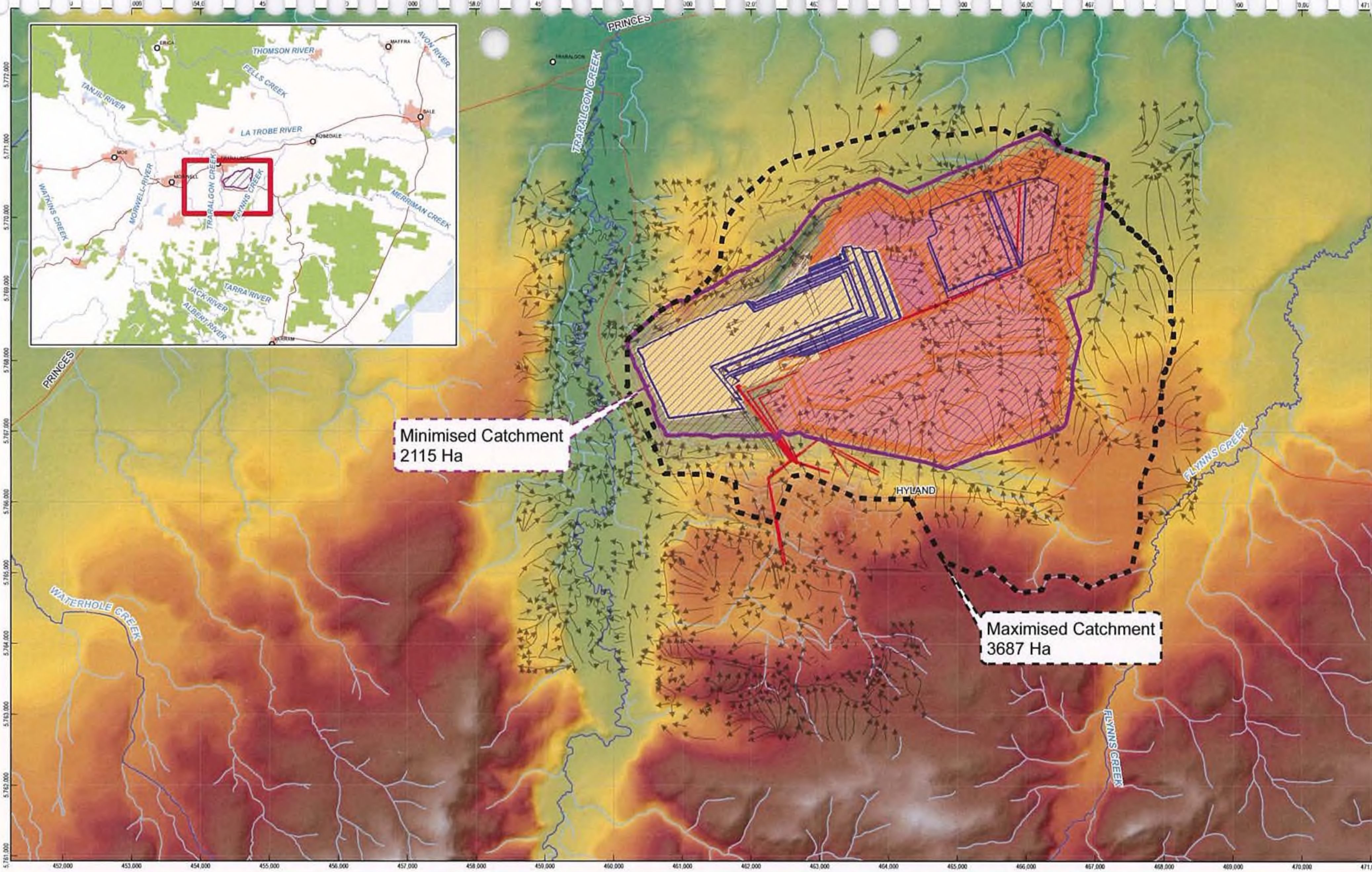
Groundwater extractions at a rate of 15 GL/yr diverted to the mine lake until lake level reaches the maximum stable level mine of RL-22.5 m AHD, uniformly distributed at a monthly time-step.

40 GL/yr Bulk Entitlement

Bulk Entitlement flows of 40 GL/yr diverted to the mine lake until lake level reaches the maximum stable level mine of RL-22.5 m AHD, uniformly distributed at a monthly time-step.

Groundwater Seepage

The relationship between groundwater seepage into the mine lake (ML/month) and the mine lake water level for the four climatic conditions were estimated by simulating the transient groundwater model for Loy Yang mine recovery period (2059 – 2455). It is noted that the groundwater seepage inflows were scaled by a factor of 50% for the Yallourn Interseam and the M2B Aquifer, as the predicted pit inflows were considered to be too high compared to known aquifer conditions in these interseams. Refer to GHD (2015) for further details on the groundwater modelling and Table 15 in Appendix A for the groundwater seepage rating tables for the four climatic conditions.



Paper Size A3

0 3 6 12 18 24 30

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Loy Yang Minimised Catchment
Loy Yang Maxinum Catchment
SMEC Drainage Flow Paths

Surface Elevation
mAHD
High : 479.925
Low : -69.577

AGL Loy Yang Pty Ltd
Loy Yang Rehabilitation and Closure Strategy

Job Number 31-1141815
Revision A
Date 16 Jan 2015

Mine Lake Water Balance Modelling
Surface Water Catchments

Figure 1

Hazelwood Drive (cnr Lignite Court) Morwell VIC 3840 Australia T 61 3 5136 5800 F 61 3 5136 5888 E mwlmail@ghd.com W www.ghd.com

G:\31\1141815\GIS\Maps\Deliverables\31141815_REALMWaterBalance.mxd

Data source: GHD, Whole of Life Mine Plan, 2012. GHD, Minimised and Maximised Catchments, 2014. SMEC, Drainage Flow Lines, 2014. DEPI, VicMap, 2014. Created by:adrummond

2.2 Model Scenarios

Six scenarios were developed using combinations of the inflow sources discussed above, and are summarised in Table 1.

Table 1 Mine Lake Inflow Scenarios

Scenario	Mine lake level below -22.5 mAHD	Mine lake level above -22.5 mAHD
1	40 GL/yr of Bulk Entitlement flows 15 GL/yr of groundwater extraction 4 GL/yr (multiplied by climate factor) flood flows from Traralgon Creek Runoff from a maximised catchment Groundwater seepage	Runoff from a minimised catchment Groundwater seepage
2	40 GL/yr of Bulk Entitlement flows 15 GL/yr of groundwater extraction Runoff from a maximised catchment Groundwater seepage	Runoff from a minimised catchment Groundwater seepage
3	15 GL/yr of groundwater extraction 4 GL/yr (multiplied by climate factor) flood flows from Traralgon Creek Runoff from a maximised catchment Groundwater seepage	Runoff from a minimised catchment Groundwater seepage
4	15 GL/yr of groundwater extraction Runoff from a maximised catchment Groundwater seepage	Runoff from a minimised catchment Groundwater seepage
5	9.8 GL/yr groundwater extraction for 10 years Runoff from a maximised catchment Groundwater seepage	Runoff from a minimised catchment Groundwater seepage
6	Runoff from a maximised catchment Groundwater seepage	Runoff from a minimised catchment Groundwater seepage

These six scenarios were simulated for four climatic conditions (historical, wet, median and dry) on mean annual runoff at 2060 (2°C global warming) and corresponding changes in rainfall and potential evapotranspiration (PET) for the Latrobe River catchment (DSE, 2011). These scenarios are based on work undertaken by the CSIRO as part of the SEACI research program, and are consistent with the median warming scenario under the "A1B" emission scenario developed by the IPCC. Refer to Table 9 in Appendix A for climate change factors applied in the REALM modelling.

These scenarios are generally consistent with the scenarios simulated in GHD (2011), with the following key differences:

- The stable lake level after which active depressurisation and groundwater pumping is not required has increased from RL -27m (GHD, 2011) to RL -22.5m based on the revised mine void and weight balance calculations.
- The minimised catchment runoff is activated in this study when the lake level reaches the stable level of RL -22.5m, whereas the previous study (GHD, 2011) assumed that the lake level would stabilise in the long term at RL -10m.

- Scenarios 1 and 3 have been modified in this study to only simulate flood flows from the Traralgon Creek until the stable lake level of RL -22.5m is reached, whereas the previous study (GHD, 2011) simulated flood flows from the Traralgon Creek for the full modelling period.
- Scenario 5 has been modified to simulate a constant groundwater extraction rate of 9.8 GL/yr for the first ten years post-mine closure, instead of a reducing rate of groundwater extractions for the first seven years post-mine closure, to align with the scenario simulated in the post-closure mine recovery model documented in *Loy Yang Groundwater Modelling – Long Term Mine Plan* (GHD, 2015).
- Scenario 6 has been modified to include groundwater seepage into the mine void, whereas the previous study (GHD, 2011) did not include groundwater seepage in this scenario.

It is also important to note that the previous study (GHD, 2011) simulated the mine void configuration adopted in the 2004 study (GHD, 2004) for Scenarios 1 and 2, and a combination of the mine void configuration from the 2006 study (GHD, 2006) and the 2004 study (GHD, 2004) for Scenarios 3, 4, 5 and 6.

3. Model Results

Figure 2, Figure 3, Figure 4 and Figure 5 show the model results for all six scenarios for the historical, wet, median and dry climate change scenarios (respectively). Appendix C contains plots of the lake level over time for each of the four climatic conditions for each scenario, as well as the results from the 2011 study (GHD, 2011). It is important to consider the modifications to scenarios between the two studies, as outlined in Section 2.2 when comparing the results.

Table 2 summarises the number of years (rounded to the nearest 5 years) for the mine lake to reach the stable water level of RL -22.5 m AHD for the six scenarios under the four climatic conditions. By diverting 15 GL/yr of groundwater extractions and Bulk Entitlement surface waters into the mine void (Scenarios 1 and 2), the time required to fill the void to RL -22.5 m AHD is substantially reduced compared with the runoff only option (Scenario 6).

Table 2 Years to reach stable lake water level of RL -22.5 m AHD

Climate	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Historical	10	10	20	25	55	65
Wet	10	10	20	25	60	70
Median	10	10	25	25	65	75
Dry	10	10	25	30	75	85

Table 3 summarises the lake level (m AHD) after 200 years of simulation for the six scenarios under the four climate change projections, rounded to the nearest meter. The results indicate that the lake level will be between 13 and 5 m AHD under the historical climatic conditions for the six inflow scenarios, and between -8 and -11 m AHD under the dry climatic conditions.

Table 3 Lake water level after 200 years (m AHD)

Climate	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Historical	13	13	11	10	7	5
Wet	4	4	3	3	1	0
Median	0	0	-1	-1	-3	-4
Dry	-8	-8	-8	-8	-10	-11

Figure 2 Loy Yang Lake Water Balance - Historical Climate Scenarios

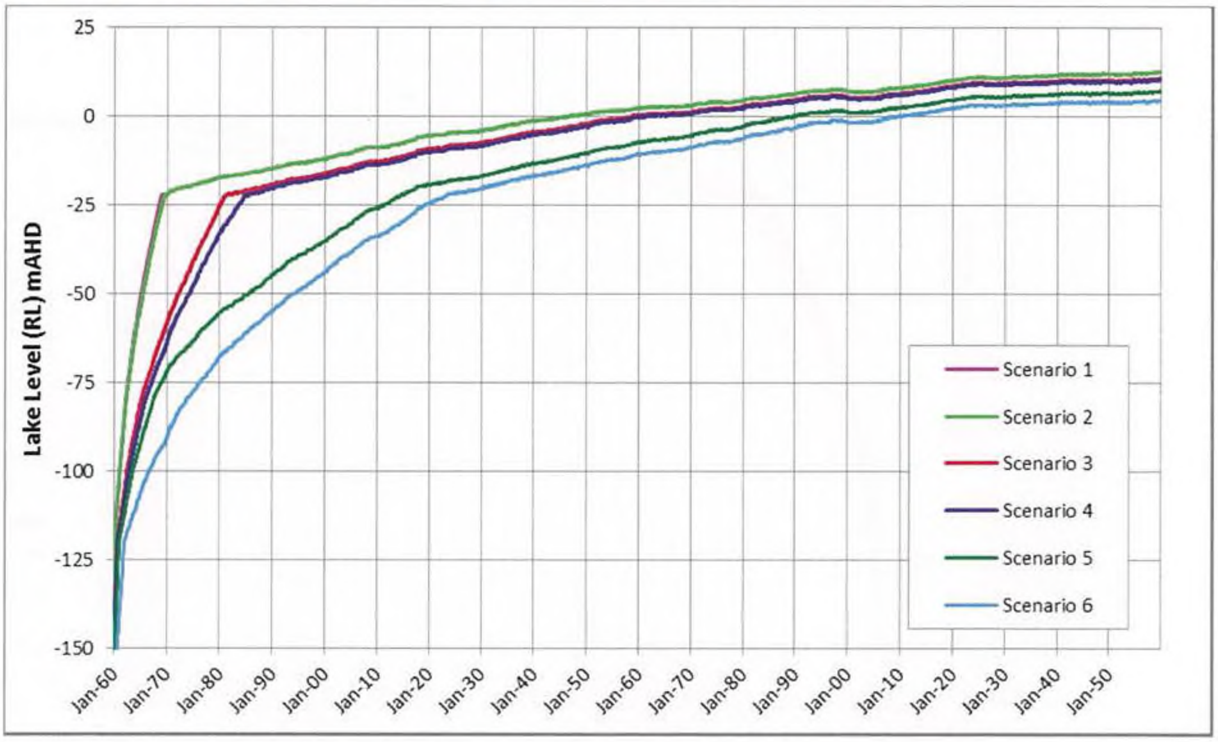


Figure 3 Loy Yang Lake Water Balance - Wet Climate Scenarios

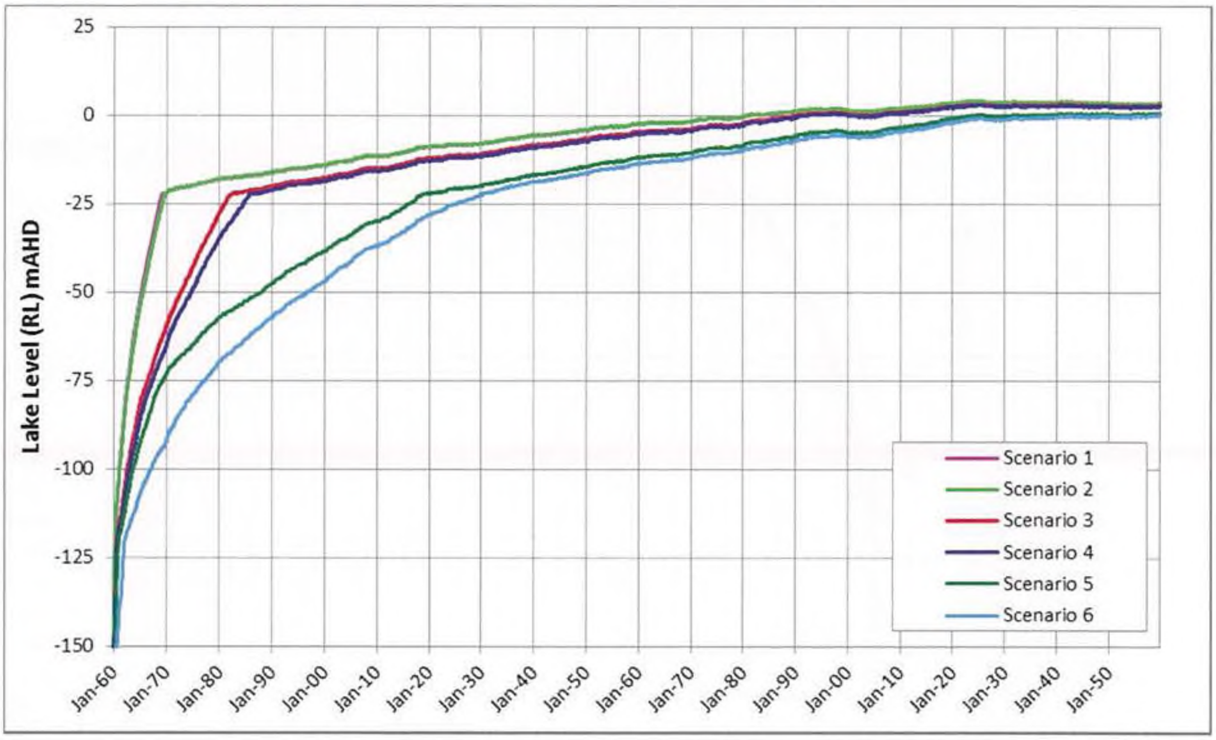


Figure 4 Loy Yang Lake Water Balance - Median Climate Scenarios

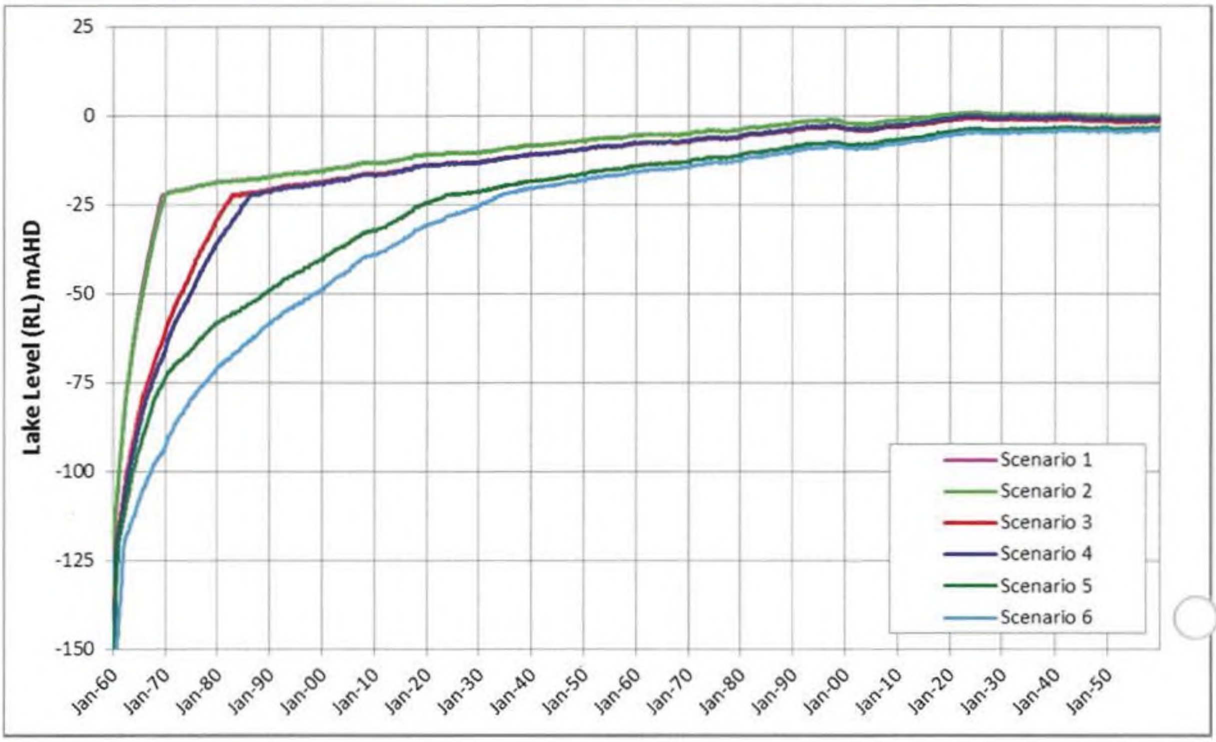
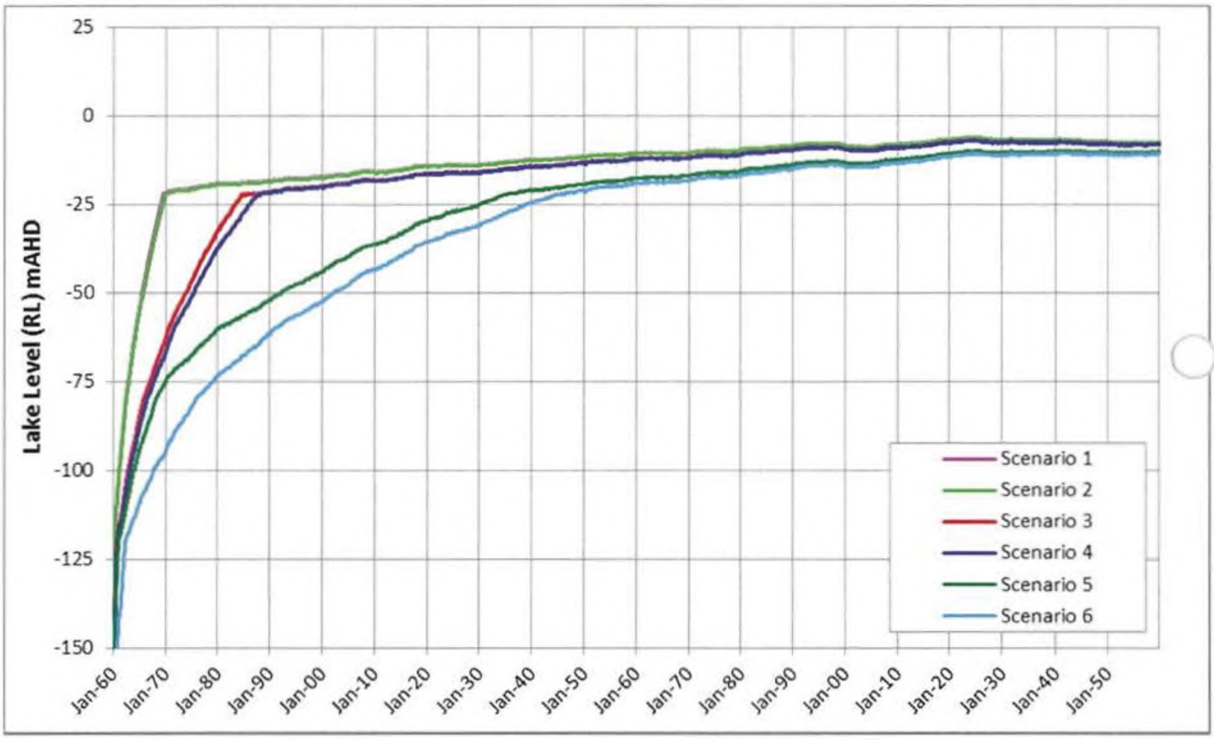


Figure 5 Loy Yang Lake Water Balance - Dry Climate Scenarios



4. Potential Water Sources

4.1 Likelihood of accessing future potential water sources

4.1.1 Traralgon Creek Flood Flows

Traralgon Creek is located within the middle reaches of Latrobe River catchment, and has a catchment area of 190 km^2. Traralgon Creek is a gauged catchment, with daily streamflow recorded from 1960 at gauge 226023 (Traralgon Creek at Traralgon). Traralgon Creek has a mean flow of 41 GL per annum with a mean flow over the winter period (June to October inclusive) of 26 GL.

Based on the 2004 sustainable diversion limit (SDL) assessment (DEPI, 2004), there is potentially up to 1,600 ML/yr available within the Traralgon Creek catchment, as a winter period (June to October inclusive) diversion. We recognise that the lower part of the catchment has a higher level of extractions, and therefore, any further impacts on flow regimes are more likely to impact upon the lower reach compared to the upper reaches of the catchment.

From this preliminary assessment, there is a low likelihood of accessing the required 4,000 ML/y from this creek. Further studies may need to be conducted in consultation with Southern Rural Water to establish the current availability of water and demonstrating that accessing the required water does not impact on existing users and the environment.

An application for a licence to take and use surface water and to operate works would need to be submitted to the licencing authority (Southern Rural Water) to access water from this stream, as a requirement under sections 51 and 67 of the Water Act. The process required to obtain a licence includes an initial discussions with Southern Rural Water to discuss the licencing needs, and submitting the application form including all supporting documentation (i.e. copies of land title(s) and accompanying maps where works are located and where the water is to be used).

4.1.2 Runoff from maximised and minimised catchments

The minimised catchment is assumed to be 2115 Ha and is limited to the area of the mine void above the mine lake surface. Minimising the catchment would be achieved by diverting flows from Sheepwash Creek and other waterways within the mining licence area, and flood flows from Traralgon Creek, away from the mine void.

The maximised catchment is assumed to be 3687 Ha and is limited to the area in proximity to the mine void where natural drainage flows. Maximising the catchment would be achieved by diverting overland flows, and flows from Sheepwash Creek and other waterways within the mining licence area, towards the mine void.

Diverting runoff from the minimised and maximised catchments requires the same approval process discussed above for the diversion of Traralgon Creek Flood Flows (Section 4.1.1). Further studies may need to be conducted in consultation with Southern Rural Water to establish the current availability of water and demonstrating that accessing the required water does not impact on existing users and the environment.

4.1.3 Bulk Entitlement

AGL Loy Yang Partnership currently holds a Bulk Entitlement (Latrobe – Loy Yang A) which was endorsed 25th March 1996. This entitles Loy Yang to access up to an annual total of 40,000 ML from a combination of Blue Rock Reservoir and Lake Narracan under a capacity share arrangement. Loy Yang has access to a 16.4% share of the total storage capacity and inflow of Blue Rock Reservoir and 32.8% share of capacity and 24.5 % share of inflow to Lake Narracan.

The water sharing arrangements defined in the Bulk Entitlement were developed based on the historical water usage practices and the inherent water use patterns. Apart from the defined shares, there doesn't appear to be any limitations described in the Bulk Entitlement to access this water related to pre- or post-mining operations. However, it would be expected that if the pattern of usage was to substantially change then this may impact on the reliability on the availability of water to Loy Yang and other users compared to historical practices. This could prompt a revisit of the Bulk Entitlement water sharing arrangements.

Further discussion with DEPI are recommended to confirm Loy Yang's rights under the Bulk Entitlement.

The ability to access 40 GL each and every year is affected by actual climate sequences, in particular drought periods. Very low water availability was evident during the Millennium Drought. Sensitivity analysis indicated that a 75% reduction in the availability of water under the Bulk Entitlement results in an extra 8 years before the threshold water level is reached.

4.1.4 Groundwater

Loy Yang Mine has been issued a 30 year extraction licence with total groundwater allocations of 15 to 20 GL/year, largely from the Traralgon Formation aquifer. This licence is valid until the end of June 2026. A new groundwater extraction licence would be expected to be issued prior to this date and it is uncertain at this stage if this would be for a further 30 year period or longer including the closure period after 2060.

Post mining groundwater pumping requirements are dependent on the rate of recovery in Traralgon Aquifer pressure relative to the rate of void filling. At the end of mining, the closer Traralgon Aquifer target levels are to aquifer pressures the greater monitoring and management requirements will be during the void filling phase to maintain stable floor condition until the lake levels reached RL-22m. To increase Traralgon Aquifer target level at mine closure placement of additional overburden in the future drainage area, on the crest of Minniedale Dome and on some areas in Block 3 such s LY2976 is required. Alternatively higher final mine grades in these locations would also increase Traralgon Aquifer target level at mine closure. Increasing the Traralgon Aquifer target levels at mine closure also has the advantage that it would lower the stable lake level from RL-22.5 m and therefore reduce the time period where management of Traralgon Aquifer pressures is required.

The results show the rate of groundwater extractions used to fill the mine void is important factor influencing the time until the stable lake level of RL-22.5 m is reached. The two rates used and the approximate post mining groundwater extractions are shown in Table 4. As a comparisons, total groundwater extractions to June 2014 at Loy Yang are approximately 233 GL of which 73% (170 GL) is sourced from the Traralgon Aquifer.

Table 4 Approximate post mining groundwater extractions

Scenario		Lower Bound
1 and 2	15 GL/year for 10 years	150 GL
3 and 4	15 GL/year for 20 to 25 years	300 to 375 GL
5	10 GL/year for 10 years	100 GL

Groundwater modelling reported in GHD 2015 indicates that with the current WOL mine plan post mining depressurisation is likely to be required to prevent Traralgon Aquifer target levels being exceeded during the initial phase of void filling. Modelling indicates and extraction rate of just under 10 GL/yr for 10 years is sufficient to prevent the majority of target levels being exceeded.

It is feasible to assume that some post mining depressurisation would be licenced and the volumes adopted for scenario 5 are considered to represent the lower range of possible future allocations and therefore more likely to be licenced. Higher allocations may be possible but there is greater uncertainty associated with these being licenced. Placement of additional overburden in critical locations would reduce the overall risk of floor instability and period of active groundwater management and would also be beneficial from the resource management perspective as would reduce the total volume of post mining groundwater extractions required.

4.2 Sensitivity Assessment

A sensitivity analysis was conducted to provide an indication of the variation in the long-term lake water level and time to reach the stable lake water level, based on the uncertainty of future water availability and the uncertainty of modelling parameters. The uncertainty of each inflow component has been classified as high, moderate or low, and assigned a lower and upper bound of what is expected to be reasonably available (Table 5). It is noted that the modelled Traralgon Creek flood flows of 4 GL/yr are beyond what is expected to be reasonably available, based on the 2004 sustainable diversion limit (SDL) assessment (DEPI, 2004) which indicates that there is potentially only up to 1.6 GL/yr available within the Traralgon Creek catchment, as a winter period (June to October inclusive) diversion.

The upper and lower bounds for runoff from a maximised and minimised catchment were estimated considering the runoff coefficient ranging between 0.2 and 0.4.

The six scenarios were simulated by adjusting the lower and upper bound of each expected inflow systematically, as summarised in Table 5, for the historical climate condition.

Table 5 Upper and lower bound of inflow components

Inflow	Uncertainty of water availability	Lower Bound	Modelled	Upper Bound
40 GL/yr Bulk Entitlement	High – dependant on climatic sequences	10 GL/yr	40 GL/yr	40 GL/yr
15 GL/yr groundwater extractions	Moderate – dependant on groundwater licencing	5 GL/yr	15 GL/yr	25 GL/yr
9.8 GL/yr groundwater extraction for 10 years	Moderate – dependant on groundwater licencing	5 GL/yr	9.8 GL/yr	25 GL/yr
Traralgon Creek flood flows	High – dependant on climatic sequences and surface water licencing	0.5 GL/yr	4 GL/yr	1.6 GL/yr
Groundwater Seepage	Moderate – uncertainty from groundwater modelling results	-25% change to seepage relationship	Seepage relationship from groundwater model	+25% change to seepage relationship
Runoff from a maximised catchments	High – dependant on climatic sequences and surface water licencing	0.2 runoff coefficient	0.3 runoff coefficient	0.4 runoff coefficient
Runoff from a minimised catchment	High – dependant on climatic sequences and surface water licencing	0.2 runoff coefficient	0.3 runoff coefficient	0.4 runoff coefficient

Table 6 summarises the modelled range in the lake water level after 200 years under the historical climate condition, estimated by adjusting the corresponding inflow parameter to the upper and lower bounds listed in Table 5. Table 7 summarises the modelled range of years to reach the stable lake water level of RL-22.5 mAHD under the historical climate condition, estimated by adjusting the corresponding inflow parameter to the upper and lower bounds listed in Table 5. The results presented in Table 6 indicate that the long-term lake water level is relatively insensitive to changes in the Bulk Entitlement, groundwater extraction rates and Traralgon Creek flood flows. This is primarily due to these inflow sources only being utilised when the mine lake water level is below the stable level of -22.5 mAHD. The results presented in Table 7 indicate that the number of years to reach the stable lake water level of -22.5 is relatively sensitive to changes to these inflow parameters.

The results presented in Table 6 indicate that the long-term lake water level is relatively sensitive to changes in the groundwater seepage estimates and runoff from the minimised catchment. This is primarily due to these inflow sources being utilised when the mine lake water level is above the stable level of -22.5 mAHD. The results presented in Table 7 indicate that the number of years to reach the stable lake water level of -22.5 is relatively insensitive to changes to these inflow parameters.

Table 6 Sensitivity Assessment: Range of lake water level after 200 years (m AHD)

Inflow	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
40 GL/yr Bulk Entitlement	11.5 - 12.6	11.1 - 12.6				
15 GL/yr groundwater extractions	12.4 - 12.8	12.2 - 12.7	9.4 - 11.5	8.6 - 11.1		
9.8 GL/yr groundwater extraction for 10 years					6.5 - 8.8	
Traralgon Creek flood flows	12.6 - 12.6		10.4 - 10.4			
Groundwater Seepage	8.9 - 18.2	8.8 - 18.1	7.5 - 15.2	7.2 - 14.8	4.1 - 10.2	3.3 - 9.2
Runoff from a maximised catchments	12.6 - 12.6	12.5 - 12.5	10.4 - 10.4	6.6 - 10.1		
Runoff from a minimised catchment	8.2 - 17.9	8.2 - 17.8	6.8 - 15.3	6.6 - 14.7	3.9 - 10.1	1.5 - 7.3

Table 7 Sensitivity Assessment: Range of years to reach stable lake water level of RL -22.5mAHD

Inflow	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
40 GL/yr Bulk Entitlement	9 - 16	10 - 18				
15 GL/yr groundwater extractions	8 - 11	8 - 11	16 - 33	18 - 42		
9.8 GL/yr groundwater extraction for 10 years					41 - 58	
Traralgon Creek flood flows	9 - 9		23 - 23			
Groundwater Seepage	9 - 9	10 - 10	21 - 22	24 - 26	51 - 58	58 - 69
Runoff from a maximised catchments	9 - 9	10 - 10	23 - 23	28 - 25		
Runoff from a minimised catchment	9 - 9	10 - 10	21 - 21	25 - 25	54 - 54	63 - 63

5. Conclusions

5.1 Conclusions

The modelling results indicate that diverting the full Bulk Entitlement allocation of 40 GL/year to the mine void (scenarios 1 and 2) results in the shortest time for the lake to reach stabilisation timeframe of approximately 10 years. However, the likelihood of accessing the full Bulk Entitlement post mine closure is unknown at this stage and could potential be affected by actual climate sequences, in particular during drought periods so their is some uncertainty associated with relying on this allocation for mine closure planning.

Inclusion of Traralgon Creek flows is the difference between scenarios 3 and 4 and not considered significant making around a 5 year difference in reaching RL-22.5 m. The modelled Traralgon Creek flood flows of 4 GL/yr are beyond what is expected to be available which is potentially up to 1.6 GL/yr as a winter period diversion.

The groundwater extraction volumes used in scenarios 4 and 5 are likely to represent the range of possible future post mining groundwater extractions. Scenario 4 with groundwater inflows of 15 GL/y effectively represents extension of the current licenced extractions for an additional 25 to 30 years after mine closures and is considered as an optimistic "best case" scenario. The licensing of post mine closure extractions has not been addressed to date by the regulators and there is uncertainty as to how it will be approached. Under scenario 4, lake levels 200 years after closure are modelled to range from RL +10 to -8 m AHD and take between 25 to 30 years to reach the stable level of RL-22.5 m depending on the climate option adopted (Table 8).

Scenario 5 with groundwater extractions of 9.8 GL/y for 10 years is considered to have a higher probability to be licenced and is a conservative approach for mine closure planning. Under scenario 5 lake levels are modelled to range from RL +7 to -10 m AHD after 200 years and take between 55 to 75 years to reach the stable level of RL-22.5 m depending on the climate option adopted. This increases to 65 to 85 years with lake levels after 200 years of RL+5 to RL-10 using "worst case" scenario 6 assumptions of catchment runoff and groundwater seepage only to the mine void.

Table 8 Summary of void filling modelling results

Scenario	Years to RL -22.5 m	Lake Level (mAHD) at 2260
4 - Best case	25 to 30	+10 to -8
5 - Likely case	55 to 75	+7 to -10
6 - Worst Case	65 to 85	5 to -11

The modelled the lake levels after 200 years for the likely, best and worst case scenarios all achieve or are greater than the assumed level of RL-10 m as adopted in the current Mine Rehabilitation Plan. The results also indicate that once RL-22.5 m lake level is reached, management of the catchment area can be used to influence the long term final lake level.

It is noted that the lake level of RL-22.5 m AHD required for long term stability is based on the WOL mine plan. To manage the uncertainty associated with the future water sources particularly licencing of bulk entitlements and groundwater extractions, modifications to the WOL mine plan could be considered at key locations to reduce the maximum stable lake level from RL-22. These modifications could include increasing the final mine grade and placement of addition overburden at selected locations thereby reducing stable lake level and void filling period to when it is reached. For example assuming scenario 5, if the stable lake level is reduced to around RL-37 m the void filling period when groundwater management may be required is between 35 and 45 m depending on the climate option adopted, a reduction of 20 to 30 years.

6. References

DSE (2011) Guidelines for the Development of a Water Supply Demand Strategy (Version 2), ISBN 978-1-74287-388-6 (online). August 2011.

GHD (2004) Loy Yang Mine Internal Overburden Dump – Preliminary Hydrogeological Assessment. Report 31/11589/91436 prepared for Loy Yang Power. December 2004.

GHD (2006) Loy Yang Mine Internal Overburden Dump – Hydrogeological Review. Report 31/11467/05/109628 prepared for Loy Yang Power. February 2006.

GHD (2011) Loy Yang Mine Rehabilitation Master Plan. Report 31/11418/11/193333 prepared for Loy Yang Power. May 2011.

GHD (2015) Loy Yang Groundwater Modelling – Long Term Mine Plan. Report 31/11584/15/235556 prepared for AGL Loy Yang, March 2015.

GHD (2015a) Long Term Aquifer Depressurisation Assessment. Report 31/11589/15/222197 prepared for AGL Loy Yang, in preparation.

Appendices

Appendix A – REALM model inputs

Table 9 Climate change factors (DSE, 2011)

Impact	Historic	Wet	Median	Dry
Runoff (% change)	1	0.86	0.53	0.34
Rainfall (% change)	1	0.96	0.93	0.85
PET (%change)	1	1.05	1.07	1.05

Table 10 2014 Study: Loy Yang Mine Volume vs. Lake Stage rating table

2014 Mine Volume (ML)	2014 Stage (mAHD)
0	-160
20,078	-120
77,931	-100
159,847	-80
285,706	-60
449,434	-40
642,233	-20
885,932	0
1,224,330	20
1,782,212	50

Table 11 2011 Study: Loy Yang Mine Volume vs. Lake Stage rating table (Scenarios 1 – 2 only)

2011 Study (Scenarios 1 – 2) Mine Volume (ML)	2011 Study (Scenarios 1 – 2) Stage (mAHD)
0	-135
41,443	-120
131,573	-100
238,656	-80
362,123	-60
530,464	-40
724,126	-20
977,565	0
1,222,029	20
1,583,954	40

Table 12 2011 Study: Loy Yang Mine Volume vs. Lake Stage rating table (Scenarios 3 – 6 only)

2011 Study (Scenarios 3 – 6) Mine Volume (ML)	2011 Study (Scenarios 3 – 6) Stage (mAHD)
0	-135
17,800	-120
74,900	-100
151,390	-80
257,730	-60
440,250	-40
648,140	-20
914,710	0
1,238,870	20
1,600,630	40

Figure 6 Loy Yang Mine Volume vs. Lake water level rating curve

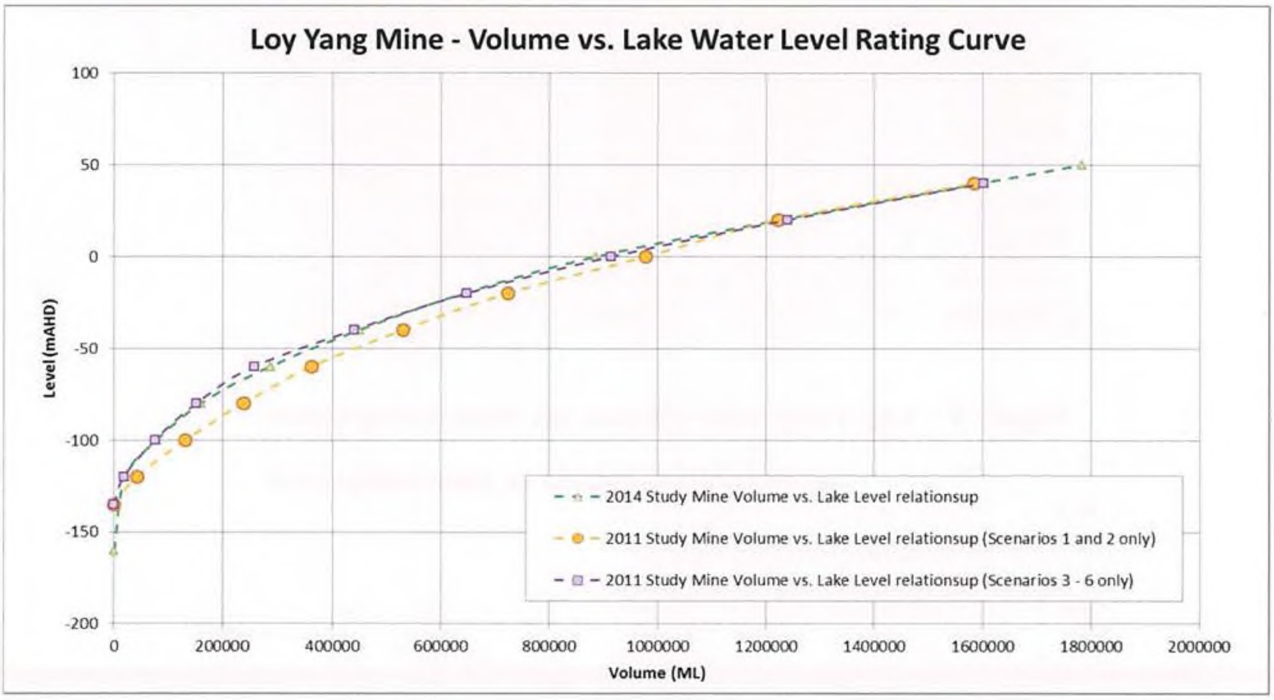


Table 13 2014 Study: Loy Yang Mine Volume vs. Area rating table

2014 Study - Mine Volume (ML)	2014 Study - Mine Area (HA)
0	0
32,585	269
95,018	351
217,210	635
364,019	824
696,143	1,108
816,212	1,325
965,110	1,659
1,224,331	1,784
1,782,212	1,957

Table 14 2011 Study: Loy Yang Mine Volume vs. Lake Stage rating table

2011 Study - Mine Volume (ML)	2011 Study - Mine Area (HA)
0	0
41,443	389
131,573	497
238,656	578
362,123	670
530,464	900
724,126	1,081
977,565	1,423
1,222,029	1,769
1,583,954	1,855

Figure 7 Loy Yang Mine Volume vs. Area rating curve

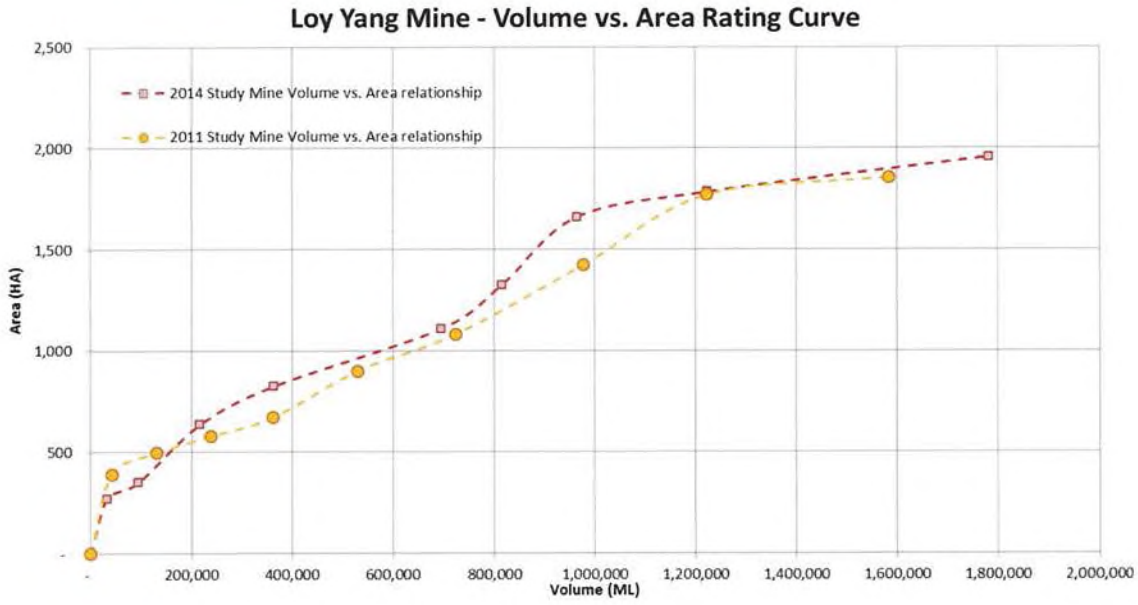


Table 15 2014 Study: Groundwater Seepage Mine Lake Inflows (kL/month)

Lake water level (mAHD)	Historical climatic condition	Wet climatic condition	Median climatic condition	Dry climatic condition
-155	405,720	404,414	403,771	402,562
-140	396,857	395,156	394,464	392,991
-125	376,628	374,345	373,403	371,440
-110	357,099	355,251	354,576	352,414
-95	341,107	338,371	337,073	334,391
-80	314,973	311,290	309,833	306,357
-65	280,619	278,126	277,421	274,525
-50	248,181	243,496	241,230	235,650
-35	205,865	199,943	197,177	189,704
-20	164,897	164,276	165,005	148,501
-5	141,072	142,405	138,674	107,539
10	125,347	120,533	112,343	66,577

Note – these relationships were established by simulating the Loy Yang mine recovery groundwater model over the period 2059 – 2455 for the four climatic conditions (GHD, 2015).

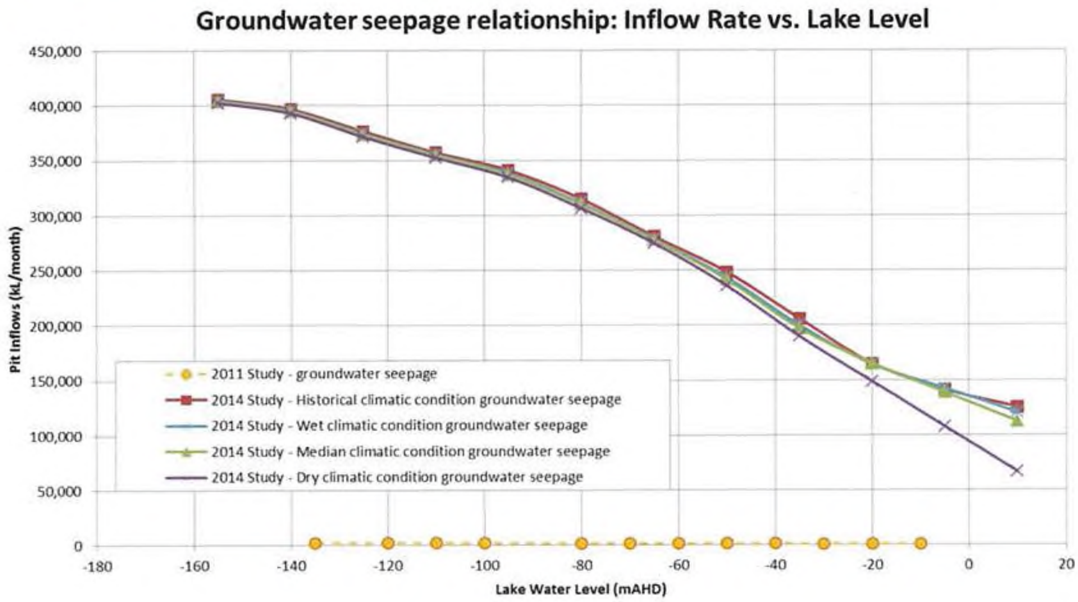
Table 16 2011 Study: Groundwater Seepage Mine Lake Inflows (kL/month)

Lake water level (mAHD)	Groundwater seepage mine (kL / month)
-10	980
-20	1109
-30	1238
-40	1367
-50	1496
-60	1625
-70	1754
-80	1883
-100	2141
-110	2270
-120	2399
-135	2593

Note – the groundwater seepage relationship applied in the 2011 study was not estimated from groundwater modelling.

Note – the groundwater seepage inflows are entered into REALM as kL/month, and are converted into ML/month in the model.

Figure 8 Groundwater seepage relationship: Inflow rate vs. lake water level



Appendix B – REALM model configuration

Figure 9 REALM System configuration

REALM SYS file key changes

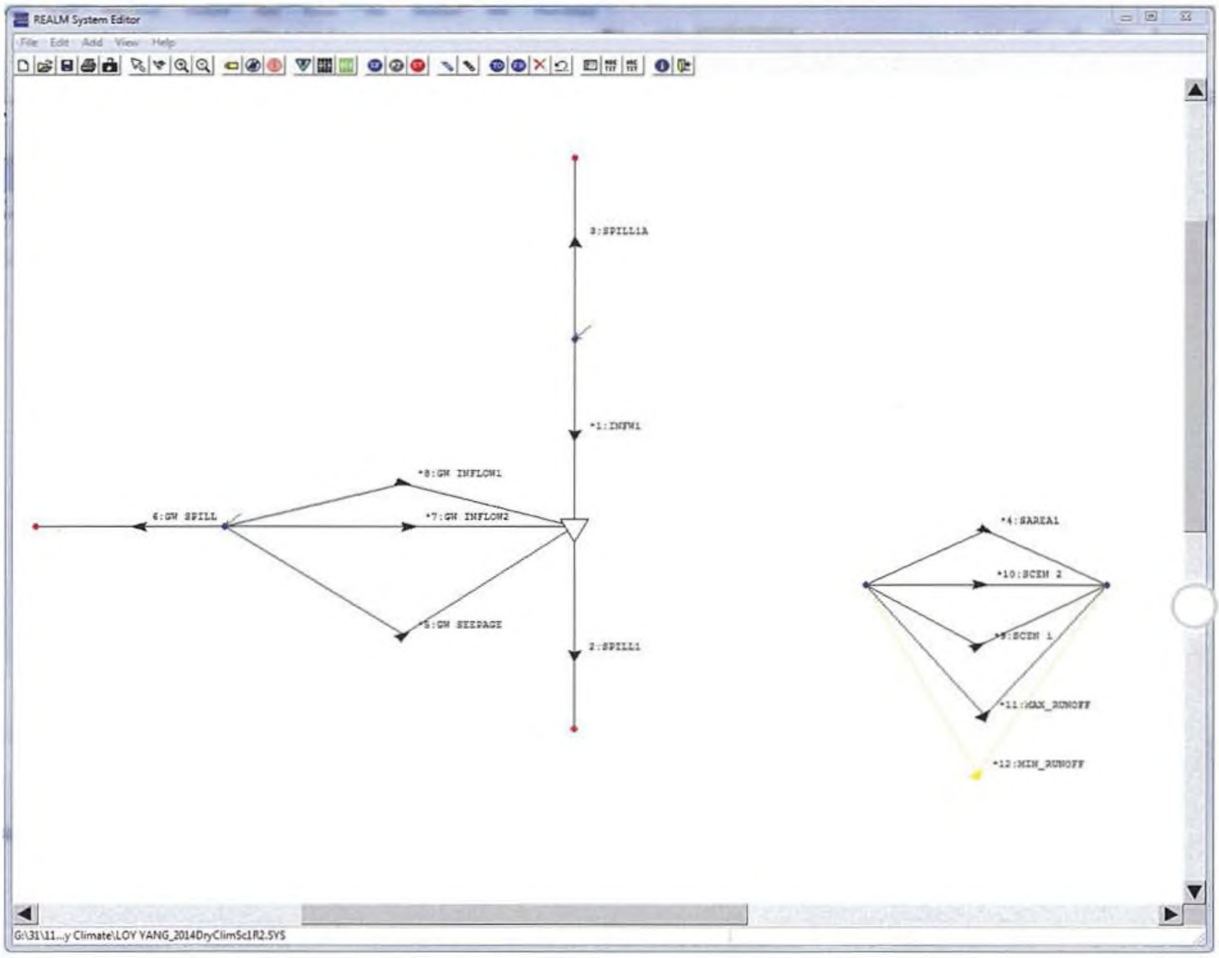
Historical climatic conditions

Dry climatic conditions

Median climatic conditions

Wet climatic conditions

Figure 9 REALM System configuration



REALM SYS file key changes

Key changes to the system file include:

- Addition of the minimised catchment area calculation for mine lake RL above -22.5 m. Calculation arcs added are carrier 11 and carrier 12. Minimum catchment 2115 Ha is based on the 2014 mine void area at +50 mAHD.
- Modified the maximum catchment area based on revised spatial mapping from 3800 Ha to 3687 Ha.
- Modified the calculation for Traralgon Creek flood flows (Scenarios 1 and 3) to be diverted into the mine lake void up to mine lake level of -22.5 mAHD, and switched off when the mine lake level is above -22.5 mAHD

Historical climatic conditions

- System file configured with the historical climate condition groundwater seepage rating table (Carrier 10)
- The historical climate factors for rainfall and potential evapotranspiration are applied to the inflow and demand files
- The historical climate factor for streamflow is applied to the Traralgon Creek flood flows in Carrier 8 for Scenarios 1 and 3.

File Path: G:\31\1158414\Technical\WB\2014\Historic Climate

Scenario number	Log file	SYS file	Inflow	Demand
1	H1r2.log	LOY YANG_2014HistClimSc1R2.SYS	200_Yr_INFW.prn	200_Yr_DEM.prn
2	H2r2.log	LOY YANG_2014HistClimSc2R2.SYS		
3	H3r2.log	LOY YANG_2014HistClimSc3R2.SYS		
4	H4r2.log	LOY YANG_2014HistClimSc4R2.SYS		
5	H5r2.log	LOY YANG_2014HistClimSc5R2.SYS		
6	H6r2.log	LOY YANG_2014HistClimSc6R2.SYS		

Dry climatic conditions

- System file configured with the dry climate condition groundwater seepage rating table (Carrier 10)
- The dry climate factors for rainfall and potential evapotranspiration are applied to the inflow and demand files
- The dry climate factor for streamflow is applied to the Traralgon Creek flood flows in Carrier 8 for Scenarios 1 and 3.

File Path: G:\31\1158414\Technical\WB\2014\Dry Climate

Scenario number	Log file	SYS file	Inflow	Demand
1	D1r2.log	LOY YANG_2014DryClimSc1R2.SYS	200_Yr_DEM_DryCC.prn	200_Yr_DEM_DryCC.prn
2	D2r2.log	LOY YANG_2014DryClimSc2R2.SYS		
3	D3r2.log	LOY YANG_2014DryClimSc3R2.SYS		
4	D4r2.log	LOY YANG_2014DryClimSc4R2.SYS		
5	D5r2.log	LOY YANG_2014DryClimSc5R2.SYS		
6	D6r2.log	LOY YANG_2014DryClimSc6R2.SYS		

Median climatic conditions

- System file configured with the median climate condition groundwater seepage rating table (Carrier 10)
- The median climate factors for rainfall and potential evapotranspiration are applied to the inflow and demand files
- The median climate factor for streamflow is applied to the Traralgon Creek flood flows in Carrier 8 for Scenarios 1 and 3.

File Path: G:\31\1158414\Technical\WB\2014\Median Climate

Scenario number	Log file	SYS file	Inflow	Demand
1	M1r2.log	LOY YANG_2014MedClimSc1R2.SYS	200_Yr_DEM_MedCC.prn	200_Yr_DEM_MedCC.prn
2	M2r2.log	LOY YANG_2014MedClimSc2R2.SYS		
3	M3r2.log	LOY YANG_2014MedClimSc3R2.SYS		
4	M4r2.log	LOY YANG_2014MedClimSc4R2.SYS		
5	M5r2.log	LOY YANG_2014MedClimSc5R2.SYS		
6	M6r2.log	LOY YANG_2014MedClimSc6R2.SYS		

Wet climatic conditions

- System file configured with the wet climate condition groundwater seepage rating table (Carrier 10)
- The wet climate factors for rainfall and potential evapotranspiration are applied to the inflow and demand files
- The wet climate factor for streamflow is applied to the Traralgon Creek flood flows in Carrier 8 for Scenarios 1 and 3.

File path: G:\31\1158414\Technical\WB\2014\Wet Climate

Scenario number	Log file	SYS file	Inflow	Demand
1	W1r2.log	LOY YANG_2014WetClimSc1R2.SYS	200_Yr_DEM_WetCC.prn	200_Yr_DEM_WetCC.prn
2	W2r2.log	LOY YANG_2014WetClimSc2R2.SYS		
3	W3r2.log	LOY YANG_2014WetClimSc3R2.SYS		
4	W4r2.log	LOY YANG_2014WetClimSc4R2.SYS		
5	W5r2.log	LOY YANG_2014WetClimSc5R2.SYS		
6	D6r2.log	LOY YANG_2014WetClimSc6R2.SYS		

Appendix C – REALM model results

Figure 10 Lake water balance modelling results – Scenario 1

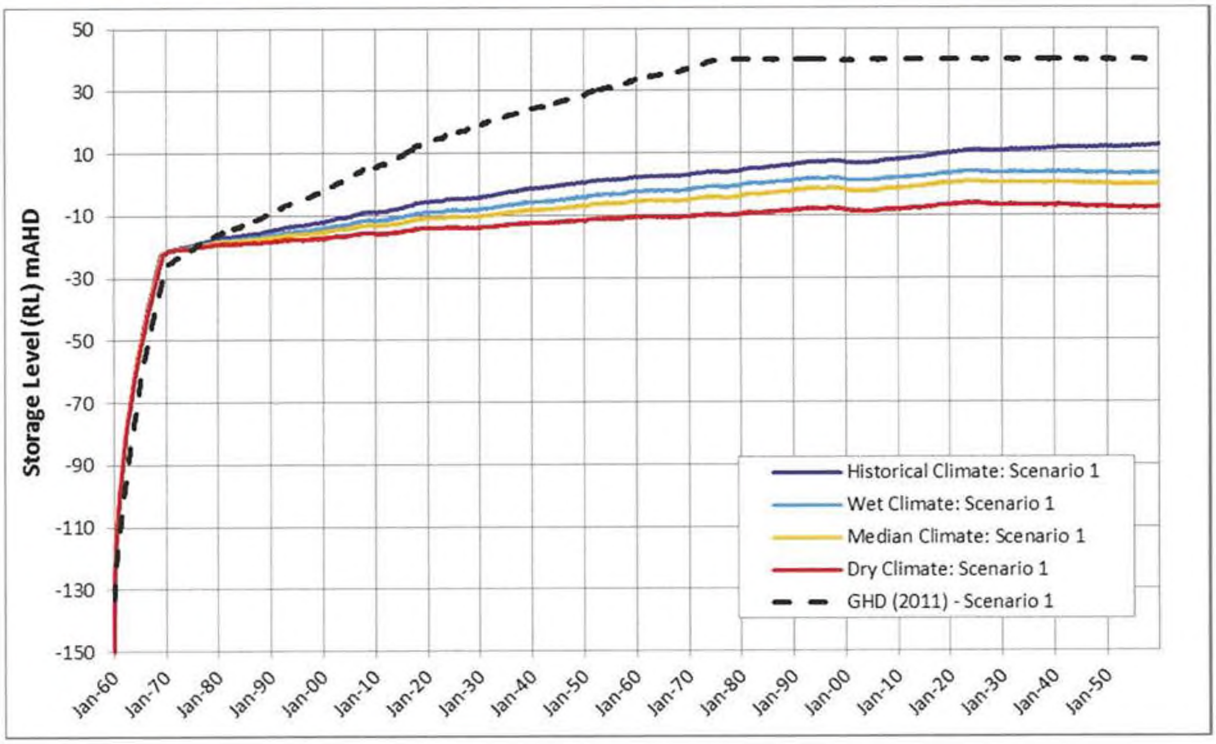


Figure 11 Lake water balance modelling results – Scenario 2

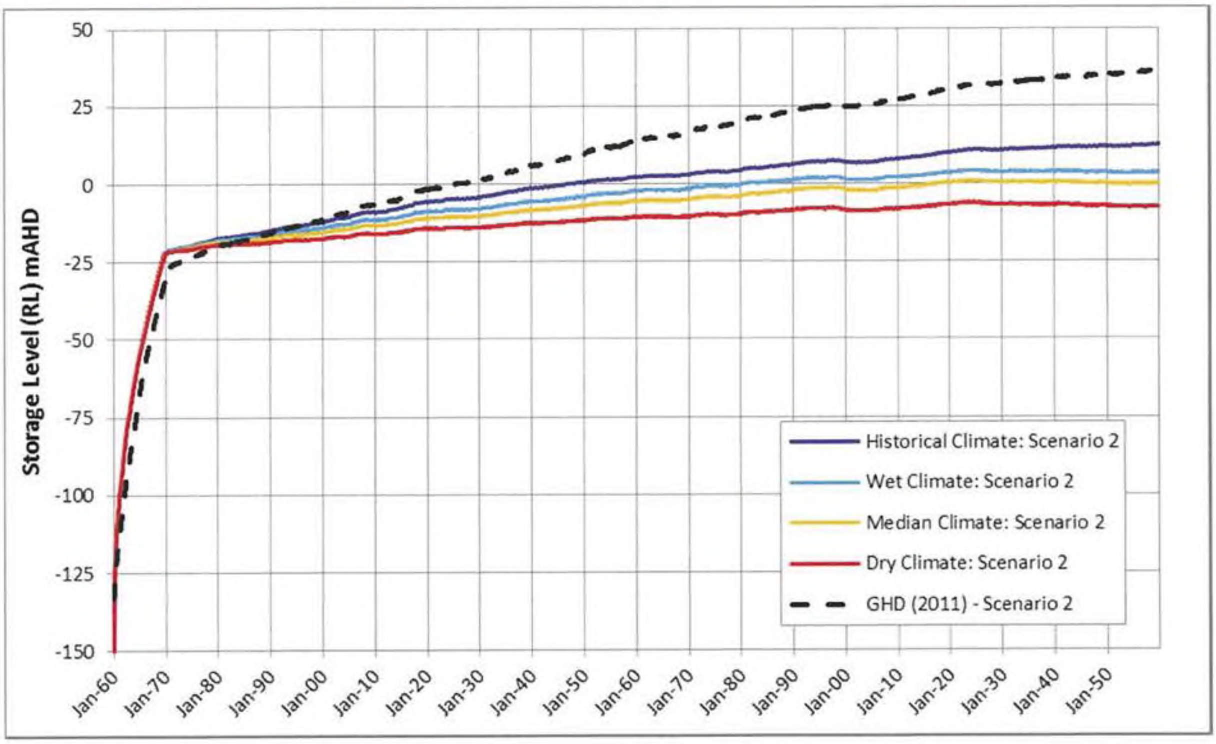


Figure 12 Lake water balance modelling results – Scenario 3

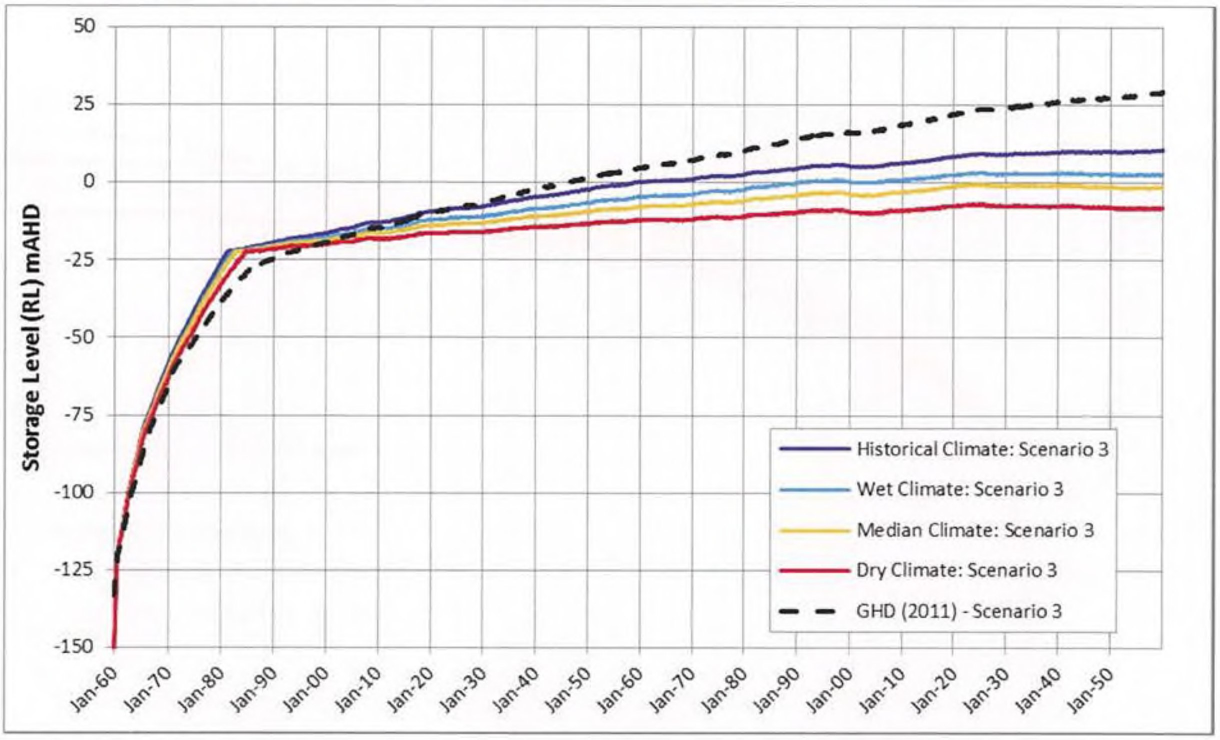


Figure 13 Lake water balance modelling results – Scenario 4

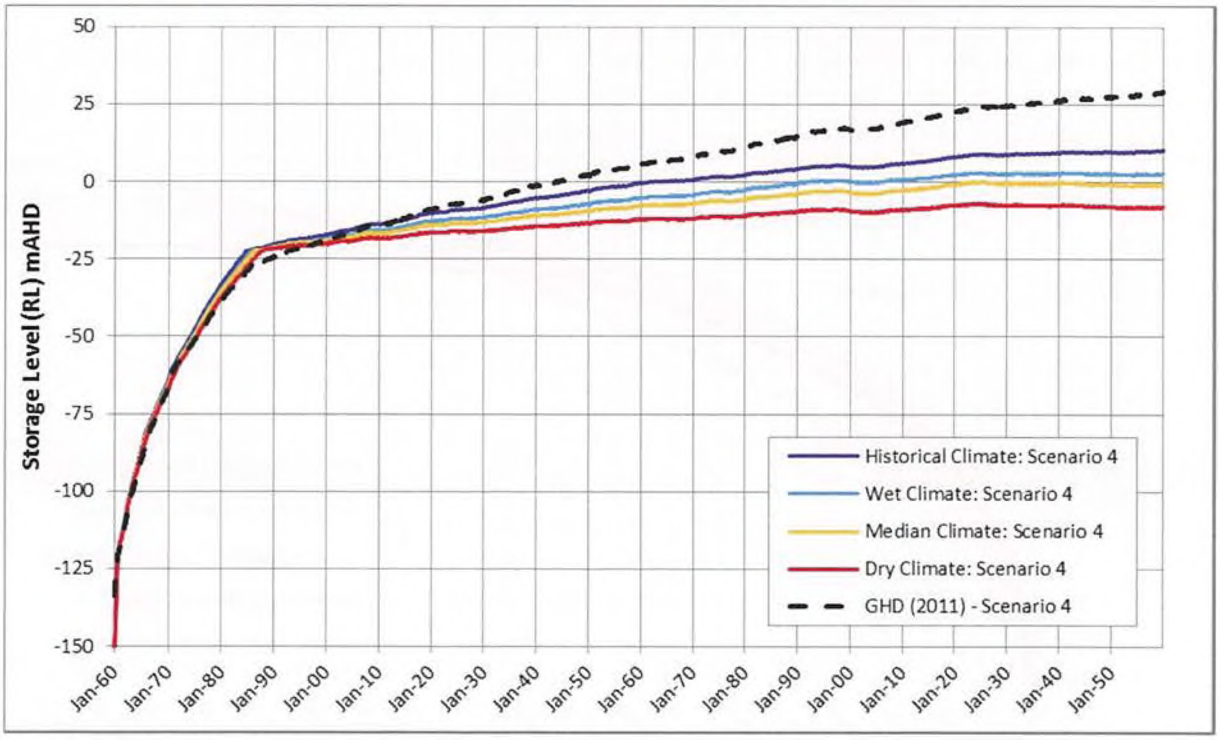


Figure 14 Lake water balance modelling results – Scenario 5

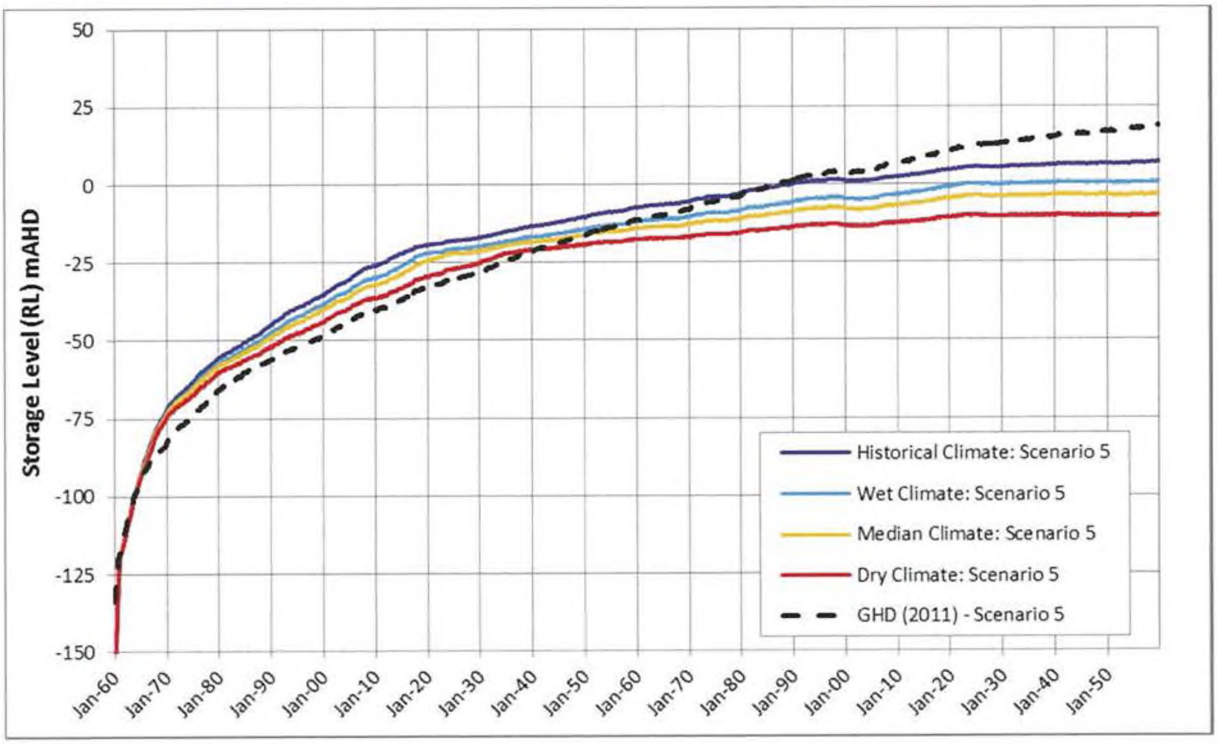
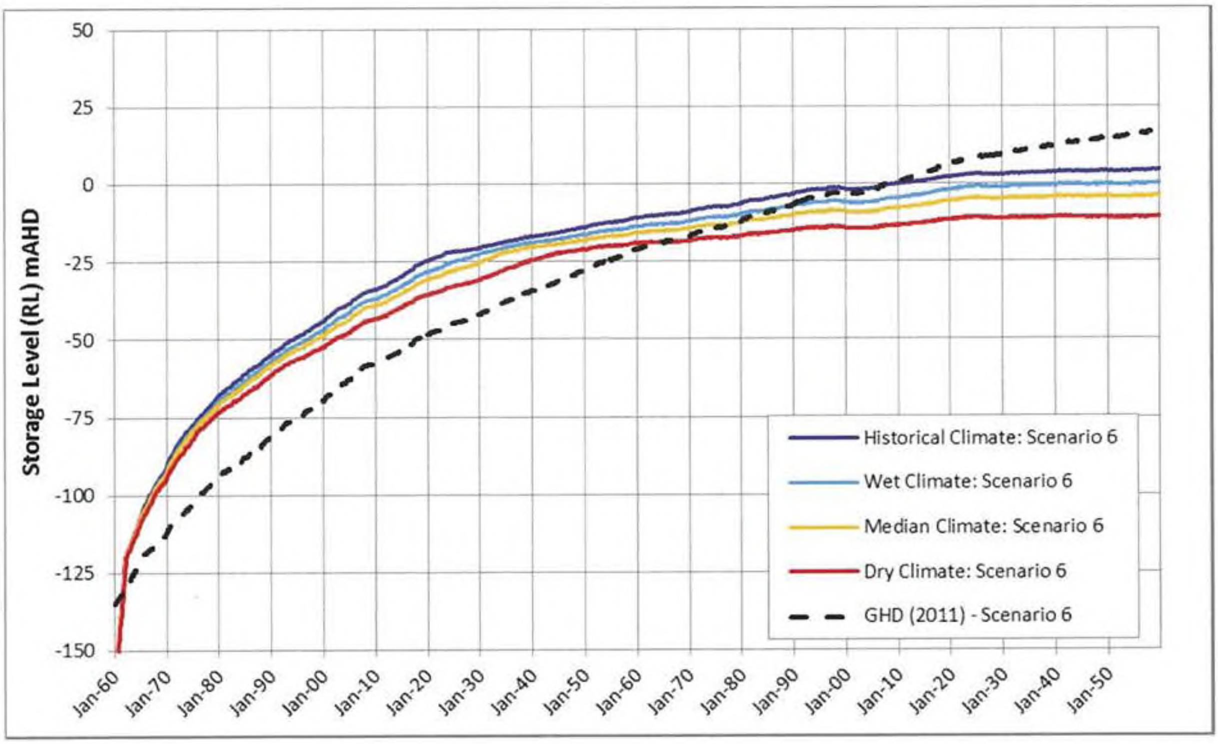


Figure 15 Lake water balance modelling results – Scenario 6



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GHD

180 Lonsdale Street
Melbourne, Victoria 3000
T: (03) 8687 8000 F: (03) 8687 8111 E: melmail@ghd.com.au

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Appendix 4 – Technical References (continued)

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Executive Summary

This report presents the results of a review of the Loy Yang External Overburden Dump strength parameters. This study included the field and laboratory test results from the 2007 and 2009 geotechnical investigation programs, the index test / strength correlations from relevant publications and the strength parameters previously used for the design of the overburden dump.

Recent investigations and laboratory testing results have been combined with the relevant empirical formulations to provide parameters for the long-term stability analysis.

In general the effective strengths obtained from the recent investigations are not significantly different from previous investigations and strength parameters adopted previously by SECV and GHD for the stability analyses of the External Overburden Dump. However, there is some variability in strength parameter interpretations and in particular the use laboratory strength test results of discrete samples for interpretation of the overall dump mass.

It is considered that the fully-softened strength parameters for the materials disposed in the overburden dump are more representative of the overall strength than the individual strength test results. Hence, the effective strength parameters are based on interpretations from published correlations to soil plasticity indices due to the nature of high plasticity of the majority of the dump materials.

Site-specific calibration factors including a Cone Factor N_k=15 and the SPT Factor of 8 were interpreted for estimation undrained strength parameters for short-term stability analysis.

The undrained strength generally increased with depth. Due to the significant height of the Overburden Dump batter, the in-situ stresses within the dump are in a large range. Long-term strength parameters for the dump materials are considered to be stress-dependent.

The average material strength parameters recommended for future stability analyses are presented below.

Undrained strength (short - term stability)

$$Su = 55 + D \text{ kPa}$$

Where D = depth below dump surface in meters

Fully Softened Strength (long – term stability)

$$c' = 0 \text{ kPa}, \quad \phi'_{fs} = 25^o$$

Based on CPTU dissipation test data the horizontal Coefficient of Permeability of the dump materials tested was found to range from 1.5e-7cm/sec to 5.3e-6cm/sec. These values are typical for the material types encountered during the drilling, but were much higher than laboratory measured values which were generally for vertical permeability.

1. Introduction

This report presents the results of a review of the Loy Yang External Overburden Dump material strength parameters. It considers the parameters previously adopted for stability assessment of this overburden dump, field and laboratory testing as well as relevant publications on strength of similar materials elsewhere in the world.

This review includes the results of recent geotechnical investigations undertaken at the Loy Yang External Overburden Dump including drilling, soil laboratory testing and Piezocone Testing (CPTU). This investigation work forms part of the ongoing effort into the optimization of the Loy Yang External Overburden Dump.

Review the geotechnical parameters used in previous studies, combining recent geotechnical investigations and empirical formulation correlated with soil index has been used to obtain parameters for long term stability analysis.

Site specific Cone Factor (N_k) was determined for the interpretation of the Undrained Shear Strength (Su) from CPTU testing. Dissipation testing was also undertaken to investigate in-situ permeability conditions.

This study was initially outlined in the May 2007, Proposal (GHD Ref No. 31/114520/7/133543). The scope for the December 2009 investigation program is outlined in the GHD Report (GHD Ref No. 31/11466/09/160908). Finally, the scope was expanded to a general strength parameter review in 2010.

The scope of work for the May 2007 investigation program was:

- Conduct two CPTU tests at pre-determined distances from the clay-capped crest until the cones encounter refusal;
- Drill two geotechnical calibration boreholes adjacent to the CPTU test sites. These holes were drilled at least 10m into the foundation of the overburden dump, the Haunted Hill Formation (HHF);
- Undertake Standard Penetration Testing to assess the in-situ strength;
- Collect representative soil samples from the geotechnical calibration boreholes for laboratory strength testing and material characterisation;
- Undertake laboratory testing including plasticity index and strength index on selected soil samples; and
- Determine the site specific Nk factor and permeability characteristics for the dump material.

The scope of work for the December 2009 investigation program was:

- Drill and install a 60m groundwater observation bore on the Loy Yang External Overburden Dump;
- Collect samples for laboratory testing as well as Standard Penetration Testing (SPT's) for strength determination; and
- Undertake laboratory testing including plasticity index and strength index on selected soil

samples.

The scope of work for the December 2010 program was:

- Analysing CPTU and SPT testing data to produce undrained shear strength;
- Review the geotechnical parameters used in previous studies; and
- Determine appropriate strength parameters for short term and long-term batter stability assessment.

The findings of the above studies are to be collated into a geotechnical report.

2. Methodology

2.1 Desktop Study

A review of the previous geotechnical and hydrogeological investigations for the Loy Yang External Overburden Dump were completed as part of this study.

Previous work was reviewed in terms of the geotechnical parameters used in the batter design of the Overburden Dump. Also, a site specific correlation factor of N_k and SPT factors was proposed to estimate the undrained strength correlated to laboratory testing. Literature review was undertaken on the correlation between soil characteristic index and long-term effective strength of high plasticity clay. Selected empirical formulations were used as the basis for estimation of the drained soil strength parameters for geotechnical assessment and risk management.

2.2 Geotechnical Investigations

The 2007 and 2009 geotechnical investigation programs are discussed in the following sections.

2.2.1 General

The 2007 investigation was conducted in two stages. The first stage comprised of CPTUtests at two sites as shown on site plan in Figure 1. The CPTU work was conducted in June 2007 using a truck-mounted testing rig supplied and operated by Geopave Materials Technology.

Two geotechnical boreholes were drilled in the area of the CPTU test locations (See Figure 1). Drilltec was engaged for the geotechnical drilling work utilising the cable tool drilling method. Drilling at the first site (Site A / LY4245) commenced on 5 September 2007 and drilling at the second site (Site B / LY4246) commenced on 1 February 2008.

The cable tool drilling method was used for the boreholes, which was preferred as water is not required during the drilling process. This will preserve the moisture content of the soil samples. Both undisturbed (tube) and disturbed samples were obtained for laboratory testing. SPT's (and vane shear testing on U63 tube samples) were conducted at 1.5m depth intervals to measure the in-situ undrained shear strength of the dump materials.

The stages in the field investigation program, for each of the two sites included:

1. CPTU testing to determine the Local Side Friction on Cone Friction Sleeve (fs), Cone Resistance (q_c) and Pore Water Pressure (u_2); and
2. Drill a geotechnical calibration borehole near each of the CPTU testing sites for soil descriptions, SPT and sample collection purposes.

A groundwater bore (LY4379) was drilled in 2009 program, with four piezometers installed at targeted depths.

Table 1 is a summary of the June 2007 and December 2009 Borehole and Test Site Locations in the State Electricity Commission of Victoria (SECV) coordinate system.

Table 1 Borehole and CPTU Locations

	Easting	Northing	RL m	Terminated Depth (m)
2007 Investigation Program				
Site A				
CPTU	414675	258383	134	26.4
Calibration Borehole (LY4245)	414676	258381	134	55.0
Site B				
CPTU	414879	258493	134	27.2
Calibration Borehole (LY4246)	415273	258336	134	44.0
2009 Investigation Program				
Geotechnical Borehole (LY4379)	416671	258130	160	60.0

Vibrating wire piezometers were installed in all three boreholes. The piezometer installation details (diagrams) are included in Appendix A.

2.2.2 Cone Penetration and Piezocone Testing

The CPTU were conducted at both Site A and B until the probes encountered refusal. The cone resistance (q_c), the local side friction on the cone friction sleeve (f_s) and the pore water pressure (u_2) were recorded and these are included in Appendix B.

Dissipation tests were conducted at Site A and B and at two different depths in each site. At Site A the dissipation test was conducted at 23.0m and 25.8m and at Site B the dissipation tests were conducted at 24.1m and 26.8m respectively. These test results are included in Appendix B.

Dissipation test results were conducted to provide an indication of the insitu permeability characteristics of the overburden material as well as obtaining pore water pressure data. The information was also used to assist in the interpretation of q_c and f_s in terms of the shear strength and deformation characteristics of the material.

2.2.3 Geotechnical Boreholes

Two boreholes were drilling for CPTU calibration purpose in 2007 program. The borehole at Site A (LY4245) drilled through the overburden dump materials and encountered the natural Haunted Hill Formation (HHF) at 47.0 m depth. Drilling continued for another 10.5m within HHF and terminated at 57.5m. The borehole at Site B (LY4246) also drilled through the overburden dump materials and encountered the natural HHF at 39.0 m and the drilling was terminated at 44.0 m depth.

During the 2009 investigation program borehole LY4379 drilled through the overburden dump materials and encountered natural HHF materials at 52.0 m depth. The drilling was terminated at 60.0 m. The borehole logs for LY4245, LY4246 and LY4379 are included in Appendix A.

2.3 Soil Laboratory Testing

A suite of laboratory tests were conducted on samples obtained from boreholes LY4245, LY4246 and LY4379 to assess material characteristics. The selected disturbed and undisturbed samples were tested. Triaxial tests were conducted under confining cell pressure that represents the stress condition at the sample depth.

For soil index determination the following tests were also completed:

- Moisture Content
- Atterberg Limits
- Linear Shrinkage
- Percentage Fines
- Unconsolidated Undrained Triaxial (UU) testing
- Consolidated Undrained Triaxial (CU) with Pore-water Pressure measurement Testing
- Permeability Testing

Soil laboratory test certificates are included in Appendix C.

3. Results of Geotechnical Investigations

3.1 General

The study combines the results from in-situ testing and laboratory testing including undrained strength, effective stress strength and empirical estimation of fully-softened strength.

The in-situ testing comprised the results from the 2007 geotechnical investigation program (CPTU, dissipation testing and geotechnical drilling) and the 2009 geotechnical investigation (one geotechnical borehole) on the Loy Yang External Overburden Dump.

The laboratory testing results including soil plasticity index and strength parameters. The index test results form the basis for estimation of the long-term strength parameters by using selected empirical formulations.

3.2 Subsurface Conditions

The subsurface conditions encountered in the geotechnical boreholes generally included the following:

Alternating layers of CLAY (CH), LIGNEOUS CLAY (OH) and COAL, distributed within the overburden dump profile at different construction stages.

Overlying

HHF Formation (natural ground), recovered as sand and clay with sand.

During the piezocone testing the groundwater table was encountered at approximately 20.0m and 21.0m depths at Site A and B respectively.

The groundwater monitoring data from LY4379 are presented in Figure 2. It indicated that a steady state groundwater table has established within the existing batter at a depth of approximately 15.0m at groundwater bore (LY3479) location.

A seepage water discharge was observed in one inspection on the northern permanent batter in eastern part of the overburden dump in December 2010. The discharged points were approximately at RL 138.0 AHD.

3.3 In-situ Testing

SPT Testing

SPT testing was conducted in the calibration boreholes (LY4245 and LY 4246) and groundwater monitoring bore LY4379 at 1.5m interval in depth. It is general practice to use the correlations between the undrained shear strength and the SPT blow counts, N60, representing the resistance for a Standard Penetration Test delivering the specified energy at an efficiency of 60 percent. Terzaghi, Peck and Mesri (1996) proposed a correlated equation to estimate the undrained shear strength.

$$s_u = 8.0N_{60}$$

In which, Su is undrained shear strength in kPa.

An estimated in-situ undrained shear strength from SPT testing is presented in Appendix D.

CPTU Interpretation Results

The interpretation of soil profile from CPTU measurements by using Robertson's methodology has been presented in Appendix B. The in-situ undrained strength estimated from CPTU testing data is discussed in this section.

The Su values used in this study were derived from CPTU data by the following relationship as proposed by Campanella (1984):

$$S_u = \frac{q_c - \sigma_v}{N_k}$$

where Su = Undrained Shear Strength

q_c = Cone Resistance

σ_v = Total Overburden Stress

N_k = Cone Factor

To determine the site specific N_k for the Loy Yang External Overburden Dump CPTU data was correlated with SPT and triaxial strength testing data. The N_k was determined from a best fit of the CPTU data for both Sites A and B. These correlations are shown in Appendix D. The derived N_k and SPT factors from this study are summarised in Table 2.

Table 2 Derived N_k and SPT Factors

N_k	SPT Factor
15	8.0

The data collected form the CPTU tests was correlated with SPT and Undrained Unconsolidated (UU) triaxial results for Site's A and B as shown on Figure D1 in Appendix D. The SPT data correlates well with the CPTU data. However, the UU triaxial test results are substantially higher when compared to the CPTU and SPT test results, particularly in the upper soil layers. These higher results may be due to the disturbance of the samples during the collection and testing process.

Dissipation Testing

The dissipation test results were used to estimate the permeability of the soil at various depths. The pore water pressure dissipation was plotted against time in logarithmic scale. The test results are included in Appendix B. The dissipation tests were used to determine the coefficient of permeability in the horizontal direction (k_h).

The time for pore water pressure dissipation to reach 50% (t_{50}) was obtained from the graph and coefficient of permeability (k_h) was calculated by using the equation proposed by Mayne

(2007). For Type 2 piezocones (with shoulder filter elements) used during the investigations the t_{50} reading from monotonic responses can be used to evaluate the permeability. The relationship between t_{50} and permeability is proposed as below:

$$k_h \approx (251 \times t_{50})^{-1.25}$$ (Mayne 2007)

where t_{50} is given in seconds.

Table 3 summarises the t_{50} values and the derived k_h from the dissipation tests.

Table 3 Coefficient of Permeability

Location	Depth (m)	Method by log time	
		t_{50} (sec)	k(cm/sec)
Site A	23	87	3.7e-6
Site A	25.8	1,165	1.5e-7
Site B	24.1	66	5.3e-6
Site B	26.8	404	5.5e-7

The derived k_h values are considered normal for the overburden dump materials.

Based on dissipation data the horizontal Coefficient of Permeability was found to range from 1.5e-7cm/sec to 5.3e-6cm/sec. These values are typical for the material types encountered during the drilling.

Permeability testing completed on the undisturbed samples from boreholes LY4245 and LY4246 indicated the coefficient of permeability in the range of 5.4e-11 cm/sec to 1.2e-8 cm/sec, which were significantly lower the estimated values from in-situ dissipation testing.

One reason may be due to estimated permeability is for horizontal direction, which can generally be much higher than vertical permeability. Another reason can be due to local high void ratio or discontinuity.

Based on the permeability calculated from the dissipation test results at the Site A and B, a correlation with permeability and the type of soil can be identified. Based on Parez and Fauriel (1988), soil type can be classified based on the permeability values measured from the dissipation tests as depicted in Figure 3.

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Table 5 Laboratory Results

Bore No.	Sample depth (m)	Soil type	Moisture content (%)	Dry Density (t/m³)	Bulk Density (t/m³)	Dry Density results (t/m³)	Atterberg Limits			Linear Shrinkage (%)	% fines	% Gravel	% Sand			% Clay	% Silt	Particle Density (t/m³)	Triaxial (UU)	Triaxial (CU)		Coefficient of Permeability
							LL (%)	PI (%)	PL (%)				Coarse	Medium	Fine				Corrected Cu	c'	Φ'	(cm/s)
LY4245	2.0	CH	14.0				53	39	14	16	71	3	7	13	8	41	28					
	5.5	CI	14.6	1.8	2.06		42	30	12	15	59	1	11	8	21				154*			
	8.5	CH	31.7	1.4	1.83		63	40	23	14	85	2	3	2	8				155*			
	12	PT	112.3				90	21	69	6.5												
	14.5	CH	35.8	1.4																12	22	
	17.5	PT	126.5	0.49	1.12		104	12	92	6	97			2	1				207*			
	19	PT	89.9				85	12	73	5.5	93	1	1	2	3	15	78					
	23	CH	23.9	1.6	2.01		64	47	17	17.5	91		2	1	6				113*			
	24.5	CH	22.1				60	42	19	12	93		1		6							
	29	OH	58.7				62	24	38	9	63	8	10	13	6				103			4e-10
	32	OH	36.7	1.23	1.69		73	27	46	11.5	94			3	3				37			
	35.9	CH	22.1				52	36	16	12	86		4	6	4							
	38	CI	63.8				46	20	27	9	93		3	3	1				45			
	41	CH	34.2				58	31	27	11	54	1	16	23	6					23	22	2e-10
	44	PT	113.7	0.55	1.17		106	16	91	10.5	95			4	1				164			
LY4246	2	CH	12.4				58	37	21		55		23	17	5							
	5.5	CI	14.1				46	30	16		62	5	8	19	6				366			5.4e-11
	7	ML	39.5				40	6	34		57		2	17	23							
	11.5	PT	111.9				91	8	83		54	1	28	12	5				227			
	14.5	ML	21.9				45	15	30		50	7	25	11	7					23	37.6	1.2e-8
	17.5	ML	51.5				44	11	33		62	2	13	18	5				101			
	19	CH	24.9				79	55	24		76		2	6	16		76	2.65				
	23	OH	65.8				58	20	38		73	3	9	10	5				99			
	29	CI	51.2				38	13	25		78	1	3	5	13				118			
	35	OH	72				108	8	100													9.7e-9
	38	CI	21.9				46	26	20		80	2	5	8	5				317			
	39	SC	17.8				26	10	16		25		24	39	9							
LY4379	6	MH	44.7				61	19	42	7.5	87											

Bore No.	Sample depth (m)	Soil type	Moisture content (%)	Dry Density (t/m^3)	Bulk Density (t/m^3)	Dry Density results (t/m^3)	Atterberg Limits			Linear Shrinkage (%)	% fines	% Gravel	% Sand			% Clay	% Silt	Particle Density (t/m^3)	Triaxial (UU)	Triaxial (CU)		Coefficient of Permeability (cm/s)
							LL (%)	PI (%)	PL (%)				Coarse	Medium	Fine				Corrected Cu	c'	Φ'	
	12	CH	26.4				61	44	17	16	72											
	13.5	CH	42.6																	2.5	26	
	18	OH	73.1				55	4	51	3.5	92											
	22.5	SC	17.1								40											
	23.5	CH	24.9																	2.5	22	
	28.5	OH	63.1				65	21	44	8.5	98											
	34.5	CH	56.8				50	23	27	10	83											
	37.5	CH	56.8				50	23	27	10	83									31.2	20.4	
	39	CI	22.6				37	25	12	10.5	84											
	43.5	SC	9.7								38											
	52.5	CL	16.1								48									0	36.3	

*Inferred values.

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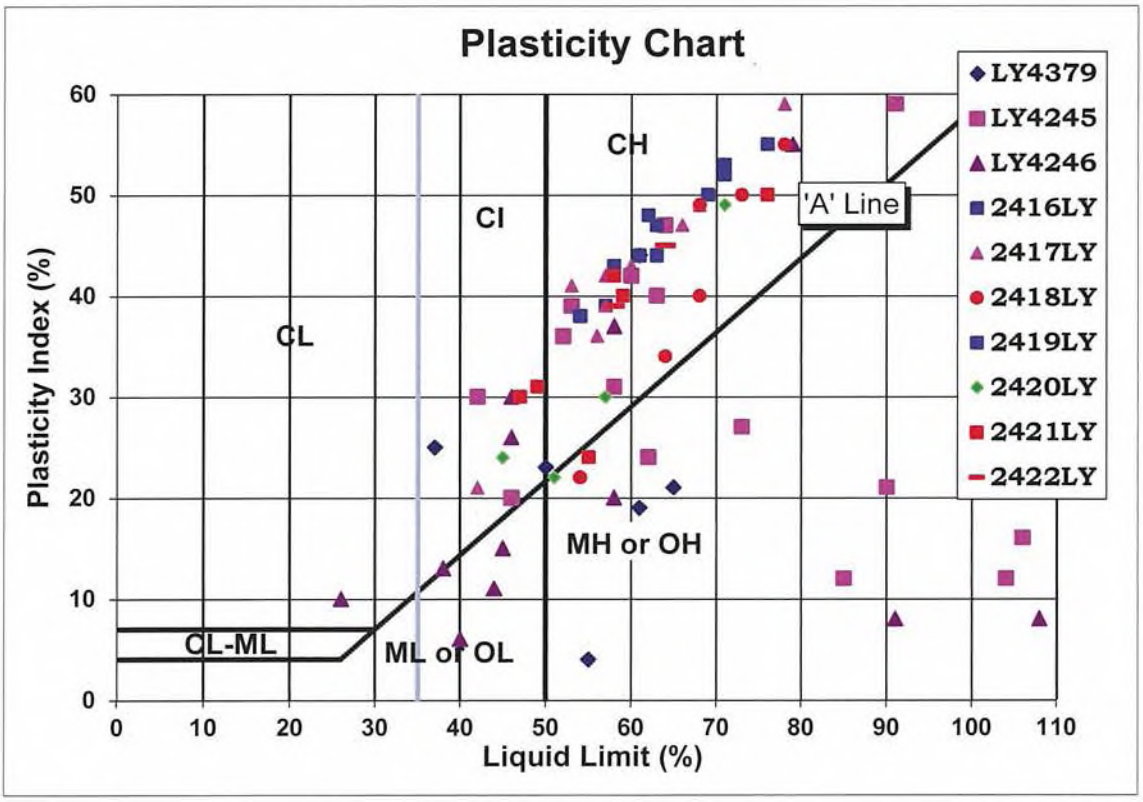
3.4 Laboratory Testing

The laboratory test certificates including soil classification and strength testing are presented in Appendix C.

Table 5 provides a summary of all the laboratory test results for the 2007 and 2009 investigation programs on the Loy Yang External Overburden Dump. It may be difficult to detect any certain patterns in terms of soil properties with depth due to the random nature of the dump materials. This is due to the heterogeneity of the material being placed by the stackers. The Atterberg Limit test data indicates high plasticity clay and silt soil types. However, the inclusion of coal fragments may affect the test results.

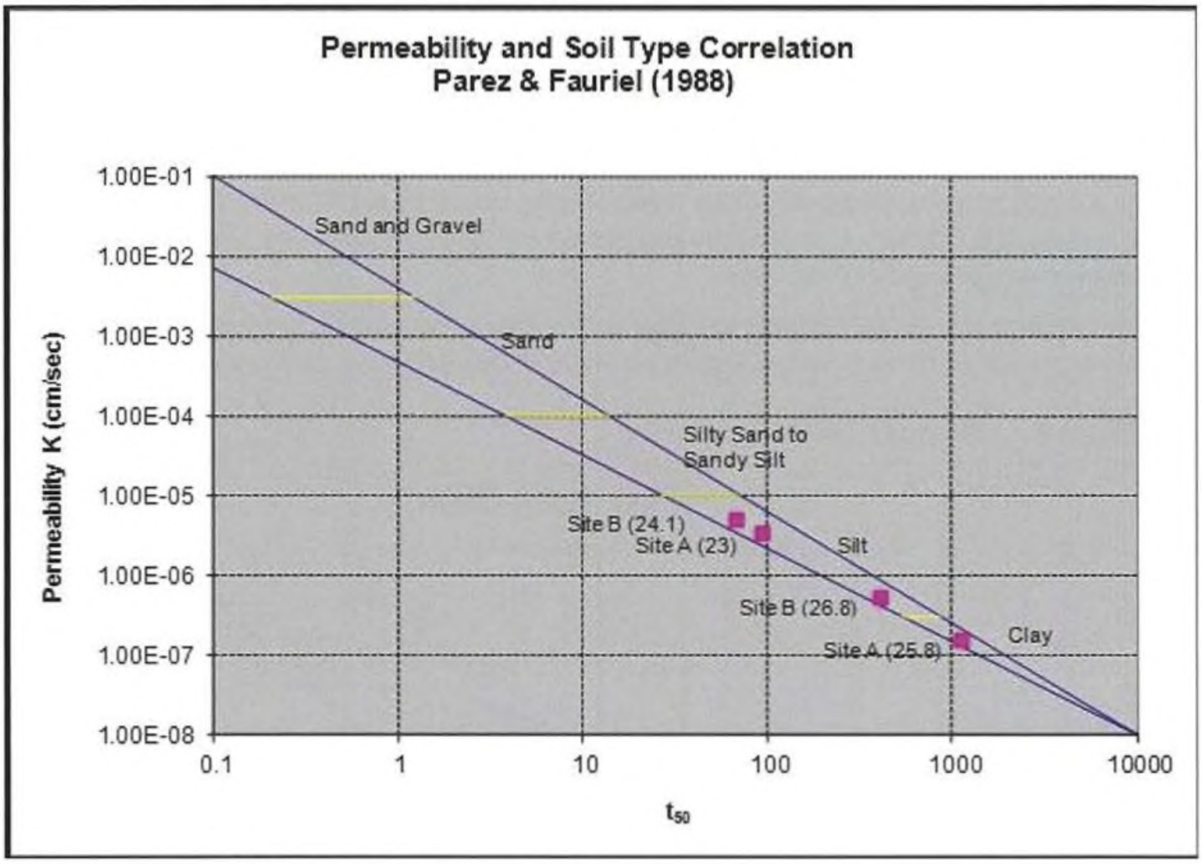
The Plasticity Index and Liquid Limits were plotted on a plasticity chart to provide information about the nature of the cohesive soils found in the overburden dump See Figure 4).

Figure 4 Plasticity Chart



Refer to Soil Description Sheets in Appendix A for abbreviations

Figure 3 Permeability and Soil Type Correlation



Based on the dissipation test data the soil type at 23m and 24.1m at site A are silt and clay, respectively. The soil type at both test depths (24.1m and 26.8m) at site B is silt. These correlations were compared with borehole logs and laboratory test data as shown in Figure 3.

In this study it was found that there is generally a good correlation between the laboratory soil descriptions and the permeability and soil type correlation methodology as proposed by Parez & Fauriel (1988).

Table 4 Material Descriptions

Location	Depth (m)	Dissipation Test Information	Borehole Logs	Laboratory Test Information
Site A	23	Silt	Ligneous Clay	Clay
Site A	25.8	Clay	Ligneous Clay	Clay (Tested at 24.5m)
Site B	24.1	Silt	Ligneous Clay	Clay with Silt (Tested at 23.0m)
Site B	26.8	Silt	Ligneous Clay	Clay with Silt (Tested at 29.0m)

4. Previous Studies

4.1 Golder Associates (1975)

An initial overburden dump stability analyses were carried out by Golder Associates (1975) used the effective strength methodology based on parameters obtained from an investigation of the Morwell Open Cut Overburden Dump. The mean effective strength parameters they proposed for design work at that stage were, c'= 26 kPa and Φ'= 25°.

Eleven (11) consolidated undrained triaxial tests with pore pressure measurements that were carried out by SECV Civil and Architectural Department were used as the basis for interpretation of the above strength parameters. Seven (7) of these tests were undertaken as part of the investigation for the proposed No. 3 Ash Pond that was proposed to be constructed on the surface of the Morwell Overburden Dump. Four (4) tests performed as part of the Loy Yang overburden investigation.

Pore-water pressure ratio, the ratio of change in pore water pressure to the applied vertical stress, Ru = 0.7 was adopted in this analysis. This assumption was unreasonable, as substantial tension existed in the upper part of the slope. The increase of pore-water pressure due to imposed loading may excess to the lateral stress at the upper part of the slope.

A lower limit of friction angle of 18°, which was based on relationship between friction angle and PI of Loy Yang and Morwell, was used in stability analysis.

4.2 State Electricity Commission of Victoria

1986 (SECV Report No DD210):

A geotechnical assessment of the stability of the multi-level overburden dump at Loy Yang Open Cut was undertaken by State Electricity Commission of Victoria (SECV), Fuel Department (refer to Stability Assessment of Multi-level Overburden Dump report by SECV, 1986). This assessment included both short and long-term stability.

Short term strength:

Su=25 kPa (from back analysis)

Long-term strength:

c' = 0 kPa, ϕ'=25° correlated PI=45

B-bar coefficient B=0.74 to 1.0

1991 (SECV Report No GDD74):

As part of an investigation program of the overburden dumps at the mines in Latrobe Valley, a number of investigation boreholes were drilled at the Loy Yang Overburden Dump. The samples taken were tested for various index and strength parameters. The following lower quartile shear strength parameters were recommended for preliminary stability assessments of the overburden dump at Loy Yang.

Short term strength:

Cu = 50-60 kPa, ϕ_u = 1.5°

Long-term strength:

$c' = 25$ kPa, $\phi' = 14°$

4.3 GeoEng 2000

In 2000, GeoEng conducted six CPT tests along the L710 Conveyor (41199) dump face and six along the L811 Conveyor (17300), (GeoEng Ref: 1100/1346/154 and 5). The CPT's were conducted from the formation level, approximately 10m from the operating batter crest. Based on the CPT results, GeoEng recommended design Su values with a range between 50kPa to 75kPa.

4.4 GHD

2005 (GHD Ref: 31/1146705/107928**)**:

The study reviewed the strength parameters provided in SECV 1991 report.

Using historic data from SECV 1991 report, a relationship between the Plasticity Index (PI) of material and the ratios of Undrained Shear Strength (Su) / Effective Stress (p') was used in this study to estimate the in-situ Su of dump material at different dump depths. An assumption of normally-consolidated clay was made for the over-burden dump materials.

Based on the work conducted by SECV (1991), an average value of PI was 43 % for the Loy Yang Overburden Dump. In this study, a Su / p' ratio of approximately 0.3 was used to estimate the Su values for different dump levels. The undrained strength values used in the stability analysis were in the range of 43 to 192 kPa, and generally increased with depth.

B-bar coefficient B=0.3 was interpreted from piezometer data.

Effective stress strength:

$c' = 20$ kPa, $\phi' = 30°$

2006 (GHD Ref: 31/114606/114045):

In April 2006 GHD completed a geotechnical study for the Loy Yang External Overburden Dump, Geotechnical Studies to Support Limited Dozing Methodology.

Back analysis of results of Western Permanent Batter produced:

$c'=0$ kPa, $\phi'=28°$

Undrained Shear Strength (Su) parameters used in this report were primarily based on 12 no. Cone Penetrometer Testing (CPT) from GeoEng 2000. Reanalysing 12 CPT test results using $N_k=15$ resulted in estimate of the undrained strength, Su=45 to 85 kPa for new dump material, Su=90 to 110 kPa for older underlying dump materials.

2009 (GHD Ref: 31/1146609/160908):

The latest study was completed by GHD in February 2009 for the External Overburden Dump Level 3 East, Northern Permanent Batter Redesign (GHD Ref No: 31/11466/09/160908).

A geotechnical assessment was undertaken for the Northern Permanent Batter redesign in the eastern part of the dump. This assessment was focused on the East end of the Northern Permanent Batter of the dump and included both short and long-term stability. Parameters were primarily based on site specific sampling and testing.

The lower quartile effective and undrained shear strength parameters were used in this study.

Short term strength:

Su=55 kPa (for level 3 dump material) and Su=95 kPa (for level 1 & 2 dump material).

Long-term strength:

c'=10 kPa, ϕ'=22°

B-bar coefficient B=0.3

4.5 Published Research on Strength of High Plasticity Clays

A substantial amount of research (Wright 2005) undertaken for TxDOT in USA on the stability analysis and the appropriate shear strengths to be used for slope design, due to significant long-term stability problems. Most of the failures involved compacted highly plasticity fills, which were generally strong immediately after construction with a factor of safety exceeding 2. The compacted soils tended to soften and weaken over time and the factor of safety decreased to values that approached 1, i.e., failure. The softening was considered to be enhanced by repeated expansion and shrinkage that accompany seasonal wetting and drying of the soil, respectively.

It was concluded that the fully-softened shear strength was the controlling shear strength in most cases, but that the residual strength may be applicable once a slide occurred. A shear strength relationship that is curved, rather than linear, was considered to be most characteristic for the fully-softened and residual strength. The cohesion value is very small or zero and taken as zero for all practical purposes. As such, no effective cohesion was considered in either fully-softened or residual strength.

An empirical equation was developed to estimate the fully-softened strength of highly plasticity (LL >50) clays from the Liquid Limits (LL).

$$\phi'_{sf} = 55.3 - 16.7\log(LL) - 6\log\left(\frac{\sigma'_f}{p_a}\right)$$

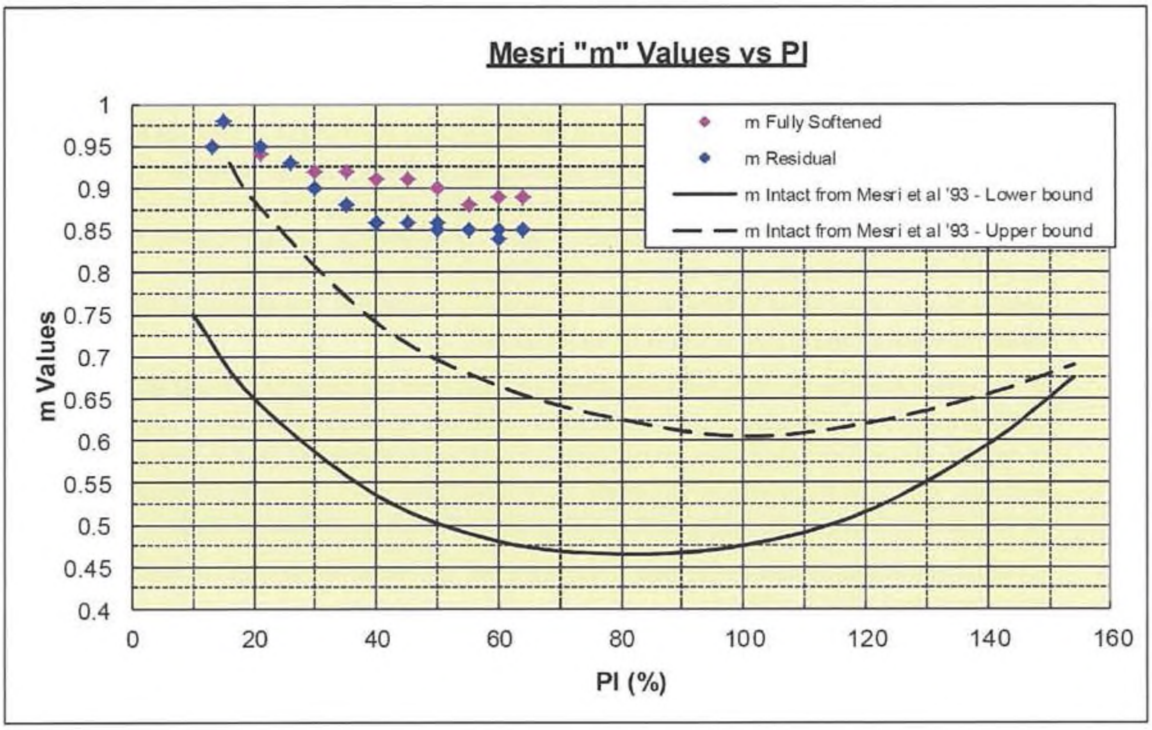
It is well known for uncemented materials that the shear strength envelope is at or near zero at zero normal stresses and the work of Wright confirms this. It is also well known that the strength envelope is curved due to the effects of dilatancy at lower stresses and confinement constraints at higher stresses (Stark & Eid (1997)).

In further confirmation of the nature of strength relationships for clays, based on back analyses of 99 case histories of slope failures in soft to stiff clay materials, Mesri and Shahien (2003) found that the fully-softened shear strength tends to the lower bound for mobilized shear strength in first time slope failure of soft to stiff clays and clay shales. The fully softened strength applied to the failure surfaces in homogeneous clay mass and across the orientation bedding planes and laminations. Residual strength was found to apply to part of the failure surfaces, usual on low angle features. The following equation was developed to characterise the fully-softened shear strength as a curved failure envelop with normal/confining stress:

$$s_{fs} = \sigma'_n \tan(\phi'_{fs})_{100} \left(\frac{p_a}{\sigma'_f} \right)^{1-m_{fs}}$$

Where $(\phi'_{fs})_{100}$ is secant fully softened friction angle at $\sigma'_n = 100kPa$. $(1 - m_{fs})$ is a reduction factor as normal/confining stress increases, which is correlated the plasticity index as demonstrated in Figure 5, derived from case studies (Mesri and Abdel-Ghaffar (1993), Mesri and Shahien (2003)). A similar form of this equation was also proposed by Mesri for assessment of the residual shear strengths.

Figure 5 Correlation between "m" and PI (Mesri 1993)



4.6 Strength Parameter Estimation

The plasticity results from recent geotechnical investigations at the Loy Yang Overburden Dump as summarised in Table 5. The results indicated that the majority cohesive soils in the dump were high plasticity clay with LL values in the range of 26% to 108% and with average of 61%.

The above equations have been used to estimate the fully-softened strength of the dump materials.

The magnitude of the fully softened shear strength is stress-dependent, which is demonstrated as the decrease of the fully softened secant friction angle with the increase of effective normal stress. Due to significant height of the Overburden Dump, the soil elements within the batter will be subject to a large range of confining pressure depending on depth below dump surface. As such, significant stress-dependence should be considered in derivation of strength parameters. The lower limit is the secant friction angle corresponding to an effective normal stress of 600 kPa. The upper limit is corresponding to an effective normal stress of 50 kPa. The estimated lower and upper limits are presented in Appendix D. However, a secant friction angle corresponding to the average effective normal stress acting on any sliding slip may be used in stability analysis.

As seen from the estimated results in Appendix D, there were not significant differences between the estimated results from the above two empirical equations from Mesri and Wright. However the correlation of strength parameters with PI might be more comprehensive with the consideration of both Liquid Limit and clay content fraction of the encountered materials. The estimated data points were generally more scattered without the consideration of clay content fraction in Wright's estimation.

The soil index parameters from the 1991 SECV report has been included in the estimation as well. However, as the 1991 results were from relatively shallow samples, the scattered data from shallow depths were generally ignored in interpreting the following upper and lower limits for the Fully Softened strength parameters.

The estimated fully softened shear strength parameters using the recent plasticity data and the above equations are summarised in Table 6.

Table 6 Estimated Fully Softened Strength Parameters

	Cohesion (kPa)	Secant Friction Angle ϕ'_{fs} (°)	
		Range	Average
Upper Limit $\sigma'_n = 50kPa$	0	24.5 - 29.5	27.0
Lower Limit $\sigma'_n = 600kPa$	0	19.5 – 23.5	22.0

The existing overburden dump may be considered to be normally consolidated.

The effective friction angle obtained from CU triaxial test results from the high plasticity clay, as summarised in Table 5, were in the range of 20.4 to 26.0, which were consistent with the Wright's predictions and slightly higher than Mesri's predictions.

The materials encountered between RL126.5 and RL111.6 in LY4245, two separate layers (RL122.5 and RL99.0) in LY4246, presented very high Liquid Limit (LL) but with very low Plasticity Index (PI). The materials were logged as inferior coal. The estimated fully-softened friction angles were significantly lower in Wright's predictions and were not considered in current estimation.

5. Discussion

5.1 Undrained Strength

In-situ testing indicated slight increase in undrained strength with depth below the dump surface, as shown in Appendix D. However, there were less significant increases of undrained strength within the dump material below the groundwater level.

Based on this investigation the average undrained shear strength profile in the overburden dump can be represented by the following expression:

Su = 55 + D kPa

Where D = depth below dump surface in meters

Note: the above does not apply to the operating face where freshly placed materials are much looser and weaker.

It is noted that the CPT test results from current and previous investigations indicates a stronger layer up to 3 meters thick below the existing surface and stronger layers found at various depths. The stronger surface layer is the formation level which is normally constructed using better materials that are track rolled to provide a suitable surface to operate dump plant on. Stronger layers are also intermittently found at depth and usually are buried formation layers or other zones that were compacted by operation of plant on them when they were placed such as on the operating face during routine dozing operations. .

5.2 Fully Softened Strength

The laboratory Consolidated Undrained Triaxial (CU) test results presented an effective friction angle in the range of 20.4° to 37.6°. Two of the tests on the sandy soils presented higher friction angle of 36.3° and 37.6° respectively. The friction angles from the tests on clayey soils ranged from 20.4° to 26.0°, with average value of 22.5°, which was approximately the average lower limit of the estimated values of fully-softened strength. However, a range of effective cohesion intercept was indicated by the CU testing in the range of 2.5 kPa to 31.2 kPa which lifts the respective failure envelopes and quite close to the published fully-softened strength parameters.

In general the effective strength parameters obtained during this study are not significantly different from the strength parameters used by SECV and GHD for previous stability analyses of the Loy Yang Overburden Dump. This confirms the ongoing validity of the previous studies completed by GHD on the overburden dump for short term to middle-term stability. However, due to the high plasticity nature of the majority materials within the dump, it is considered more suitable to use fully-softened strength for the long-term stability analysis. The variation of shear strength with depth may be considered in the analysis with different batter height of the dump.

Table 7 summarises the upper and lower limits of material strength parameters that may be considered for use for stability analysis for the Loy Yang External Overburden Dump. These proposed parameters were obtained from a collation of all the in-situ, laboratory testing data conducted on the overburden dump and published correlations. It should be noted that the stress-dependence of strength parameters were considered and a range of values are provided in Table 7 below.

However, for simplicity it is suggested that the following average fully softened shear strength be adopted for long-term stability analysis of the Loy Yang Overburden Dump for screening analyses:

$$c' = 0 \text{ kPa}, \quad \phi'_{fs} = 25°$$

For more detailed study it is recommended that the values in Table 7 be adopted, preferably through the implementation of a full curved strength envelope.

Table 7 Ranges of Material Strength Parameters

Unit Weight (kN/m^3)	Long-term strength			Short-term strength	
	c' (kPa)	Φ' (°)		Su (kPa)	
		Lower value	Upper value	Lower value	Upper value
17	0	22	27	55	90

6. Recommendations

The following recommendations are made based on this review of Loy Yang Overburden Dump material parameters:

- Undrained Shear Strength Parameters for overall stability assessment:
  - Su = 55 + D kPa, where D = depth below dump surface in meters
- Effective Strength Parameters for overall long-term stability assessment:
  - Secant effective stress friction angle, are stress-dependent and ranges from $\phi'_{lower} = 22^{\circ}$ to $\phi'_{upper} = 27^{\circ}$;
  - Average effective stress friction angle ϕ' = 25° ; and
  - Zero cohesion.
- Limited number of groundwater bore has been installed in the Overburden Dump area. It is recommended the existing network be reviewed for adequacy of coverage in combination with the groundwater monitoring network in ash pond area. The network should be enhanced where required by installation of additional groundwater monitoring bores in the Loy Yang External Overburden. This will improve the understanding of the groundwater conditions and support the geotechnical risk management;
- Continue with in-situ and laboratory testing programs. This is to help identify any changes in material types and strengths that can impact on operating batter or long term overall dump stability;
- Incorporate all the available laboratory and in-situ strength testing data from the Loy Yang External Overburden Dump into a 3D model to help identify material strength changes or trends both laterally and vertically. This should include the development of a material strength database. This will allow for easy reference and help optimise future analysis work. Review the both the short and long term stability of the overburden dump by adopting the revised material strength parameters obtained in this study. Both probabilistic and deterministic analysis methodologies should be considered for the review;
- To consider the stress-dependence of strength parameters of the dump materials due to significant stress range, it is recommended the stress state within the overburden dump be analysed by using Finite Element Analysis (FEM) method to provide reference for the stability analysis; and
- Operating face stability analyses should continue to be based on the strength of loosely placed materials on the batter and the condition of the foundation materials.

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Figures

GHD CLIENTS | PEOPLE | PERFORMANCE

Loy Yang Power
External Overburden Dump
Plan of CPT and Boreholes

scale | for A4 date

job no. 311145210
rev no. A

Figure 1

Level 8, 180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au W www.ghd.com.au

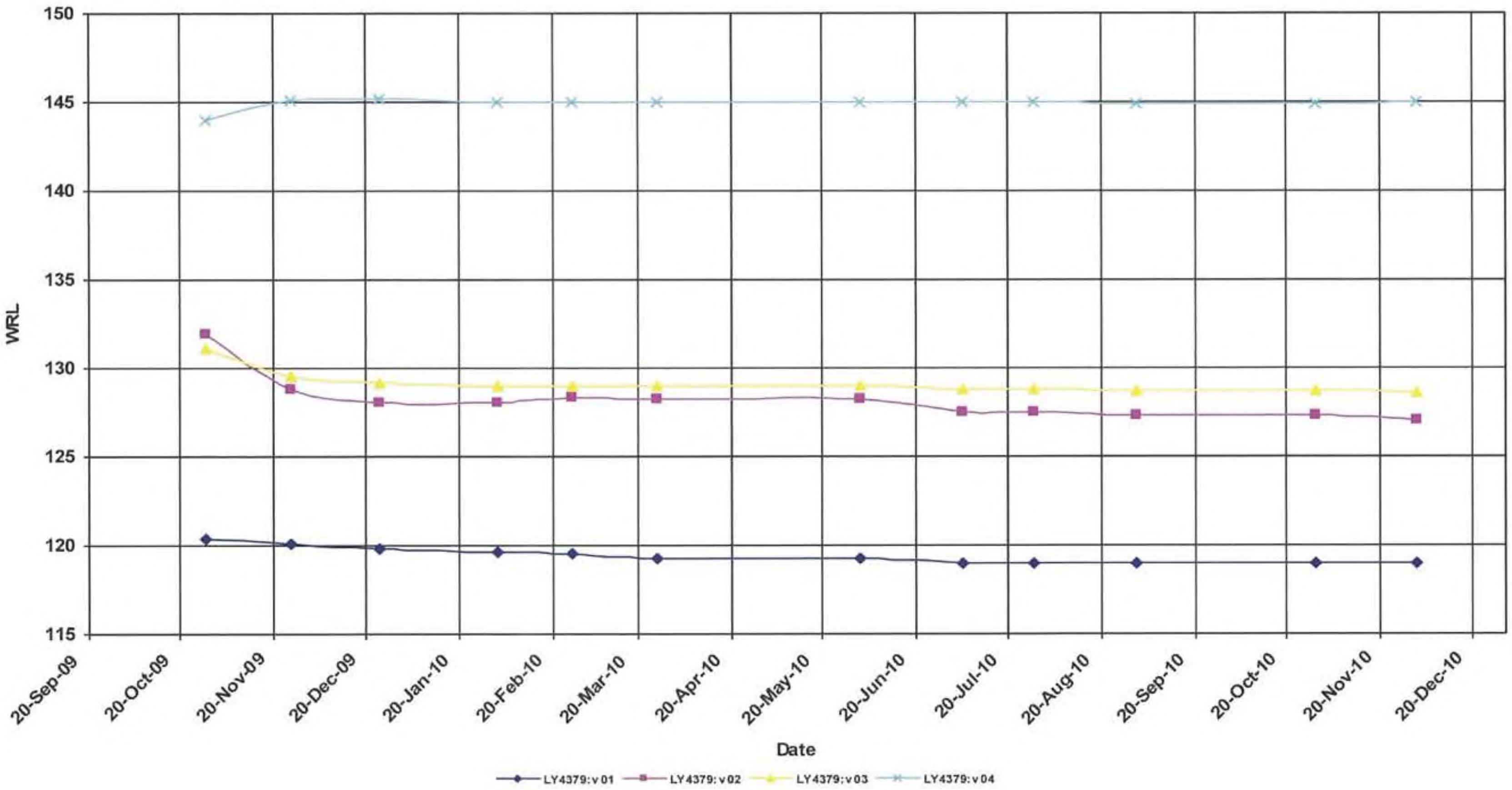

Figure 2 -- Groundwater Bore Hydrograph-LY4379

Project Name: External Overburden Dump Material Parameters Review

Client Name: Loy Yang Power

Job Number : 311145210

LOY YANG power

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