

Baal Bone Colliery
ENVIRONMENTAL ASSESSMENT

March 2010

Volume 2 - Appendices A to I

Prepared for The Wallerawang Collieries (TWCL)
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APPENDIX A

Director-General's Environmental Assessment Requirements and Agency Consultation

Major Projects Assessment
Mining
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Email: colin.phillips@planning.nsw.gov.au
Room 306
23-33 Bridge Street
GPO Box 39
SYDNEY NSW 2001

Our Ref: S03/00074

Mr Tony King
Environment and Community Coordinator
Baal Bone Colliery
PO BOX 139
LITHGOW NSW 2790

Dear Mr King

Baal Bone Colliery Continued Operations Project
Director-General's Requirements

I refer to your application for the Baal Bone Colliery Continued Operations Project.

I have attached a copy of the Director-General's requirements for the project. These requirements have been prepared in consultation with the relevant public authorities, and are based on the information you have provided to date. I have attached the comments received from public authorities for your information.

Please note that the Director-General may alter these requirements at any time.

If your proposal is likely to have a significant impact on matters of National Environmental Significance, it will require an approval under the Commonwealth *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act). This approval is in addition to any approvals required under NSW legislation. It is your responsibility to contact the Department of Environment, Water, Heritage and the Arts in Canberra (6274 1111 or http://www.environment.gov.au) to determine if the proposal requires an approval under the EPBC Act. The Commonwealth Government has accredited the NSW environmental assessment process, so if it is determined that an approval is required under the EPBC Act, please contact the Department immediately as supplementary Director-General's requirements may need to be issued.

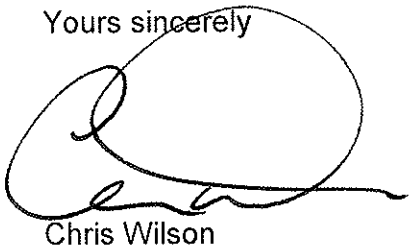
I would appreciate it if you would contact the Department at least two weeks before you submit the Environmental Assessment for the project. This will enable the Department to determine:

- the applicable fee; and
- number of copies (hard-copy or CD-ROM) of the Environmental Assessment that will be required.

The Department is required to make all the relevant information associated with the project publicly available on its website. Consequently, I would appreciate it if you would ensure that all the documents you subsequently submit to the Department are in a suitable format for the web, and arrange for an electronic version of the Environmental Assessment to be hosted on a suitable website during the assessment process.

If you have any enquiries about these requirements, please contact Colin Phillips.

Yours sincerely



28.10.07

Chris Wilson
Executive Director
Major Projects Assessment
As delegate of the Director-General

Director-General's Requirements

Section 75F of the *Environmental Planning and Assessment Act 1979*

Application Number	TBA
Project	The Baal Bone Colliery Continued Operations Project, which includes: • underground mining in previously approved areas, including Longwalls 28 to 31 and remnant coal areas within existing mining leases, at a maximum extraction rate of 2.8 million tonnes run-of-mine coal a year; • continued use of the mine's surface infrastructure, including processing and rail loading facilities; • continued road haulage of product coal to local markets at currently approved quantities; and • rehabilitating the site.
Location	Approximately 25 kilometres northwest of Lithgow
Proponent	The Wallerawang Collieries Limited
Date of Issue	28 October 2009
General Requirements	The Environmental Assessment of the project must include: • an executive summary; • a detailed description of: - existing and approved mining operations and infrastructure on the site, including a copy of all relevant statutory approvals; - existing and approved mining operations in the vicinity of the site; - historical mining operations on the site; - any existing and/or approved biodiversity and heritage offset areas relating to these operations; and - the existing environmental management regimes for these operations; • a detailed description of the project, including the: - need for the project; - alternatives considered, including justification for the proposed mine plan; - likely staging of the project; - likely interactions between the project and existing and approved mining operations; and - projected life of the mine; • a risk assessment of the potential environmental impacts of the project, identifying the key issues for further assessment; • a detailed assessment of the key issues specified below, and any other significant issues identified in the risk assessment (see above), which includes: - a description of the existing environment, using sufficient baseline data; - an assessment of the potential impacts of all stages of the project on this environment, including any cumulative impacts, taking into consideration any relevant laws, policies, guidelines and plans; and - a description of the measures that would be implemented to avoid, minimise, and if necessary offset the potential impacts of the project; • a statement of commitments, outlining the proposed environmental management and monitoring measures; • a conclusion justifying the project, taking into consideration the economic, social and environmental impacts of the project as a whole; and whether the project is consistent with the objects of the *Environmental Planning & Assessment Act 1979*; and • a signed statement from the author of the Environmental Assessment, certifying that the information contained within the document is neither false nor misleading.

Key Issues	• **Subsidence** – including: - accurate predictions of potential subsidence effects (both systematic and non-systematic) including potential cumulative effects and a sensitivity analysis; - identification of sensitive receptors potentially affected by subsidence (such as environmental features and infrastructure) and an assessment of significance of those receptors; - assessment of the potential impacts of subsidence effects on the natural and built environment, with particular reference to sensitive receptors such as cliff lines and other geomorphologic features; - identification of how mine design has been or will be used or adapted to manage and mitigate subsidence impacts; - identification of how subsidence impacts will be rehabilitated, including methodologies and response times; and - identification of further research required to address any uncertainties or information gaps. • **Traffic and Transport** – including: - accurate predictions of road and rail traffic resulting from the project; - a road safety audit of the roads used by traffic from the project, including consideration of school bus routes; and - justification for the proposed continuation of coal haulage via public roads, including a detailed consideration of alternatives. • **Soil & Water** – including: - a site water balance for the project; - an assessment of the potential impacts of the project on surface and ground water resources, including water quality and quantity; • **Aboriginal Heritage**; • **Air Quality** – including a greenhouse gas assessment; • **Noise** – including an assessment of the potential low frequency noise and off-site road and rail noise; • **Biodiversity** – including: - a detailed assessment of the potential impacts of the project on any terrestrial and aquatic threatened species, populations, ecological communities or their habitats; and - a detailed description of the measures that would be implemented to maintain or improve the biodiversity values of the surrounding region in the medium to long term; and • **Rehabilitation** – a detailed description of the proposed rehabilitation strategy, including: - rehabilitation objectives and demonstration that these objectives can be achieved; - identifying specific domains for rehabilitation and proposed final land use/s and final landforms for each domain, having regard to any relevant strategic land use planning or resource management plans or policies; - a description of the proposed rehabilitation techniques, particularly for natural features affected by subsidence; and - identifying the strategic level rehabilitation success/completion criteria for each domain having regard to each stage of rehabilitation and also for natural features affected by subsidence. • **Mine Closure** – including the measures that would be implemented to minimise the potential socioeconomic impacts for the mine's employees following closure.
References	The environmental assessment of the key issues listed above must take into account relevant guidelines, policies, and plans. While not exhaustive, the following attachment contains a list of some of the guidelines, policies, and plans that may be relevant to the environmental assessment of this project.
Consultation	During the preparation of the Environmental Assessment, you should consult with the relevant local, State or Commonwealth Government authorities, service providers, community groups or affected landowners.

	In particular you must consult with the: • Department of Environment, Climate Change and Water, • NSW Office of Water; • Department of Industry and Investment; • Roads and Traffic Authority; and • Lithgow City Council. The consultation process, and the issues raised during this process, must be described in the Environmental Assessment.
Deemed refusal period	60 days

Policies, Guidelines & Plans

Aspect	Policy /Methodology
Risk Assessment	
	AS/NZS 4360:2004 Risk Management (Standards Australia)
	HB 203: 203:2006 Environmental Risk Management – Principles & Process (Standards Australia)
Subsidence	
	Guideline for Application for Subsidence Management Approvals (DMR)
Traffic and Transport	
	Guide to Traffic Generating Development (RTA)
	Road Design Guide (RTA)
Soil and Water	
Soil	Rural Land Capability Mapping (DLWC)
	Agricultural Land Classification (DPI)
	Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites (ANZECC & NHMRC)
	National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPC, 1999)
	State Environmental Planning Policy No. 55 – Remediation of Land
	Managing Land Contamination – Planning Guidelines SEPP 55 – Remediation of Land (DOP)
Surface Water	National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ)
	National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ)
	National Water Quality Management Strategy: Guidelines for Sewerage Systems – Effluent Management (ARMCANZ/ANZECC)
	National Water Quality Management Strategy: Guidelines for Sewerage Systems – Use of Reclaimed Water (ARMCANZ/ANZECC)
	Using the ANZECC Guideline and Water Quality Objectives in NSW (DEC)
	State Water Management Outcomes Plan
	NSW Government Water Quality and River Flow Objectives (DECC)
	Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (DEC)
	Managing Urban Stormwater: Soils & Construction (Landcom)
	Managing Urban Stormwater: Treatment Techniques (DECC)
	Managing Urban Stormwater: Source Control (DECC)
	Floodplain Risk Management Guideline (DECC)
	A Rehabilitation Manual for Australian Streams (LWRRDC and CRCCH)
	Technical Guidelines: Bunding & Spill Management (DECC)
	Environmental Guidelines: Use of Effluent by Irrigation (DECC)
Groundwater	National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC)
	NSW State Groundwater Policy Framework Document (DLWC)
	NSW State Groundwater Quality Protection Policy (DLWC)
	Draft NSW State Groundwater Quantity Management Policy (DLWC)
	Murray-Darling Basin Groundwater Quality. Sampling Guidelines. Technical Report No 3 (MDBC)
	Murray-Darling Basin Commission. Groundwater Flow Modelling Guideline (Aquaterra Consulting Pty Ltd)
	Guidelines for the Assessment & Management of Groundwater Contamination (DECC, 2007)
Aboriginal Heritage	
	Draft Guidelines for Aboriginal Cultural Heritage Impact Assessment and Community Consultation (DEC, 2005)

	The Burra Charter (The Australia ICOMOS charter for places of cultural significance)
	NSW Heritage Manual (NSW Heritage Office & DUAP)
Air Quality	
	Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (EPA)
Noise	
	NSW Industrial Noise Policy (DECC)
	Environmental Criteria for Road Traffic Noise (NSW EPA)
Greenhouse Gas	
	National Greenhouse Accounts (NGA) Factors (AGO)
Rehabilitation	
	Mine Rehabilitation – Leading Practice Sustainable Development Program for the Mining Industry (Commonwealth of Australia)
	Mine Closure and Completion – Leading Practice Sustainable Development Program for the Mining Industry (Commonwealth of Australia)
	Strategic Framework for Mine Closure (ANZMEC/MCA)
Social & Economic	
	Draft Economic Evaluation in Environmental Impact Assessment (DOP)
	Techniques for Effective Social Impact Assessment: A Practical Guide (Office of Social Policy, NSW Government Social Policy Directorate)

NSW GOVERNMENT | Industry & Investment

Your Reference: S03/03083
Our Reference: V09/499
OUT09/13473

Mr Howard Reed
A/Manager Mining
Department of Planning
GPO Box 39
SYDNEY NSW 2001

Attention Mr Paul Freeman

Dear Mr Reed

Baal Bone Colliery Continuation of Operations Project
Director General's Requirements

I refer to your letter of 8 October 2009 regarding the Part 3 application made by Wallerawang Collieries Limited for its proposal.

Industry and Investment NSW (I&I NSW) has reviewed the Preliminary Environmental Assessment and the draft Director-General's requirement (DGRs) for the full Environmental Assessment (EA) and provide the following comments.

MINERAL RESOURCES ISSUES:

The draft DGRs currently includes the following requirements:

Rehabilitation / Mine Closure – including a detailed description of the proposed long-term rehabilitation strategy for the Baal Bone site, having regards to:
the key objectives and principles in the Strategic Framework for Mine Closure *(ANZMEC/MCA);*
- *any relevant strategic land use planning or resource management plan or polices; and*
- *the measures that would be implemented to minimise the potential socioeconomic impacts for the mine's employees following closure.*

Due to the lack of certainty regarding the meaning and requirements for a "*rehabilitation strategy*", I&I NSW recommends the following text replace the above draft requirement.

Rehabilitation– including a detailed description of the proposed rehabilitation strategy which addresses the following:

Minerals and Energy Division
Level 6, 201 Elizabeth Street, Sydney NSW 2000
PO Box K220 HAYMARKET NSW 1240
Tel: (02)8289 3930 Fax: 02 9286 3208
ABN 51 734 124 190
www.industry.nsw.gov.au

- Nominate rehabilitation objectives and demonstrate that these objectives can be achieved;
- Nominate specific domains for rehabilitation and identify proposed final land-use/s and landforms for each domain, having regard to any relevant strategic land use planning or resource management plan or polices;
- Describe proposed rehabilitation techniques, particularly in relation to natural features affected by subsidence; and
- Nominate the strategic level rehabilitation success/completion criteria for: each domain having regard to each stage of rehabilitation; and for natural features affected by subsidence. Rehabilitation success/completion criteria must be supported by precedent or by nominating a research program aimed at demonstrating long term feasibility.

Subsidence

I&I NSW recommend the following text replace the draft subsidence requirement.

Subsidence –

Including

- including potential cumulative subsidence effects and sensitivity analyses;
- identification of sensitive receptors potentially affected by subsidence (such as environmental features and infrastructure items) and an assessment of significance of those receptors;
- an assessment of the potential impacts subsidence effects on the natural and built environmental with particular reference to sensitive receptors including cliff lines and other geomorphological features and consequential impacts;
- predictions of potential subsidence effects (systematic and non-systematic) identification of how mine design has been or will be used or adapted to manage and mitigate subsidence impacts;
- identification of how expected environmental impacts resulting from subsidence will be addressed in respect of rehabilitation methodologies and rehabilitation response times;
- identification of further research required to address any uncertainties or information gaps.

FISHERIES ISSUES:

The DGRs cover threatened aquatic species impacts and makes reference to examining the impacts of mine subsidence on cliff faces and geomorphological features, but does not mentioned the impacts of subsidence on aquatic habitats and potential compensatory aquatic habitat/rehabilitation.

I&I NSW is responsible for managing fish (including aquatic invertebrates), and fish habitat throughout NSW. The Department's goals encompass protecting the aquatic environment and promoting the rehabilitation of degraded aquatic environments. This includes protecting rare and threatened species and maintaining aquatic biodiversity.

The proposed area of development does contain some Key Fish Habitat and so may potentially have adverse impacts on aquatic habitats and threatened species, populations or ecological communities listed under the *Fisheries Management Act 1994*. The EA should specifically address impacts on the aquatic ecology as a result of mine subsidence or vibration as outlined below.

General Description of Aquatic Habitat

- A topographic map of the locality at a scale of 1:25000 or finer detailing the location of all parts of the proposal, any areas of aquatic habitat, and aquatic habitat likely to be impacted.
- Description and maps of aquatic habitat areas (creeks and wetlands) within the study area including mapping and description of aquatic and riparian vegetation.
- Description of proposal and study area and size of the area affected.
- Hydrological information of watercourses such as bed substrate and flow duration.
- The extent of aquatic habitat modification which may result from the proposed development, particularly disturbance of rivers and creeks due to subsidence and vibration.
- Discuss the potential impacts of this subsidence or vibration on aquatic habitats.
- Aspects of the management of the proposal which relate to impact minimisation eg Environmental or Subsidence Management Plans.

Compensatory Habitats and Rehabilitation Plans

I&I NSW have guidelines for compensatory habitat outlined in the document *Policy and Guidelines Aquatic Habitat Management and Fish Conservation 1999.* Compensatory habitats may be a requirement if the environmental assessment indicates there may be loss of or direct impact on aquatic or riparian habitats, or may need to be included in site rehabilitation plans.

FORESTRY ISSUES

As the proposal is within Ben Bullen State Forest it is recommended the company contact Mr Warwick Bratby Acting Regional Manager, Western Region, Forests NSW on 02 6841 4202 for specific forestry issues to be addressed in the EA.

Should you have any questions regarding this proposal please contact Vince Fallico, Project Officer, Development Coordination on telephone 8289 3930.

Yours sincerely

20.10.09

for Brad Mullard
Executive Director Mineral Resources

RTA

258.5395 94/4 2; C09/1209

The Manager, Mining
NSW Department of Planning
GPO Box 39
SYDNEY NSW 2001

Dear Sir

Baal Bone Colliery Continuation of Operations – Director General's Requirements

I refer to correspondence from Mr Howard Reed dated 8 October 2009 (reference S03/03083) concerning the endorsement of the Director-General's Requirements (DGRs).

It is noted that Baal Bone Colliery has development consents which allow transportation of coal via both road and rail and that the Castlereagh Highway is the currently approved road haulage route for transportation to local markets at currently approved quantities. Further that road haulage of coal via this route has been approved until December 2015 subject to detailed reviews of alternative coal haulage options every three years.

The following comments should be considered in the Environmental Assessment:

Traffic Study: A traffic study is to be undertaken which includes, but is not limited to, origin-destination of vehicles, including staff, contractors, construction, and maintenance personnel during all stages of the project/development. Any cumulative impacts associated with the concurrent operation of the Project with other existing or approved mining operations in the region should also be considered. The study should include vehicle types, volumes and times of peak travel and include existing, proposed, and 10 year projected figures for Castlereagh Highway, associated roads and the development access intersection.

Road Safety Audit: A road safety audit should be undertaken of the roads noted in the 'Traffic Study' to allow assessment of the suitability for the proposed traffic volumes and types, including 10 year projected traffic figures, on these roads and any requirements for remedial works or restricting access by mine related vehicles to these roads. Current reviews of alternate coal haulage options every three years are strongly supported.

Speed & Fatigue Management: Employee and contractor vehicle speed on public roads, and employee and contractor driver fatigue, are of significance under the conditions proposed for this development with 24 hour operation.

School Bus Route: There is potential for conflict between employee and contractor vehicles with school buses. Consideration should be given to the timing of shift changes to be outside the normal operating times of school buses.

Roads and Traffic Authority ABN 64 480 155 255

51-55 Currajong Street Parkes NSW 2870
PO Box 334 Parkes NSW 2870 DX20256
www.rta.nsw.gov.au | 13 17 82

Train Operations Study: The number, timing, length and travel speed of trains should be assessed, with particular attention to safety and efficiency of level crossings. This study is to cover the extent of travel between the coal loader and a point where trains can reasonably be expected to have reached normal line operating speed; should no level crossings be encountered in this distance further investigation is not required.

Subsidence: Affect on public roads where there is a potential for subsidence.

Blasting: Affect on public roads where there is potential for blasting to affect operation or structures such as bridges.

Should you have any further enquiries please contact Joe Sulicich on 08 8082 6625.

Yours faithfully

Stuart Peden
A/Road Safety and Traffic Manager
Western

NSW GOVERNMENT | Office of Water

Howard Reed
Department of Planning
GPO Box 39
SYDNEY NSW 2001

Contact: Tim Baker
Phone: 02 6841 7403
Fax: 02 6884 0096
Email: Tim.Baker@dnr.nsw.gov.au

Attention: Paul Freeman

Our ref: ER20871
Your ref: S03/03083

8 December 2009

Dear Mr Freeman

Subject: BAAL BONE MINE - LONGWALLS 29-31 – DIRECTOR GENERALS REQUIREMENTS

I refer to the Preliminary Environmental Assessment (PEA) dated 26 August 2009 for the proposed expansion at Baal Bone Colliery, Cullen Bullen. The NSW Office of Water (NOW) has reviewed this document and provides the following input to assist the proponent in preparation of the Environmental Assessment.

Outcomes

NOW requires the Environmental Assessment (EA) for the proposal to demonstrate that the proposed mining operation will achieve the following:

- no hydraulic connection between the mining operation and surface water sources, including the Coxs River catchment, Coxs River Swamp and the Turon River catchment.
- no impact on adjacent licensed water users, basic landholder rights, or minimum base flows, or groundwater-dependent ecosystems
- adequate water licensing under the *Water Act 1912* for existing and proposed groundwater extraction and groundwater interception, and compliance with the S.113A *Water Act 1912* embargo on groundwater licences in the Murray Darling Basin which is provided as a supplement to this letter.

Key Issues

NOW requires the Environmental Assessment (EA) for the proposal to demonstrate the following:

1. Adequate and secure water supply.
2. Identification of site water demands, water sources (surface and groundwater), water disposal methods and water storage structures in the form of a water balance. This is to also include details of any water reticulation infrastructure that supplies water to the site.
3. Proposed water management on the site based on the site water balance. This is to also include an outline of a proposed surface water and groundwater management plan.

4. An assessment of impact on adjacent licensed water users, basic landholder rights, and groundwater-dependent ecosystems.

5. Requirement to intercept groundwater and predicted dewatering volumes, seepage volumes, water quality and disposal/retention methods. Intercepted and dewatered volumes need to be predicted throughout mine life and for any post mine life recovery period to reach equilibrium.

6. Restoration works along Ben Bullen Creek to be in accordance with the stream categorisation and objective setting approach, and DWE's guidelines for Controlled Activity Approvals. Further information on this is provided in Attachment 1.

7. Identification of works requiring licensing under the *Water Act 1912* or *Water Management Act 2000,* eg. monitoring bores, aquifer interception, groundwater extraction.

8. Adequate mitigating and monitoring requirements to address surface and groundwater impacts.

Groundwater Licensing

NOW advises that groundwater licensing at the Baal Bone site is subject to the requirements of the *Water Act 1912* which is not exempt from approval under Part 3A of the *Environmental Planning and Assessment Act 1979.* NOW has had informal communication with Tony King from Baal Bone Colliery advising of the requirement for all groundwater extraction and/or interception to be licensed appropriately, which includes the need for all volumes to be accounted for by licensed entitlement. This is a current policy requirement of the Office of Water to manage the groundwater sources and impacts in the area, and to assist in the transition to the *Water Management Act 2000* in 2010 which has a legislative requirement for all volumes to be accounted.

The licenses currently held by Wallerawang Collieries Ltd for Baal Bone Colliery for dewatering/drainage activities do not have a volume, hence it is the proponent's obligation to provide the relevant information and to ensure the necessary licences are amended or obtained. This will require the proponent to initially predict the volumes to be dewatered and intercepted throughout the mine life and in any recovery period. Adequate entitlement is required for both active extraction and induced inflows created by void establishment and/or aquifer fracturing.

In determining the predicted dewatering and seepage volumes NOW requests this information to be provided on a surface water catchment basis, specifically the Coxs River catchment and the Turon River catchment. This is due to differing legislative requirements between catchments. Groundwater licensing in the Turon River catchment is currently subject to the NSW Inland Groundwater Shortage Zone Order 2 embargo. NOW advises that this embargo prevents applications being made for additional groundwater entitlement. The proponent however has the ability to make application for an exemption to this embargo and these are listed under Schedule 2. If an exemption application is approved, NOW would be able to receive a licence application under the *Water Act 1912* which would require a licensing assessment prior to approval. The proponent alternatively has the ability to obtain the necessary water entitlement through the purchase and transfer of entitlement from existing users in accordance with the "*Guideline to the Policy for Groundwater Transfers in Inland NSW outside water sharing plan areas*". This guideline can be found at the following link:

http://www.water.nsw.gov.au/Water-Management/Water-availability/Groundwater/default.aspx

State Government Technical and Policy Documents

Groundwater

NSW State Groundwater Policy Framework Document (1997)
NSW State Groundwater Quantity Management Policy (1998)
NSW State Groundwater Quality Protection Policy (1998)
NSW State Groundwater Dependent Ecosystems Policy (2002)
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)
Australian and New Zealand Guidelines for Water Quality Monitoring and Reporting (2000)
Guidelines for the Assessment and Management of Groundwater Contamination (2007)
Guidelines for Groundwater Protection in Australia (1995)
Guideline to the Policy for Groundwater Transfers in Inland NSW outside water sharing plan areas

Surface Water

NSW State Rivers and Estuaries Policy (1993)
NSW Wetlands Management Policy (1996)
Guidelines for Controlled Activity Approvals

Mining Activities

Management of stream/aquifer systems in coal mining developments guideline (2005)

Further detail is provided on the next five pages on what information is required in the EA in order to address the issues raised above.

Based on the need to address critical water licensing issues at this site, it is recommended the proponent contact NOW to discuss this further. Tim Baker is the appropriate contact on (02) 6841 7403.

Yours sincerely



Tim Baker
Senior Planning and Assessment Coordinator

cc: Tony King, Baal Bone Colliery

ATTACHMENT 1

General Environmental Risk Analysis

The Environmental Assessment report must include the following for all water-related aspects of the proposal:

- an environmental risk analysis to identify potential environmental impacts associated with the project (construction and operation);
- proposed mitigation measures and potentially significant residual environmental impacts after the application of proposed mitigation measures; and
- where additional key environmental impacts are identified through this environmental risk analysis, an appropriately detailed impact assessment of these additional key environmental impacts must be included in the Environmental Assessment report.

Water supply and water balance

The Environmental Assessment must include assessment of water supply and/or water interception and extraction against any Water Sharing Plan, or any embargo in force affecting the site or potential water supply to the proposal. A full description of water supply to all stages of the proposal must be included, which includes:

- water source(s) which may be used to supply water to the proposal, and a checklist against any regulatory water sharing or other ministerial plans or other instruments applying to that water source
- explanation of any embargoes or full commitment declarations for the proposal, and any identified means to source water supply for the proposal
- examination of reliability of water supply to the proposal, including alternatives to site rainfall runoff harvesting in the event of drought
- demonstration of prioritisation and effective reuse of saline or other contaminated water within the proposal
- explanation of water circuitry and means to segregate contaminated, sediment-laden and clean water volumes within the proposal and proposal site

Groundwater Resource Protection

The Environmental Assessment report must include demonstration that the project is consistent with the spirit and principles of the NSW State Groundwater Policy Framework Document, the NSW State Groundwater Quality Protection Policy, the NSW State Groundwater Dependent Ecosystems Policy and the Draft NSW State Groundwater Quantity Management Policy. This must include, for the pre-, during, and post- development phases of the project the following:

- identification of surrounding water users and any groundwater dependent ecosystems;
- detailed explanation of potential groundwater volume, piezometric level, water table heights and the direction of flow and quality, through mine life and projections into the post-mine period, applying to the connected alluvium to Glennies Creek, any identified aquicludes/aquitards underlying the connected alluvial water source and all seams targetted for extraction
- detailed explanation of groundwater drawdown or other impacts upon connected groundwaters associated with the Goulburn River water source, compared with all predicted seepage flow migrating from fractured hard rock into the proposed underground mine workings

- explanation of the site water balance for the proposed extension and total site operations, including any changes to water balance inputs from rainfall runoff and/or groundwater seepage to the open cut extension;
- detailed description of any proposed water supply system utilising groundwater as a source, and assessment of current licensing arrangements against this;
- detailed analysis of the impacts of dewatering if required for the project, identifying the magnitude and duration of pumping, the areal extent of water level drawdown, the likely quality of extracted groundwater, alterations to site water balance, and the monitoring and reporting protocols to be adopted to meet licensing requirements;
- measures to prevent contamination of either the Goulburn River water source, or its connected alluvium resulting from changes in groundwater tables;
- identification of potential and likely groundwater-dependent ecosystems, and any impact upon these ecosystems which may result from the proposal; this must include
    - Terrestrial vegetation with seasonal or episodic reliance on groundwater, and
    - Aquatic and riparian ecosystems in, or adjacent to, streams or rivers dependent upon the input of groundwater to minimum base flows

Protection of the waterways and riparian land

The NOW encourages and supports the rehabilitation of waterways and vegetated riparian zones on the site and recommends the proposal seeks to protect, maintain and restore waterways as natural systems and the values and functions of riparian land at the Baal Bone Colliery site.

The NOW's considerations for protecting and enhancing waterways and riparian lands are embodied in natural resource policy documents including:

- The New South Wales State Rivers and Estuaries Policy. The objective of the policy are to manage the rivers and estuaries of NSW in ways which:
  - *Slow, halt or reverse the overall rate of degradation in their systems*
  - *Ensure the long term sustainability of their essential biophysical functions, and*
  - *Maintain the beneficial use of these resources.*
- The New South Wales Wetlands Management Policy
- The State Natural Resource Management (NRM) Targets (particularly Targets 1 and 5) covered by priority E4 in the State Plan:
  - *Target 1: By 2015 there is an increase in native vegetation extent and an improvement in native vegetation condition*
  - *Target 5: By 2015 there is an improvement in the condition of riverine ecosystems.*
- State wide manual: Managing Urban Stormwater: Soils and Construction (NSW Government, Chapter 5 4th edition 2004) (the Blue Book).

Stream Classification:

The NOW has undertaken desk top assessment of the waterways in the vicinity of the site using the Riparian Corridor Management Study / Riparian Corridor Objective Setting (RCMS/RCOS) stream categorisation of watercourses to identify minimum riparian corridor widths along watercourses.

The RCMS/RCOS stream classification uses three categories which reflect the environmental significance of watercourses. The minimum widths to achieve the riparian categories are as follows:

Category 1 – Environmental Corridor (Red)

- Purpose: to protect and enhance ecological connectivity between key remnant native vegetation within and between catchments.
- Minimum width : a CRZ width of **40 metres** (measured from the top of bank) along both sides of the watercourse **+ a 10 metre** vegetated buffer (VB)

Category 2 – Terrestrial and Aquatic Habitat (Green)

- Purpose: to provide for a viable and robust node or reach of riparian habitat (both aquatic and terrestrial)
- This habitat does not necessarily provide connectivity to other key remnant native vegetation due to constraints from existing development.
- Minimum width: a CRZ width of **20 metres** (measured from the top of bank) along both sides of the watercourse **+ a 10 metre** VB.

Category 3 – Bank Stability and Water Quality (Blue)

- Category 3 recognises the critical role of riparian vegetation for stabilising the bed and banks of watercourses and filtering catchment run-off and the contribution this makes to overall catchment health and retention of land (eg protection of property and assets).
- Minimum width: a CRZ width of **10 metres** (measured from the top of bank) along both sides of the watercourse (generally no vegetated buffer is required)

Note: Category 1 and 2 watercourses comprise two distinct zones (the CRZ and VB). Category 3 watercourses are only required to comprise a CRZ. The CRZ is the land contained adjacent to (and including within) the channel of the watercourse. A VB is that part of the riparian corridor that is outside the CRZ.

Please note, the above riparian widths are minimum widths and opportunities for achieving greater corridor widths are encouraged. Additional width may be required for geomorphological and environmental considerations (eg to protect and enhance remnant native vegetation adjacent to the riparian corridor and biodiversity). The riparian zones should be protected and/or enhanced with native riparian vegetation.

Stream Mapping at the site:

The NOW has desk top mapped and classified the waterways at the site and the proposal should be consistent with the stream categorisation.

The NOW recommends the EA provides on a scaled plan the location of:

a. all waterways (watercourses, creeks, rivers and wetlands) at the site and top of bank ,
b. the riparian zones, including the Core Riparian Zone (CRZ) and Vegetated Buffers
c. any Asset Protection Zone requirements,
d. the footprint of the proposed development and any other areas of disturbance,
e. any proposed revegetation of the riparian land
f. land uses associated with the proposal which are proposed to be located adjacent to the riparian zones (eg roads, basins and any other works adjacent to the riparian corridor).

The EA needs to identify any waterways and riparian land which may potentially be adversely impacted by the project and the mitigative measures to protect and enhance the waterways and riparian zones

The NOW recommends the proposal incorporates the following outcomes:

(i) the riparian zones to be retained/ rehabilitated in accordance with RCMS stream categorisation,
(ii) The CRZ width be measured from top of bank in accordance with the RCOS categories
(iii) The CRZ and VB is to remain, or become vegetated, with fully structured local native vegetation (trees, shrubs and groundcover species) at a density that would occur naturally
(iv) Any Asset Protection Zone (APZ) requirement be located outside the CRZ or VB.
(v) All uses be located outside the CRZ and VB (with the exception of environmental protection works, drainage and crossings (e.g. roads, service utilities, paths)
(vi) Any waterway crossings be designed and constructed in accordance with *the DWE Guidelines for Controlled Activities Watercourse Crossings (February 2008).*

Surface Water Resource Protection

The Environmental Assessment report must include demonstration that the project is consistent with the spirit and principles of the NSW State Rivers and Estuaries Policy, Wetlands Management Policy, and relevant groundwater policies defined below. This must include, for the pre-, during, and post- development phases of the project the following:

- general description of channel form, river style or other descriptive category of any affected channel, including identification of key geomorphologic indicators and conditions within the zone of influence for the proposal (ie either between most distant riverine controls surrounding the area of disturbance to the proposal area, and/or within the area of groundwater depressurisation)
- hydrologic character of the riverine system, stream energy and power relationships, energy relationships at bankfull height and at peak flow and assessment of stream power and critical tractive stress for existing and any modified conditions for any rivers affected by the proposal, which provides details of:
  - long profile and cross sectional survey along the channel, and identification of at least the closest upstream and downstream controls on the channel
  - assessment of bed and bank material, identification of critical entrainment and destabilisation thresholds
  - assessment of the constriction and resultant change in afflux through, past or over the structure, and resultant changes in energy profiles involving the structure
  - nature of bedload transport, and mechanism(s) to permit bedload transport through the structure
- procedures to develop stream relocation and reconstruction criteria which utilise best practice management, which must include the principles which underpin any embargoes currently in force under the *Water Act, 1912*, or operational rules of any Water Sharing Plan in force over the site
- methodologies by which proposed relocation or reinstatement of watercourses will be undertaken, and whether any proposed ecological offset provisions will provide adequate protection to any instream or groundwater dependent ecosystems which exist on the site

- Mechanism to maintain long profile grade through the structure, or to provide energy dissipation through the structure at the re-entry point design volumes/velocity downstream
- Nature of existing controls along all watercourses on the site, and proposed use of engineered structures and vegetation to provide long term control to the channel
- final configuration of any relocation, modification or other impact upon rivers and watercourses on or surrounding the site, including geomorphic character mimicking conditions of undisturbed rivers or watercourses adjacent to the proposal area

Rehabilitation, Landform or Void Rehabilitation

The Environmental Assessment report must include:

- justification of the proposed final landform with regard to its impact on local and regional groundwater systems;
- a detailed description of how the site would be progressively rehabilitated and integrated into the surrounding landscape;
- detailed modelling of potential groundwater volume, flow and quality impacts of the presence of an inundated final void on identified receptors specifically considering those environmental systems that are likely to be groundwater dependent;
- a detailed description of the measures to be put in place to ensure that sufficient resources are available to implement the proposed rehabilitation; and
- the measures that would be established for the long-term protection of local and regional aquifer systems and for the ongoing management of the site following the cessation of the project.

Your reference: S03/03083
Our reference: LIC07/2615-02: DOC09/49031
Contact: Andrew Helms, (02) 6332 7604

Mr Howard Reed
Major Projects Assessment - Mining and Industry
NSW Department of Planning
GPO Box 39
SYDNEY NSW 2001

16 October 2009

Dear Mr Reed

I refer to your letter, dated 8 October 2009, seeking the Department of Environment, Climate Change and Water's (the Department) Director General's requirements for Wallerawang Collieries Limited's application under part 3A of the *Environmental Planning and Assessment Act, 1979* for the continued operation of the Baal Bone Colliery.

The Department has reviewed the Director-General's requirements included in your draft letter to Wallerawang Collieries Limited and endorses the content there-in with respect to air, water and noise pollution, Aboriginal cultural heritage and threatened flora and fauna matters. Please note however, that the Office of Water (formerly the department of Water and Energy), while part of the Department, has sole responsibility for the regulation of the *Water Management Act, 2000*. Accordingly, in this instance NSW Department of Planning should seek comment on the draft Director General's requirements directly from the Office of Water.

Should you wish to discuss these matter further please contact Andrew Helms at the Department's Bathurst Office by telephoning (02) 6332 7604.

Yours sincerely

RICHARD WHYTE
Manager Bathurst
Environment Protection and Regulation

PO Box 1388 Bathurst NSW 2795
203-209 Russell Street Bathurst NSW
Tel: (02) 6332 7600 Fax: (02) 6332 7630
ABN 30 841 387 271
www.environment.nsw.gov.au

16. OCT. 2009 13:30 DECC EPRG BATHURST NO. 173 P. 2/2

GWr
Regional Services

Received
21 OCT 2009
Major Development Assessment

16 October 2009

NSW Department of Planning
Major Development Assessment
Mining & Industry
GPO Box 39
SYDNEY 2001

ATTN: Howard Reed/Paul Freeman

PROPOSED CONTINUATION OF OPERATIONS – BAAL BONE COLLIERY

I refer to the above application and advise that Council has investigated the documentation provided and can concur with the Director Generals requirements for the lodgement of an Environmental Assessment for the continued operation at Baal Bone Colliery.

Please do not hesitate to contact Gary Wallace in Council's Regional Services Division should you require any additional information in relation to this matter.

Yours faithfully

Mr Andrew Muir
GROUP MANAGER REGIONAL SERVICES

(02) 6354 9999
(02) 6351 4259
www.lithgow.nsw.gov.au
council@lithgow.nsw.gov.au
ADDRESS CORRESPONDENCE
TO GENERAL MANAGER
PO BOX 19, LITHGOW NSW 2790

Tilden, Kate

From: Tilden, Kate
Sent: Wednesday, November 11, 2009 10:50 AM
To: 'joe.sulicich@rta.nsw.gov.au'
Cc: 'howard.reed@planning.nsw.gov.au'; 'Paul Freeman'; England, Michael; 'tking@xstratacoal.com.au'
Subject: Baal Bone Colliery Environmental Assessment

Dear Joe,

AECOM is preparing an Environmental Assessment (EA) for the continued operations at Baal Bone Colliery. Correspondence received from the RTA indicated that a road safety audit would be required as part of the EA.

As discussed with Michael England this morning, the project involves the continuation of current operations at the Colliery. Currently, coal is transported from the Colliery via rail, although the Colliery holds an existing consent to transport up to 900,000 tonnes of coal per annum via road to local power stations. While it is not envisaged that road haulage will recommence at this stage, Baal Bone Colliery will retain the existing consent as part of operations at the site.

Given that no additional traffic would be generated above what is approved under the existing development consent, a full road safety audit is not considered to be required.

As discussed with you, AECOM is proposing to undertake a road assessment which considers the Castlereagh Highway from the intersection of the Colliery's private access road, south to Boulder Road and the access to Mt Piper Power Station, and from Boulder Road / Castlereagh Highway intersection south to the Wallerawang Power Station access from the Castlereagh Highway.

The assessment would examine the condition of the existing road network to identify issues that may arise if road traffic volumes from the Colliery were to increase from the existing level. The assessment would consider the following:

- Number of lanes;
- Alignment;
- Visibility / sight distance;
- Intersection layout;
- Presence of safety barriers; and
- Speed limits.

Mitigation measures would be recommended as required, if traffic volumes were to increase from the Colliery.

Could you please confirm by return email that the above proposed scope for the road assessment would satisfy the RTA's requirements for this project?

Please do not hesitate to contact Michael England on 0400 369 775 or myself on 02 8484 8934 if you wish to discuss further.

Regards,

Kate Tilden
Project Scientist
D +61 2 8484 8934
Kate.Tilden@aecom.com

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Level 5, 828 Pacific Highway, Gordon, NSW 2072
PO Box 726 Pymble NSW 2073
T +61 2 8484 8934 F +61 2 8484 8989
www.aecom.com

Please consider the environment before printing this email.

Tilden, Kate

From: FRANCIS Fiona K [Fiona_FRANCIS@rta.nsw.gov.au]
Sent: Friday, November 13, 2009 1:52 PM
To: Tilden, Kate; 'paul.freeman@planning.nsw.gov.au'
Cc: SULICICH Joe
Subject: RE: Baal Bone Colliery Environmental Assessment

Hi Kate,

I have been speaking with Joe Sulicich regarding your below email, he is currently out of the office and has requested me to reply on his behalf.

In addition to the points outlined below, the road assessment or traffic study is also to include the cumulative traffic impacts of existing approved developments along the Castlereagh Highway. This would include assessment of approved haulage (tonnage) for surrounding mining sites together with the haul tonnage for Baal Bone.

A formal road safety audit will not be required.

Regards,

Fiona Francis
Development Assessment Officer
RTA Western
02 68611688
0417 431 982

From: Tilden, Kate [mailto:Kate.Tilden@aecom.com]
Sent: Wednesday, 11 November 2009 3:14 PM
To: SULICICH Joe
Subject: FW: Baal Bone Colliery Environmental Assessment

From: Tilden, Kate
Sent: Wednesday, 11 November 2009 10:50 AM
To: 'joe.sulicich@rta.nsw.gov.au'
Cc: 'howard.reed@planning.nsw.gov.au'; 'Paul Freeman'; England, Michael; 'tking@xstratacoal.com.au'
Subject: Baal Bone Colliery Environmental Assessment

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- Speed limits.

Mitigation measures would be recommended as required, if traffic volumes were to increase from the Colliery.

Could you please confirm by return email that the above proposed scope for the road assessment would satisfy the RTA's requirements for this project?

Please do not hesitate to contact Michael England on 0400 369 775 or myself on 02 8484 8934 if you wish to discuss further.

Regards,

Kate Tilden
Project Scientist
D +61 2 8484 8934
Kate.Tilden@aecom.com

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APPENDIX B

Stakeholder Newsletter

Baal Bone
Continued mining operations

Community information sheet
June 2009

Continued Operations at Baal Bone Colliery

The Wallerawang Collieries Limited (TWCL) is proposing to continue its existing mining operations at Baal Bone Colliery, Cullen Bullen, beyond the expiration of its existing development consent in August 2010. The purpose of this newsletter is to introduce the project to the community and identify points of contact for further information.

Baal Bone is located on the Castlereagh Highway approximately 5 km north-east from the township of Cullen Bullen. The site, including the existing mining lease boundary is shown in Figure 1.

The primary development consent under which Baal Bone Colliery operates expires on 1 August 2010 due to provisions in NSW legislation. Under the State Environmental Planning Policy (Major Projects) 2005 (Major Projects SEPP), underground mining which occurs on or after 1 August 2010 is required to obtain a Project Approval under Part 3A of the Environmental Planning and Assessment Act 1979.

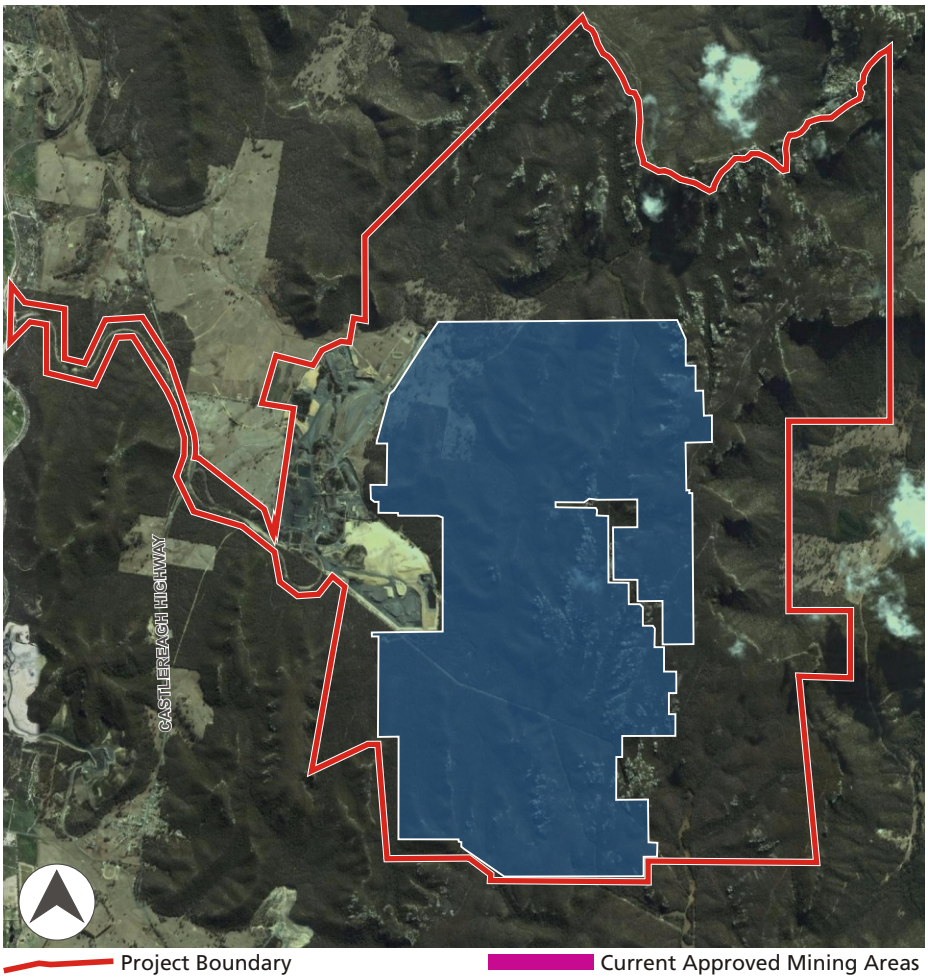
The Colliery has an expected life beyond 2010, and as such, a Project Approval under Part 3A is required for Baal Bone to continue existing underground mining operations, and operation of existing surface infrastructure.

TWCL has engaged ENSR Australia Pty Ltd (trading as AECOM) to prepare a Project Application and an accompanying Environmental Assessment (EA) to assess potential environmental impacts of the continued operations at Baal Bone Colliery.

The project includes the following components:

- Continued operation of existing surface infrastructure including the Coal Handling and Preparation Plant, coal stockpiles, and other facilities;
- Continuation of current and approved underground longwall mining;
- Continued haulage of coal to markets in accordance with current approvals; and
- Potential mining of other isolated remnant unmined areas within the existing workings.

TWCL is seeking Project Approval for the proposal under Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A Act).



Project Boundary
Current Approved Mining Areas
Previous Underground Mining Areas

What's happened so far?

AECOM has prepared a Project Background Report which discusses the key issues to be considered in the EA and has lodged it with the Department of Planning (DoP). The Project Background Report will be used by the DoP to determine the likely environmental impacts of the project. The DoP would then issue the Director-General's Requirements, which would detail the issues to be assessed in the EA.

Preliminary stakeholder consultation has been undertaken for the proposed project with stakeholders including community representatives, non-government organisations, and statutory agencies. This consultation included discussions on the proposed continuation of operations at Baal Bone, as well as discussions regarding a potential new area of proposed underground mining within the northern section of the existing lease boundary.

Since the preliminary consultation was undertaken an additional assessment of the economic viability of this area has been undertaken. As a result, proposed northern underground mining will no longer be assessed as part of the EA, currently in preparation.

As part of the preliminary consultation, a stakeholder meeting was held with nearby landowners and members of the Baal Bone Community Consultative Committee on 29 January 2009 at Cullen Bullen. This meeting provided an introduction to the project, background information and the opportunity for attendees to discuss any environmental issues of concern regarding the project. The AECOM Project Team also discussed how these issues would be addressed in the EA.

Preliminary consultation with local Aboriginal groups has also been undertaken in accordance with the Department of Environment and Climate Change Interim Guidelines. In addition face to face meetings have been held with the Colong Foundation and the Blue Mountains Conservation Society.



What's happening next?

AECOM has commenced preparation of the EA. As part of the assessment, a number of specialist studies are being undertaken to ensure that potential impacts to the environment are identified and that appropriate environmental safeguards can be implemented. The specialist reports addressing air quality, groundwater, surface water, noise, flora, fauna and heritage issues, reject and tailings management, are anticipated to be completed by July 2009. Other matters to be addressed as part of the EA include social and economic impacts, mine closure and rehabilitation, odour, traffic and land use.

The EA is expected to be lodged with the Department of Planning for public exhibition second half of 2009.

Ongoing communication with the community

AECOM's Project Team will be providing the community with updates on the project throughout the EA process. A second community newsletter will be sent out once the specialist reports have been prepared. This newsletter will provide information about the findings of the specialist reports.

In addition, information regarding the continued operations at Baal Bone Colliery will be provided at meetings with the existing Baal Bone Community Consultative Committee (CCC). Interested community members can also contact the AECOM Community Consultation Coordinator. Contact details are provided below.

Who can I contact for further information?

If you have any queries or would like to learn more about the project, you can contact Kate Tilden (AECOM Community Consultation Coordinator) in one of the following ways:

Phone: 02 8484 8999
Fax: 02 8484 8989
Email: baalbone@aecom.com
Postal Address: Baal Bone Continued Operations Environmental Assessment Community Liaison
C/- AECOM
PO Box 726
Pymble NSW 2073

For further information contact:
Kate Tilden
AECOM Community Consultation Coordinator
Telephone (02) 8484 8999
Email baalbone@aecom.com



APPENDIX C

Subsidence Impact Assessment Reports

SCT Operations Pty Ltd
ABN 23 078 328 953
www.sct.gs

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Cnr Kembla & Beach Streets Wollongong NSW 2500 Australia
PO Box 824 Wollongong NSW 2520 Australia
Telephone: + 61 2 4222 2777 Fax: + 61 2 4226 4884
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Telephone: +61 3 5443 5941
Email: s.macgregor@sct.gs

11 December 2009

Tony King
Environment and
Community Co-ordinator
Baal Bone Colliery
PO Box 13
LITHGOW NSW 2790

Dear Tony,

CURRENCY OF SCT SUBSIDENCE IMPACT ASSESSMENT REPORTS FOR CONTINUED OPERATIONS AT BAAL BONE COLLIERY

Baal Bone Colliery is seeking Project Approval under Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A Act) for continued mining operations at the mine. SCT Operations Pty Ltd (SCT) has previously undertaken subsidence assessment for Longwalls 29 to 31 and for possible future mining of isolated remnant areas within the existing mine footprint. Baal Bone Colliery commissioned SCT to confirm the currency of these previous assessments for the continued operations at the mine and to summarise the findings of these assessments. This letter confirms the currency of these previous assessments and provides a summary of the findings of the previous assessments.

1. BACKGROUND

Project Approval is being sought under Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A Act) for the continuation of operations at Baal Bone Colliery, including:

- Continuation of underground mining, including Longwalls 29 to 31, which are the subject of a current approved Subsidence Management Plan (SMP) and Mine Operations Plan (MOP);
- Mining of other isolated remnant areas within the footprint of the existing workings.

The mining of Longwalls 29 to 31 has previously been assessed and approved under Part 5 of the EP&A Act and in accordance with the Mining Act 1912. A subsidence assessment was prepared for Longwalls 29 to 31 by SCT (2007a) which assessed subsidence predictions and potential impacts on surface features in the vicinity. A more generic summary of previous experience of mining under cliff formations was undertaken at the same time SCT (2007b) as a supporting document describing the results of experience of mining under and close to sandstone cliff formations at Baal Bone Colliery.

A Subsidence Management Plan for Longwalls 29 to 31 was approved by DPI-MR, but Section 15 of the approval conditions required the development of a specific management plan for the Wolgan Escarpment. Baal Bone Colliery commissioned SCT to prepare a technical basis for this management plan (SCT 2008). This technical basis included reducing the width of Longwall 31 by 30m to enlarge the protection barrier to the Wolgan Escarpment.

The continued operations at Baal Bone also include the potential for mining various remnant areas located within the footprint of the existing mine workings using pillar extraction methods. Baal Bone Colliery commissioned SCT to identify surface features within the proposed mining area likely to require particular consideration during the design of mining operations (SCT 2009).

The findings of these reports remain current except for SCT Report BBO3248 which is based on Longwall 31 being at full width of 250m. Following the acceptance of the recommendations in the subsequent SCT Report BBO3432, Longwall 31 was reduced in width by 30m to 220m wide.

2. SUMMARY OF FINDINGS OF SCT REPORTS

In this section, the findings of the four SCT reports referred to in the previous section are summarised. The full reports are included as attachments to this covering letter.

2.1 SCT Report BBO3248

SCT Report BBO3248 was prepared at a time when Baal Bone Colliery was proposing to mine Longwalls 29, 30 and 31 in an area to the south and east of previous longwall panels at the mine. The colliery commissioned SCT Operations Pty Ltd to undertake a subsidence assessment suitable for submission as part of the SMP Approval Documentation being prepared by Xstrata Coal (Baal Bone). The report presents an assessment of the subsidence and subsidence impacts that are expected to occur as a result of the proposed mining.

The report identifies that the natural features of most significance from a subsidence perspective are the Wolgan Escarpment and the major sandstone cliff formations to the south of the panels. By re-aligning the longwall panels and adjusting their width and length, these major natural features have been protected by design. The sheer face of the Wolgan Escarpment and all rock formations that are regarded as being associated with the escarpment are protected by an angle of draw of greater than 26.5°. Sandstone formations to the south of the longwall panels greater than 20m high are also fully protected with barriers based on angles of draw greater than 26.5°.

There is some potential for cracking of minor sandstone features located within and close to the edge of the mining area, but the potential significance of this impact is considered low and largely imperceptible.

Maximum subsidence is estimated to be 1.6m in the centre of each panel with less than 0.5m of subsidence over the chain pillars. Systematic tensile strains of up to 16mm/m and systematic compressive strains of up to 21mm/m are expected. Tensile strains are expected to be greatest on ridge tops and near the start of the panel. Compressive strains are expected to be greatest in valleys. Maximum ground tilt of up to approximately 50mm/m is expected to occur at a distance of approximately 0.3 times overburden depth from the goaf edge.

None of the subsidence impacts are particularly sensitive to the magnitude of the vertical subsidence or any of the strain and tilt parameters. Impacts on rock formations are more likely to be sensitive to location and orientation relative to the longwall panels, surface topography and the particular geometries of each formation.

The report concludes that the proposed design of these three longwall panels provides a good compromise between protecting surface features and maximising recovery of the underlying coal resource.

2.2 SCT Report BBO3259

SCT Report BBO3259 was prepared as a summary of previous experience of mining in the vicinity of steep topography and sandstone cliff formations at Baal Bone Colliery based on the colliery's ongoing program of subsidence monitoring. Baal Bone Colliery commissioned SCT to review this subsidence monitoring and summarise the findings with particular focus on the impacts of longwall mining on cliff formations. The report presents the results of the review that was undertaken and a summary of the findings.

Details of subsidence monitoring programs at Baal Bone Colliery are presented in SCT reports compiled at the completion of each longwall panel or, in some cases, each group of longwall panels. The review of these reports focuses on the results of particular relevance to the development of protection barriers for sandstone cliff formations. The results are consistent across a broad range of mining and cliff geometries so that the understanding of mining impacts on sandstone cliff formations is considered to be well developed.

The results of subsidence monitoring at Baal Bone Colliery and elsewhere indicate that rock falls are essentially limited to within the boundary of the mining area (i.e. that area directly above the longwall panels and the chain pillars isolated between adjacent longwall panels). There are a few cases where rock falls occur immediately outside the mining area (within 0.1 times overburden depth) when the slope below has been mined under, but the significantly larger subsidence movements that occur within the mining area clearly influence the likelihood of rock falls and other impacts.

Tension and shear fractures are commonly observed on sandstone cliff formations within the mining area. The orientation of these cracks appears to be influenced by the orientation of natural jointing deep within the overburden strata rather than the alignment of the longwall panel itself.

Tension cracks are also observed at distances up to approximately 0.4 times overburden depth from the edge of the mining area, decreasing in width as a function of distance from the goaf edge. Rock falls are not associated with the formation of these tension cracks.

The impacts of mining on sandstone cliff formations can be controlled by designing the size of the protection barrier between the edge of longwall mining and the sandstone cliff formations to be protected.

If there is no barrier and sandstone cliff formations are mined under, on average some 10-20% of the total length of sandstone cliff formations is likely to experience rock falls. This ratio may be locally higher in some cliff geometries depending on their height, shape, continuity and location and orientation relative to mining. Tension and shear cracking is likely to be perceptible over the area of sandstone cliff formations that have been mined under.

If the longwall panels are designed so that mining occurs right up to the edge of cliff formations, but they are not directly mined under, a moderate level of protection is provided. Tension cracking may be evident to a distance of 0.4 times overburden depth (typically about 80-100m) from the goaf edge, but rock falls are unlikely, particularly if mining occurs on the plateau side of the cliffs so that the slopes below the cliffs are not fully mined under.

If a protection barrier equivalent to 26.5° angle of draw (typically 100-120m) is provided between longwall mining and sandstone cliff formations, the impacts of mining become imperceptible and a high level of protection is provided to the cliff formations.

The width of the protection barrier necessary to protect cliff formations is less at the corners of longwall panels and is essentially the same whether mining is on the low side or the high side of the cliff formations.

Monitoring results also indicate that sandstone cliff formations can be substantially protected by limiting the width of individual longwall panels and maintaining substantial chain pillars between panels, but the widths required are unlikely to be economically viable from a mining perspective. A high level of protection is achieved if the width of individual longwall panels is limited to less than 0.3 times overburden depth (i.e. less than about 60m) and a moderate level of protection is provided if the mining width is limited to less than 0.6 times overburden depth (i.e. less than 120m).

It is noted that the sheer nature of sandstone cliff formations is testament to natural weathering processes that, from time to time, induce rock falls. The presence of a barrier to mining of any size does not preclude the possibility of rock falls occurring before, during or after mining, but subsidence monitoring indicates that the influence of mining can be removed with the provision of a protection barrier equivalent to 26.5° angle of draw, and substantially removed if mining does not proceed directly under cliff formations.

2.3 SCT Report BBO3432

SCT Report BBO3432 was prepared to address the requirements of Section 15 of the Subsidence Management Plan (SMP) Approval for Baal Bone Colliery Longwalls 29-31 for a specific management plan for the Wolgan Escarpment and subsequent discussions with the Department of Primary Industries. Baal Bone Colliery commissioned SCT Operations Pty Ltd to prepare a technical basis for a management plan based on previous experience of mining near high cliffs at the mine. The report presents the results of the assessment of the potential impacts based on previous experience, changes to the mine layout to provide additional protection, and recommendations for monitoring.

Previous experience indicated that reducing the width of Longwall 31 by 30m to an overall width of 220m and keeping the panel full length would ensure a high level of protection to the Wolgan Escarpment equivalent, at the northern pinch point, to the protection that has been provided to high escarpments at Baal Bone in the past and sufficient at the southern pinch point to prevent any potential for rock falls recognising the more stable nature of the cliff formation in this southern area.

There have been a variety of strategies used to determine the appropriate barrier to high cliffs such as the Wolgan Escarpment. An angle of draw of 26.5° is considered to be effective, but an additional barrier has typically been added for a range of reasons to do with mining geometry and cliff line geometry. At Baal Bone Colliery, previous experience indicates that the barrier has ranged from 20m to 85m with an additional barrier of 50m being the median. An angle of draw of 35° is equivalent to an angle of draw of 26.5° plus 40-50m at the pinch points on Longwall 31.

At the northern pinch point where the cliff formations of the Wolgan Escarpment are in a current state of imminent instability, a barrier equivalent to 26.5° angle of draw plus 50m is expected to be sufficient to demonstrate that any coincidental rock falls are not associated with mining activity. At the southern pinch point, the cliff formation is considered to be long term stable and a protection barrier equivalent to 26.5° angle of draw plus 30m is considered more than sufficient to protect against any potential for rock falls at this location.

Rock falls are a natural characteristic of the development of cliff features such as the Wolgan Escarpment, so it is not possible to fully protect against the possibility of a rock fall occurring naturally. The protection barriers proposed are considered to be more than sufficient to provide a high level of protection to the cliff formations of the Wolgan Escarpment. However, given the northern pinch point in particular is currently in a state of imminent instability, the monitoring program proposed is intended to demonstrate that Longwall 31 has an impact on the Wolgan Escarpment that is less than natural changes associated with diurnal and seasonal temperature variations.

Short subsidence lines and permanent reflectors along the top of the cliff formations are recommended to provide confirmation of the level of subsidence movement. Stress change monitoring within the cliff forming sandstones is expected to provide a greater resolution of change than is possible with subsidence monitoring. Stress change monitoring instruments at both the northern and southern pinch points are recommended. Monitoring of thermal changes within rock formations in the vicinity of the northern pinch point is recommended to give a measure of the natural variations in temperature experienced on the Wolgan Escarpment.

A higher level of investigation and monitoring, particularly at the northern pinch point, would involve detailed measurement of the cliff geometry using airborne terrestrial photogrammetry, in situ stress measurement within the cliff forming sandstone, laboratory testing of core samples recovered from monitoring holes, and an analysis of the likely state of stability of the sandstone cliff formations at the northern pinch point. The southern pinch point has already been assessed as stable and tolerant to subsidence movements anticipated at 26.5° angle of draw from the nearest goaf edge.

2.4 SCT Letter Report BBO3559

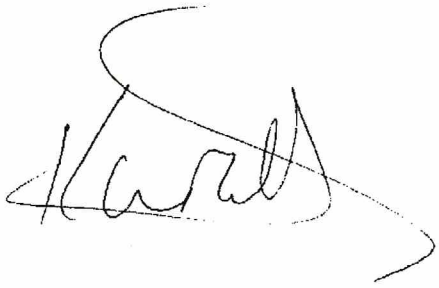
SCT Letter Report BBO3559 dated 10 August 2009 identified areas likely to require special consideration from a subsidence impact perspective during possible future pillar extraction operations in remnant pillar areas at Baal Bone Colliery.

The report indicates that there are three areas where cliff lines would be impacted if all the remnant areas were mined and one area where Ben Bullen Creek would be mined under at an overburden depth of approximately 40m. These four areas would need special consideration in terms of extraction layout design if potential subsidence impacts on the overlying surface features are to be maintained at low levels.

Similar surface features adjacent to all four areas have previously been impacted by longwall subsidence. However, the community tolerance to surface impacts has changed since these areas were longwall mined. It is anticipated that mining layouts would need to be designed to minimise surface subsidence to low levels to prevent rock falls on cliff formations and loss of surface water from Ben Bullen Creek without undue difficulty.

If you have any queries or would like further clarification of any of these issues, please don't hesitate to contact me directly.

Regards



Ken Mills
Senior Geotechnical Engineer

References:

SCT 2007a "Subsidence Assessment Longwalls 29, 30 and 31 Baal Bone Colliery" SCT Report BBO3248 to Baal Bone Colliery dated 13 March 2007.

SCT 2007b "Review of Subsidence Monitoring and Impacts of Mining on Sandstone Cliff Formations at Baal Bone Colliery" SCT Report BBO3259 to Xstrata Coal dated 24 April 2007.

SCT 2008 "Protection of Wolgan Escarpment from Longwall 31 Mining Subsidence" SCT Report BBO3432 to Baal Bone Colliery dated 9 December 2008.

SCT 2009 "Subsidence Zones In Remnant Areas at Baal Bone Colliery" SCT Letter Report BB3559 to AECOM dated 10 August 2009.



Strata Control Technology

REPORT TO:

BAAL BONE COLLIERY

Subsidence Assessment
Longwalls 29, 30 and 31
Baal Bone Colliery

BBO3248

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REPORT TO

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SUBJECT

Subsidence Assessment for Longwalls 29, 30 and 31 at Baal Bone Colliery

REPORT NO

BBO3248

PREPARED BY

Ken Mills

DATE

13 March 2007

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Senior Geotechnical Engineer

Winton J. Gale
Managing Director

SUMMARY

Baal Bone Colliery is proposing to mine Longwalls 29, 30 and 31 in an area to the south and east of previous longwall panels at the mine. The colliery commissioned SCT Operations Pty Ltd to undertake a subsidence assessment suitable for submission as part of the SMP Approval Documentation being prepared by Xstrata Coal (Baal Bone). This report presents our assessment of the subsidence and subsidence impacts that are likely to occur as a result of mining Longwalls 29, 30 and 31 at Baal Bone Colliery.

The natural features of most significance are considered to be the Wolgan Escarpment and the major sandstone cliff formations to the south of the panels. By re-aligning the longwall panels and adjusting their width and length, these major natural features have been protected by design. The sheer face of the Wolgan Escarpment and all rock formations that are regarded as being associated with the escarpment are protected by an angle of draw of greater than 26.5°. Sandstone formations to the south of the longwall panels greater than 20m high are also fully protected with barriers based on angles of draw greater than 26.5°.

There is some potential for cracking of minor sandstone features located within and close to the edge of the mining area, but the potential significance of this impact is considered low and largely imperceptible.

Subsidence parameters have been estimated from previous subsidence monitoring at Baal Bone Colliery and other collieries in the Western Coalfield based on guidelines for the Western Coalfield forwarded by Holla (1991).

Maximum subsidence is estimated to be 1.6m in the centre of each panel with less than 0.5m of subsidence over the chain pillars. Systematic tensile strains of up to 16mm/m and systematic compressive strains of up to 21mm/m are expected. Tensile strains are expected to be greatest on ridge tops and near the start of the panel. Compressive strains are expected to be greatest in valleys. Maximum ground tilt of up to approximately 50mm/m is expected to occur at a distance of approximately 0.3 times overburden depth from the goaf edge.

None of the subsidence impacts are particularly sensitive to the magnitude of the vertical subsidence or any of the strain and tilt parameters. Impacts on rock formations are more likely to be sensitive to location and orientation relative to the longwall panels, surface topography and to the particular geometries of each formation.

The proposed design of these three longwall panels is considered to provide a good compromise between protecting surface features and maximising recovery of the underlying coal resource.

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1. INTRODUCTION

Baal Bone Colliery is proposing to mine Longwalls 29, 30 and 31 in an area to the south and east of previous longwall panels at the mine. The colliery commissioned SCT Operations Pty Ltd to undertake a subsidence assessment suitable for submission as part of the SMP Approval Documentation being prepared by Xstrata Coal (Baal Bone). This report presents our assessment of the subsidence and subsidence impacts that are likely to occur as a result of mining Longwalls 29, 30 and 31 at Baal Bone Colliery.

The report is structured to provide:

- A description of the general area including the proposed mining geometry, overburden depth and other parameters relevant to a subsidence assessment.
- Detail of the features, both natural and man-made, that have been identified as likely to be impacted by mining subsidence.
- A review of the requirements of the SMP Approval process.
- A review of the results of previous subsidence monitoring at Baal Bone and at other sites where relevant.
- Subsidence estimates based on previous subsidence monitoring at Baal Bone Colliery and general experience.
- Specific assessments of the surface features identified.
- Recommendations for subsidence monitoring programs and strategies to manage the subsidence impacts identified.

2. SITE DESCRIPTION

Figure 1 shows a plan of the proposed longwall area, the SMP application area and the location of key surface features superimposed onto a 1:25,000 topographic series map of the area. The surface area is entirely undeveloped bushland located within Ben Bullen and Wolgan State Forests and some Crown land. The forests are managed by Forests NSW, a section of the NSW Department of Primary Industries.

Figure 2 shows more detailed plan of the site with the surface topography, seam floor contours (in the area for which they are available) and the location of the escarpment and other rock features superimposed onto the mine plan. The top of the escarpment and any rock features that have been assessed as being associated with the upper slopes of the escarpment are also shown.

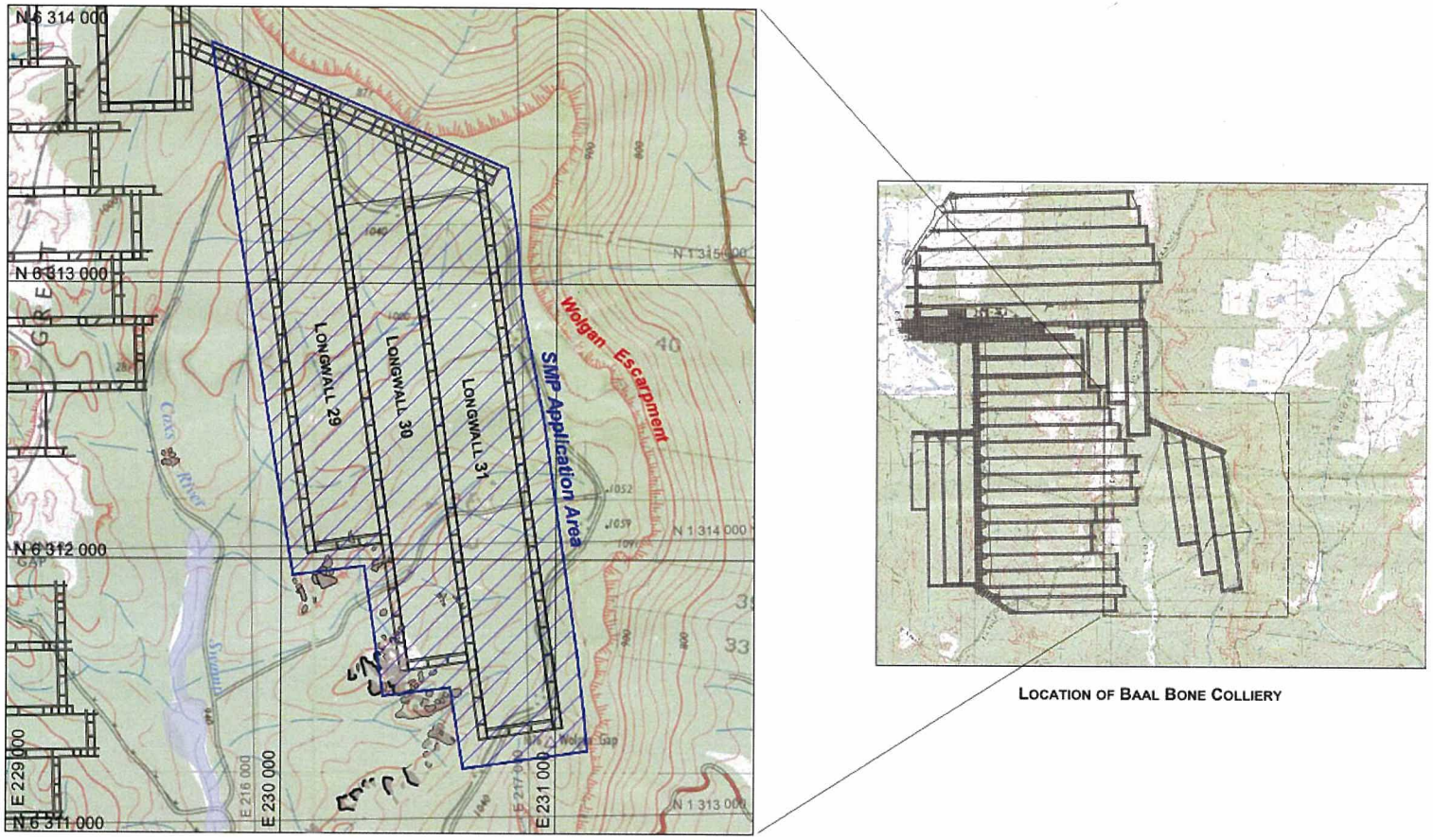


Figure 1 Siteplan showing proposed mine layout superimposed on 1:25,000 series topographic map (Cullen Bullen 8931-3-N).

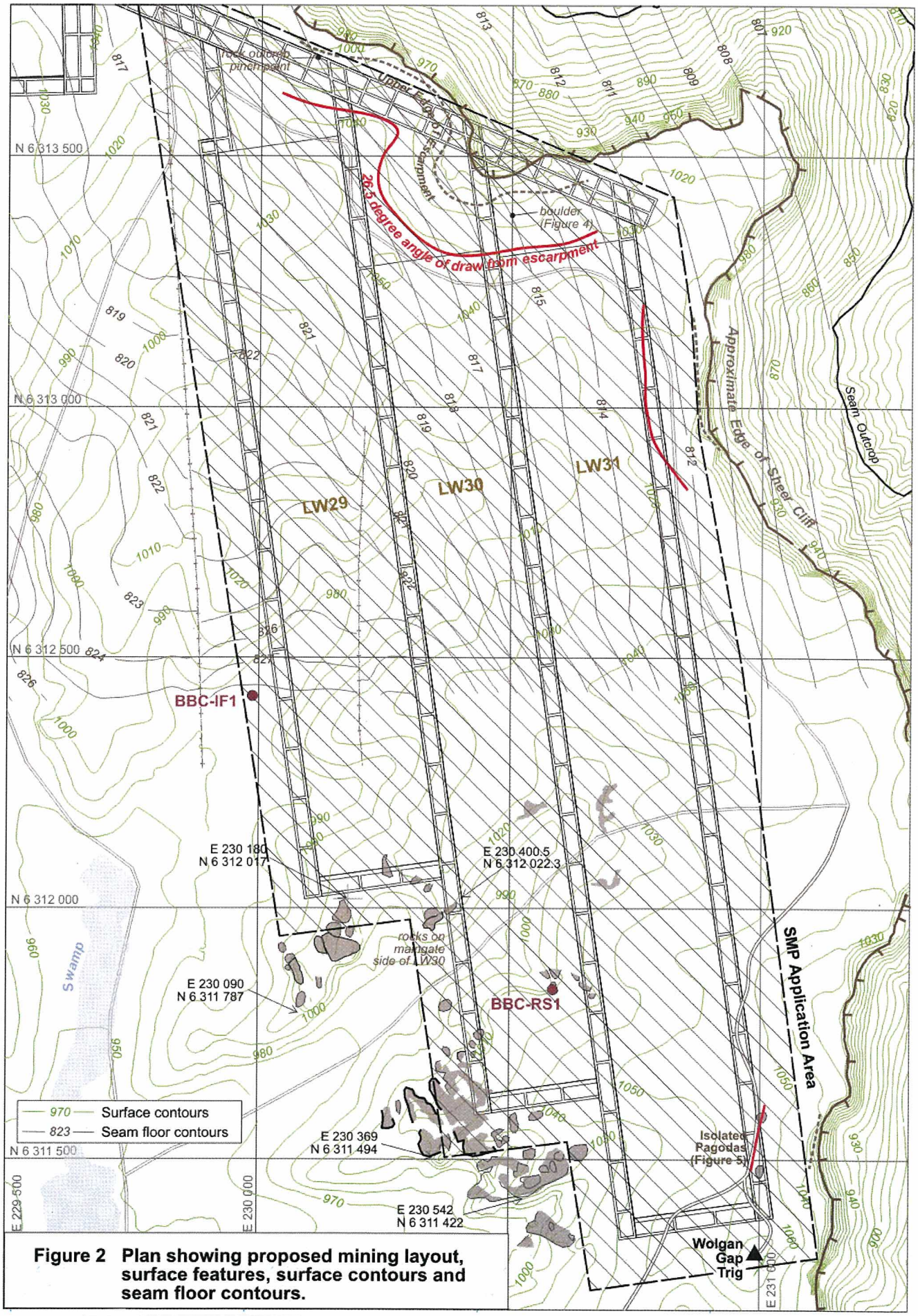


Figure 2 Plan showing proposed mining layout, surface features, surface contours and seam floor contours.

The longwall panels are proposed to be 250m wide (total void width) in Longwall 29, 226m wide in Longwall 30 and 250m wide in Longwall 31. The chain pillars and main heading pillars are proposed to be 25m wide (rib to rib).

The seam floor level ranges from approximately RL830m on the south-western part of Longwall 29 to RL813m on the eastern side of Longwall 31. Overburden depth varies mainly as a result of surface topography and ranges over the longwall panels from 150m below a valley midway along Longwall 29 to 240m at the southern end of Longwall 31. Typical overburden depth over most of the longwall area is in the range 200-230m. Seam thickness in this area is approximately 2.4m.

The main natural features in the vicinity of the proposed longwall area are the Wolgan Escarpment, other sandstone rock formations mainly at the southern end of the longwall panels and a swamp approximately 300m to the south-west of the longwall panels. Other features include archaeological sites, forestry and public access four-wheel drive tracks and the Wolgan Gap Trig.

The layout of the longwall panels has been designed to optimise resource recovery while providing protection against subsidence impacts for most of the natural features in the area. The proposed longwall panels are bounded to the north and east by the Wolgan Escarpment and to the south by "internal" sandstone cliff formations that are visible from nearby public access roads and are greater than 20m high. To the west, the longwall area is bounded by the Cox's River lineament, a geological fault structure of sufficient magnitude to provide a boundary to longwall mining operations. The exact location of this structure is yet to be determined and will be defined as mining operations proceed, but it has been located to within ±10m and the throw has been confirmed.

3. DESCRIPTION OF NATURAL FEATURES AND SURFACE IMPROVEMENTS

The natural features and surface improvements within the application area have been identified on the basis of several site visits, discussion with colliery personnel and review of other specialist reports relating to the area. In this section, these features and improvements are described in greater detail to provide a context for the assessment of likely subsidence impacts.

3.1 Wolgan Escarpment

The Wolgan Escarpment comprises a sheer vertical cliff ranging in height from about 40m to 80m high. Figure 3 shows a photograph looking along a typical section of the escarpment to the east of the SMP application area.

The dotted grey line shown in Figure 2 indicating the edge of the escarpment represents the upper limit of rock formations that are in any way associated with the escarpment. At the northern end of the SMP application area, the slope above the top of the vertical cliff has rock outcrops that, while not strictly part of the vertical cliff, are nevertheless regarded as part of the

escarpment. In this northern area, the line defining the top of the escarpment is located well back from the edge of the vertical drop, typically 20-50m. On the eastern side of the SMP application area, the edge of the escarpment is sharply defined and does not have any significant upslope rock formations. In this eastern area, the line defining the top of the escarpment is only 5-10m back from the edge of the vertical cliff.

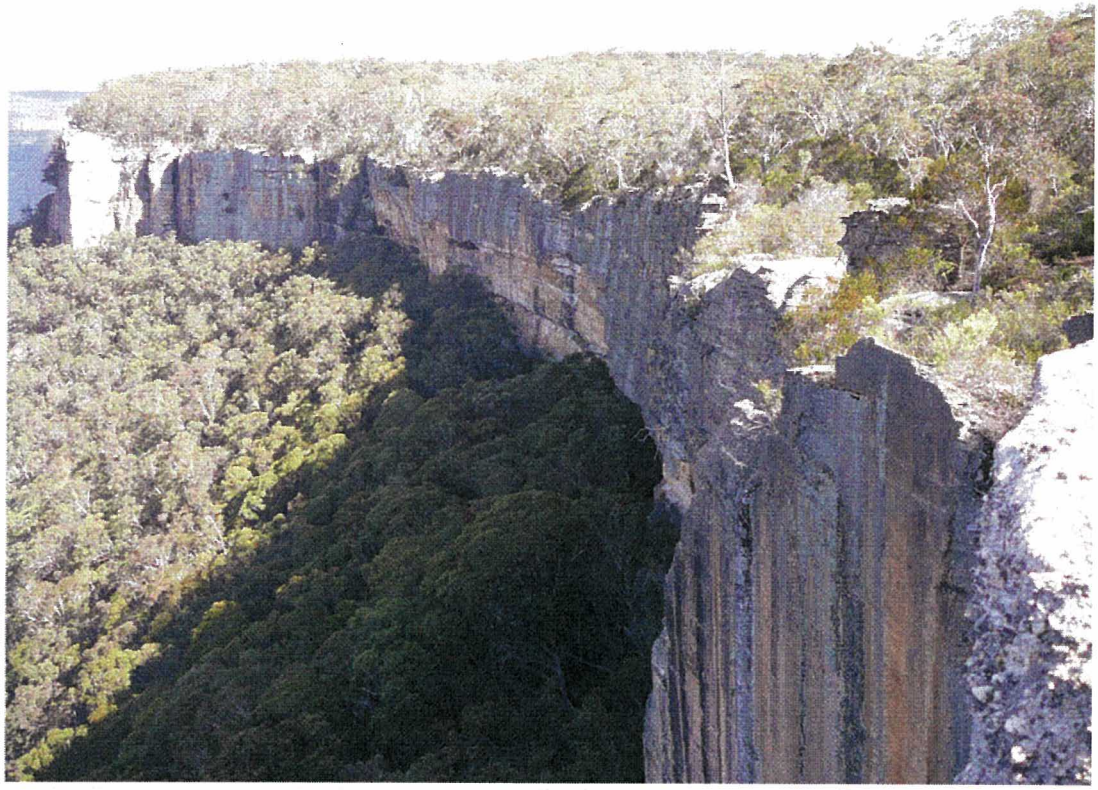


Figure 3 Photograph of Wolgan escarpment looking to the south from a point east of Longwall 31.

The grey dotted line shown in Figure 2 defining the edge of the escarpment was surveyed using a hand-held GPS device. Direct comparison with the known location of the Wolgan Gap Trig indicates that the accuracy of these readings is of the order of 2m in the open. It is possible that the accuracy is somewhat degraded in areas where the vegetation is thicker, but for the purposes of this assessment, the accuracy achieved is considered adequate given that a conservative approach to defining the upper edge of the escarpment has been taken.

The reduced level of the coal seam floor is approximately 810m in the area between the proposed longwall panels and the Wolgan Escarpment. The reduced level of the top of the Wolgan Escarpment ranges from approximately 1020m at the northern ends of the panel, to 1015m in the north-eastern corner of Longwall 31 to 1040m at the southern end of Longwall 31.

Protection barriers based on 26.5° angle of draw to the edge of the Wolgan Escarpment as defined by the grey dotted line are shown in Figure 2 as red lines. These are 105m wide at the northern end of the panel, 103m at the north-eastern corner of Longwall 31 and 115m at the southern end of Longwall 31.

More conservative barriers consistent with the protection provided at the start of Longwall 25 would be 40m wider. However, monitoring at the start of Longwalls 19, 20, 21 and 25 and previous experience elsewhere indicates that such large barriers are unnecessarily conservative to provide full protection to large cliff formations such as the Wolgan Escarpment.

3.2 Other Rock Formations Associated with Wolgan Escarpment

There are several isolated rock formations located closer to the goaf edge, but in each case these are unlikely to be impacted by mining subsidence or if any rock falls were to occur, material would have no potential to roll over the escarpment. The location of these formations is shown in Figure 2. The rock formation at the northern end of Longwall 31 is no more than an isolated boulder some 5m in size on gently sloping ground as shown in Figure 4.

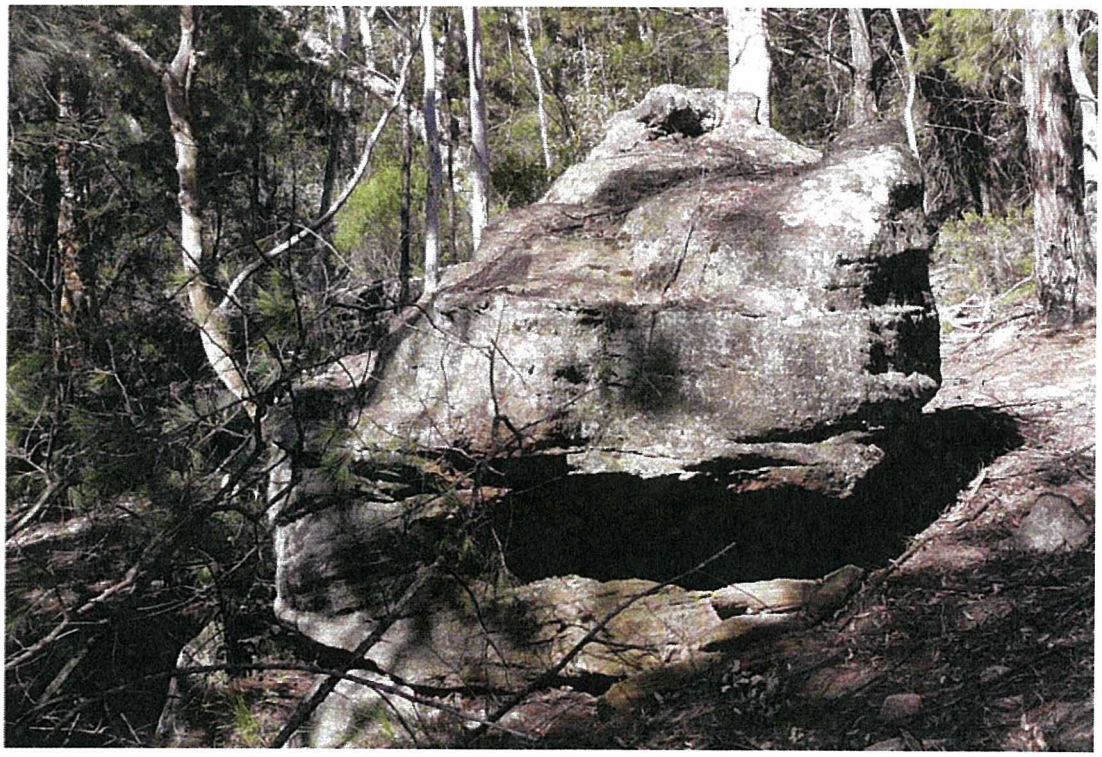
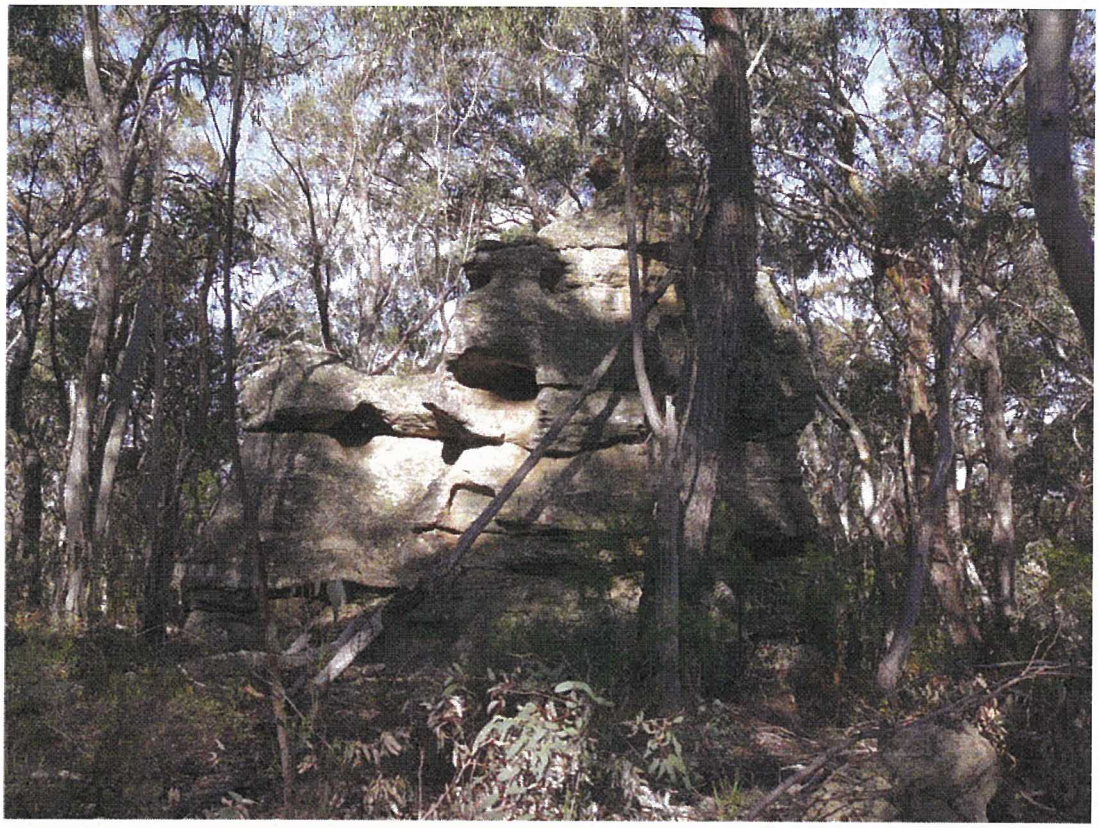


Figure 4 Photograph of isolated bolder at the northern end of Longwall 31.

There are also two isolated sandstone formations at the southern end of Longwall 31. These are both remnant pagoda formations some 5-10m high and 10-25m in length as shown in Figure 5.



a) Northern Pagoda.



b) Southern Pagoda.

Figure 5 Photographs of isolated pagoda features at the southern end of Longwall 31.

3.3 Other Sandstone Cliff Formations

There are numerous sandstone cliff formations located at the southern end of the proposed longwall panels, some of which are greater than 20m high.

The group of sandstone formations at the southern end of Longwall 29 outcrop as 5-10m high rock formations on their northern side, but increase in height on the southern side as the ground slopes away into the valley to be greater than 20m high in some places. Figure 6 shows a photograph of these formations. The longwall layout is designed to protect these formations.

The group of sandstone cliff formations at the southern end of Longwall 30 has a similar geometry to those described above. The northern edge is a bare rock plateau that emerges from the ground with some 3-5m high pagoda style formations in the north. The cliff formations increase in prominence to the south and west, reaching heights of more than 20m in the southwest, outside of the SMP application area. Figure 7 shows a photograph of the rock formations in this area. The longwall layout is designed to protect these formations.

3.4 Swamp in Upper Reaches of Cox's River

A large swamp located in the upper reaches of the Cox's River is located to the west of the SMP application area. This swamp is located more than 300m outside the western edge of Longwall 29 and is well outside the SMP application area.

3.5 Archaeological Sites

The locations of two archaeological sites identified by Ozark Environmental & Heritage (2007) are shown in Figure 2.

BBC-IF1 is an isolated find considered to be a one-off drop artefact of low overall significance located near the western edge of Longwall 29.

BBC-RS1 is a rock shelter located over Longwall 30 that has no surface evidence of Indigenous occupation but is considered to be a potential occupation site (Ozark Environmental & Heritage 2007). Figure 8 shows some photographs of the rock shelter. The rock shelter comprises a rock overhang that is part of a significantly weathered rock formation. Several large boulders have fallen from the roof of the overhang indicating that the rock formation is in the advanced stages of weathering. It would appear as though the overhanging rock formation is substantially isolated from the ground.

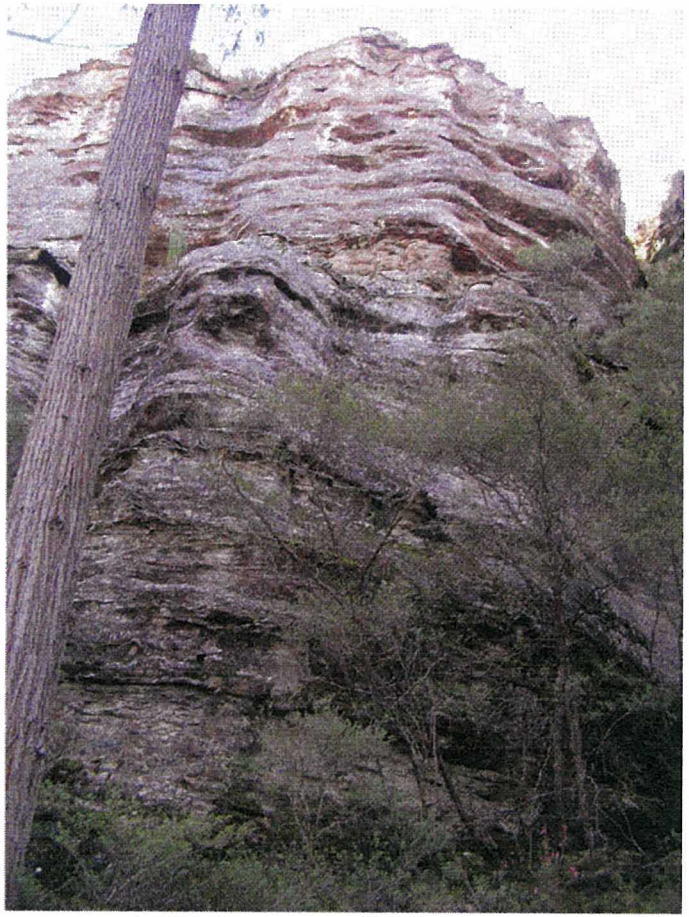




Figure 6 Photographs of sandstone cliff formations at the southern end of Longwall 29 protected by proposed mining geometry.

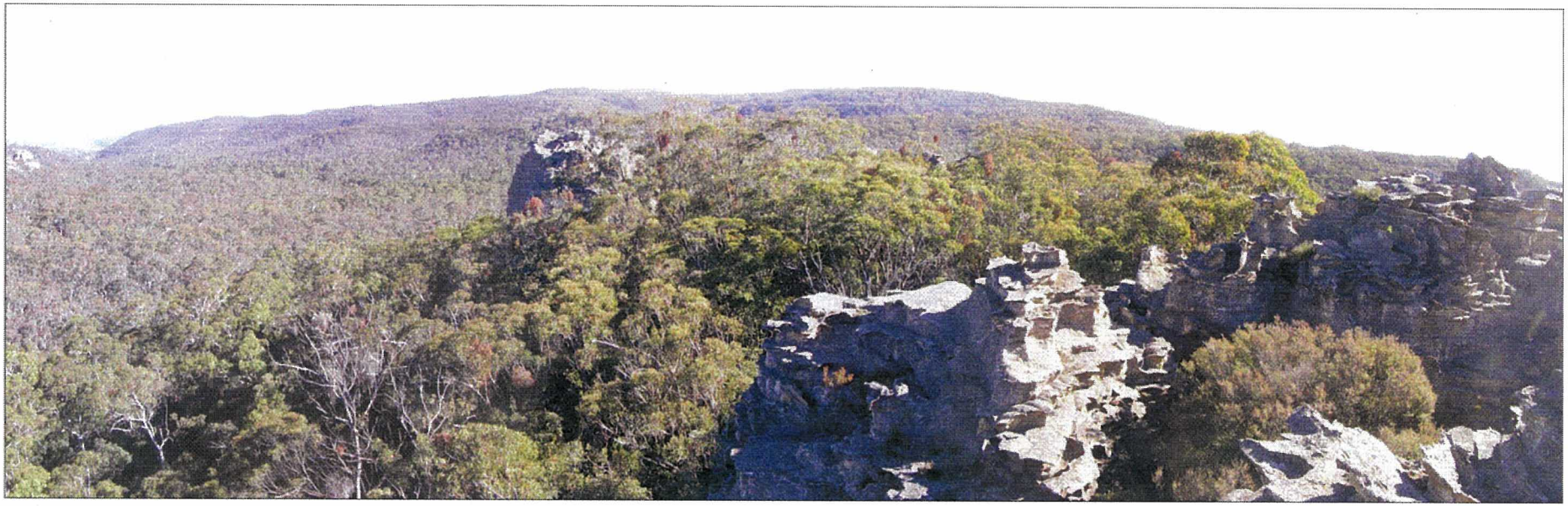


Figure 7 Rock formations south of the start of Longwall 30 protected by proposed mining geometry.



Figure 8 Photograph of BBC - RS1 that would be mined under by Longwall 30.

3.6 Forestry and Public Access Tracks

There are three forestry tracks that cross the SMP application area. All the tracks are essentially four-wheel drive tracks although recent maintenance work has made them more suitable for general traffic. The tracks are all accessible to the public. The western-most of these tracks follows the Cox's River and only crosses the SMP application area in the north in an area outside of the longwall panels where subsidence movements are likely to be imperceptible. The eastern-most track skirts around the eastern and northern edges of the longwall panels. The third track is a connecting track that crosses Longwalls 30 and 31. It passes along the valley below the cliff formations located at the southern end of Longwalls 29 and 30.

3.7 Wolgan Gap Trig

Wolgan Gap Trig is located in the south-eastern corner of the SMP application area, some 80m beyond the start of Longwall 31.

A short track provides access to the area. The trig is understood to still be used for surveying purposes.

4. REVIEW OF SMP APPROVAL REQUIREMENTS FOR SUBSIDENCE PREDICTIONS

The subsidence estimates provided in this report are intended to be used in the context of an Application for Subsidence Management Approval as outlined in the guidelines produced by the NSW Department of Mineral Resources (December 2003). These guidelines require:

1) A description of methods employed to estimate subsidence resulting from the proposed underground coal mining.

2) A discussion of all factors that may affect the development of subsidence over the application area.

3) Relevance of all input data, including results of previous relevant subsidence monitoring, which has been utilised or considered to develop the predictions.

4) Identification of all assumptions used, especially those which may significantly affect the outcome of the subsidence predictions, and discussion of their relevance.

5) Reliability of the subsidence predictions and the level of uncertainties involved, in particular, any potential deviations from the predictions due to factors such as topographic, geological or geotechnical conditions or variations.

Our assessment is aimed to address each of these issues in the following sections. The subsidence estimates are based on guidelines for the Western Coalfield forwarded by Holla (1991). These guidelines have been

found to be consistent with the monitoring of subsidence behaviour over 27 previous longwall panels at Baal Bone Colliery over a range of overburden depths from 27m through to approximately 240m.

Factors that affect the development of subsidence over the application area are described. Previous subsidence monitoring experience relating to mining under sandstone cliff formations is reviewed in the context of assessing the potential impact of mining under and near the Wolgan Escarpment and other sandstone cliff formations.

4.1 Review of Subsidence Prediction Methodology

Holla (1991) presented a summary of the characteristics of subsidence behaviour in the Western Coalfield based on subsidence monitoring experience over the first four longwall panels at Baal Bone Colliery and other nearby collieries. This data provides a comprehensive empirical basis for estimating subsidence behaviour at Baal Bone Colliery.

Subsequent subsidence monitoring experience over some 28 previous longwall panels at Baal Bone Colliery and a similar number of longwall panels at nearby Angus Place Colliery at somewhat greater overburden depth have shown subsidence behaviour that continues to be consistent with the subsidence database presented by Holla.

Estimates of maximum subsidence, tilt and strain over Longwalls 29 to 31 at Baal Bone Colliery presented in this assessment are based on Holla's empirical approach to estimating subsidence parameters in the Western Coalfield. While subsequent monitoring has revealed that these parameters are not particularly critical to the subsidence impacts observed, they are nevertheless provided for completeness.

4.2 Factors Affecting the Development of Subsidence over the SMP Application Area

The main factor that influences the maximum vertical subsidence developed at Baal Bone Colliery is the height of seam extracted because, in general, individual longwall panels are wide enough for maximum subsidence to develop in the centre of each longwall panel. As the overburden depth increases above about 200-250m and individual panels begin to become narrow relative to depth (known as subcritical width in subsidence engineering terms), maximum subsidence in the centre of each panel reduces as a function of the ratio of extracted panel width to overburden depth.

At shallow depths (less than about 150m), most of the subsidence movements (1.6-1.8m) occurs over individual longwall panels with only low levels of subsidence over the chain pillars isolated between extracted longwall panels (typically less than 0.2m). At greater overburden depths, the magnitude of subsidence over the chain pillars increases in response to the greater weight of overburden strata bearing down on the chain pillars while maximum subsidence in the centre of each longwall panel remains essentially similar. For typical pillar and panel geometries, up to about 0.4m

of chain pillar compression subsidence is typical at 200m overburden depth and this may increase up to about 0.7m of vertical subsidence over the chain pillar at 250m overburden depth.

The relationships developed by Holla (1991) for maximum tilt and strain indicate that these values are essentially proportional to the value of maximum subsidence, and in general terms they are. More recent subsidence monitoring has shown that while this proportionality is true for tilt and broadly true for strain, surface topography has a significant influence on the magnitude and direction of horizontal movements. The magnitude of maximum strain is significantly influenced by the relative magnitudes of horizontal movements, so the strain magnitude and the location of maximum strain are more usefully determined from consideration of surface topography rather than maximum subsidence.

The impacts of mining subsidence in a steep bushland environment tend to be mainly a function of horizontal subsidence movements rather than vertical subsidence or its derivatives tilt and curvature. So while vertical subsidence is a fundamental driver of subsidence impacts, it is more commonly the interaction of horizontal subsidence movements with natural features such as rock formations that control the actual subsidence impacts.

4.3 Review of Previous Experience

Given that the most significant features identified within the SMP application area are rock formations, it is useful to consider the previous experience of mining under and adjacent to rock formations. A summary of recent subsidence behaviour at Baal Bone is presented in a separate report (SCT Report BBO3233, 2007).

Over almost 20 years of longwall mining, Baal Bone Colliery has established one of the most complete subsidence monitoring databases in Australia, particularly in relation to the impacts of mining subsidence on rock formations. Subsidence monitoring at Baal Bone Colliery has provided SCT and others with the opportunity to study the impacts of mining on cliff formations and the mechanics of the rock failure processes involved. The experience at Baal Bone appears to be entirely consistent with the experience reported by others at other collieries.

Pells et al (1987) conducted a review of rock falls and landslides within eight areas in the Sydney Basin where rockfalls had been observed to that time. They concluded that "the major failures appear to be associated with areas of full extraction immediately beneath or, more usually, beyond the top edge of the escarpment. Extraction behind the escarpment causes surface cracking but not major rock falls."

Kay (1991) provides a comprehensive report on the experience of mining under and adjacent to sandstone cliff formations in NSW. This report also presents the results of three dimensional subsidence monitoring in the vicinity of fifty eight rock falls at Baal Bone Colliery using the then new technique of reflector monitoring. Kay concludes that "no damage occurred

to cliff faces before they were undermined". Kay recognised the contribution of opposing horizontal subsidence movements to horizontal compression along the cliff face as a factor influencing the potential for rock falls on cliff formations.

Pells (1991) presented further results of analysis concluding that rock falls and cliff line collapses in the Sydney Basin have all occurred in areas where total extraction mining has occurred either directly beneath or in front of the cliff lines. A summary of the rock falls observed where Angus Place undermined the Wolgan Escarpment showed that all the rock falls observed were within the mining area.

The Mount Airly Inquiry (Simpson 1993) provides a summary of the protection barriers that were seen as appropriate. On the recommendations of Dr Holla, Simpson concluded that that "mining protection zones be provided under all substantial cliffs beneath the outer escarpment of the mesa and under unusual rock formations of community concern such as the Grotto, Valley of the Kings, and the Hidden Valley. The zones should initially be based on a draw angle of 25 degrees."

Studies of subsidence behaviour about cliff formations at Baal Bone Colliery have been ongoing since Longwall 1. Initial work included conventional subsidence monitoring (SCT Report BBO306/2, 1992). From Longwall 4-7, three dimensional subsidence monitoring was used to study the impacts of mining subsidence on cliff formations (Kay 1991). From Longwalls 8 onward, routine subsidence monitoring and various targeted studies (Various SCT Reports, 1993, 1994, 1995, 1998, 1999, 2003, 2004, 2005) have included use of photogrammetry, GPS, three dimensional surveying and close spaced, round-the-clock monitoring to provide insights into the mechanics of subsidence behaviour at Baal Bone Colliery and its impact on cliff formations.

From Longwalls 19-21, the impacts of start up of each panel on the cliff formations of the deeply incised valley east of the panels was intensively monitored using conventional subsidence monitoring, GPS surveying and photogrammetry (SCT Reports BBO1976, 2001, and BBO2056, 2003). This work showed that all movements to the east of the start line were in the direction of mining and tensile in nature. Some minor tensile cracking, mainly opening up of existing joints was observed to the east of the start line to a distance of about 0.4 times depth. Rock falls and large tension cracks were observed over the mining area. These observations are entirely consistent with previous observations at Baal Bone Colliery and elsewhere.

A program of survey monitoring of points on and around the escarpment at the commencement of Longwalls 24 and 25 has also been undertaken. The results are reported in SCT Letter Report BBO2784 dated 5 November 2005, and SCT Letter Report BBO2784b dated 26 March 2006. So far the monitoring program has showed subsidence behaviour consistent with previous experience within the limitations of the survey techniques used.

In summary:

- There is no experience of rock falls on cliff formations unless the cliff formations themselves or the downslope side of the cliff formations is directly undermined.

- The Department of Mineral Resources recommended a 25° angle of draw barrier in the Mount Airly Inquiry for the protection of "substantial cliffs beneath the outer escarpment" as suitable for initial protection purposes.

- Experience and the understanding of the mechanics of mining induced cliff deformations developed from this experience would be entirely consistent with the expectation that a 26.5° angle of draw would be effective in protecting the Wolgan Escarpment from the effects of mining.

4.4 Identification of Assumptions

The main assumption that would impact on the outcome of the subsidence assessment is that the subsidence behaviour in this area is essentially similar to the subsidence behaviour evident over the previous longwall panels at Baal Bone Colliery.

In terms of vertical subsidence, there would not appear to be any significant factors that would differentiate the area of Longwalls 29-31 from previous areas.

In terms of impacts on the Wolgan Escarpment, there is considered to be one difference that is worth consideration. The stability of cliff formations is recognised to be a function of lateral compression along the line of the cliff. Given the geometry of Longwall 31, it is considered possible that horizontal stresses may be concentrated between the goaf of the extracted longwall panel and the Wolgan Escarpment. Such concentration would have the potential to contribute to lateral compression along the line of the Wolgan Escarpment.

The horizontal stresses in the sandstone strata that forms the Wolgan Escarpment are expected to be low because of proximity to the free surface that is the Wolgan Escarpment and the concentration in horizontal stress caused by mining is expected to be slight. Furthermore, previous experience of mining close to the Wolgan Escarpment has not been observed to increase the potential for rock falls. Nevertheless, we recommend a monitoring program to monitor the magnitude of the stress concentration adjacent to Longwall 26 in a similar geometry and we understand that the colliery has accepted this recommendation.

It should be noted that the sheer nature of the Wolgan Escarpment is testament to natural weathering processes that from time to time induce rock falls. So the presence of a barrier to mining of any size does not preclude the possibility of rock falls occurring before, during or after mining. However, the provision of a barrier based on 26.5° angle of draw is regarded

as providing a high level of protection, recognising that this protection is provided in the context of ongoing natural instability.

4.5 Assessment of Reliability of Predictions

The reliability associated with the subsidence predictions outlined in this report is considered to be consistent with the natural variations that have occurred over previous longwall panels at Baal Bone Colliery. In terms of maximum vertical subsidence, the predictions are considered to provide an upper limit on the maximum subsidence that can be regarded. The actual maximum vertical subsidence is likely to be within 20% of the predicted maximum.

Estimates of tilt and strain are also based on maximum values from past experience so the predictions are likely to be conservative and overestimate the actual tilts and strains at any given point.

In terms of impact assessments on individual features such as cliff formations, there is likely to be a high degree of variability because of the different stages at which individual formations are in the natural erosion cycle and variations in their location and orientation in terms of subsidence processes that affect them. This is evidenced by the general observation that rock falls are only observed on about 15-20% of cliff formations undermined at Baal Bone Colliery. The other 80-85% undergo similar levels of subsidence movement but for a range of reasons the subsidence movements are not sufficient to cause rock falls.

In recognition of this uncertainty, a conservative approach has been adopted. This approach is based on assessing rock features in general terms and developing a management strategy on the basis of a reasonable worst case scenario. Where possible, an estimate of likelihood of this worst case scenario is made based on previous experience.

5. REVIEW OF PREVIOUS EXPERIENCE

Previous subsidence monitoring experience has been reviewed on a panel by panel basis for most of the longwall panels at Baal Bone Colliery. SCT Report BBO306/2 provides a summary of subsidence monitoring to the end of Longwall 8.

Subsidence monitoring from other mines in the Western Coalfield, including Baal Bone Colliery is presented in Holla (1991). The experience of subsidence monitoring to the end of Longwall 24 at Baal Bone Colliery is consistent with the results presented by Holla (1991), so the results presented continue to provide a sound basis for estimating subsidence behaviour at Baal Bone Colliery.

Most of the subsidence monitoring since Longwall 8 has been focused on specific issues of relevance to each longwall, particularly issues relating to horizontal movements, shallow cover, specific rock features and the mechanics of these processes. An update of this experience based on

subsidence monitoring to the end of Longwall 24 is currently in preparation as a separate document.

Figure 9 shows a summary of the subsidence profiles measured over solid goaf edges at Baal Bone Colliery. Figure 10 shows a summary of the tilt and Figure 11 a summary of the strain values. These are plotted as a function of distance from the goaf edge divided by overburden depth.

Goaf edge subsidence is typically 70mm and almost always less than 100mm. Angle of draw is typically less than 8-10° and almost always less than 17° (0.3 times depth). The few higher values are associated with factors such as steep cross-slope which make the measurements unrepresentative of general ground behaviour.

5.1 Effect of Panel Width and Overburden Depth

Subsidence behaviour is strongly influenced by the ratio of the width of individual longwall panels to overburden depth, and by the thickness of coal that is mined. Figure 12 shows a summary of the relationship between these parameters for the Western Coalfield.

In Longwalls 29-31, the overburden depth ranges from 150-240m, so for longwall panel widths of 225-250m, the panel width to overburden depth ratio is in the range 1.0-1.7. The upper part of this range is associated with what is known in subsidence engineering terms as super-critical subsidence behaviour. Maximum subsidence in the centre of each panel reaches full subsidence of 55-65% of seam thickness. For a 2.4m thick coal seam, maximum subsidence is expected to be in the range 1.3-1.6m.

5.2 Chain Pillar Compression and Goaf Edge Subsidence

The subsidence that develops over the chain pillars is governed by compression of the chain pillars and the strata above and below the chain pillars that becomes loaded as a result of the adjacent extraction. At overburden depths in the range 150-240m, chain pillar compression on a 25m wide chain pillar is typically in the range 0.25-0.50m.

Goaf edge subsidence at Baal Bone Colliery has historically been less than 100mm and typically about 70mm. Angle of draw is almost always less than 17° (0.3 times depth) and usually less than 6-10° (0.1-0.15 times depth).

5.3 Subsidence Profiles

Figure 13 shows a contour plan of the subsidence troughs that are expected to develop at the completion of mining. The 20mm subsidence contour is shown at 26.5° angle of draw (0.5 times depth), although subsidence data from Baal Bone Colliery indicates that the actual angle of draw is typically much lower than this.

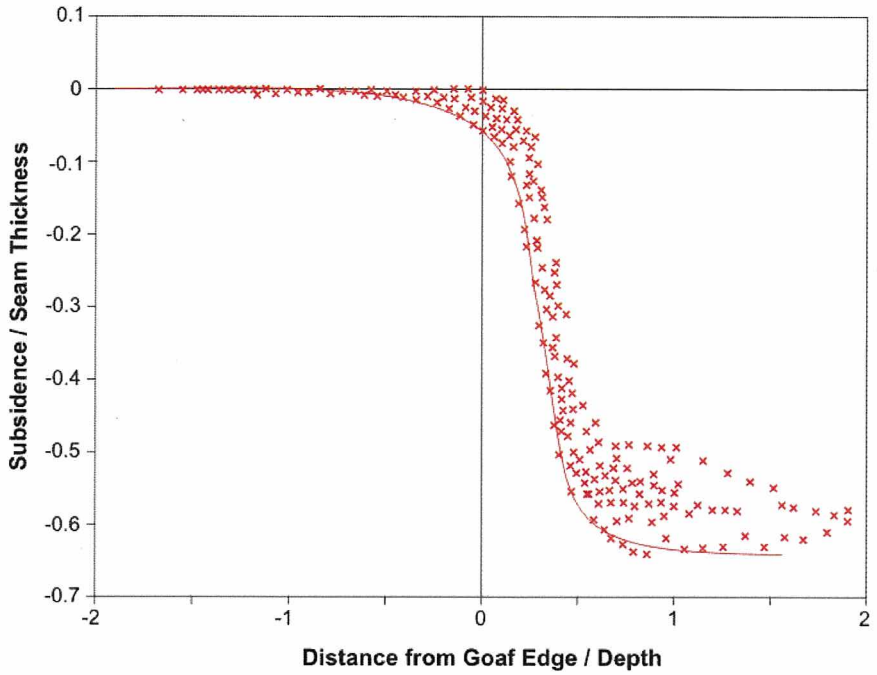


Figure 9 Subsidence distribution over longitudinal rib at Baal Bone Colliery.

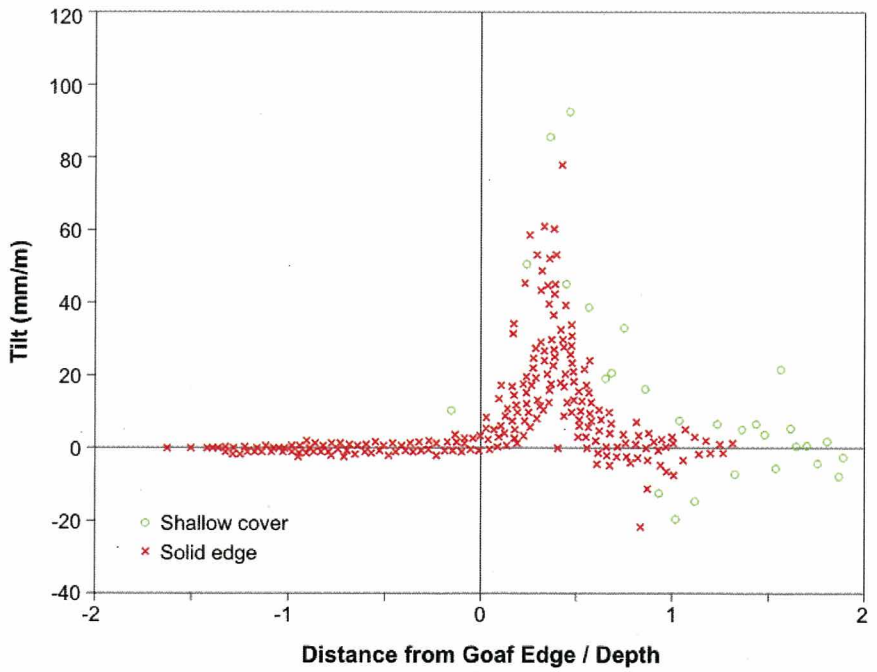


Figure 10 Tilt over longitudinal rib at Baal Bone Colliery.

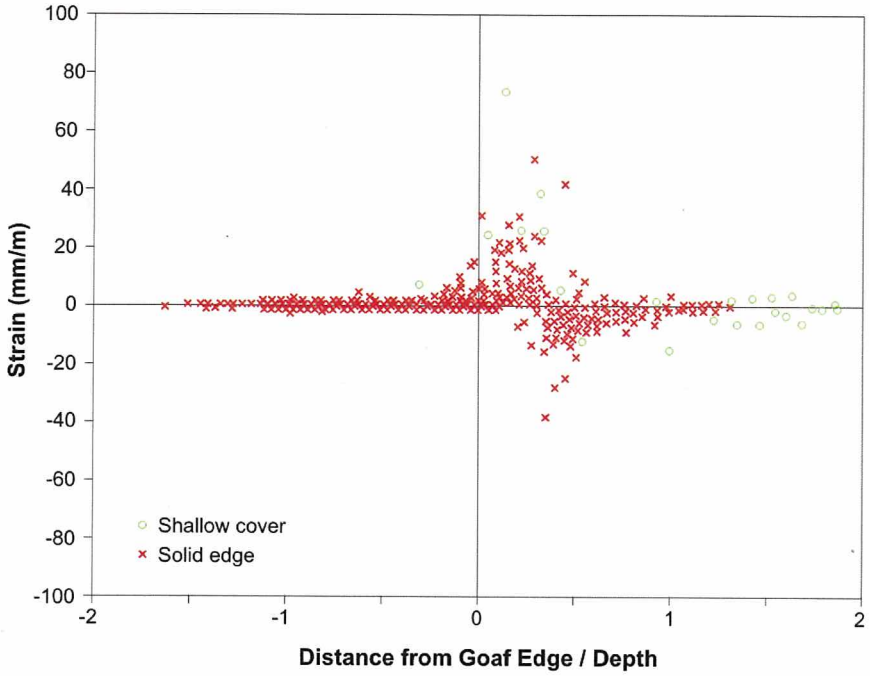


Figure 11 Horizontal strain over longitudinal rib at Baal Bone Colliery.

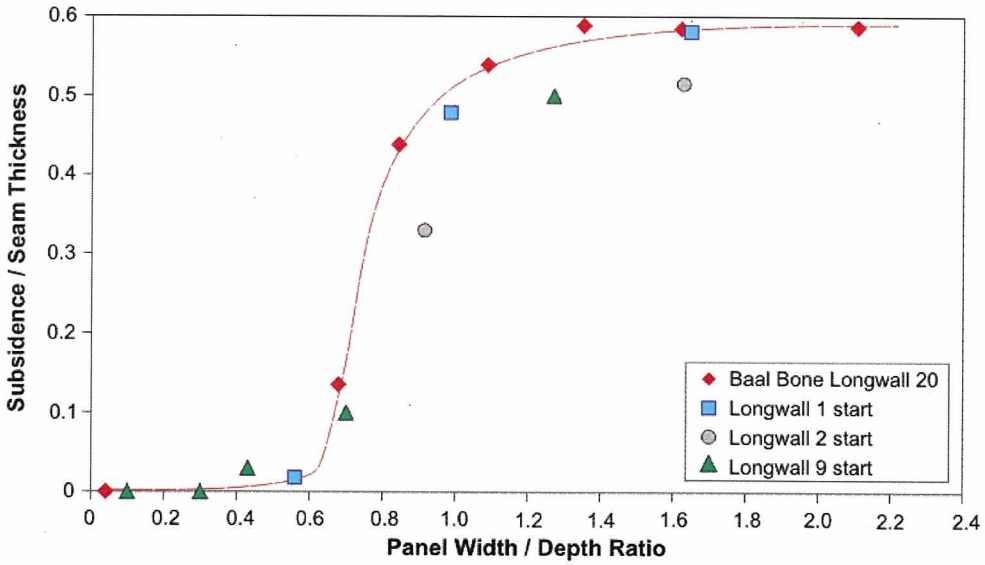


Figure 12 Relationship between maximum surface subsidence and panel width for Baal Bone Colliery.

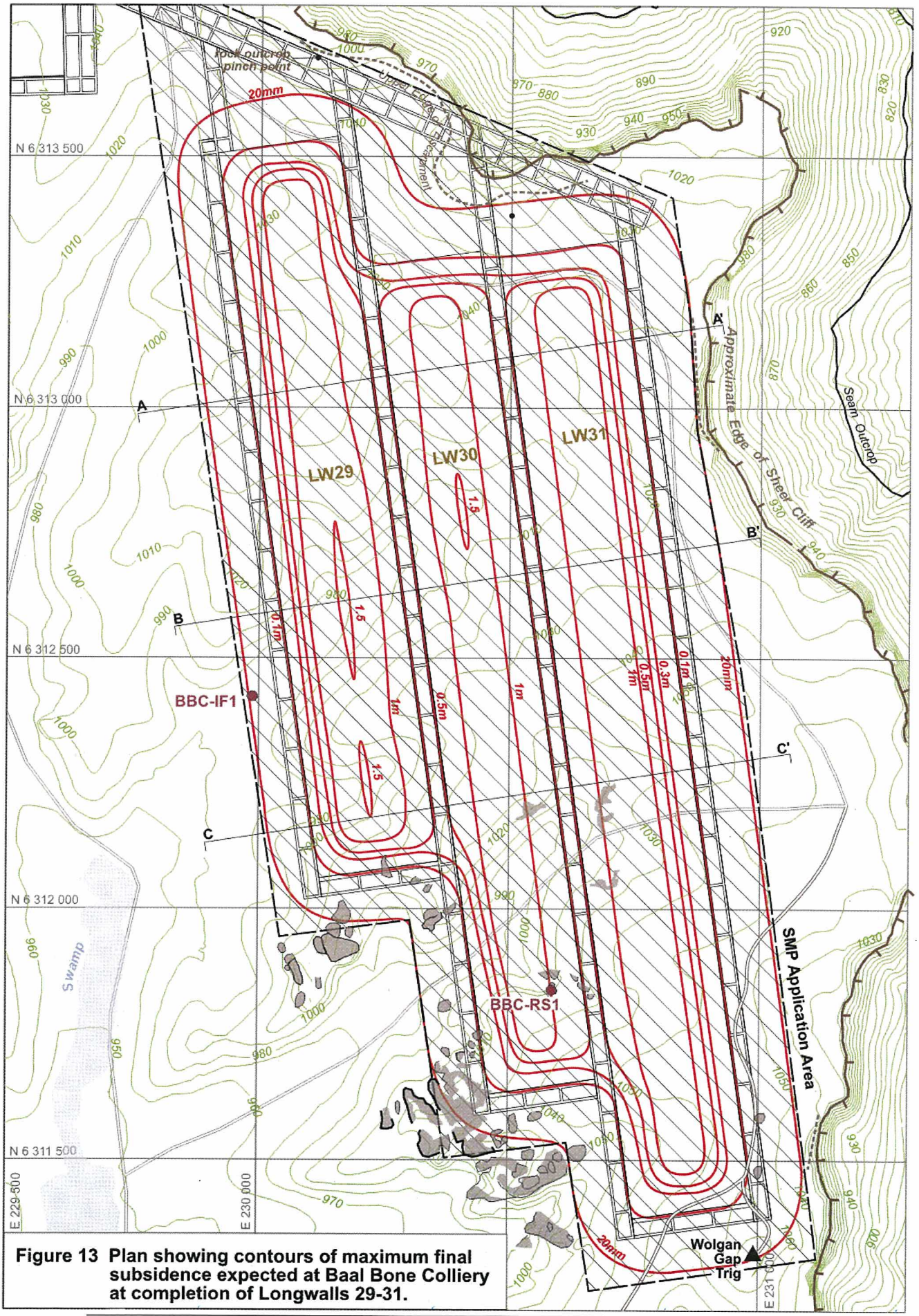


Figure 13 Plan showing contours of maximum final subsidence expected at Baal Bone Colliery at completion of Longwalls 29-31.

Figure 14 shows a summary of the vertical subsidence profile that is predicted over the SMP application area at three cross-sections shown in Figure 13. The final subsidence profile predicted starts 0.3 times depth outside the goaf edge at 20mm, increases to 100mm at the solid goaf edge and then increases to a maximum of 1.6m over the centre of the first longwall panel before increasing over the chain pillar to be 0.5m and back to 1.4m over the centre of the second panel. The subsidence profile over the third panel is similar to the second but with slightly reduced maximum subsidence because of the greater overburden depth.

5.4 Subsidence Parameters

Table 1 provides a summary of the subsidence movements expected based on the extensive database of previous monitoring at Baal Bone Colliery and adjacent collieries.

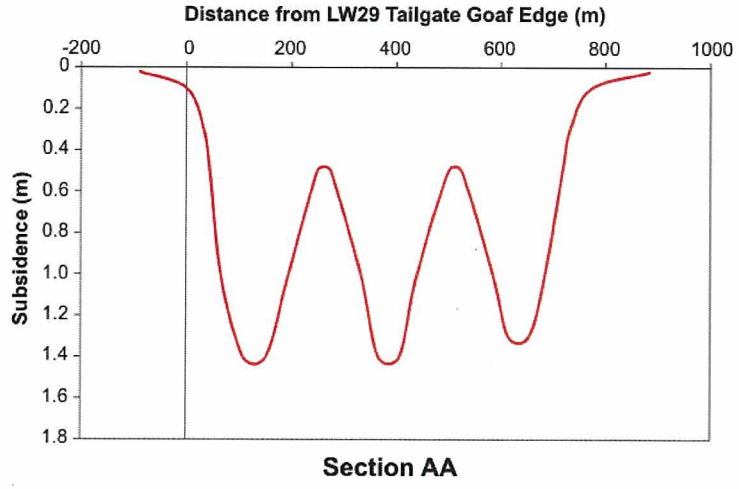
Table 1: Subsidence Predictions for Longwalls 29, 30 and 31

	LW29	LW30	LW31
Depth Range (m)	150-220	165-230	210-240
Panel Width (m)	250	226	250
Panel W/D Ratio Range	1.1-1.7	1.0-1.4	1.0-1.2
Smax / Thickness Ratio	0.58-0.65	0.54-0.65	0.54-0.6
Maximum Subsidence (m)	1.4-1.6	1.3-1.6	1.3-1.4
Horizontal Movements (m)	0.4	0.4	0.4
Tensile Strain (mm/m) K=1.5	9-16	8-14	8-10
Compressive Strain (mm/m) K=2.0	13-21	11-19	11-14
Tilt (mm/m) K=5.0	32-52	28-47	27-34

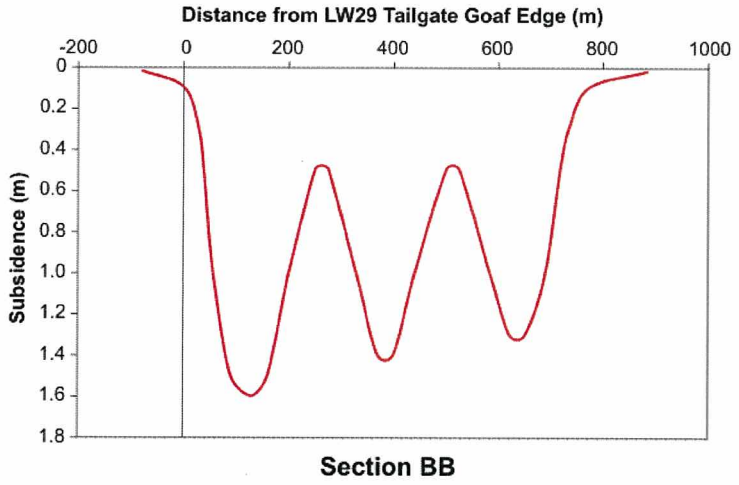
The general nature of the surface topography within the SMP application area at Baal Bone Colliery means that the vertical subsidence, of itself, is of no particular significance. For all practical purposes vertical subsidence is imperceptible. Associated tilts do not impact significantly on stream gradients or general slope, because these are naturally much higher than the mining induced tilts.

Horizontal subsidence movements of approximately 100-150mm are typical in flat terrain areas in a direction toward the active mining. Downslope movements of up to about 1.5m have been observed in steep terrain at shallow depth, but would generally be expected to be less than about 0.4m in the terrain above Longwalls 29-31.

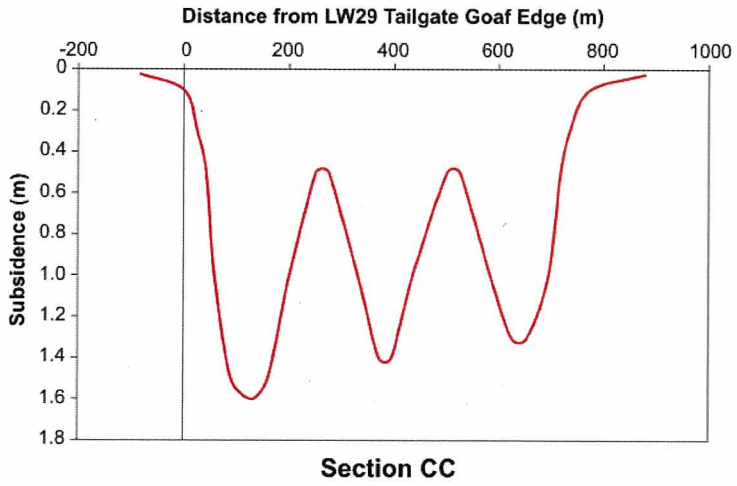
Localised strains of 10-20mm/m would be expected to cause perceptible cracking of hard surfaces such as bare rocks with cracks of 50-100mm wide a possibility particularly near the start of panels and along permanent goaf edges.



Section AA



Section BB



Section CC

Figure 14 Final maximum subsidence profiles expected on three cross-sections at completion of Longwalls 29-31 at Baal Bone Colliery.

Valley closure and associated upsidence are likely to occur, but because of the ephemeral nature of the watercourses and the nature of the surface material, they are not expected to have any perceptible impact.

Localised tilts of up to 50mm/m are not expected to have any perceptible impacts on the surface.

There is anticipated to be significant fracturing of the overburden strata with potential for increased levels of hydraulic conductivity similar to that which has been observed over previous longwall panels at the colliery.

6. SPECIFIC ASSESSMENT OF IMPACTS ON FEATURES IDENTIFIED

In this section, potential subsidence impacts on the natural features and surface improvements identified in Section 3 are assessed.

6.1 Wolgan Escarpment

The Wolgan Escarpment is located entirely outside of 26.5° angle of draw of the proposed goaf edge. This barrier was achieved by specific design of the proposed longwall panels to maximise coal resource recovery while providing a protection barrier to the escarpment of greater than 26.5° angle of draw.

While there is always some potential for natural rock falls to occur along the length of the Wolgan Escarpment irrespective of mining activity, the protection afforded by a barrier equivalent to a 26.5° angle of draw is regarded as unlikely to significantly increase the risk of rock falls above that which would have existed if there had been no mining activity.

There is considered to be some potential for horizontal stress concentrations between the goaf of Longwall 31 and the Wolgan Escarpment. These stress concentrations are considered unlikely to be large enough to cause rock falls, but a program of stress change monitoring is recommended to provide confidence that the magnitude of the stress changes is indeed small.

6.2 Other Rock Formations Associated with Wolgan Escarpment

Subsidence impacts associated with the proposed mining on the isolated boulder at the northern end of Longwall 31 and the two isolated sandstone formations at the southern end of Longwall 31 are assessed in this section.

The isolated boulder at the northern end of Longwall 31 is located outside the goaf. Mining subsidence impacts at this site are likely to be imperceptible. Subsidence movements are expected to be less than 50mm. Such small movements are not expected to cause this boulder to become unstable.

The remnant pagoda formations at the start of Longwall 31 are some 5-10m high and 10-25m in length. They may experience some cracking as a continuation of general ground fracturing, but given their size as generally less than 20m, their location near the starting corner of the panel and their nature as pagoda formations, rock falls are not expected to occur.

6.3 Other Sandstone Cliff Formations

There are numerous sandstone cliff formations located at the southern end of the proposed longwall panels, some of which are greater than 20m high. In general, the sandstone formations are smaller and lower in height in a direction toward the longwall panels. The longwall panels have been aligned and shortened so that the impacts of mining subsidence are limited to not mining within 26.5° angle of draw of large sandstone cliff formations greater than 20m high and not mining directly under most of the smaller formations. Recognising the general experience that mining induced rock falls do not occur outside of the mining area (the area defined as directly above the longwall goaf and intermediate chain pillars), a high level of protection has been afforded to these cliff formations by the proposed layout.

The group of sandstone formations at the southern end of Longwall 29 outcrops as 5-10m high rock formations on their northern side, but increases in height on the southern side as the ground slopes away into the valley to be greater than 20m high in some places. Longwall 29 has been shortened so that the start line is beyond 26.5° angle of draw from the 20m high cliffs. The sandstone formation that is located directly over the panel is less than 6m high and of a pagoda-like nature where rock falls are unlikely. A large crack may develop through this formation as a continuation of the ground fracturing that is expected to occur adjacent to the start of the panel.

The group of sandstone cliff formations at the southern end of Longwall 30 has a similar geometry to the cliff formations described above. The northern edge is a bare rock plateau that emerges from the ground with some 3-5m high pagoda style formations in the north. The cliff formations increase in prominence to the south and west, reaching heights of more than 20m in the south-west.

Longwall 30 has been designed to mine up to and slightly under the rock plateau and some of the small peripheral sandstone formations that are typically less than 3m high. Some opening of pre-existing joints may occur on these formations and some cracking may occur on the plateau, but both are likely to be of a minor nature and barely perceptible. The high cliff formations in the southwest are sufficiently remote from mining activity to be fully protected.

Some small sandstone rock formations are located within the area of Longwall 30. The impacts of mining on these formations are considered in Section 6.5.

6.4 Swamp in Upper Reaches of Cox's River

A large swamp located in the upper reaches of the Cox's River is located to the west of the SMP application area. This swamp is located more than 300m outside the western edge of Longwall 29 and is well outside the 26.5° angle of draw and the SMP application area. There is unlikely to be any physical subsidence impacts from mining on the swamp itself. We understand that the impacts of the proposed mining on the groundwater system have been assessed by others.

6.5 Archaeological Sites

Two potential archaeological sites have been identified in the survey of the SMP application area.

BBC-IF1 is an isolated find considered to be a one-off drop artefact of low overall significance located near the western edge of Longwall 29. Mining subsidence movements are not expected to have any significant impact on this isolated find or the area around it.

BBC-RS1 is a rock shelter associated with some sandstone cliff formations located over the southern end of Longwall 30. While not identified as an actual archaeological site, this rock shelter is considered by the archaeologists undertaking the assessment to be a potential occupation site (Ozark 2007).

The rock shelter comprises a rock overhang that is part of a significantly weathered rock formation. Several large boulders have fallen from the roof of the overhang indicating that the rock formation is in the advanced stages of weathering.

The rock formation that comprises the overhang appears to be substantially isolated from the surrounding ground and is therefore considered likely to be less sensitive to mining induced subsidence movements. The sandstone formations are of relatively small overall size, so there would not appear to be potential for large opposing horizontal forces to develop and cause mining induced rock falls.

6.6 Forestry and Public Access Tracks

Three forestry tracks cross the SMP application area. All of these tracks are essentially four-wheel drive tracks although recent maintenance work has made them more suitable for general traffic. The tracks are all accessible to the public.

Previous experience of undermining similar tracks at Baal Bone indicates that there is a possibility of cracks developing, but in general mining subsidence has not caused perceptible impacts, especially at overburden depths above 200m. Where cracks have developed previously, remediation has involved minor earthworks taking less than an hour to back fill cracks

that have developed. The cracks that have developed do not significantly change the character of the tracks.

We recommend the placement of signage indicating the potential for mine subsidence and surface cracking in those sections of the track that are mined under and a contact phone number in the event that cracking is observed. Given the nature of the tracks, an appropriate response would be considered to be regular inspection of the sections of road where mining is occurring and back filling, in a timely manner, any cracks that develop.

The central track that crosses all three longwall panels passes below several cliff formations located south of the start of Longwall 29. Rock fall debris from these cliff formations may have the potential to impact on the road should a rock fall occur during the mining period. However, the road is located on the opposite side of the valley to these cliff formations across a deep water course. Given that there is currently a potential for natural rock fall debris to roll down the hill and impact on the road, and this potential is considered acceptably low, and given that the cliff formations that have potential to impact on the road are located outside of the mining area so the potential for mining induced rock falls is very low, there would not appear to be any requirement for additional controls.

Nevertheless, we recommend that signage is placed indicating the potential for subsidence impacts including rock falls. We note that there are alternate routes if it is considered necessary to temporarily close this section of road during mining of Longwalls 29 and 30.

6.7 Wolgan Gap Trig

Wolgan Gap Trig is located in the south-eastern corner of the SMP application area, some 80m beyond the start of Longwall 31. A short track provides access to the trig.

The trig and access road are located outside of the mining area and vertical subsidence associated with Longwall 31 is likely to be of the order of 20mm. Horizontal movements of up to 100mm may occur as Longwall 31 commences, most likely in a direction toward the active mining area. By the time Longwall 31 has mined 500m, it is considered likely that most of the horizontal movements at the Wolgan Gap Trig would be complete.

We recommend the Department of Lands is advised of the intent to mine adjacent to the Wolgan Gap Trig. No physical damage to the trig station is expected, but its location may change slightly, most likely in a north-westerly direction some 20-50mm soon after Longwall 31 commences. All subsidence movement would be expected to be complete within 6 months of mining.

7. RECOMMENDED MONITORING AND MANAGEMENT STRATEGIES

The major subsidence issues identified relate to the Wolgan Escarpment and to the other sandstone cliff formations located in the area above Longwalls 29-31. The orientation, width and length of these three longwall panels have been designed to maximise resource recovery while providing a high level of protection to the Wolgan Escarpment and to the other major sandstone cliff formations in the area. The strategy of managing the potential impacts by design of the longwall panels is recognised as a primary control that provides a high level of protection to the features of most significance in the area.

A program of monitoring general subsidence behaviour is recommended over Longwalls 29-31 to confirm that subsidence behaviour is consistent with expectation. This monitoring would comprise a cross line located at a convenient location across the centre of the three panels. We recommend a peg spacing of 10m and monitoring in three dimensions before, during and after mining. The line does not need to be perfectly straight and perpendicular to the gate roads, but should be approximately so.

Mining Longwall 31 sub-parallel to the Wolgan Escarpment is recognised to have the potential to cause horizontal stress concentrations between the mined goaf and the free surface of the escarpment. While these concentrations are expected to be small, they are nevertheless considered to have potential to contribute to lateral compression of the escarpment, a process that is recognised to contribute to rock falls.

A program of stress monitoring is recommended in the cliff forming sandstones (upper 80m of the overburden strata) between Longwall 26 goaf and the Wolgan Escarpment at a point near the start of Longwall 26. The intent of this monitoring is to confirm that the horizontal stress concentrations between the escarpment and an adjacent longwall panel are indeed as low as expected and within the tolerance of sandstone cliff formations to mining induced compression movements. The results of this monitoring would be available well in advance of mining Longwall 31 to confirm the adequacy of the barrier between Longwall 31 and the Wolgan Escarpment.

Short subsidence lines at the "pinch" points along the edge of Longwall 31 are recommended to provide further confirmation that the horizontal and vertical subsidence movements that occur when Longwall 31 is mined are consistent with expectation.

Specific subsidence monitoring of other sandstone cliff formations may be useful to confirm that the levels of subsidence movements are indeed less than expected and within the general tolerance limits of sandstone cliff formations.

Managing subsidence impacts on the archaeological site BBC-RS1 is a matter of balancing the potential loss of the site against the potential for any mining induced impacts. It would appear that there is a reasonable prospect that mining subsidence will not significantly impact on the site at

all, but there is certainly some potential for impact. The potential for rock falls is considered to be less than 10%. It is recommended to develop a management strategy in consultation with the archaeologists.

The four-wheel drive tracks have previously been successfully managed by appropriate signage advising of the potential for mining subsidence impacts in the area. This strategy would appear to be adequate over Longwalls 29-31. There does not appear to be any compelling reason to close any of the tracks during mining.

8. CONCLUSIONS

The potential for subsidence impacts within the SMP application area has been assessed.

The natural features of significance are the Wolgan Escarpment and the major sandstone cliff formations to the south of the panels. By re-aligning the longwall panels and adjusting their width and length, these major natural features have been protected by design. The sheer face of the Wolgan Escarpment and all rock formations that are regarded as being associated with the escarpment are protected by an angle of draw of 26.5°. Sandstone formations to the south of the longwall panels greater than 20m high are also protected with angles of draw of 26.5°.

Although there is some potential for cracking of minor sandstone features located within and close to the edge of the mining area, this potential is considered of low significance and of low consequence compared to the benefits of optimising recovery of the coal resource.

Subsidence parameters have been estimated from previous subsidence monitoring at Baal Bone Colliery and other collieries in the Western Coalfield based on guidelines for the Western Coalfield forwarded by Holla (1991). Maximum subsidence is estimated to be 1.6m in the centre of the panels with less than 0.5m of subsidence over the chain pillars. Systematic tensile strains of up to 16mm/m and systematic compressive strains of up to 21mm/m are expected. Tensile strains are expected to be greatest on ridge tops and near the start of the panel. Compressive strains are expected to be greatest in valleys. Maximum ground tilt of up to approximately 50mm/m is expected to occur at a distance of approximately 0.3 times overburden depth from the goaf edge.

None of the subsidence impacts are particularly sensitive to the magnitude of the vertical subsidence or any of the strain and tilt parameters. Impacts on rock formations are more likely to be sensitive to location and orientation relative to the longwall panels, surface topography and to the particular geometries of each formation.

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Strata Control Technology

REPORT TO:

XSTRATA COAL

Review of Subsidence Monitoring and Impacts of Mining on Sandstone Cliff Formations at Baal Bone Colliery

BBO3259

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SUBJECT

Review of Subsidence Monitoring and Impacts of Mining on Sandstone Cliff Formations at Baal Bone Colliery

REPORT NO

BBO3259

PREPARED BY

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DATE

24 April 2007

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Winton J. Gale
Managing Director

SUMMARY

The surface at Baal Bone Colliery is characterised by steep topography and sandstone cliff formations. The colliery has undertaken an ongoing program of subsidence monitoring aimed, inter alia, to develop an understanding of the impacts of longwall mining on cliff formations with a view to being able to provide protection from mining impacts when necessary. Baal Bone Colliery has commissioned SCT Operations Pty Ltd (SCT) to review this subsidence monitoring and summarise the findings with particular focus on the impacts of longwall mining on cliff formations. This report presents the results of our review and a summary of the findings.

The detailed results of subsidence monitoring programs at Baal Bone Colliery are presented in SCT reports compiled at the completion of each longwall panel or, in some cases, each group of longwall panels.

Subsidence monitoring at Baal Bone Colliery has been reviewed and the results of particular relevance to the development of protection barriers for sandstone cliff formations have been presented in detail. The results are consistent across a broad range of mining and cliff geometries so that the understanding of mining impacts on sandstone cliff formations is considered to be well developed.

The results of subsidence monitoring at Baal Bone Colliery and elsewhere indicate that rock falls are essentially limited to within the boundary of the mining area (i.e. that area directly above the longwall panels and the chain pillars isolated between adjacent longwall panels). There are a few cases where rock falls occur immediately outside the mining area (within 0.1 times overburden depth) when the slope below has been mined under, but the significantly larger subsidence movements that occur within the mining area clearly influence the likelihood of rock falls and other impacts.

Tension and shear fractures are commonly observed on sandstone cliff formations within the mining area. The orientation of these cracks appears to be influenced by the orientation of natural jointing deep within the overburden strata rather than the alignment of the longwall panel itself.

Tension cracks are also observed at distances up to approximately 0.4 times overburden depth from the edge of the mining area, decreasing in width as a function of distance from the goaf edge. Rock falls are not associated with the formation of these tension cracks.

The impacts of mining on sandstone cliff formations can be controlled by designing the size of the protection barrier between the edge of longwall mining and the sandstone cliff formations to be protected.

If there is no barrier and sandstone cliff formations are mined under, on average some 10-20% of the total length of sandstone cliff formations is likely to experience rock falls. This ratio may be locally higher in some cliff geometries depending on their height, shape, continuity and location and orientation relative to mining. Tension and shear cracking is likely to be perceptible over the area of sandstone cliff formations that have been mined under.

If the longwall panels are designed so that mining occurs right up to the edge of cliff formations, but they are not directly mined under, a moderate level of protection is provided to cliff formations. Tension cracking may be evident to a distance of 0.4 times overburden depth (typically about 80-100m) from the goaf edge, but rock falls are unlikely, particularly if mining occurs on the plateau side of the cliffs so that the slopes below the cliffs are not fully mined under.

If a protection barrier equivalent to 26.5° angle of draw (typically 100-120m) is provided between longwall mining and sandstone cliff formations, the impacts of mining become imperceptible and a high level of protection is provided to the cliff formations.

The width of the protection barrier necessary to protect cliff formations is less at the corners of longwall panels and is essentially the same whether mining is on the low side or the high side of the cliff formations.

Monitoring results also indicate that sandstone cliff formations can be substantially protected by limiting the width of individual longwall panels and maintaining substantial chain pillars between panels, but the widths required are unlikely to be economically viable from a mining perspective. A high level of protection is achieved if the width of individual longwall panels is limited to less than 0.3 times overburden depth (i.e. less than about 60m) and a moderate level of protection is provided if the mining width is limited to less than 0.6 times overburden depth (i.e. less than 120m).

It is noted that the sheer nature of sandstone cliff formations is testament to natural weathering processes that from time to time induce rock falls. The presence of a barrier to mining of any size does not preclude the possibility of rock falls occurring before, during or after mining, but subsidence monitoring indicates that the influence of mining can be removed with the provision of a protection barrier equivalent to 26.5° angle of draw, and substantially removed if mining does not proceed directly under cliff formations.

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1. INTRODUCTION

The surface at Baal Bone Colliery is characterised by steep topography and sandstone cliff formations. The colliery has undertaken an ongoing program of subsidence monitoring aimed, inter alia, to develop an understanding of the impacts of longwall mining on cliff formations with a view to being able to provide protection from mining impacts when necessary. Baal Bone Colliery has commissioned SCT Operations Pty Ltd (SCT) to review this subsidence monitoring and summarise the findings with particular focus on the impacts of longwall mining on cliff formations. This report presents the results of our review.

The detailed results of subsidence monitoring programs at Baal Bone Colliery are presented in SCT reports compiled at the completion of each longwall panel or, in some cases, each group of longwall panels. This report aims to review the available monitoring and summarise the findings.

It is noted that the understanding of subsidence impacts on cliff formations that has been developed from monitoring at Baal Bone Colliery has been used to design the layout of longwall panels at the mine for more than a decade. All specific sandstone cliff formations identified as requiring protection have been successfully protected.

The impacts of mining on sandstone cliff formations that were not specifically protected have been consistent with the levels of impacts expected. These impacts include perceptible cracking on exposed sandstone at about 20m centres and rock falls over 10-20% of the cliff line length directly over the mining area. The understanding of subsidence impacts on cliff formations is considered to be relatively well developed given the numerous uncertainties associated with the ongoing natural erosion processes associated with sandstone cliff formations.

The report is structured as follows:

Section 2 provides a description of the geological setting, the mining geometry and an overview of the subsidence monitoring that has been conducted at Baal Bone Colliery.

Section 3 describes the generalised subsidence behaviour at Baal Bone Colliery and provides a summary of the outcomes of the subsidence monitoring including a review of angle of draw measurements.

Section 4 describes a general description of the observations of mining impacts on sandstone cliff formations.

Section 5 presents a more detailed review of the monitoring results relevant to the design of subsidence protection barriers for longwall mining approaching cliff formations from the downslope side. Monitoring from Longwalls 11, 12 and 19 is presented.

Section 6 presents a more detailed review of monitoring results relevant to the design of subsidence protection barriers for longwall mining approaching cliff formations from the high side. Monitoring from Longwalls 20, 21, 24 and 25 is presented.

Section 7 presents the conclusions and Section 8 a list of references.

2. SITE DESCRIPTION

In this section, the geological and mining settings are described to provide a context for interpretation of the subsidence behaviour. An overview of the subsidence monitoring conducted at Baal Bone is also presented.

2.1 Geological Setting

Baal Bone Colliery mines the Lithgow Seam located within the Permian Coal Measures. At Baal Bone Colliery, the coal measure strata and the overlying Triassic sandstones of the Burra-Moko Head Group are relatively flat and dip gently to the east-north-east. The Triassic sandstones have eroded completely away over much of the mining lease. In areas where they remain, they have acted as cap rocks preventing the erosion of the underlying strata and have formed prominent and, in some cases spectacular, formations characterised by sheer cliffs and steep topography.

The base of the cliff formations is defined by the upper boundary of the Caley Formation. At Baal Bone Colliery, the Caley Formation is approximately 20m thick and consists of claystones and shales that are more friable and prone to erosion.

The Lithgow Seam is overlain by approximately 130m of Permian Strata from the Illawarra Coal Measures. The seam ranges in thickness over the Baal Bone mining lease from 2.1m to 2.6m thick and in elevation from 800m in the east to 860m in the west.

Overburden depth ranges from outcrop (0m) to approximately 240m, primarily as a result of variations in surface topography.

2.2 Mining Layout

Baal Bone Colliery mines the full seam section of the Lithgow Seam using the retreat longwall method. Longwall panels 1-19 were mined to give a final void width that was 211m wide in most cases. The longwalls panel voids have been 250m wide from Longwall 20 onward.

2.3 Overview of Subsidence Monitoring at Baal Bone Colliery

Figure 1 shows the layout of Baal Bone Colliery and the location of the subsidence monitoring conducted at the mine.

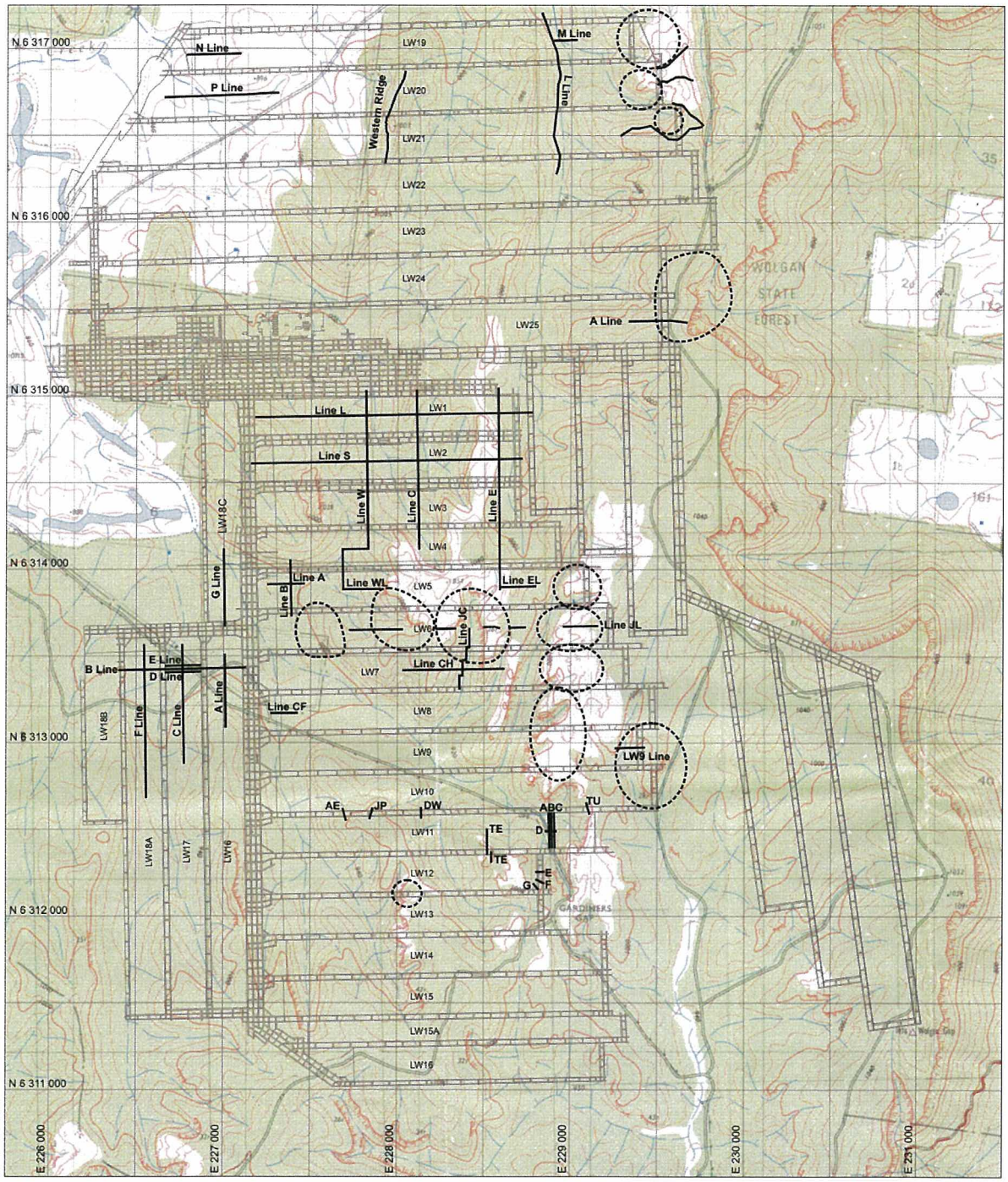


Figure 1 Site plan showing location of subsidence lines and subsidence monitoring areas at Baal Bone Colliery.

A relatively intensive program of subsidence monitoring was conducted over Longwalls 1-5 using the conventional method of levelling and peg-peg chaining. While effective in terms of characterising general subsidence behaviour, this monitoring did not allow the three dimensional nature of the subsidence movements in steep topography to be fully appreciated because only one component of the horizontal movement was measured. A complete analysis of the results of this monitoring is presented in SCT Report BBO0306/2 (1992).

In the steep topography and cliff formations at the start of Longwall 5 and in Longwalls 6 and 7, a different style of subsidence monitoring was required because conventional surveying pegs were simply not practical in the very steep terrain. A technique involving the use of three dimensional surveying and an array of fixed reflectors was pioneered by the colliery in Longwall 5 and by Kay (1991) in Longwalls 6 and 7. The technique proved to be effective and provided some of the first quantitative measurements of the effects of surface topography on horizontal subsidence movements and the relationships between these horizontal movements and the impacts on cliff formations.

Monitoring in three dimensions of subsidence line CH over the centre of Longwall 7 provided a most convincing indication of the interaction between surface topography and horizontal subsidence movements (SCT Reports BBO0306/2 and Mills 2001). A summary of this monitoring is reproduced in Figure 2 and the significant influence of slope can be seen quite clearly.

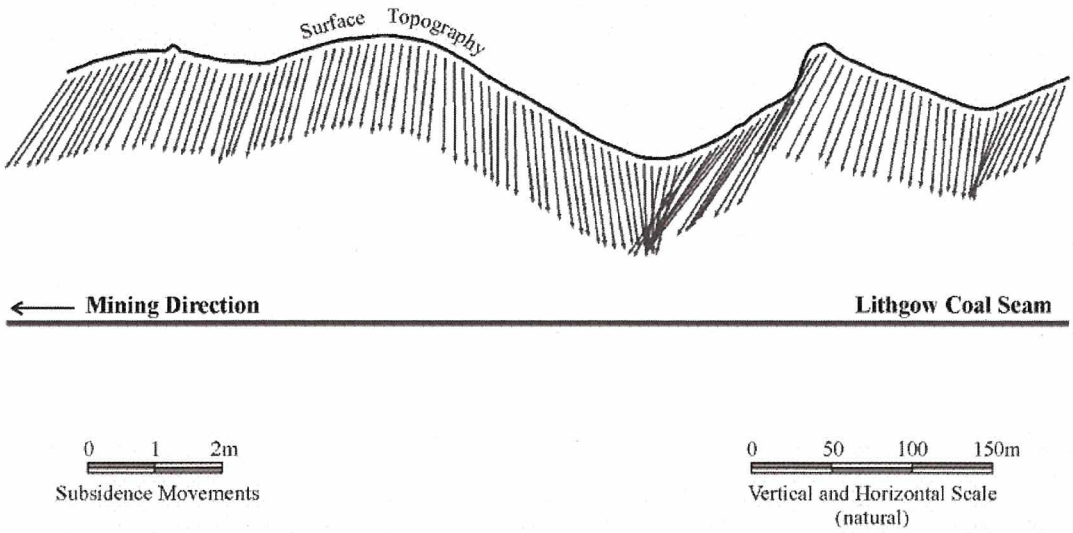
SCT became involved in analysis of the subsidence data from Longwall 7 onwards. The routine subsidence monitoring conducted over most of the longwall panels has been focussed on studying the impacts of mining on a range of topographic features including cliff formations.

Further three dimensional reflector monitoring near the start of Longwalls 8, 9 and 10 provided greater understanding of the interaction between cliff falls and the horizontal movements associated with longwall mining in steep topography and the development of horizontal movements at the start of a longwall panel (SCT Reports BBO0306/2 and BBO0387).

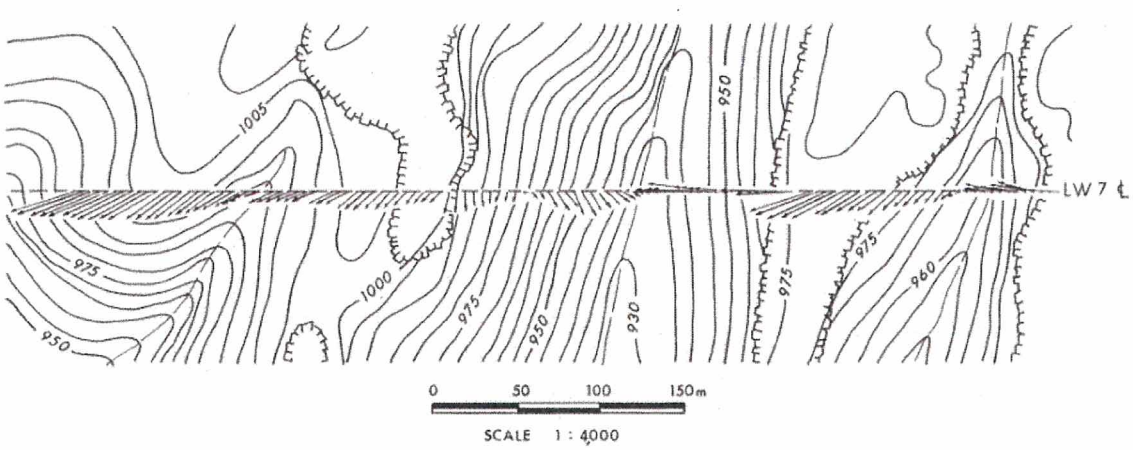
Close spaced monitoring at the outbye end of Longwall 8 in shallow cover showed the essentially gradual and incremental nature of overburden caving behaviour at Baal Bone Colliery. A summary of these results are shown in Figure 3. Each increment of longwall face advance caused an associated increment of subsidence.

Subsidence monitoring in Longwall 9 focussed mainly on the subsidence impacts on electricity transmission infrastructure (SCT Report BBO0392).

Subsidence monitoring in Longwall 10 focussed on goaf edge subsidence profiles at a range of overburden depths and different topographic environments, further study of impacts on electricity transmission infrastructure and start area monitoring (SCT Report BBO0520). The accuracy and repeatability of reflector measurements was confirmed.



a) Vertical section showing longitudinal displacement vectors.



b) Plan showing horizontal displacement vectors superimposed on topography.

Figure 2 Permanent post mining displacement vectors Longwall 7 centre-line, subsidence line CH.

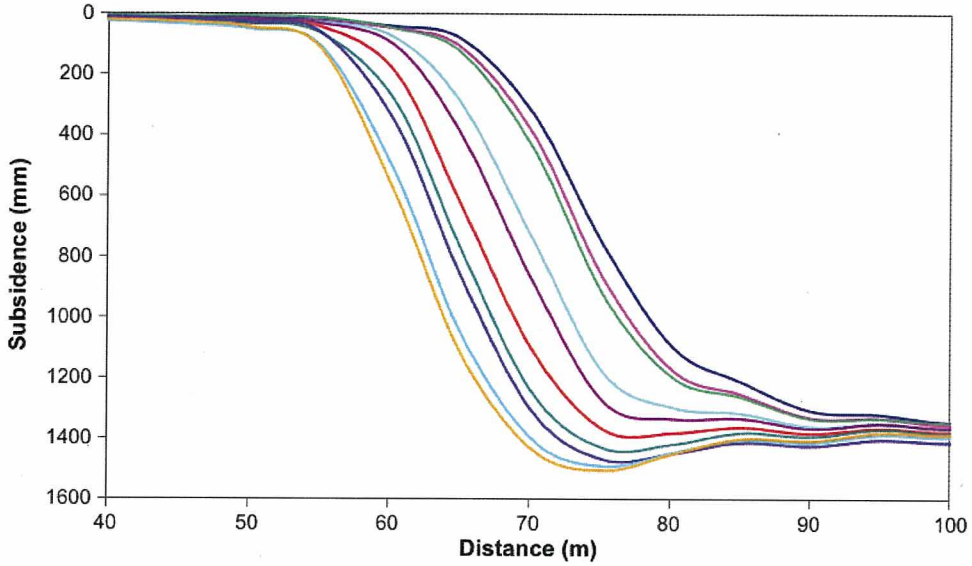


Figure 3 Longwall 8 finish line subsidence monitoring.

Subsidence monitoring over Longwalls 11 and 12 was focussed on determining the magnitude of subsidence over the start of longwall panels with a view to providing suitable protection barriers to the cliff formations of Gardiners Gap. Four conventional lines at the start of Longwall 11 and three radiating lines at the start of Longwall 12 provided confirmation of the distribution of subsidence movements about the start of longwall panels. The influence of steep topography sloping parallel to a longwall panel was investigated on T Line. These results are presented in SCT Report BBO0509.

A study of the potential to use terrestrial photogrammetry was undertaken at a small sandstone outcrop site located over Longwall 12 (SCT Report BBO0567). The application of the technique was compromised by the target visibility but the intensive control survey monitoring undertaken provided insight into the nature of subsidence movements on sandstone cliff formations and the potential for subsidence movements to be accommodated by movements on natural joints. It was recognised that individual formations need to be greater than about 20m in size and capable of colliding with adjacent formations for mining subsidence to cause rock falls.

Subsidence monitoring over Longwalls 13-15B was limited to fine tuning predictive capability at a range of sites and comparing predictions with outcomes. It was recognised during these assessments that overhanging cliff formations are more susceptible to rock fall impacts than pagoda style formations and that rock fall impacts are limited almost entirely to within the mining area (i.e. that area that is directly above the longwall goaf or the intermediate chain pillars).

Subsidence monitoring over Longwalls 16-18C and the western ends of Longwalls 19 and 20 was focussed on subsidence monitoring at shallow depths as low as 27m (SCT Reports BBO1296 and BBO1694). This monitoring was helpful in terms of understanding the development of horizontal movements in relation to vertical subsidence but is not relevant to cliff formations and is not discussed further in this report.

Subsidence monitoring at the start of Longwalls 19-21, 24 and 25 has been focussed on confirming the level of protection provided to cliff formations located beyond the end of longwall panels. The results of this monitoring are presented in detail in SCT Reports BBO2056, BBO1976C and BBO2874a. These results are considered in more detail in Sections 5 and 6 of this report.

3. GENERALISED SUBSIDENCE BEHAVIOUR AT BAAL BONE COLLIERY

The overburden depths at Baal Bone Colliery are typically less than 200m and therefore typically less than the longwall panel width. Subsidence behaviour at panel width to depth ratios of greater than about 1-1.2 is referred to in subsidence engineering terms as super-critical subsidence behaviour. In super-critical width panels, full subsidence is developed in the central part of each longwall panel with much lower levels of subsidence over the chain pillars isolated between longwall goafs.

3.1 Vertical Subsidence

Figure 4 shows a summary of the relationship between maximum subsidence over each longwall panel and the ratio of longwall panel width to overburden depth based on subsidence monitoring at Baal Bone Colliery. This behaviour is consistent with subsidence behaviour elsewhere in the Western Coalfield.

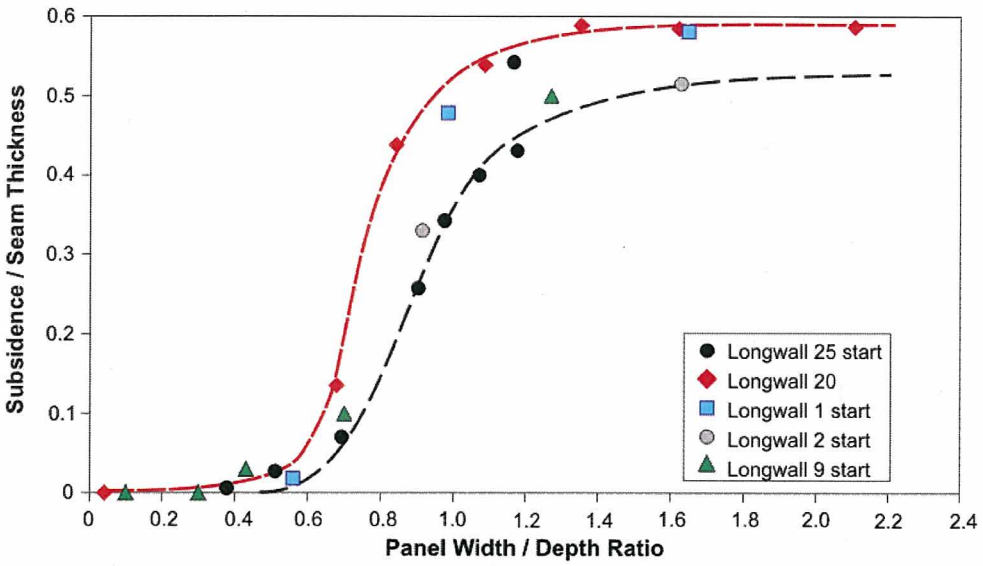


Figure 4 Relationship between maximum surface subsidence and panel width for Baal Bone Colliery.

The magnitude of full subsidence in the centre of each panel is a function of the seam thickness mined and is typically equal to a maximum of about 65% of seam thickness. At Baal Bone Colliery, the seam thickness mined is in the range 2.1-2.4m so the maximum subsidence in the centre of each longwall panel is typically in the range 1.4-1.6m.

By comparison, the subsidence over the chain pillars is typically less than 0.2m at shallow depths and only increases to about 0.5m when the overburden depth increases to more than 200m.

Figure 5 shows a typical final subsidence profile across a longwall panel at an overburden depth of approximately 150m. This one is measured on L Line at the start of Longwalls 19-21.

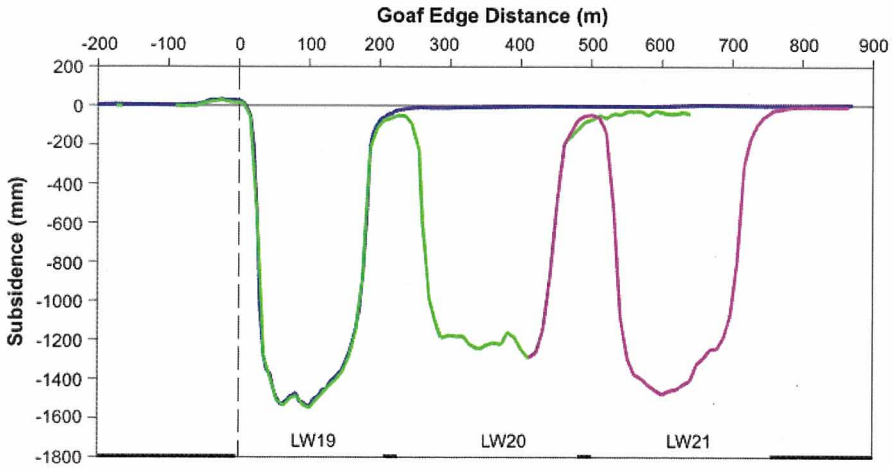


Figure 5 Subsidence movements on L Line showing typical final subsidence profiles over longwall panels at Baal Bone.

Figure 6 shows a summary of the goaf edge subsidence measured over previous longwall panels at Baal Bone Colliery. While there is a range, there is a characteristic shape to the subsidence profile over the solid goaf edge. There are low levels of subsidence over the solid, a transitional zone of changing subsidence that extends a distance from the goaf edge about 0.6-0.7 times overburden depth, and a zone of full subsidence remote from the goaf edge.

3.2 Tilt

Tilting of the ground surface occurs over the longwall panel as the overburden strata drapes down to reach full subsidence in the centre. In the central part of each panel, this tilting is transient in nature, while on the sides and at the ends of the panel, tilting is permanent.

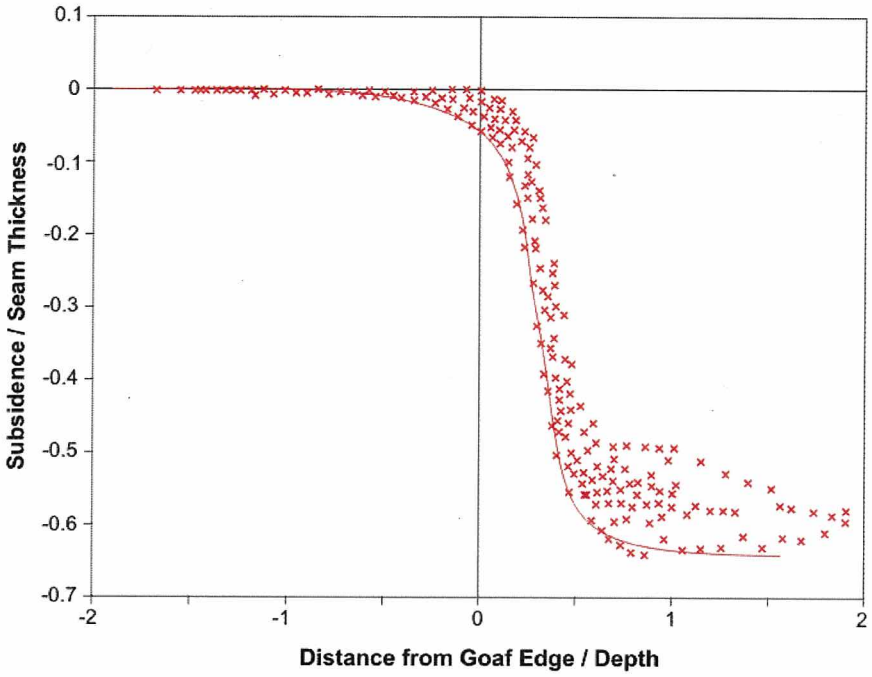


Figure 6 Subsidence distribution over longitudinal rib at Baal Bone Colliery.

The overburden strata drapes or sags over the solid edges of the panel. The distance it can support the ground surface and prevent it from fully subsiding is a function of overburden depth. As the overburden depth increases, the distance that the overburden strata can support the surface increases and the differential between subsidence over the chain pillars and in the centre of each panel decreases. As a result, the ground tilt required to accommodate the differential subsidence between the centre of each panel and the chain pillars decreases as the overburden depth increases.

Figure 7 shows a summary of the tilt behaviour measured at Baal Bone Colliery presented as a function of distance from the goaf edge divided by overburden depth. Maximum tilt is observed to occur at a distance for approximately 0.3 times overburden depth from the goaf edge.

3.3 Horizontal Movement

Horizontal subsidence movements in flat terrain are characterised by movement toward the approaching goaf and then soon after the longwall face has passed, a reversal toward the direction of mining. The magnitude of the initial movement toward the approaching goaf is typically 100-150mm and the magnitude of the movement to toward the retreating goaf is typically 150-200mm, so the ground surface is usually left permanently displaced in the direction of mining by 50-100mm. Figure 8 shows the form of the subsidence movements in flat terrain.

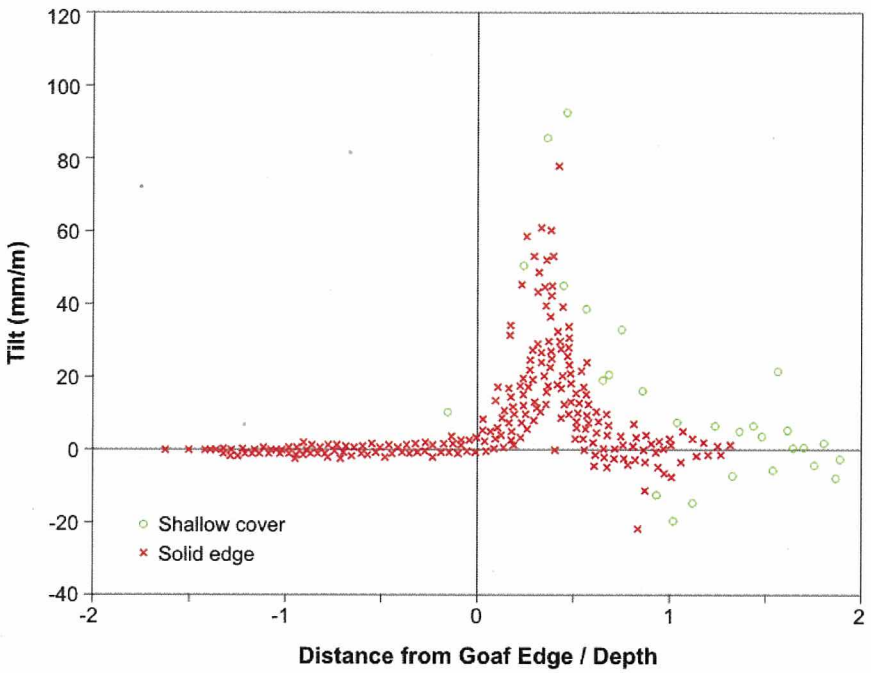


Figure 7 Tilt over longitudinal rib at Baal Bone Colliery.

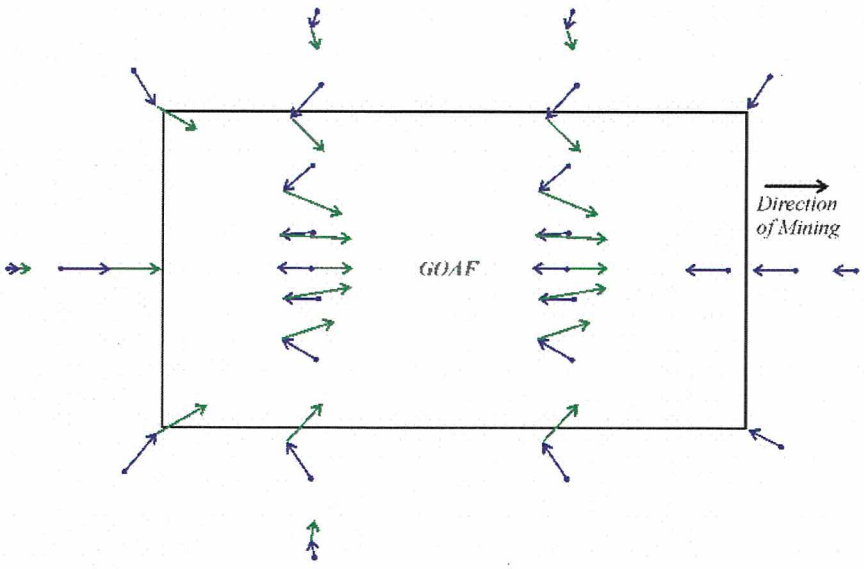


Figure 8 Horizontal subsidence movements in flat terrain.

In steep terrain, significant downslope movements are observed in addition to the systematic flat terrain subsidence movements. The magnitude of the downslope movement is sensitive to a combination of factors, including the slope of the ground, the stratigraphic horizons and the direction of mining relative to the slope (Mills 2001). Inevitably there is movement from the high points toward the valleys, so that the ground surface is stretched along topographic high points and compressed in valleys. Tension cracks are evident on ridges and other topographic highs and suppressed in valleys.

3.4 Horizontal Strain

Horizontal strain is a measure of the differential horizontal subsidence movement divided by the horizontal distance between adjacent measuring points (typically 1/20th of overburden depth). In flat terrain, tensile or stretching strains tend to be concentrated near the edge of the panel and compressive strains toward the panel centre. In steep terrain, the direction and magnitude of horizontal strains tends to be dominated by downslope movements. Figure 9 shows a summary of the horizontal strains measured at Baal Bone Colliery plotted as a function of distance from the goaf edge divided by overburden depth.

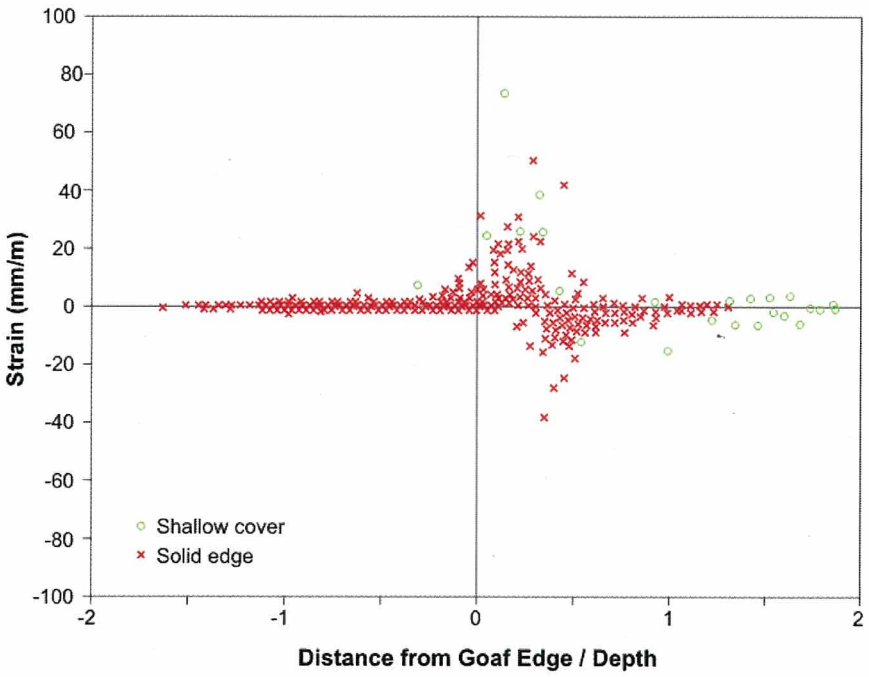


Figure 9 Horizontal strain over longitudinal rib at Baal Bone Colliery.

3.5 Angle of Draw

An angle of draw is used to define the practical limit of vertical subsidence outside a mining area. The angle of draw is defined as the angle between vertical and a line joining the goaf edge at seam level and a point on the surface where the vertical subsidence becomes less than some value, typically 20 mm. A value of 20 mm is usually adopted as the limit of vertical subsidence because this approaches the practical limit of routine survey accuracy and approaches a point where fluctuations in ground level caused by natural processes become larger than the subsidence movements.

Angle of draw is usually determined through measurement as a site specific parameter. However, angles of draw of 26.5° and 35° are used by regulatory authorities to provide a practical limit to the extent of vertical subsidence impact. Angles of draw of 26.5° and 35° correspond to distances on the surface from the goaf edge of 0.5 and 0.7 times depth respectively.

Measurements of angle of draw at Baal Bone Colliery in the early panels at Baal Bone Colliery range up to 17° (0.3 times depth) with an average of 6° (0.11 times depth) and goaf edge subsidence ranges from -13mm to 87mm with an average of 36mm (SCT Report BBO306/2). Most subsequent measurements have fallen within this range.

Surveys conducted at the start of Longwall 21 indicate angles of draw up to 23-25° in circumstances where the longwall starts just under a cliff formation and mines toward the valley. A higher than average angle of draw would be expected in this circumstance.

Monitoring at the start of Longwalls 11 and 12 shows that the 20mm subsidence contour cuts across the corner of each longwall panel as the overburden strata bridges the panel corners in these areas. These results are discussed in more detail in Section 5.

It should be noted that an angle of draw is defined in relation to vertical subsidence. Horizontal movements are known to occur well beyond the limit of vertical subsidence so consideration needs to be given to the effects of horizontal movement outside of the angle of draw for structures and surface features that may be sensitive to such movements.

Cliff formations are not particularly sensitive to far field horizontal movements because far field horizontal movements tend to be of low magnitude and tensile in nature. Sandstone cliff formations are less sensitive to tensile horizontal movements because tensile movements are accommodated by stretching of joints and, close to the goaf edge, by tensile cracking. Neither of these processes cause rock falls. Opening of joints is usually imperceptible outside of 0.4 times overburden depth from the goaf edge.

3.6 Goaf Edge Subsidence

Goaf edge subsidence at Baal Bone Colliery is characterised by vertical subsidence at the goaf edge of generally less than 70mm decreasing in magnitude away from the mining area to be less than 20mm at a distance generally less than 40-50m from the goaf edge.

Vertical subsidence at the centreline of longwall start areas is similar to, but slightly greater than, vertical subsidence over other solid goaf edges.

In terrain that is steeply dipping toward the mining area, goaf edge subsidence is higher (60mm-90mm) than in flat terrain where it is typically 30mm-50mm.

Horizontal movements above the solid goaf edge are typically slightly greater in magnitude than vertical subsidence and are mainly in a direction toward the goaf.

The magnitude of horizontal movements appears to be variable depending on the direction of dip of the surface terrain. Horizontal movements over the solid goaf edge range from 50mm-150mm in flat and gently dipping terrain to 200mm-400mm in steeply dipping terrain.

Horizontal movements above the solid increase toward the goaf and tend to have a uni-directional stretching effect on the surface, causing cracking of, rather than collision between, surface sandstone formations.

4. GENERAL OBSERVATIONS OF SUBSIDENCE IMPACTS ON SANDSTONE CLIFF FORMATIONS

Observations of the impacts of mining on sandstone cliff formations have been made throughout the monitoring of subsidence at Baal Bone Colliery. These observations show that the impacts of mining on rock formations can be divided into three main categories: rock falls, tensile cracking and shear cracking.

4.1 Rock Fall Observations

At Baal Bone Colliery, rock falls range in size from relatively minor falls involving only a few cubic metres of sandstone material to rock falls involving several thousand cubic metres of material. Observation of these rock falls and the fracture surfaces that have developed in the rock are described and discussed in this section.

Rock falls are limited to within the mining area or very occasionally just outside the mining area (within 0.1 times overburden depth). At Baal Bone Colliery, SCT is aware of only three occasions when subsidence related rock falls on cliff formations have occurred outside of the mining area and all three occurred immediately outside of the mining area.

Rock falls are almost universally associated with horizontal compression movements acting in a direction parallel to the rock face sometimes in association with differential shear movements.

Rock falls typically do not occur unless there is capacity within the rock mass to generate and resist horizontal compression movements. Free standing sandstone formations less than 20m in size are typically unaffected by mining subsidence and do not experience rock falls because the compression forces necessary to cause rock falls cannot be generated.

When rock fall fracture surfaces are inspected closely, it is common to see a combination of existing joints, tree root jacking in these joints and shear through fresh rock. The shearing through fresh rock is consistent with lateral compression along the line of the rock formations.

Rock falls occur over 10-20% of the length of cliff formations that are mined under. This average increases locally and it is possible to estimate which formations are more likely to be affected by mining. Kay (1991) reported 16% of cliff formations undermined at Baal Bone Colliery in Longwalls 1-7 experienced rock falls.

The principal failure mechanism associated with mining induced rock falls involves the generation of opposing horizontal compressive forces along the face of cliff formations that develop when a cliff formation is subject to opposing lateral movements along its length. The triaxial strength characteristics of sandstone rock strata are such that the strength of the intact rock is significantly reduced by the generation of tensile stresses in a plane perpendicular to the cliff face.

High and overhanging cliffs are more susceptible to compressive rock failure and the rock falls that result from such failure. High and overhanging cliff formations have larger zones of tensile stress and a greater magnitude of peak tensile stress. As a result, high and overhanging cliff formations experience a greater reduction in rock strength along the cliff and require lower levels of relative lateral compression before rock failure occurs.

Another factor that increases the likelihood of rock falls is the shape of the cliff line in plan. Re-entrant or concave cliff features tend to concentrate horizontal stress when cliff formations are laterally compressed. These sites tend to be more susceptible to rock falls.

4.2 Tensile and Shear Cracking

Tensile cracking and shear cracking tend to occur in combination directly over the mining area and are generally perceptible as permanent open fractures at regular intervals on sandstone formations greater than 20m in size. Figure 10 shows an example of a tensile crack developed in sandstone strata in steep terrain near the start of Longwall 21.



Figure 10 Tensile fracture in sandstone strata at the start of Longwall 21.

Tensile cracking of sandstone rock strata typically follows a pattern that is aligned with regional joint directions rather than the alignment of mining activity, suggesting that the sandstone cliff formations are moving in response to systematic subsidence movements dictated by pre-existing defects deeper within the overburden strata.

A crack survey conducted over Longwall 9 maingate chain pillar between cut-throughs 18 and 20 showed that the cracks aligned primarily with pre-existing structural weaknesses rather than with the longwall panel geometry. The results of the study are presented in SCT Report BB00387.

Figure 11 shows the locations and widths of the cracks that were observed. The following conclusions were reached from this study.

1) There is a general trend in an east-north-easterly direction, which is not parallel with the goaf edge.

2) The largest cracks (up to 400mm wide) exist over the goaf area of Longwall 9, but smaller cracks (1mm-50mm) are present outside the extracted panel over the solid.

3) The furthest distance from the goaf edge where a crack was observed was 70m (0.32 times overburden depth) although at this distance the crack was only 1mm wide and barely perceptible. The same crack was 15mm wide at 50m from the goaf edge (0.22 times overburden depth). This particular crack occurred on a large plateau area which may have influenced the distance it was able to extend from the goaf edge.

4) There is generally no noticeable shear displacement across the cracks. They generally dip at 10°-15° toward the solid. These observations indicate the cracks are primarily tension cracks with only a small component of shearing.

5) The horizontal displacements of the surface toward the goaf are indicated by the sum of the crack widths from the solid side. Horizontal displacement above the goaf edge is in the range 25mm-60mm over the length of the section surveyed.

6) Although crack directions appear to be slightly modified by the surface topography, going around rather than through rock formations, the overall crack direction appears to emanate from deeper down within the overburden strata.

The minor set of regional fractures is oriented in an east-north-easterly direction. This orientation aligns closely with the surface cracking observed supporting the view that the crack formation is influenced by pre-existing structural weaknesses in the overburden strata.

At the start of Longwall 19, tensile cracking is also apparent outside the mining area to a distance equal to approximately 0.4 times overburden depth. Figure 12 shows a photograph of the cliff formation at the start of Longwall 19. Several vertical cracks have developed in this cliff formation. Their accumulated width is approximately equal to the horizontal goaf edge subsidence movements. No rock falls occurred on this formation despite the development of tension cracks.

While horizontal movements are measured beyond 0.4 times overburden depth, their magnitude is too small to be perceptible.

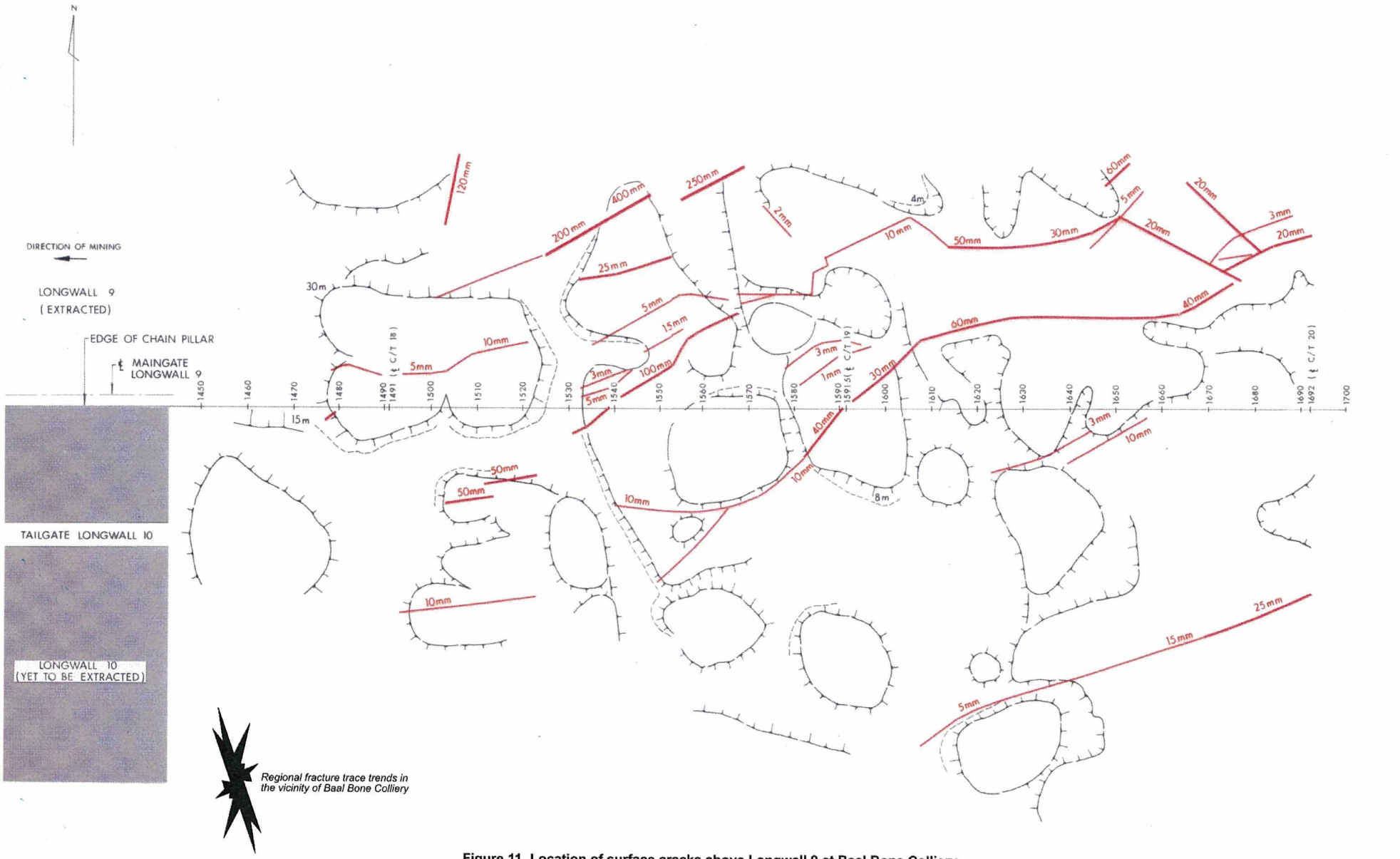


Figure 11 Location of surface cracks above Longwall 9 at Baal Bone Colliery.

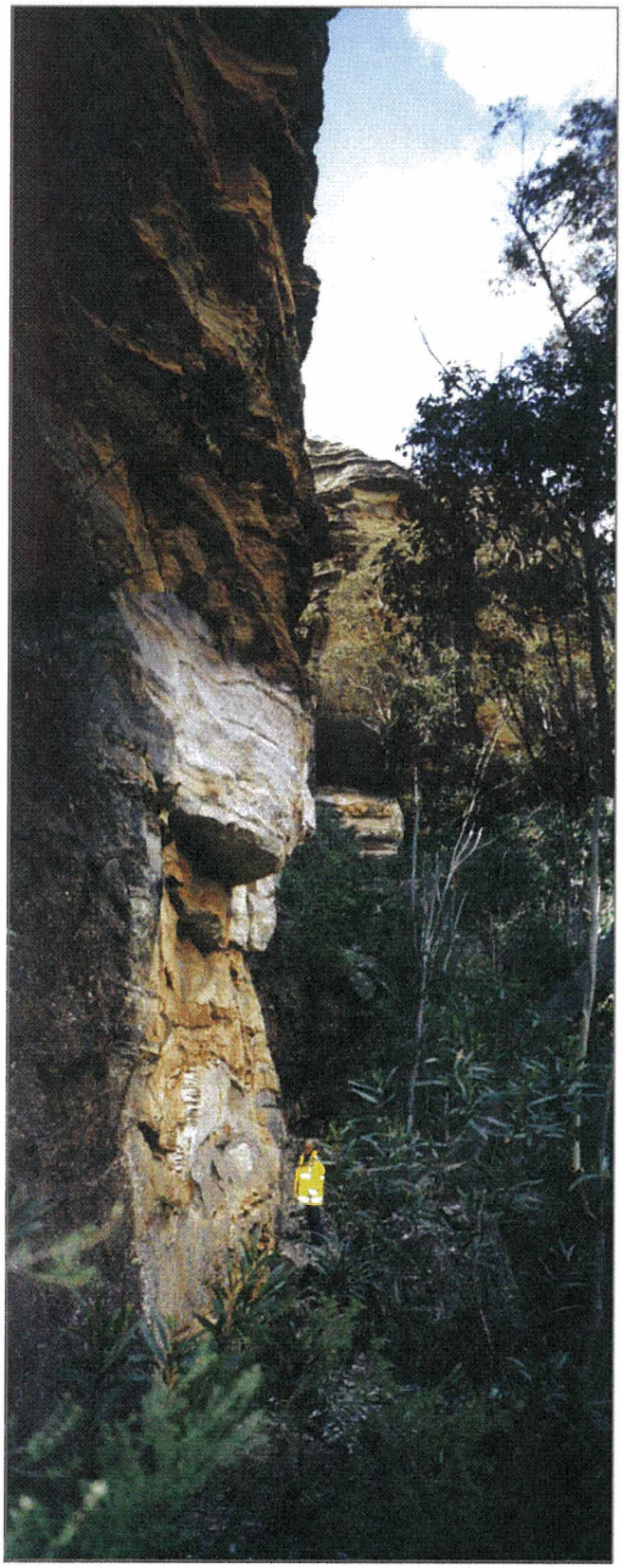


Figure 12 Cliff formations to the east of Longwall 19 start, (man standing approximately 45m from goaf edge.) There are no rock falls in this formation but some tension cracks.

The tensile cracking outside the mining area is unidirectional toward the goaf so that it does not cause rock falls which are associated with compression movements. The largest tension cracks are observed at the start of longwall panels in steep topography and may be 0.5-0.6m wide.

Shear movements are most evident along bedding planes, particularly on low strength horizons that tend to be located at the base of cliff formations.

5. SUBSIDENCE PROTECTION BARRIERS AT THE FOOT OF CLIFF FORMATIONS

The subsidence monitoring at Baal Bone Colliery of relevance to the design of subsidence protection barriers located at the foot of sandstone cliff formations is presented in this section. This includes a summary of the subsidence monitoring conducted at the start of Longwalls 11, 12 and 19 (SCT Reports BB00509 and BB02056). The results are presented in summary form and then described in more detail.

The results of monitoring at the start of Longwalls 11 and 12 indicate that:

- In the corners of longwall panels, the overburden strata bridges between the solid abutment and the chain pillar which significantly reduces the amount of surface subsidence in this area. Angles of draw at the corners of longwall panels are much less, and typically negative (i.e. the 20mm line is located over the longwall panel), compared to angles of draw determined from straight goaf edges.

- When a longwall is mined adjacent to an existing goaf, significant horizontal movement occurs above the chain pillar in a direction toward the existing goaf. The magnitude of this movement appears to increase with depth and the steepness of terrain.

The results from monitoring at the start of Longwall 19 indicate that:

- No rock falls occurred on 10-20m high sandstone cliff formations when the longwall panel started at the toe of sandstone cliff formations, indicating that the cliff formations were protected from rock falls provided they were not directly mined under.

- Tensile surface cracking was observed on the sandstone cliff formations to a distance of about 0.4 times depth from the goaf edge outside the mining area. This cracking did not cause any rock falls on the cliff formations even though they were greater than 20m high in places.

5.1 Start Area of Longwall 11

Four subsidence lines were surveyed above the solid abutment adjacent to the start line of Longwall 11 to measure the extent of surface subsidence beyond the limit of the longwall panel, particularly in the panel corners. The lines were installed and surveyed prior to the start of mining of Longwall 11,

and after Longwall 10 had been mined. They were resurveyed once, three months later, when Longwall 11 had retreated approximately 1km.

The location of the subsidence lines and the subsidence measured is shown in Figure 13. The depth of overburden in the area ranges from 105m-125m and is approximately 115m in the centre of the panel. The seam thickness mined was approximately 2.6m.

The surface subsidence was measured adjacent to the start line area of Longwall 11 above the solid rib side. The measurements indicate that:

- In the centre of the face, the subsidence behaviour above the start line of Longwall 11 is consistent with subsidence behaviour over other solid ribs at the colliery. The angle of draw measured is 8° (0.14 times depth) and the goaf edge subsidence is 71mm.

- Near the corners of the panel, the surface subsidence is significantly less as a result of the overburden strata bridging across the corners of the panel. The 20mm subsidence contour crosses the goaf edges approximately 25m in from the corners of the panel giving a negative angle of draw in this area.

- Horizontal subsidence movements are toward the goaf and are greater in magnitude in the vicinity of the goaf edge than the vertical subsidence.

5.1.1 Vertical Subsidence

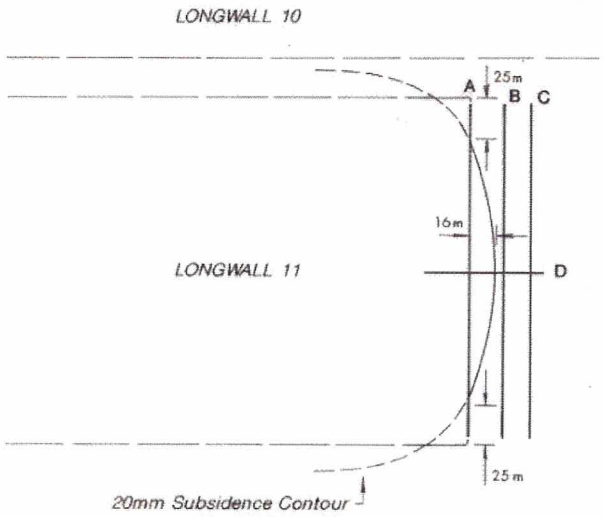
Figure 13 shows that the vertical subsidence above the solid start line abutment increases toward the centreline of the longwall panel on the three subsidence lines that are parallel to the face. The subsidence is greatest near to the goaf edge and decreases to less than 20mm within 16m of the goaf edge.

Line D indicates an angle of draw of 8° and goaf edge subsidence of 71mm.

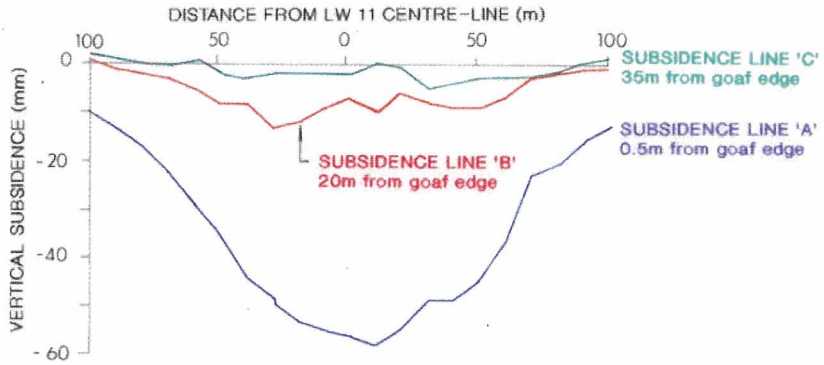
The angle of draw and goaf edge subsidence measured above the start area of Longwall 11 are therefore within the ranges of previous measurements at the colliery but towards the upper end of the range for goaf edge subsidence.

In the corners of the panel, the overburden strata bridges between the solid abutment inbye of the start line and the chain pillars. This bridging behaviour appears to be similar in the maingate and tailgate corners, although there may have been some additional subsidence in the tailgate corner that occurred when Longwall 10 was mined. Any subsidence due to Longwall 10 would have occurred prior to installation of the subsidence lines.

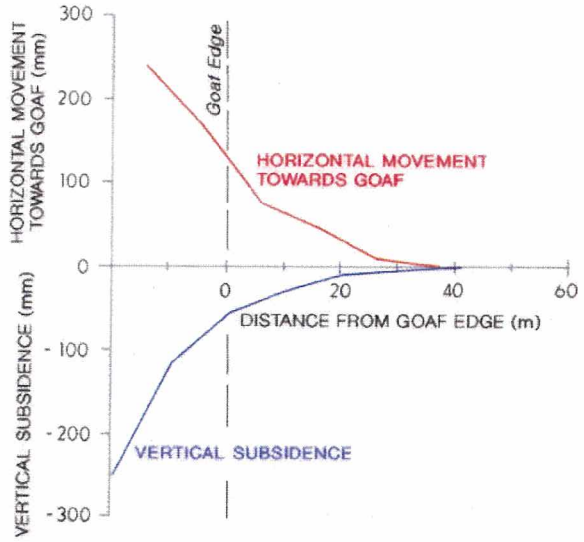
The 20mm subsidence contour at the start of Longwall 11 crosses the goaf edges approximately 25m in from the panel corners. Thus the effective angle of draw from the corners of the panel is negative.



a) Layout of subsidence lines A, B, C and D showing 20mm subsidence contour.



b) Vertical subsidence along A, B and C lines.



c) Subsidence along longwall centre-line (D Line).

Figure 13 Subsidence in start area of Longwall 11.

In terms of providing a subsidence protection barrier at the corner of longwall panel, the subsidence data from Longwall 11 would indicate that the corner of the longwall panel could be brought right up to, and even slightly under, the area required to be protected. The use of an angle of draw determined from straight goaf edges would seem to be overly conservative when applied to the corners of a longwall panel.

5.1.2 Horizontal Movements

Horizontal movements were measured on lines A-D by chaining between pegs. The displacements measured on line D indicate that the horizontal displacements in the vicinity of the goaf edge are toward the goaf and greater in magnitude than the vertical subsidence at the same relative position. At the goaf edge, the horizontal displacement is 145mm compared to a vertical displacement of 71mm.

The horizontal movements measured toward the goaf act in a direction across the three subsidence lines parallel to the face, A, B and C. This sideways component, which is much greater than the longitudinal component, would be expected to significantly affect the horizontal movements that were measured between pegs. The full three dimensional displacements were measured on the subsidence lines at the start of Longwall 12 to overcome the inability of peg to peg chaining to measure sideways movements.

5.1.3 Impacts on Cliff Formations

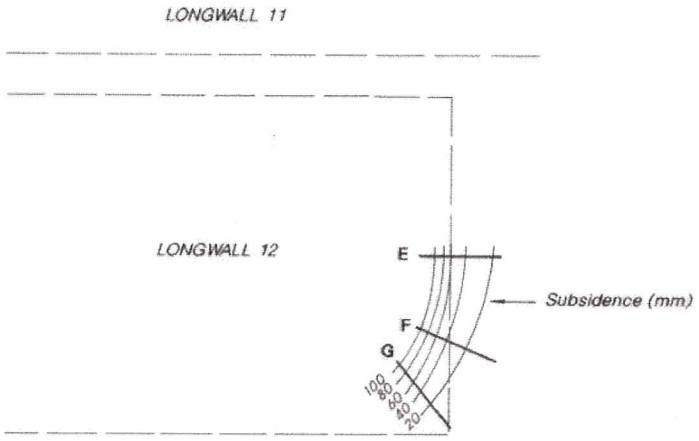
There were no perceptible impacts on the cliff formations located just inside 26.5° angle of draw of the start line of Longwall 11.

5.2 Start Area of Longwall 12

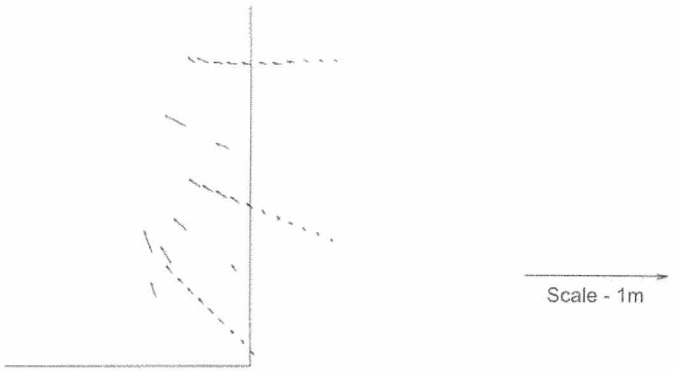
The three dimensional co-ordinates of thirty eight subsidence points were surveyed above the starting area of Longwall 12. Most of these points were arranged in three lines radiating from above the longwall panel to over the face start line as shown in Figure 14. Five points were located between the lines to extend the coverage of subsidence information obtained. The eastern ends of the two corner subsidence lines terminated at the foot of significant sandstone formations.

The subsidence points were resurveyed once, approximately two months after Longwall 12 started, when the longwall had retreated approximately 600m.

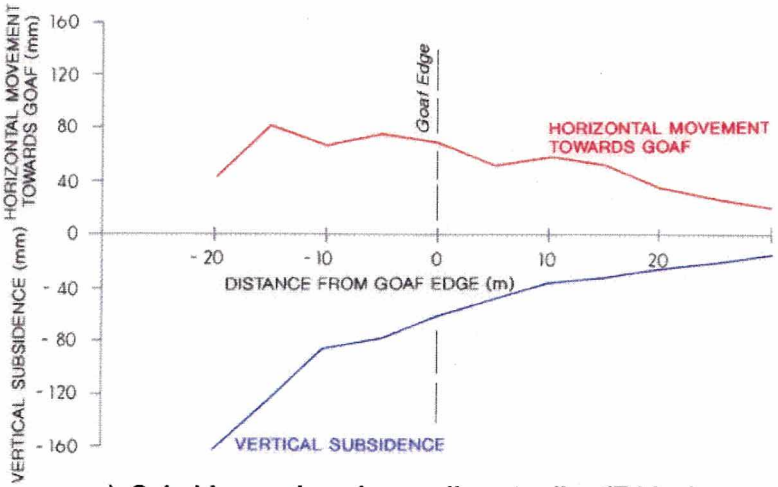
The depth of overburden in the area ranges from 110m-140m and is approximately 116 in the centre of the panel at the start line. The seam thickness mined was approximately 2.6m.



a) Layout of subsidence lines E, F and G showing subsidence contours.



b) Horizontal displacements.



c) Subsidence along longwall centre-line (E Line).

Figure 14 Subsidence in start area of Longwall 12.

The measurements indicate that:

- In the centre of the face, the subsidence behaviour above the start line is consistent with subsidence behaviour over other solid ribs at the colliery. The angle of draw measured is 12° (0.22 times depth) and the goaf edge subsidence is 62mm.

- Near the corners of the panel, the surface subsidence is significantly less as a result of the overburden strata bridging across the corners of the panel. The 20mm subsidence contour crosses the goaf edges approximately 30m in from the corners of the panel giving a negative angle of draw in this area.

- Horizontal subsidence movements are toward the goaf and are slightly greater in the vicinity of the goaf edge than vertical movements.

5.2.1 Vertical Subsidence

The 20mm subsidence contour for Longwall 12 follows a similar path to the 20mm subsidence contour for Longwall 11. In the centre of the face, it is located over the solid abutment and curves around over the corner of the panel, crossing the face start line approximately 35m from the corner of the panel, and the chain pillar goaf edge at a distance of approximately 30m from the panel corner.

The vertical subsidence profile measured above the centreline of the longwall panel is within the range of subsidence profiles measured over previous longwall panels at the colliery.

5.2.2 Horizontal Movements

All horizontal displacements measured above the start line area of Longwall 12 are in a direction toward the centre of the longwall panel. The surface topography also dips in this direction so that downslope movement would be expected to complement any horizontal movements toward the goaf.

The magnitude of the horizontal movements is less than above the start area of Longwall 11. At the goaf edge, horizontal displacement toward the goaf is 69mm.

5.2.3 Impacts on Cliff Formations

Sandstone cliff formations located above the start area in the corner of Longwall 12 did not show any perceptible cracking or other effects associated with mining activity.

6. PROTECTION BARRIERS TO CLIFF FORMATIONS WHEN MINING UNDER PLATEAUS

The subsidence monitoring at Baal Bone Colliery of relevance to the design of subsidence protection barriers located on the high side of sandstone cliff formations is presented in this section. The monitoring results presented relate to subsidence monitoring conducted at the start of Longwalls 20, 21, 24 and 25 (SCT Reports BBO1976c, BBO2874a and BBO2874b).

Longwalls 20 and 21 at Baal Bone Colliery start under sandstone cliff formations on a ridge system adjacent to a deeply incised valley that cuts right through the full section of the Triassic sandstone cliff forming strata. A considerable subsidence monitoring effort was focused on these two panels to develop a better understanding of the mining induced cliff deformation mechanics and protection strategies that could be used when starting adjacent to major cliff formations. The results of subsidence monitoring over both panels and the implications for protection barriers to the Wolgan Escarpment are presented in this section.

At the start of Longwalls 20 and 21, an angle of draw of 26.5° (or 0.5 times depth) to the top of the ridge was shown to provide protection to the major cliff formations of the deeply incised valley. No cracking or rock falls were observed either on the cliff formations or on the rock formations within 26.5° angle of draw from the goaf edge. Monitoring showed that the protection barrier was unnecessarily conservative.

The monitoring provided further confirmation that cliff formations do not experience mining-induced rock falls as long as they are not directly mined under. The implication is that, provided some tensile cracking and a low risk of rock falls is regarded as acceptable, a moderate level of protection against rock falls is provided to cliff formations as long as mining does not proceed directly under them.

Monitoring of horizontal and vertical subsidence movements at the start of Longwalls 20 and 21 showed the significant difference in magnitude over the mining area compared to outside the mining area. Over the mining area, horizontal and vertical subsidence movements are of the order of 1-1.5m, whereas outside the goaf area, the magnitude of subsidence movements is typically less than 200mm and decreases to less than 20mm within the vertical subsidence movements.

The monitoring showed that the level of protection afforded to the cliffs increases as the distance from mining increases until at about 0.4 times overburden depth even tensile cracking becomes imperceptible. By 0.5 times overburden depth (26.5° angle of draw), vertical subsidence is less than the resolution of the surveying equipment in steep terrain and horizontal subsidence movements are small and unidirectional toward the goaf.

Monitoring at the start of Longwalls 20 and 21 showed that some level of protection can be afforded to cliff formations located directly over the mining

area if the panel width is reduced and inter-panel pillar size increased. However, the geometries formed may not be economically viable from a mining perspective. A moderate level of protection against mining induced rock falls is likely to be achieved by keeping panels narrower than about 0.6 times overburden depth (80-100m) and chain pillars wider than about 0.2 times overburden depth (30-40m).

A higher level of protection is likely to be provided if mining widths are maintained at less than 0.3 times overburden depths and chain pillars wider than 0.2 times overburden depth.

The evidence of rock falls occurring at the start of Longwalls 20 and 21 suggest that by the time the panel width is 1.0 times the overburden depth (to the base of the cliff formations) rock falls become evident.

Longwalls 24 and 25 start adjacent to the Wolgan Escarpment. Monitoring of three dimensional subsidence movements on the Wolgan Escarpment has been compromised by the low levels of subsidence movement being measured and the difficulties of surveying accurately in rugged and remote terrain.

The near goaf edge movements observed are consistent with previous monitoring with the magnitude of both horizontal and vertical subsidence increasing with proximity to the goaf. Small magnitude far field movements were initially affected by inaccuracies in the GPS and associated survey technique. In recent surveys over Longwall 25, these inaccuracies have been reduced and the low levels of movement at the Wolgan Escarpment have been confirmed.

No mining-induced rock falls have occurred on the Wolgan Escarpment at the start of Longwalls 24 and 25 for an angle of draw to the uppermost rock formations of 35°. No impacts are perceptible at an angle of draw of 26.5°.

6.1 Monitoring at Start of Longwalls 20 and 21

Figure 15 shows a plan of the start area of Longwalls 20 and 21 overlain with overburden depth contours and the location of the various subsidence monitoring areas. Baal Bone Colliery mines the Lithgow Seam at an average mining height of 2.5m. The Lithgow Seam dips gently to the northeast in this area and is essentially flat. Both Longwall 20 and 21 are nominally 250m wide measured goaf edge to goaf edge.

The cliff formations at the start of Longwall 20 provided several unique opportunities for the study of subsidence behaviour. These cliffs are up to 50m high and are located directly over the start of the longwall panel. There is a plateau extending back behind the cliffs to a deeply incised valley several hundred metres to the east of the start line. The plateau is flat enough for subsidence monitoring using conventional three dimensional subsidence lines. The southern side of the cliffs is able to be observed from an adjacent cliff line that is unaffected by mining.

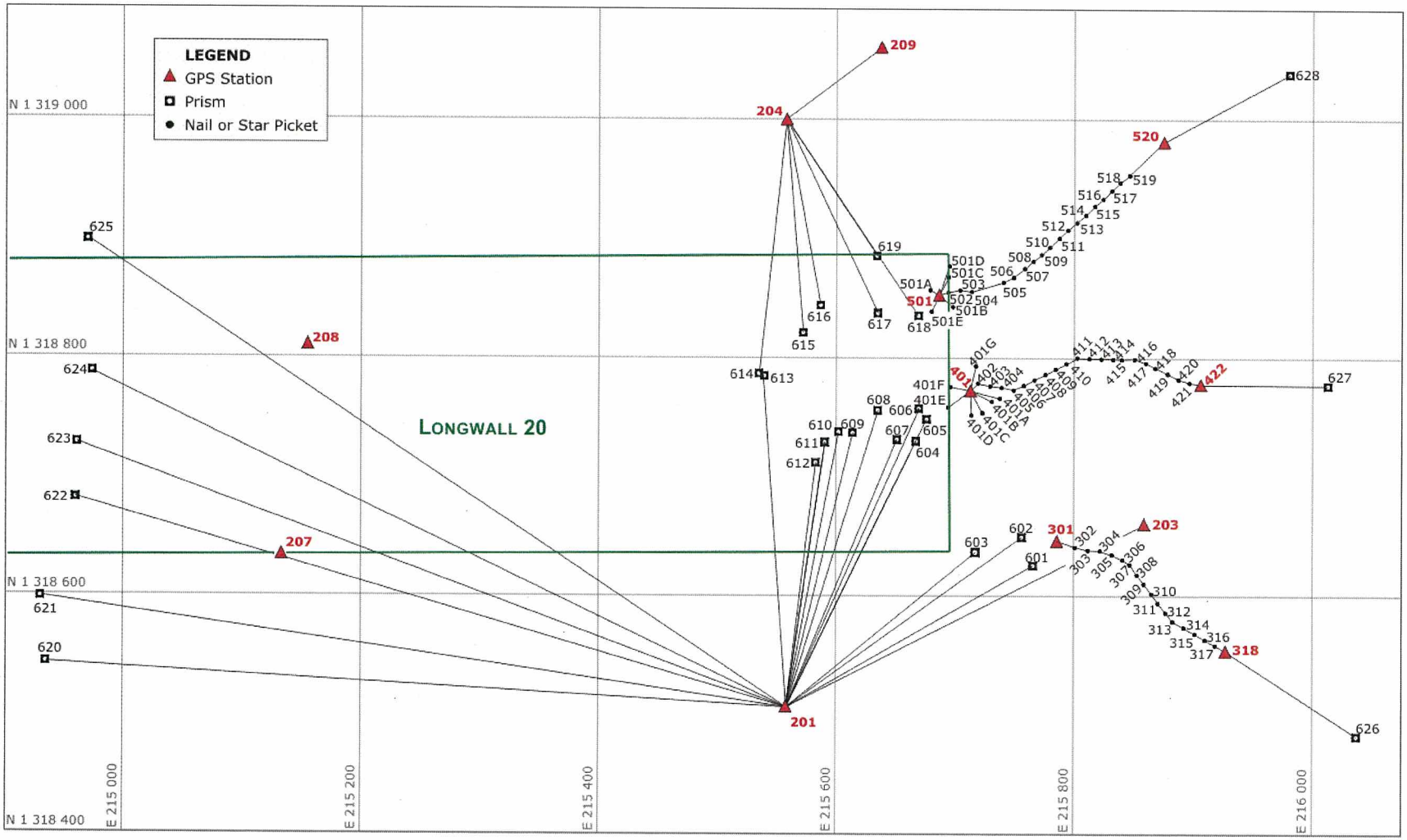


Figure 15 Detail of the layout of subsidence monitoring at the start of Longwall 20.

The site provided the opportunity to:

1. Study the behaviour of large cliffs near the start of a longwall panel.

2. Get accurate measurements of horizontal subsidence movements on a plateau area adjacent to steep terrain outside the mining area at the start of a panel.

3. Measure the effect of longwall panel width on subsidence impacts to large cliff formations.

The subsidence monitoring comprised three dimensional subsidence monitoring on three lines radiating out from the start line of the panel and an array of distributed points over the panel. Pegs were spaced at approximately 10m centres out as far as the edge of the Deeply Incised Valley to the east of the monitoring area.

Subsidence monitoring was controlled using dual station GPS. The quoted accuracy of the measurements was 10mm although the results are presented at 1mm resolution recognising the greater accuracy able to be achieved along some sections of subsidence line.

Figure 16 shows an aerial photograph overlaid with geological structure identified on the ground and the location of rock falls observed during mining of Longwalls 20 and 21.

Access to the area above the longwall panel was restricted while mining was in progress for safety reasons, so subsidence points over the longwall panel were monitored remotely using monitoring glass prism reflectors attached to the rock.

The subsidence array was surveyed when the longwall had mined 120m, 150m, 200m, 300m, 400m and 700m to simulate a range of longwall panel widths and confirm the protection that such geometries might afford the overlying cliff formations. The surveyors recorded their observations of subsidence impacts at the various stages of mining as surveys were made. Unfortunately these records were not sufficient to give exact detail of when and where various rock falls occurred, particularly those on the northern side of the cliff formations.

Conventional subsidence monitoring to the east of Longwall 20 included five resurveys of the pegs on three radiating subsidence lines. These surveys measured peg movements in three dimensions. Two additional surveys T250 and T700 only measured the movements on the reflectors that were mainly located over the block. Table 2 shows the panel widths at the times of the resurveys.



Figure 16 Aerial photograph of the cliff formations at the start of Longwalls 20 and 21 showing geological structures and the location of rock falls.

Table 2: Effective Void Widths at Time of Resurveys

SURVEY	DATE	CHAINAGE	VOID WIDTH (M)	WIDTH/ DEPTH RATIO	COMMENTS
T0	20/10/00	CH3256	8	0.04	Longwall Not Started
T100	14/11/00	CH3132	133	0.68	
T150	17/11/00	(CH3100)	165	0.84	Chainage Estimated
T200	21/11/00	CH3051	213	1.09	
T250	24/11/00	CH3002	265	1.35	Reflectors Only
T300	30/11/00	CH2947	318	1.62	
T400	7/12/00	CH2851	413	2.11	
T700	19/01/01	CH2508	758	3.87	Reflectors Only

6.1.1 Effect of Panel Width on Subsidence and Rock Fall Potential

One of the principal aims of monitoring the start of Longwall 20 in detail was to assess the effect of panel width on mining induced subsidence damage to cliff formations. At the beginning of a longwall panel, the minimum width of the panel is in the direction of mining. This dimension changes as the longwall face moves forward. Surface subsidence can then be measured for a range of panel widths using the same subsidence line simply by resurveying survey markers located above the start area of the panel.

The relationship between maximum surface subsidence and panel width measured at the start of Longwall 20 is shown in Figure 4. The monitoring at the start of Longwall 20 shows essentially similar behaviour to that previously measured at Baal Bone Colliery and elsewhere. It shows that when the panel width to depth ratio is less than 0.6, maximum subsidence is less than about 70mm (0.03 times seam thickness). At these subsidence levels, surface impacts are imperceptible.

For panel width to depth ratio above about 0.6, the maximum subsidence increases as a linear function of panel width, reaching about 0.5 times seam thickness at a panel width to depth ratio of 1.0. Above 1.0, the rate of subsidence increases more slowly to reach a maximum of 0.6-0.65 times seam thickness at a panel width to depth ratio of 1.4. Above 1.4, further increase in panel width does not cause an increase in maximum subsidence, and other factors related to horizontal movements become more significant than panel width in terms of controlling maximum subsidence.

The surveyors noted the first rock falls occurred in the period between the T100 survey and the T150 survey at the base of the cliffs some 40-50m out from the start line. This rock fall occurred during the period where vertical subsidence increased greatly. The subsidence went from 325mm to 1050mm, and the panel width went from 133m to 165m.

This data suggests that in order to avoid mining induced rock falls, the panel width to overburden depth ratio would need to remain less than 0.68 to the top of the cliff formations and less than 1.0 calculated from the base of the cliff formations.

These observations suggest that panels would need to be less than about 0.6 times the total overburden depth or 1.0 times the overburden depth to the base of the cliff if immediate damage to the rock formations is to be avoided. This monitoring does not provide insight into long term stability. Given that rock strata is stronger in the short term than in the long term, the panel widths would need to be narrower than the minimum at which rock falls were first observed to maximise the potential for long term stability.

6.1.2 Subsidence Outside Mining Area

Figure 17 shows the subsidence measured over the solid to the east of the Longwall 20 start area on three subsidence lines radiating out from the installation face. Three sets of measurements are shown, T100, T150 and T400.

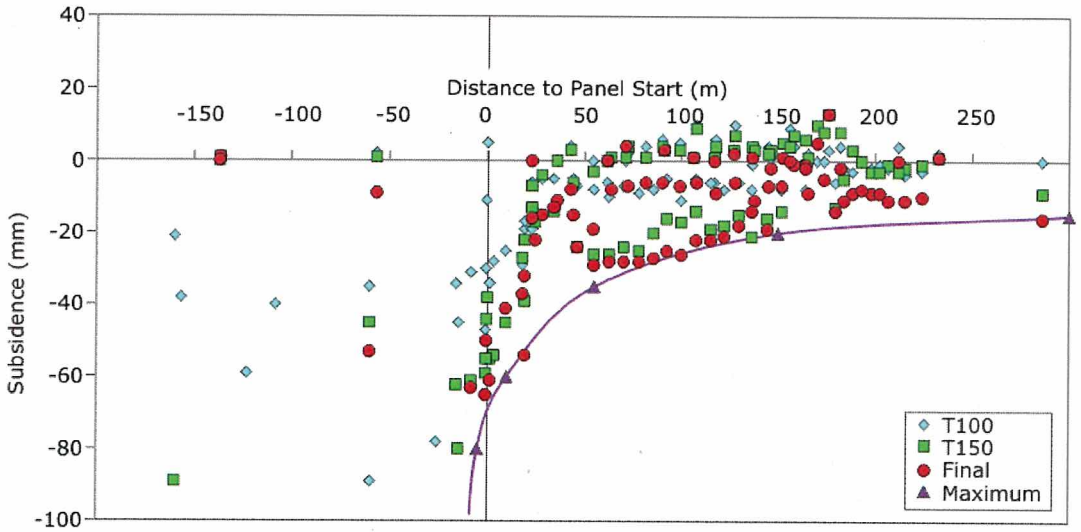


Figure 17 Vertical subsidence over the solid to the east of Longwall 20 start line.

The T100 measurement represents the subsidence movements when maximum subsidence over the panel was still small (325mm). The T150 measurement was the next survey made and shows when subsidence was well developed (1050mm maximum). The T400 measurement was the last complete measurement taken and shows only a very small change from T150.

These measurements indicate that most of the vertical subsidence outside of the mining area occurred during the period when the main subsidence occurred over the block (i.e. in the period when the panel dimension was between 0.6 and 1.0 times overburden depth.

6.1.3 Goaf Edge Subsidence and Angle of Draw

Goaf edge subsidence of 60-70mm was measured over the start of Longwall 20 on the central subsidence line.

Angle of draw is different on each of the three radiating lines and appears to be influenced by a systematic survey error that increases to the north. On the southern line (300 series pegs) subsidence is less than 20mm over the full line indicating an angle of draw of less than 7°. On the central line (400 series pegs), the angle of draw is 7° (although subsidence of 22mm measured on one isolated peg could be interpreted to mean an angle of draw of 15°).

On the northern (500 series pegs) there appears to be a systematic survey error of about 16mm along the whole line that is not significant but does affect the calculation of angle of draw. If the subsidence values are corrected to be zero at the end of the line (some 286m from the goaf edge and therefore well outside the mining area) systematic survey error is effectively eliminated. The angle of draw on the northern line is then calculated to be 12°.

It is also possible that Longwall 19 might have influenced the angle of draw in the northern area. This concept is attractive at first glance because there is a trend of more subsidence from south to north across the three lines. However on closer examination, this explanation is not credible because Longwall 19 started some 150m outbye of the start of Longwall 20 and is therefore too remote to have had any influence.

6.1.4 Horizontal Movements over the Solid

Figure 18 shows the total horizontal movements plotted as a function of distance from the starting goaf edge of Longwall 20. Horizontal movements from the first resurvey (T100) and from the final resurvey (T400) are plotted. The lower group of data is from the southern line (300 series pegs) and the upper group is from the other two lines.

The data shown in Figure 18 indicates that the magnitude of horizontal movements decreases linearly as a function of distance from the goaf edge reading zero at a distance of about 340m (or 1.6 times depth). At the goaf edge, horizontal movements are typically less than 100mm but there are several locations where the magnitude of horizontal movement reaches 140mm.

A significant characteristic of this horizontal subsidence movement is that a high proportion of the total final movement has already occurred before the vertical subsidence begins to accelerate. At the time T100 was surveyed, the panel width to depth ratio was 0.68 and the vertical subsidence was only 325mm. However, the maximum horizontal movement outside of the goaf area was already 70mm and nearly fully developed. Further subsidence (from 325mm to 1500mm) only increased the magnitude of horizontal movements outside the goaf edge from 70mm to about 100mm.

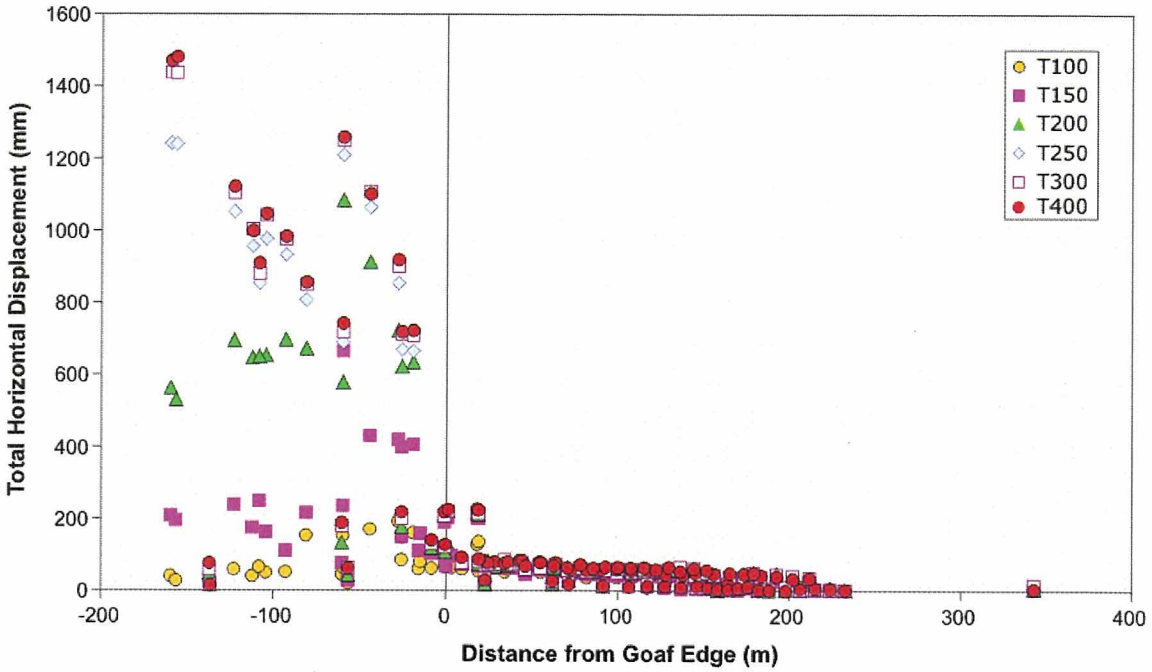


Figure 18 Horizontal subsidence movements over the goaf at the start of Longwall 20.

On the southern subsidence line, the magnitudes of horizontal movement are lower, but all of the horizontal movements occurred by the time of the T100 survey, when the panel width to depth ratio was only 0.68.

This characteristic may be significant if it becomes necessary to protect sensitive structures from horizontal subsidence impacts. Simply reducing the magnitude of the vertical subsidence may not be sufficient to provide a high level of protection, if the horizontal movements develop before vertical subsidence starts to accelerate.

The detailed monitoring indicates that the magnitude of horizontal movement decreases approximately linearly with distance from the goaf edge. This lateral displacement profile is not consistent with the surface strata being dragged inward by vertical subsidence over the goaf. The timing of the horizontal movements before vertical subsidence confirms that the horizontal movements could not be induced by any sort of drag effect related to vertical subsidence.

Another mechanism for horizontal movement relates to stress relief effects. Mining creates a fractured zone above the longwall panel so that horizontal stresses that previously existed in equilibrium in the ground are no longer in balance. To re-establish equilibrium, the overburden strata moves horizontally toward the area of low stress which is the goaf. The fact that the lateral displacement profiles are essentially linear suggests that the changes in horizontal stress are constant. This is an unexpected result, because it suggests that there must be very little frictional resistance at one or more horizons through the overburden section.

Given that the horizontal profile suggests a constant stress change from the goaf edge back to 300m. Displacement of 100mm over 300m represents a strain of about 300uS. In rock with an average modulus of 5GPa, this would represent an average stress change of 1.5MPa. The magnitude of this change is consistent with the changes that might be expected in the goaf over this distance.

6.1.5 Horizontal Movements over the Goaf

Figure 19 shows the magnitude of total horizontal movement over the goaf plotted as a function of distance from the goaf edge. This data is derived from reflector monitoring on points located over the first 200m of the panel.

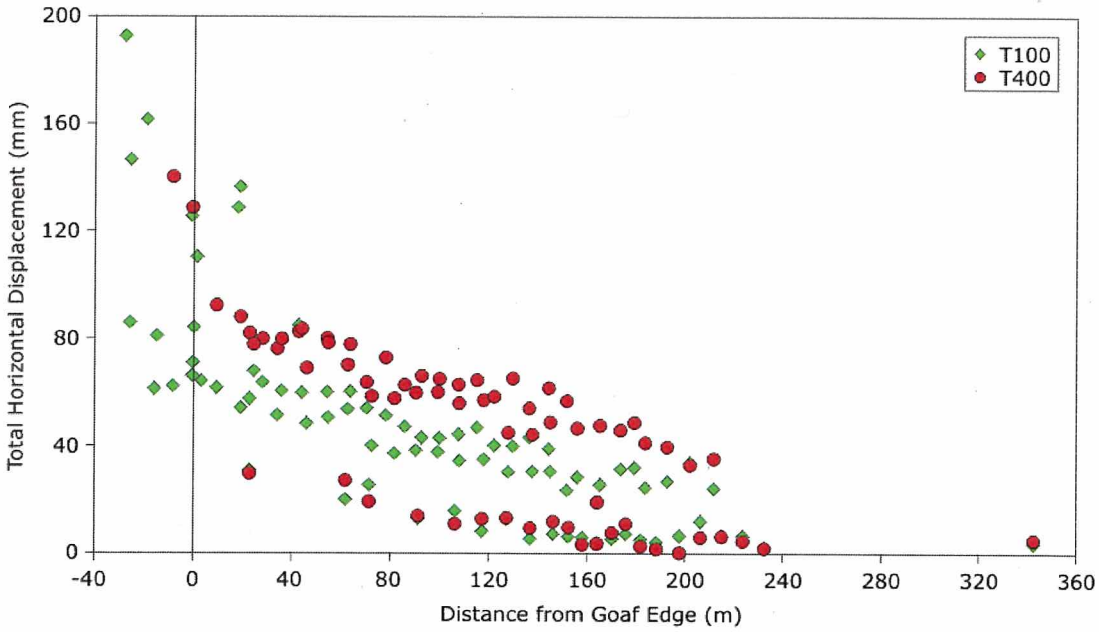


Figure 19 Horizontal subsidence movements over the solid to the east of Longwall 20 start line.

The maximum horizontal movements measured over the goaf are of the same magnitude as the vertical subsidence. The horizontal movements increase sharply from about 200mm at the goaf edge to over 1000mm some 30m over the goaf. This increase occurs as step changes at several large mining induced fractures and on natural joints that have opened. The maximum horizontal movements reach 1500mm at about 100m from the goaf edge.

In contrast to the horizontal movements over the solid, which occurred very early in the subsidence cycle, the horizontal movements over the goaf are clearly a function of the developing vertical subsidence. With each resurvey, the magnitude of horizontal movement has increased so that maximum horizontal movements do not occur until the vertical subsidence is also fully developed.

These observations suggest that the large magnitude horizontal movements that occur over the goaf are related to the vertical subsidence while lateral movements outside the goaf are principally related to stress changes associated with development of sub surface caving prior to the onset of vertical subsidence.

6.1.6 Direction of Horizontal Movements

Figure 20 shows the pathway of horizontal movements for the subsidence points through various stages of longwall face retreat. The location of the points and the horizontal movements are all shown at natural scale, but the horizontal movements are exaggerated (10,000 times) relative to the scale of the longwall panel. The starting point is shown as a small circle. For most of the points, the direction of movement is from east to west i.e. in the direction of mining.

The movement vectors plotted in Figure 20 show that the directions of horizontal movements are not parallel to the panel. Instead, the direction of movement for most points is slightly to the south of west. This direction coincides with a direction normal to the major joints sets observed through the area, and suggests that these geological structures are significant in determining the direction of horizontal movement.

Mining induced fracturing observed on a plateau area over Longwalls 9 and 10 showed similar behaviour. In that area, the orientation of the mining induced fractures did not align with the panel, but rather with the regional joint set directions, even though these joints were not evident in the unstructured cap rock that formed the plateau.

The alignment of the movement with major joint sets would be consistent with the model of overburden caving where downslope movement is driven by dilation of the subsiding overburden strata. When a structured rock mass subsides, it is likely that dilation will tend to be greatest in directions normal to the pre-existing joint sets. When the sandstone strata is unconstrained, or floating, on the lower strata – as at the start of Longwall 20 – the propensity for dilation perpendicular to major joint sets is likely to be greater than in other directions.

6.2 Start Of Longwall 21

Subsidence monitoring at the start of Longwall 21 included a subsidence line, an array of isolated pegs, the southern line off the end of Longwall 20, reflectors along the cliff edge over the panel and various other stations along the Wolgan Escarpment. There were also some visual observations of the timing and location of rock falls that provide insight into maximum panel width for cliff protection. These results and observations are described in this section.

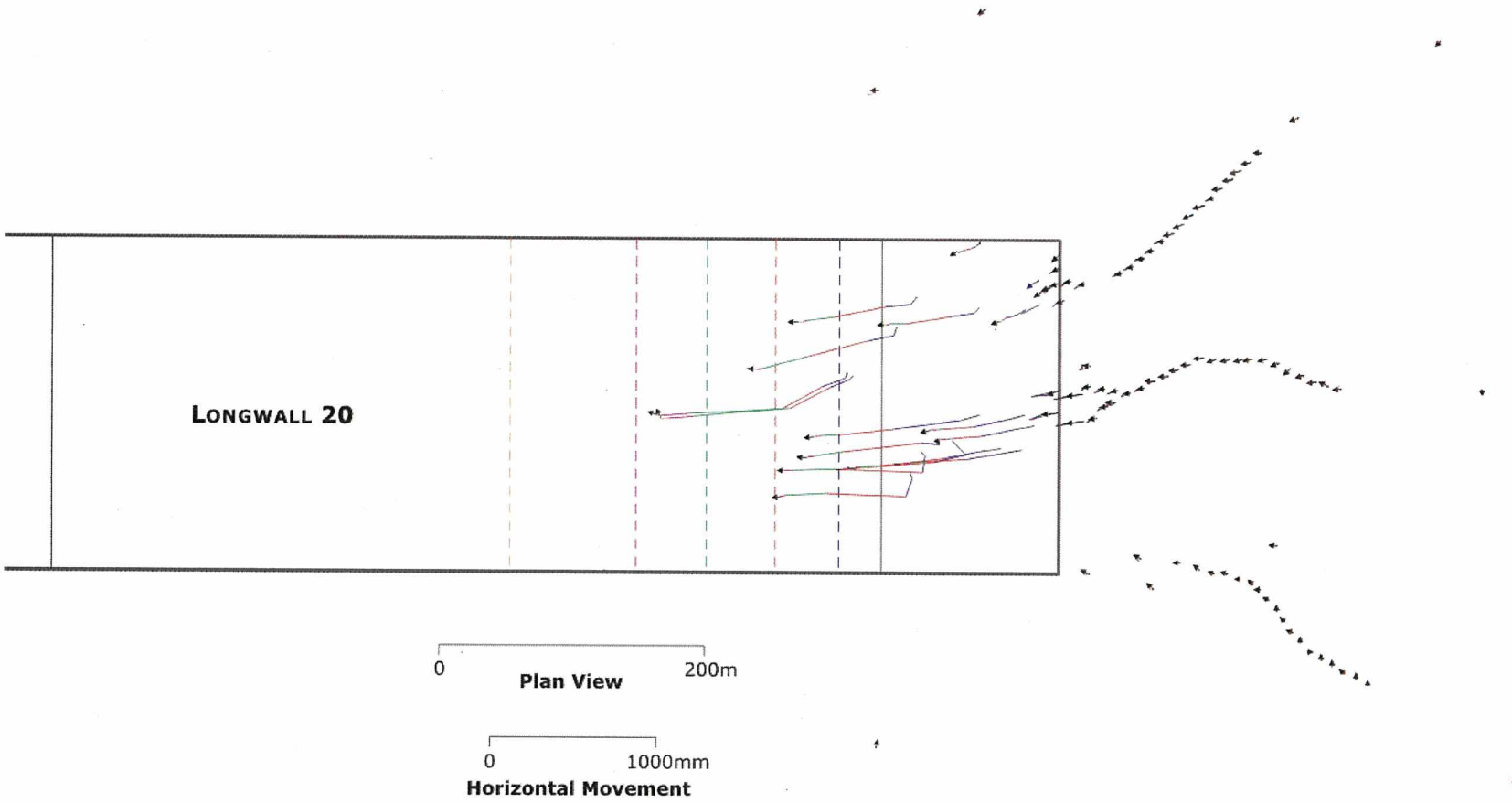


Figure 20 Plan showing vectors of horizontal movement at the start of Longwall 20.

6.2.1 Subsidence Monitoring

Figure 21 shows the array of subsidence points monitored in the start area of Longwall 21 and the vectors of horizontal movement observed.

Subsidence movements increase toward the goaf area and are largest directly over the mining area. There is also general movement in a downslope direction particularly along the top of the cliff lines.

The subsidence monitoring at the start of Longwall 21 indicates that no resolvable movements of points along the Wolgan Escarpment were observed. The effective resolution of the surveying technique used for the distributed points appears to have been about 20mm, so movements on the Wolgan Escarpment are less than 20mm and it is likely, based on trends of movement closer in to the goaf, that the movements are essentially zero.

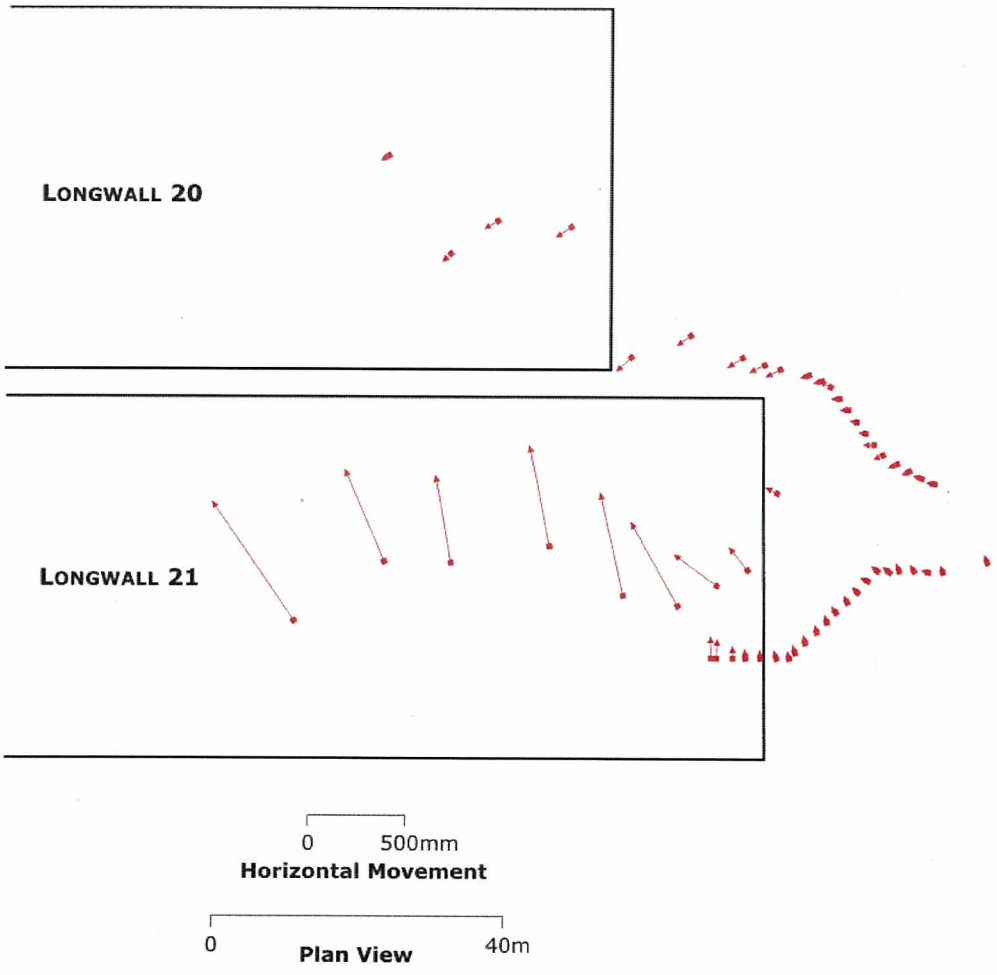


Figure 21 Plan view of peg locations and horizontal subsidence movements at the start of Longwall 21.

6.2.2 Observations of Rock Falls at the Start of Longwall 21

The first rock failure was observed over Longwall 21 at the base of the cliff on the evening of 18 September 2001. The longwall goaf was 118m wide at that time and it is possible that the fall could have occurred any time since the 13 September 2001 when the longwall was 110m wide. These observations are very close to the predictions made prior to mining. It was predicted that the zone of large downward movement would begin to cause rock falls when the panel had advanced 120m. That this prediction was so accurate provides practical verification of the understanding of subsidence behaviour at Baal Bone Colliery developed over many years.

Figure 22 shows a photograph of the first rock fall. It was located at the base of the cliff and did not affect the upper parts of the cliff at all. With the cliff face vertical at this location it was like looking at a cutaway of the overburden strata as the caving processes occurred. As the longwall retreated, the rock fall progressed up the cliff and then cracks developed high up on the cliff.

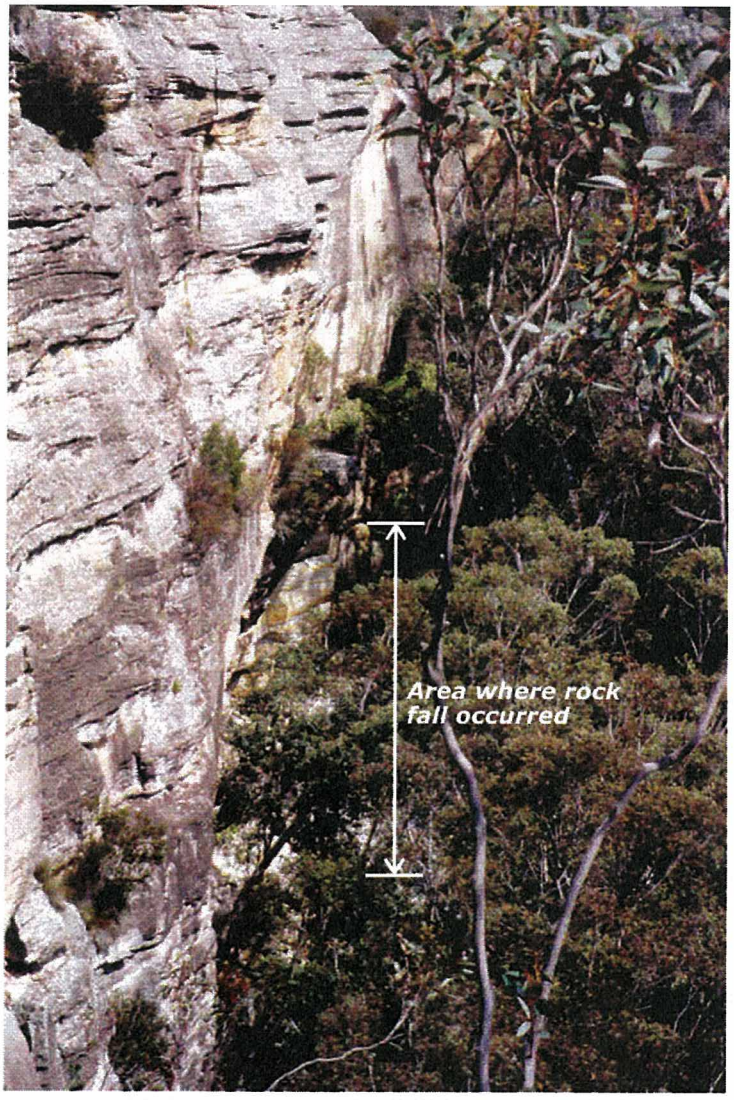


Figure 22 First rock fall at the start of Longwall 21.

Figure 23 shows a plan and cross-section of the site and the location of the first rock fall. It is apparent that the rock fall occurred over the centre of the panel at the location where the top of the zone of large downward movement intersects the surface sufficiently to cause a rock fall. Sub-surface monitoring and observations of the onset of subsidence indicate that the height of the zone of large downward displacement is typically 1.0-1.4 times the panel width (Mills 1998, Mills & O'Grady 1998). In this case, the surface is about 130-140m above the coal seam, so the ratio of height of zone of large downward movement to panel width is between 1.1 and 1.3.

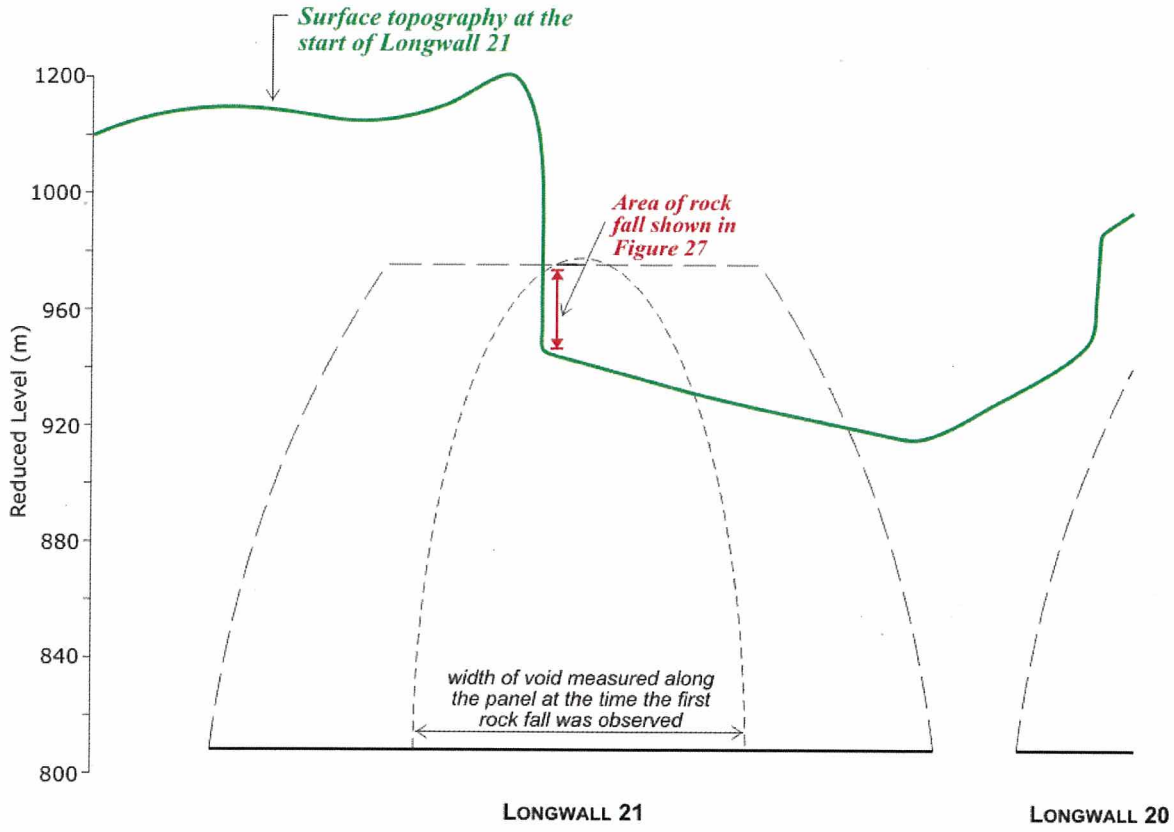


Figure 23 Cross section of the area above the start of Longwall 21 showing the development of the zone of large downward movement.

This ratio is commonly expressed as a reciprocal in subsidence terms and is referred to as the bridging width. The bridging width is expressed as the panel width to depth ratio at which the surface strata just begins to move downward rapidly in respond to increased panel width. Subsidence observations shown in Figure 4 indicate that the bridging width is in the range 0.6-0.7 at Baal Bone Colliery. Recognising that in the particular geometry at the end of Longwall 21, the zone of large downward movement would need to move up the cliff face some distance before a rock fall would be initiated, the timing of the rock fall is consistent with observations of bridging width.

The observations of roadway deformation underground are also consistent with the subsidence movements observed on the surface. Mills and Doyle (2000) describe observations of roadway deformation at Dartbrook that are consistently biased by a small change in the alignment of the stressfield relative to the opening. Tarrant (2003) describes a mechanism whereby lateral movement of the overburden strata above a longwall panel contributes to rotation of the stressfield at seam level.

Subsidence observations on the top of the cliffs above Longwall 21 indicate lateral movement of the order of 700mm across the panel. At seam level there is likely to be some lateral movement, but much less than the 700mm observed at the surface. As a result of this differential, shear stresses are set up in the overburden strata with the upper strata being sheared northward relative to the lower strata. Rotation of the stressfield caused by this shear would be consistent with the biased roadway deformation observed.

Figure 24 shows photographs of the Longwall 21 cliff formations taken before and after mining. These cliff formations are located in the centre of Longwall 21. They are essentially continuous and typically greater than 20m high. The cliff formations are therefore of a nature, location and orientation that makes them very susceptible to mining impacts.

Mining of this section of Longwall 21 has caused rock falls to occur along approximately 25% of the length of cliff line that has been mined under with locally higher rock fall densities of about 50%. This density of rock falls is higher than the typical 10-20% of mined cliff line length that experience rock falls. The reason for this higher density of rock falls is attributed to the cliff formation being:

- high and continuous,
- located entirely within the central part of the longwall panel where opposing horizontal movements are greatest,
- oriented in a direction likely to experience maximum impact from opposing horizontal movements.

This is considered to represent an upper limit on the likely extent of damage to cliff formations that could be expected from mining induced subsidence when susceptible cliffs are undermined.

6.3 Subsidence Monitoring at Start of Longwall 24

A program of survey monitoring of points on and around the Wolgan Escarpment at the commencement of Longwalls 24 and 25 has been used to confirm the level of impact of mining on the Wolgan Escarpment if any. The monitoring program has showed subsidence behaviour consistent with previous experience within the accuracy of the survey techniques used.



Pre-mining - September 2001



Post-mining - January 2002

Figure 24 Before and after mining photographs of cliff formations at the start of Longwall 21.

Unfortunately, random errors associated with GPS control of the survey compromised the accuracy of these datasets, in particular the Longwall 24 dataset and the early horizontal movements in the Longwall 25 dataset. The vertical and horizontal subsidence movements measured on the centre line of Longwall 24, the vertical subsidence movements on A Line above Longwall 25 and the last three surveys of horizontal and vertical far field movements at the start of Longwall 25 are considered unaffected by these errors (SCT letter reports BBO2874 and BBO2874b).

Figure 25 shows the locations of the various survey marks that were monitored as Longwalls 24 and 25 were mined. These points were selected as a distributed array on top of the vertical cliffs that form the escarpment and on the slopes west of the escarpment to the start point of the longwall panels. The monitoring points include a series of points that are regarded as defining the effective top of the escarpment from which a 26.5° angle of draw protection barrier could reasonably be defined. The number of distributed points surveyed during retreat of Longwall 25 was reduced and A Line was installed.

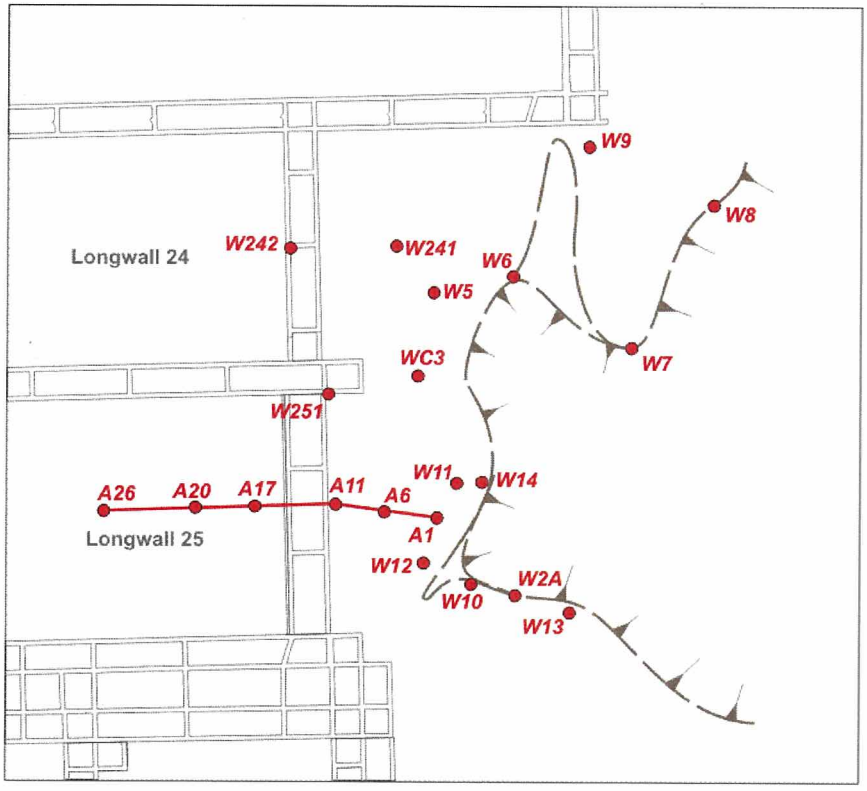


Figure 25 Plan showing location of subsidence pegs at the start of Longwall 24.

The overburden depth at the site is approximately 220m on the ridge, with the coal seam located at an RL of approximately 815m AHD. The mining section is nominally 2.3m. The longwall panels form a void that is 250m wide measured rib to rib. The chain pillars are 25m wide (rib to rib) with cut-throughs at 100m centres.

Figure 26 shows the vertical subsidence measured at seven survey marks located approximately on the centreline of Longwall 24 but outside of the goaf beyond the start of the panel.

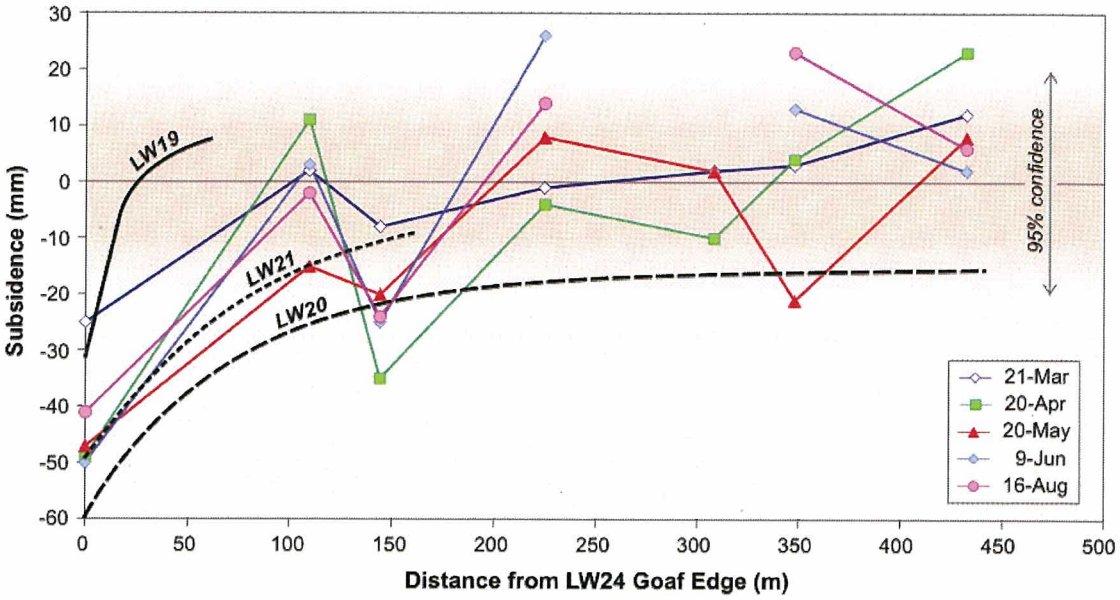


Figure 26 Vertical subsidence on panel centreline beyond the start of Longwall 24.

The results of observations over the start of Longwalls 19, 20 and 21 are shown for reference. The vertical subsidence measured at the start of Longwall 24 is consistent, within the accuracy of the measurements, with previous subsidence monitoring results observed over the start of previous longwall panels at Baal Bone Colliery.

Figure 27 shows the total horizontal movement measured on seven points located approximately on the centreline of Longwall 24, but outside of the goaf beyond the start of the panel. Results of similar monitoring from the start of Longwalls 19, 20 and 21 are also shown for reference. The goaf edge subsidence movements measured on W242 at the centreline of the panel above the starting rib are approximately 100mm.

The horizontal subsidence movements measured at the start of Longwall 24 are consistent with the observations made over previous longwall panels at Baal Bone Colliery within the accuracy of the survey technique.

There have been no perceptible impacts such as cracking or rock falls on the Wolgan Escarpment from mining Longwall 24.

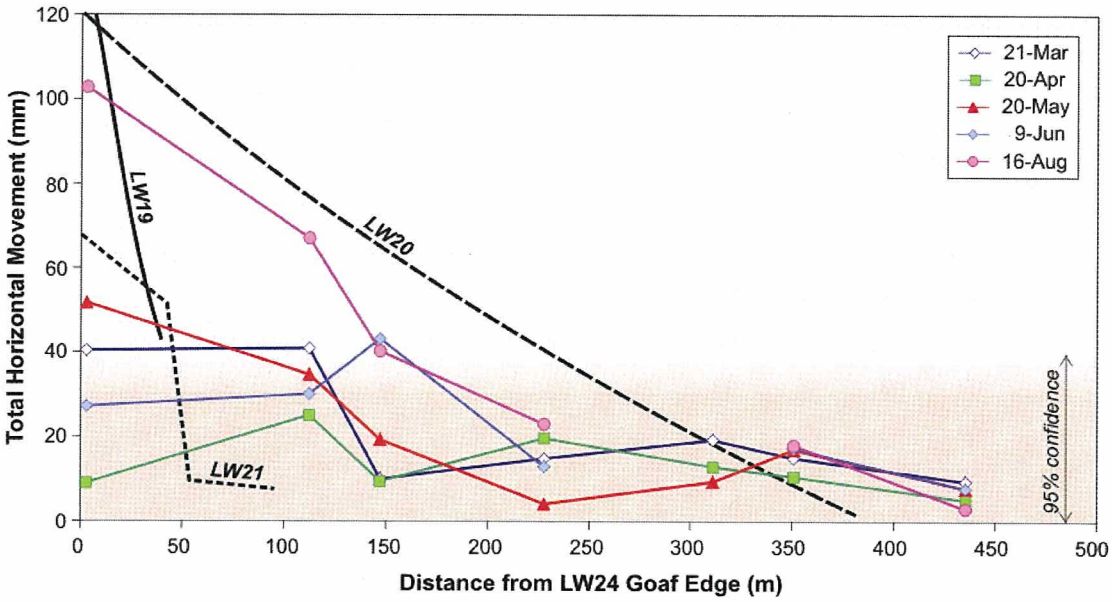


Figure 27 Horizontal movement on panel centreline beyond the start of Longwall 24.

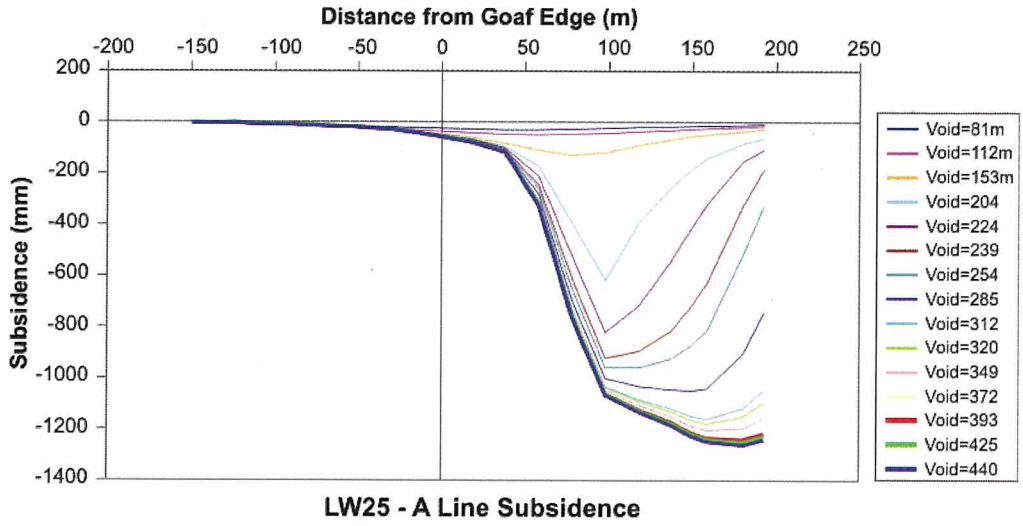
6.4 Subsidence Monitoring at Start of Longwall 25

Subsidence surveys were undertaken at the start of Longwall 25 to confirm the magnitude of movements between the start line and the Wolgan Escarpment. Two pre-mining surveys were undertaken to assess the repeatability of the surveying technique. Surveys were then undertaken as the longwall retreated to monitor the development of subsidence movements both over the goaf and over the solid.

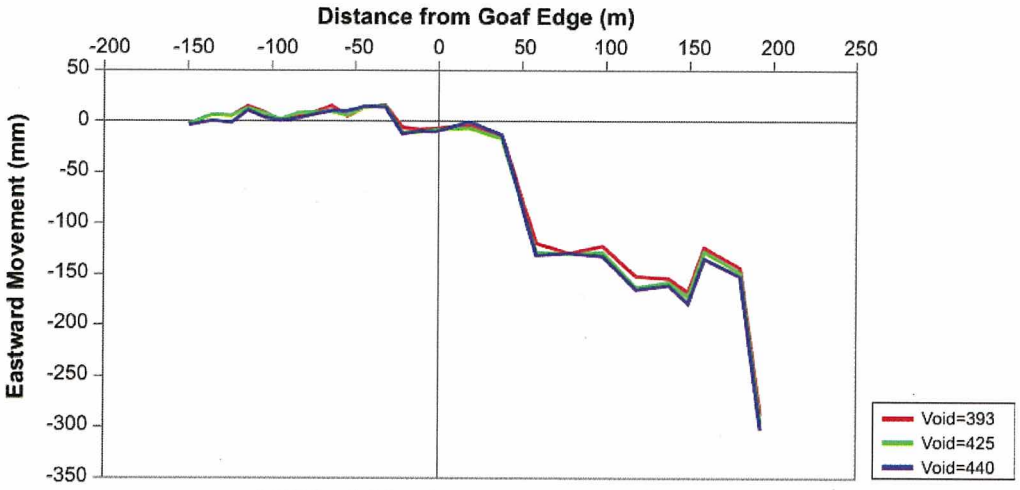
Figure 25 shows a plan of the survey marks relative to Longwall 25 and the Wolgan Escarpment. Pegs W11, A1 and W12 are located on rock formations that are regarded as the upper edge of the Wolgan Escarpment. W12 is the nearest of these points to the start of Longwall 25. W12 is 120m from the starting rib. The overburden depth at the goaf edge is approximately 220m, so W12 is protected by a barrier equal to 26.5° plus 10m.

The nearest point on the sheer face of the Wolgan Escarpment is approximately 160m east of the Longwall 25 start line and is effectively protected by an angle of draw of 26.5° plus 50m or an angle of draw of just over 35°. No perceptible impacts were observed on any of the rock formations associated with the Wolgan Escarpment and no rock falls have occurred on the Wolgan Escarpment as a result of mining at Baal Bone Colliery.

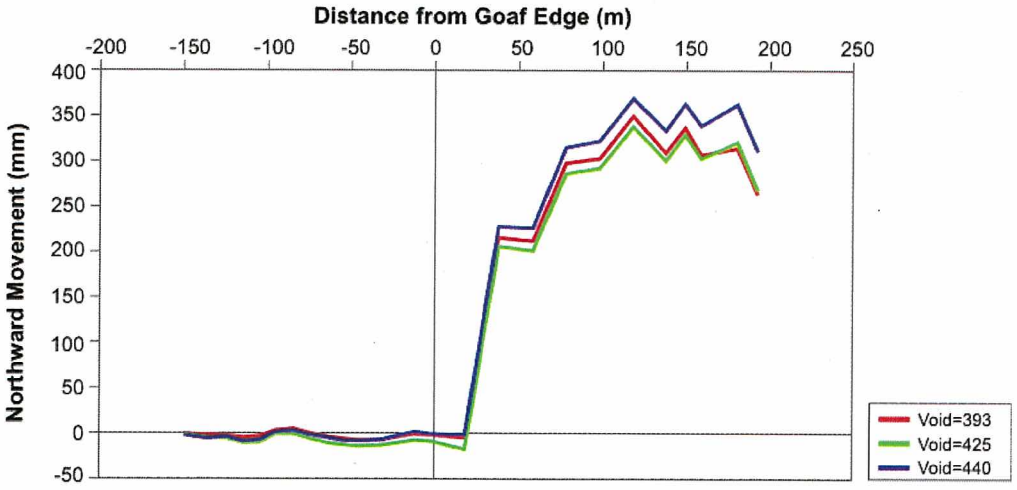
Figure 28 shows a summary of the subsidence movements that were measured in three dimensions on A Line. Figure 29 shows a summary of the subsidence movements on points located close to the Wolgan Escarpment for the last three surveys.



LW25 - A Line Subsidence



LW25 - A Line Long Panel Movement



LW25 - A Line Cross Panel Horizontal Movement

Figure 28 Subsidence movements measured on A Line at the start of Longwall 25.

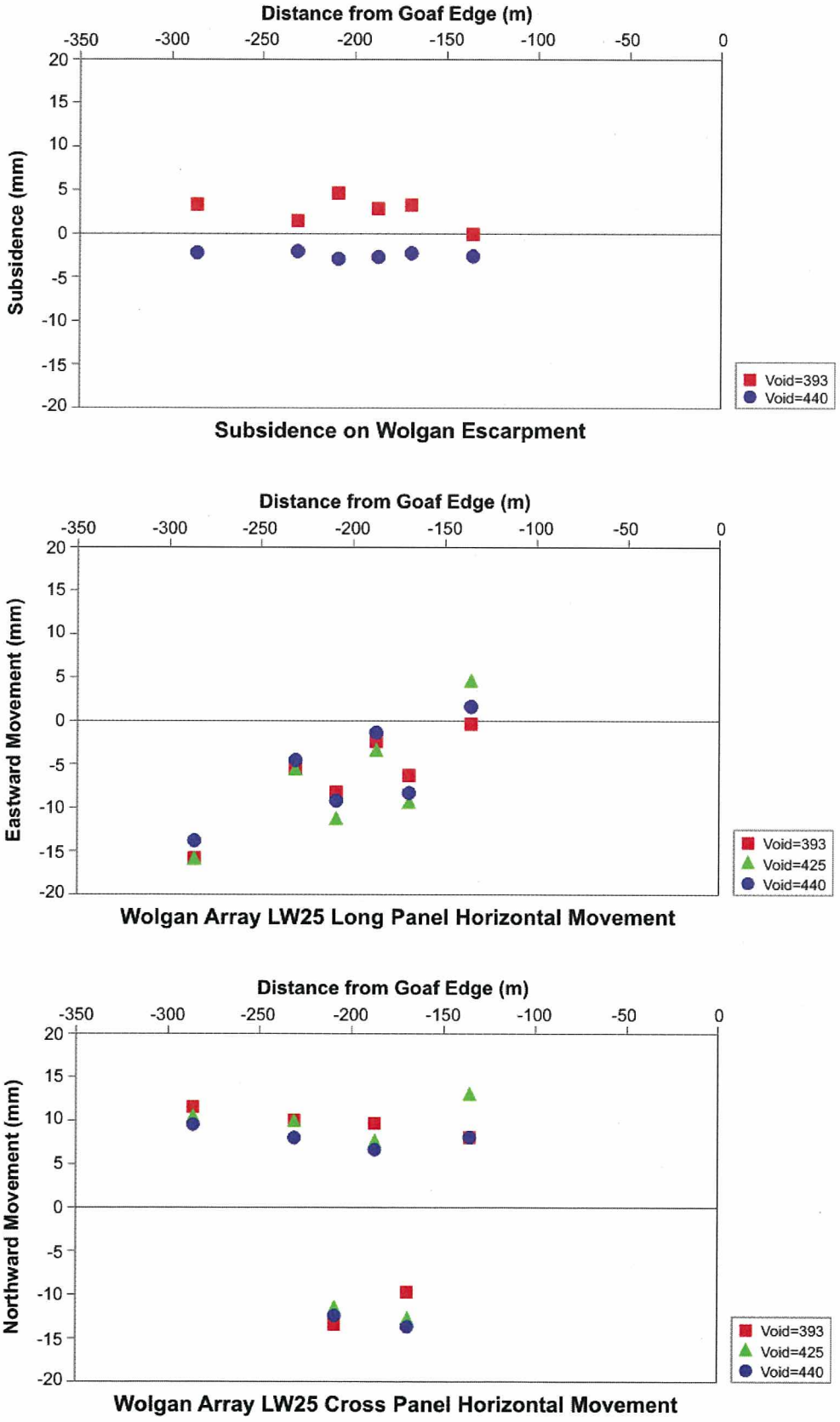


Figure 29 Subsidence movements measured on Wolgan Escarpment at the start of Longwall 25.

The subsidence movements are consistent with expectation and show the systematic development of ground movements as mining progresses.

The subsidence movements measured initially on the distributed array of monitoring points around the perimeter of the escarpment and the horizontal movements on A Line were affected by random survey error associated with the way the survey control was determined from slight variations in GPS measurements. The magnitude of the error was magnified in an easterly direction because of the particular geometry of the survey points in the steep terrain. The movements indicated were misleading, variable and are disregarded. This source of random error was eliminated in the final three surveys by a change in survey technique.

All the results which were not affected by the random survey control error are shown. The results not affected include all the vertical subsidence profiles on A Line, which were independently levelled, and the horizontal movements measured in three dimensions on all the points in the last three surveys. The full subsidence movements are captured in the results of the final three surveys.

Vertical subsidence over the start of Longwall 25 develops as a function of void width consistent with previous experience. The relationship between maximum subsidence divided by seam thickness and the ratio of void width to overburden depth is plotted in Figure 4. Surface subsidence begins to be perceptible (>20mm) when the void width increases above about 0.3 times overburden depth. Once the void width reaches about 0.7 times overburden depth, the rate at which further subsidence develops as a function of void width increases significantly.

From 20m over the longwall panel, horizontal subsidence movements are westward toward the longwall void and northward in a downslope direction increasing in magnitude to a maximum of about 0.5m at a distance of 200m from the starting goaf edge. Over the solid and for some 20m over the longwall, the horizontal movements are less than the 20mm random survey error.

Subsidence movements along the edge of the Wolgan Escarpment are less than the 20mm random survey error measured during the pre-mining surveys in all three dimensions.

The subsidence monitoring at the start of Longwall 25 confirms that low levels of subsidence movements occur outside of the mining area and that the Wolgan Escarpment would be adequately protected by an angle of draw of 26.5°.

6.5 Observations from Other Collieries

In this section, the experience of mining adjacent to sandstone cliff formations at other collieries is reviewed. The experience at Baal Bone Colliery appears to be entirely consistent with the experience reported at other collieries.

Pells et al (1987) conducted a review of rock falls and landslides within eight areas in the Sydney Basin where rock falls had been observed. They concluded that "the major failures appear to be associated with areas of full extraction immediately beneath, or usually, beyond the top edge of the escarpment. Extraction behind the escarpment causes surface cracking but not major rock falls."

Kay (1991) provides a comprehensive report on the experience of mining under and adjacent to sandstone cliff formations in NSW. This report also presents the results of three dimensional subsidence monitoring in the vicinity of fifty eight rock falls at Baal Bone Colliery using the then new technique of reflector monitoring. Kay concluded that "no damage occurred to cliff faces before they were undermined". Kay recognised the contribution of opposing horizontal subsidence movements to horizontal compression along the cliff face as a factor influencing the potential for rock falls on cliff formations.

Pells (1991) presented further results of analysis concluding that rock falls and cliff line collapses in the Sydney Basin have all occurred in areas where total extraction mining has occurred either directly beneath or in front of the cliff lines. A summary of the rock falls observed where Angus Place undermined the Wolgan Escarpment is reproduced in Figure 30 from Pells' paper. All the rock falls observed are within the mining area.

The Mount Airly Inquiry (Simpson 1993) provides a summary of the protection barriers that were seen as appropriate. On the recommendations of Dr Holla, Simpson concluded that that "mining protection zones be provided under all substantial cliffs beneath the outer escarpment of the mesa and under unusual rock formations of community concern such as the Grotto, Valley of the Kings, and the Hidden Valley. The zones should initially be based on a draw angle of 25 degrees."

In summary, the experience reported indicates:

- Rock falls on cliff formations do not occur unless the cliff formations themselves or the immediate downslope side of the cliff formations is directly undermined.

- The Department of Mineral Resources recommended a 25° angle of draw barrier in the Mount Airly Inquiry for the protection of "substantial cliffs beneath the outer escarpment" as suitable for initial protection purposes.

This experience is consistent with the monitoring experience at Baal Bone Colliery described in this report.

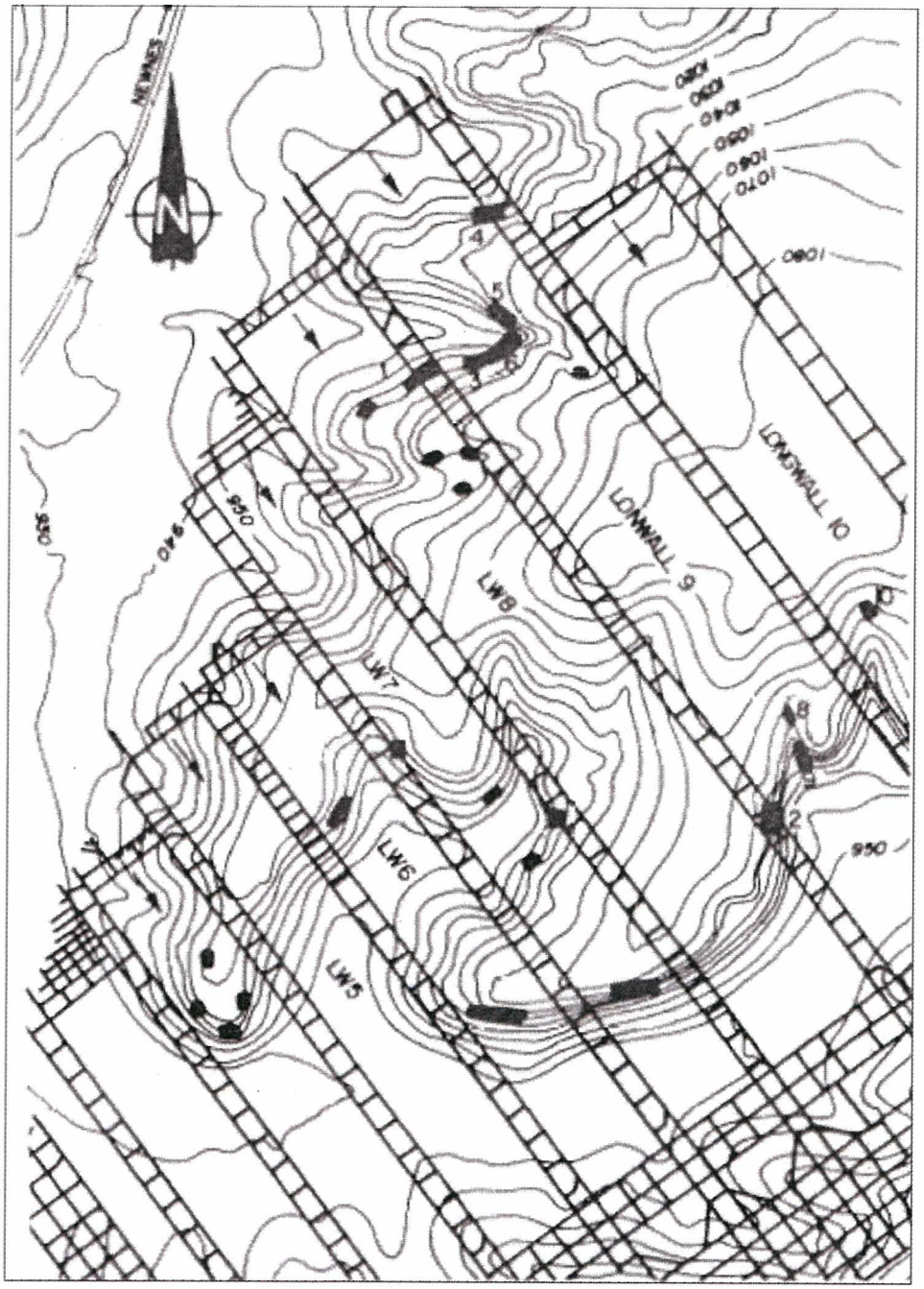


Figure 30 Summary of rock falls over Angus Place Colliery *(after Pells, 1991)*

6.6 General Comments

Experience and the understanding of the mechanics of mining induced cliff deformations developed from this experience would be entirely consistent with the expectation that a 26.5° angle of draw would be effective in protecting the Wolgan Escarpment from the effects of longwall mining.

It should be noted that the sheer nature of the Wolgan Escarpment is testament to natural weathering processes that from time to time induce rock falls. So the presence of a barrier to mining of any size does not preclude the possibility of rock falls occurring before, during or after mining. Indeed at least one natural rock fall has been noted on rock formations remote from mining activity during the period of longwall mining at Baal Bone Colliery. Figure 31 shows a photograph of this rock fall located north of Longwall 19. The rock fall occurred prior to the commencement of Longwall 19 when the nearest longwall mining was several kilometres away and could not possibly have influenced the stability of this formation.

However, the provision of a barrier based on 26.5° angle of draw is regarded as providing a high level of protection within the context of ongoing natural instability.

7. CONCLUSIONS

Subsidence monitoring at Baal Bone Colliery has been reviewed and the results of particular relevance to the development of protection barriers for sandstone cliff formations have been presented in detail.

These results indicate that rock falls are essentially limited to within the boundary of the mining area (i.e. that area directly above the longwall panels and the chain pillars isolated between adjacent longwall panels). There are a few cases where rock falls occur immediately outside the mining area (within 0.1 times overburden depth) when the slope below has been mined under.

Tension and shear fractures are commonly observed on sandstone cliff formations within the mining area. The orientation of these cracks appears to be influenced by the orientation of natural jointing deep within the overburden strata rather than the alignment of the longwall panel itself.

Tension cracks are also observed at distances up to approximately 0.4 times overburden depth from the edge of the mining area, decreasing in width as a function of distance from the goaf edge. Rock falls are not associated with the formation of these tension cracks.

The impacts of mining on sandstone cliff formations can be controlled by designing the size of the protection barrier between the edge of longwall mining and the sandstone cliff formations to be protected.

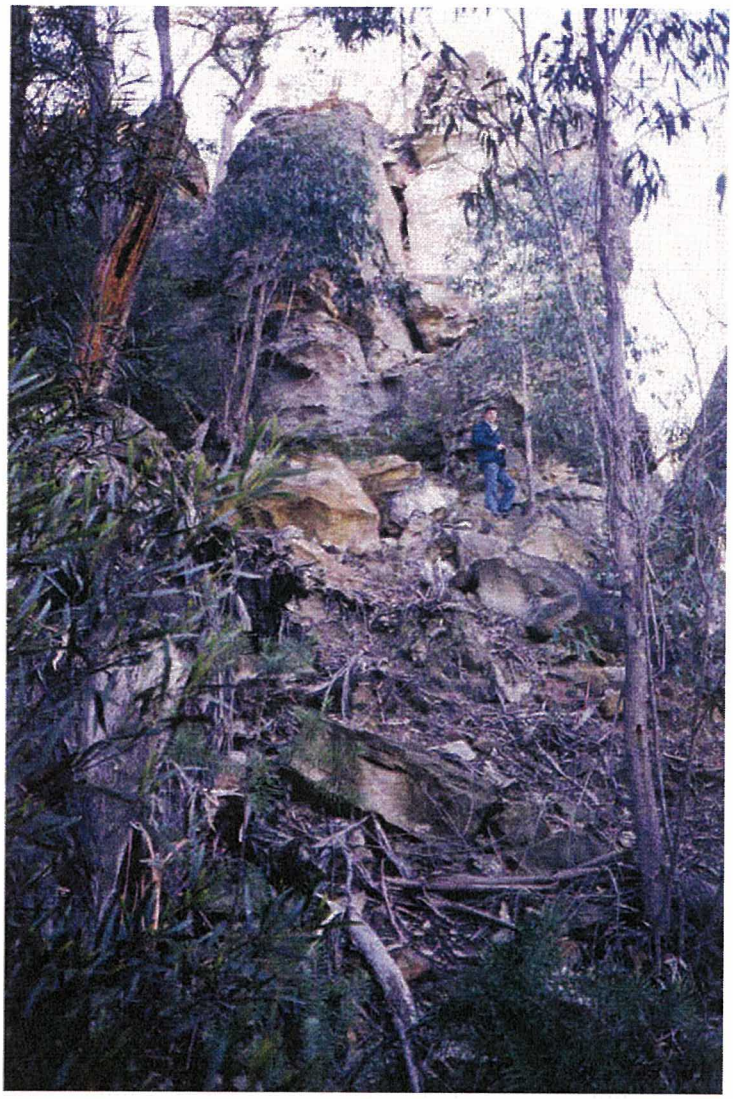


Figure 31 Natural rock fall north of Longwall 19 unrelated to mining activity.

If there is no barrier and sandstone cliff formations are mined under, on average some 10-20% of the total length of sandstone cliff formations is likely to experience rock falls. This ratio may be locally higher in some cliff geometries depending on their height, shape, continuity and location and orientation relative to mining. Tension and shear cracking is likely to be perceptible over the area of sandstone cliff formations that have been mined under.

If the longwall panels are designed so that mining occurs right up to the edge of cliff formations, but they are not directly mined under, a moderate level of protection is provided to cliff formations. Tension cracking may be evident to a distance of 0.4 times overburden depth (typically about 80-100m) from the goaf edge, but rock falls are unlikely, particularly if mining occurs on the plateau side of the cliffs so that the slopes below the cliffs are not fully mined under.

If a protection barrier equivalent to 26.5° angle of draw (typically 100-120m) is provided between longwall mining and sandstone cliff formations, the impacts of mining become imperceptible and a high level of protection is provided to the cliff formations.

The width of the protection barrier necessary to protect cliff formations is less at the corners of longwall panels and is essentially the same whether mining is on the low side or the high side of the cliff formations.

Monitoring results also indicate that sandstone cliff formations can be substantially protected by limiting the width of individual longwall panels and maintaining substantial chain pillars between panels, but the widths required are unlikely to be economically viable from a mining perspective. A high level of protection is achieved if the width of individual longwall panels is limited to less than 0.3 times overburden depth (i.e. less than about 60m) and a moderate level of protection is provided if the mining width is limited to less than 0.6 times overburden depth (i.e. less than 120m).

It is noted that the sheer nature of sandstone cliff formations is testament to natural weathering processes that from time to time induce rock falls. The presence of a barrier to mining of any size does not preclude the possibility of rock falls occurring before, during or after mining, but subsidence monitoring indicates that the influence of mining can be removed with the provision of a protection barrier equivalent to 26.5° angle of draw.

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Strata Control Technology

REPORT TO:

BAAL BONE COLLIERY

Protection of Wolgan Escarpment from Longwall 31 Mining Subsidence

BBO3432

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REPORT TO

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SUBJECT

Protection of Wolgan Escarpment from Longwall 31 Mining Subsidence

REPORT NO

BBO3432

PREPARED BY

Ken Mills

DATE

9 December 2008

Ken Mills
Senior Geotechnical Engineer

SUMMARY

Baal Bone Colliery is planning to mine Longwall 31 in an area adjacent to the Wolgan Escarpment. Section 15 of the Subsidence Management Plan (SMP) Approval for Baal Bone Colliery Longwalls 29-31 requires Xstrata Coal to submit to the Director Environmental Sustainability of the Department of Primary Industries a management plan for the Wolgan Escarpment prior to the commencement of extraction for Longwall 29. Baal Bone Colliery has commissioned SCT Operations Pty Ltd to prepare a technical basis for such a management plan. This report presents the results of our assessment of the potential impacts based on previous experience and recommendations for monitoring.

Our assessment indicates that reducing the width of Longwall 31 by 30m to an overall width of 220m and keeping the panel full length would ensure a high level of protection to the Wolgan Escarpment equivalent at the northern pinch point to the protection that has been provided to high escarpments at Baal Bone in the past and sufficient at the southern pinch point to prevent any potential for rock falls recognising the more stable nature of the cliff formation in this southern area.

There have been a variety of strategies used to determine the appropriate barrier to high cliffs such as the Wolgan Escarpment. An angle of draw of 26.5° is considered to be effective, but an additional barrier has typically been added for a range of reasons to do with mining geometry and cliff line geometry. At Baal Bone Colliery, previous experience indicates that the barrier has ranged from 20m to 85m with an additional barrier of 50m being the median. An angle of draw of 35° is equivalent to an angle of draw of 26.5° plus 40-50m at the pinch points on Longwall 31.

At the northern pinch point where the cliff formations of the Wolgan Escarpment are in a current state of imminent instability, a barrier equivalent to 26.5° angle of draw plus 50m is expected to be sufficient to demonstrate that any coincidental rock falls are not associated with mining activity. At the southern pinch point, the cliff formation is considered to be long term stable and a protection barrier equivalent to 26.5° angle of draw plus 30m is considered more than sufficient to protect against any potential for rock falls at this location.

It should be recognised that rock falls are a natural characteristic of the development of cliff features such as the Wolgan Escarpment, so it is not possible to fully protect against the possibility of a rock fall occurring naturally. The protection barriers proposed are considered to be more than sufficient to provide a high level of protection to the cliff formations of the Wolgan Escarpment. However, given the northern pinch point in particular is currently in a state of imminent instability, the monitoring program proposed is intended to demonstrate that Longwall 31 has an impact on the Wolgan Escarpment that is less than natural changes associated with diurnal and seasonal temperature variations.

The intention is that if a rock fall were to occur coincidentally, it could be demonstrated to be independent of any mining activity. Stress monitoring at the Longwall 26 site indicated that the changes detected were less than the thermal stress changes estimated for with diurnal and seasonal temperature variations on the surface of the cliff formation.

Short subsidence lines and permanent reflectors along the top of the cliff formations are recommended to provide confirmation of the level of subsidence movement. Stress change monitoring within the cliff forming sandstones is expected to provide a greater resolution of change than is possible with subsidence monitoring. Stress change monitoring instruments at both the northern and southern pinch points are recommended. Monitoring of thermal changes within rock formations in the vicinity of the northern pinch point is recommended to give a measure of the natural variations in temperature experienced on the Wolgan Escarpment.

A higher level of investigation and monitoring, particularly at the northern pinch point, would involve detailed measurement of the cliff geometry using airborne terrestrial photogrammetry, in situ stress measurement within the cliff forming sandstone, laboratory testing of core samples recovered from monitoring holes, and an analysis of the likely state of stability of the sandstone cliff formations at the northern pinch point. The southern pinch point has already been assessed as stable and tolerant to subsidence movements anticipated at 26.5° angle of draw from the nearest goaf edge.

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1. INTRODUCTION

Baal Bone Colliery is planning to mine Longwall 31 in an area adjacent to the Wolgan Escarpment. Section 15 of the Subsidence Management Plan (SMP) Approval for Baal Bone Colliery Longwalls 29-31 requires Xstrata Coal to submit to the Director Environmental Sustainability of the Department of Primary Industries a management plan for the Wolgan Escarpment prior to the commencement of extraction for Longwall 29. Baal Bone Colliery has commissioned SCT Operations Pty Ltd to prepare a technical basis for such a management plan. This report presents the results of our assessment of the potential impacts based on previous experience and recommendations for monitoring.

The report is structured to provide a description of the cliff formations on the Wolgan Escarpment in the vicinity of Longwall 31, a background to the mine design originally proposed, the basis for a more conservative approach to protect the cliff formations, the implications of this design for the width and length of Longwall 31, and a recommended monitoring strategy aimed to protect the Wolgan Escarpment from mining induced rock falls.

2. SITE DESCRIPTION

Figure 1 shows the layout of Longwalls 29-31 as proposed in the SMP and the location of the Wolgan Escarpment based on a 1:25,000 topographic series plan.

Figure 2 shows an oblique aerial photograph of the Wolgan Escarpment with the locations of the two pinch points shown. The escarpment extends several kilometres north and south of the area of interest and ranging in height from 30m to 80m, occasionally in a series of formations, but more generally as a single sheer cliff.

Figure 3 shows photographs of the cliff formations at the southern pinch point. The sheer cliff face is estimated to be approximately 25m high. The cliff formation at this pinch point is at the intersection of an intact sandstone cliff defined by a regional joint set and a weathered pagoda-like formation that is slightly overhanging to the north. The general nature of this formation indicates that it is currently quite stable and likely to be tolerant to subsidence movements. Figure 4 shows a photograph of these formations taken from the base of the cliff.

Figure 5 shows a photograph of the cliff formations in the vicinity of the northern pinch point. The cliff formation immediately south of the pinch point is estimated to be approximately 30m high and overhanging a distance of approximately 8m at its base. Figure 6 shows a photograph taken from the base of the cliff showing the overhang.

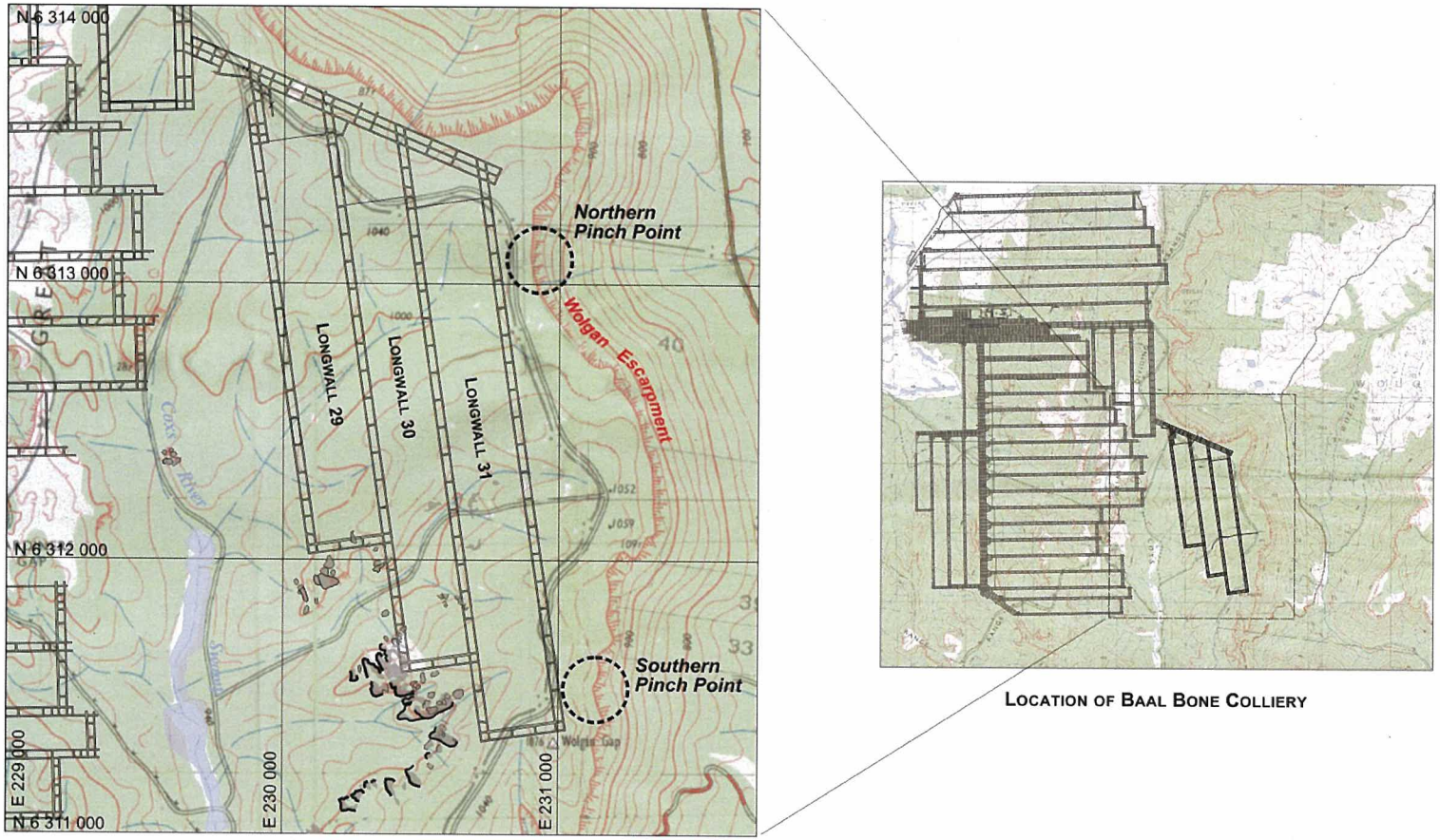


Figure 1 Site plan showing originally proposed mine layout superimposed on 1:25,000 series topographic map (Cullen Bullen 8931-3-N).

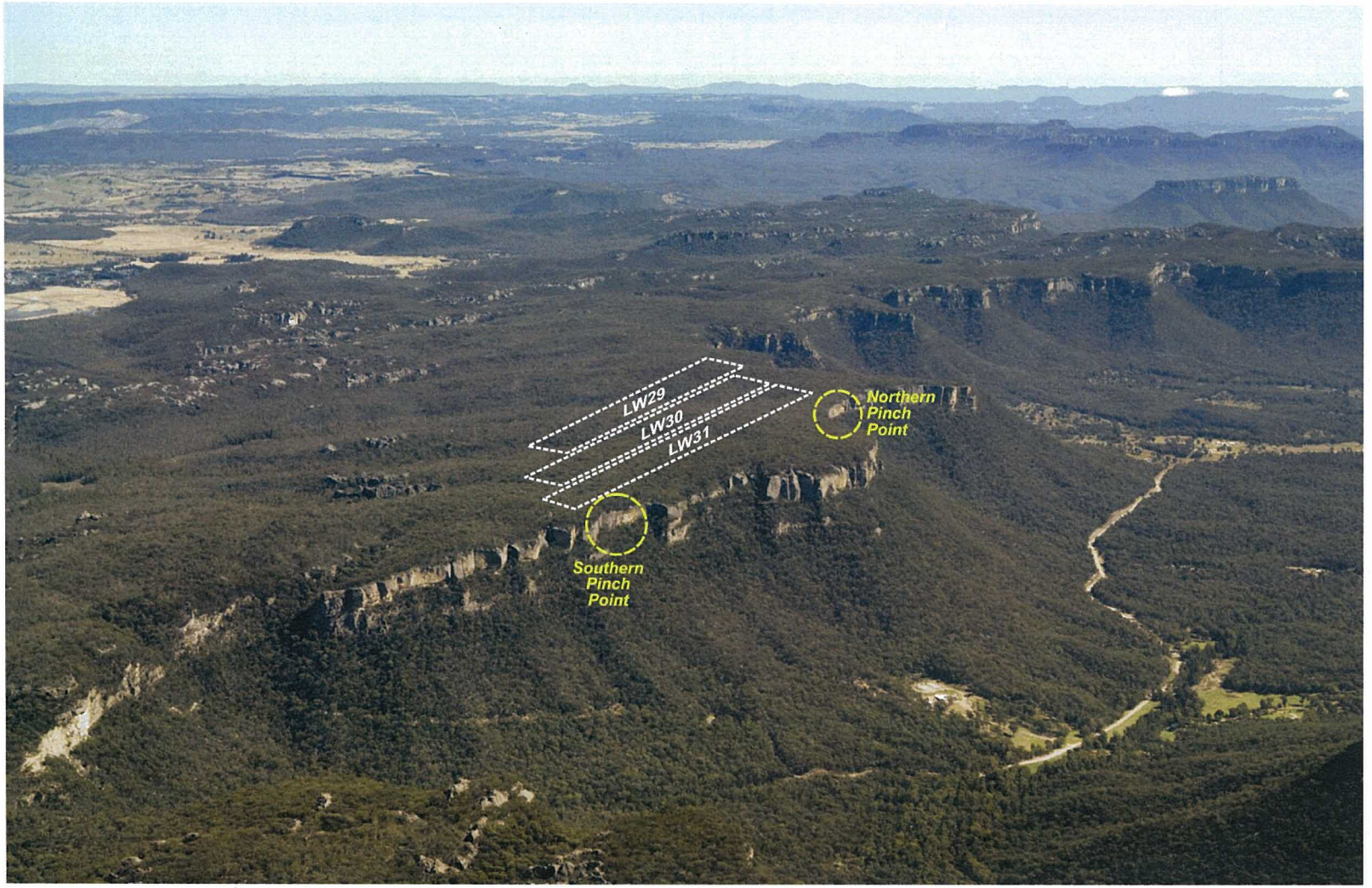


Figure 2 Oblique photograph showing location of the two pinch points adjacent to Longwall 31.

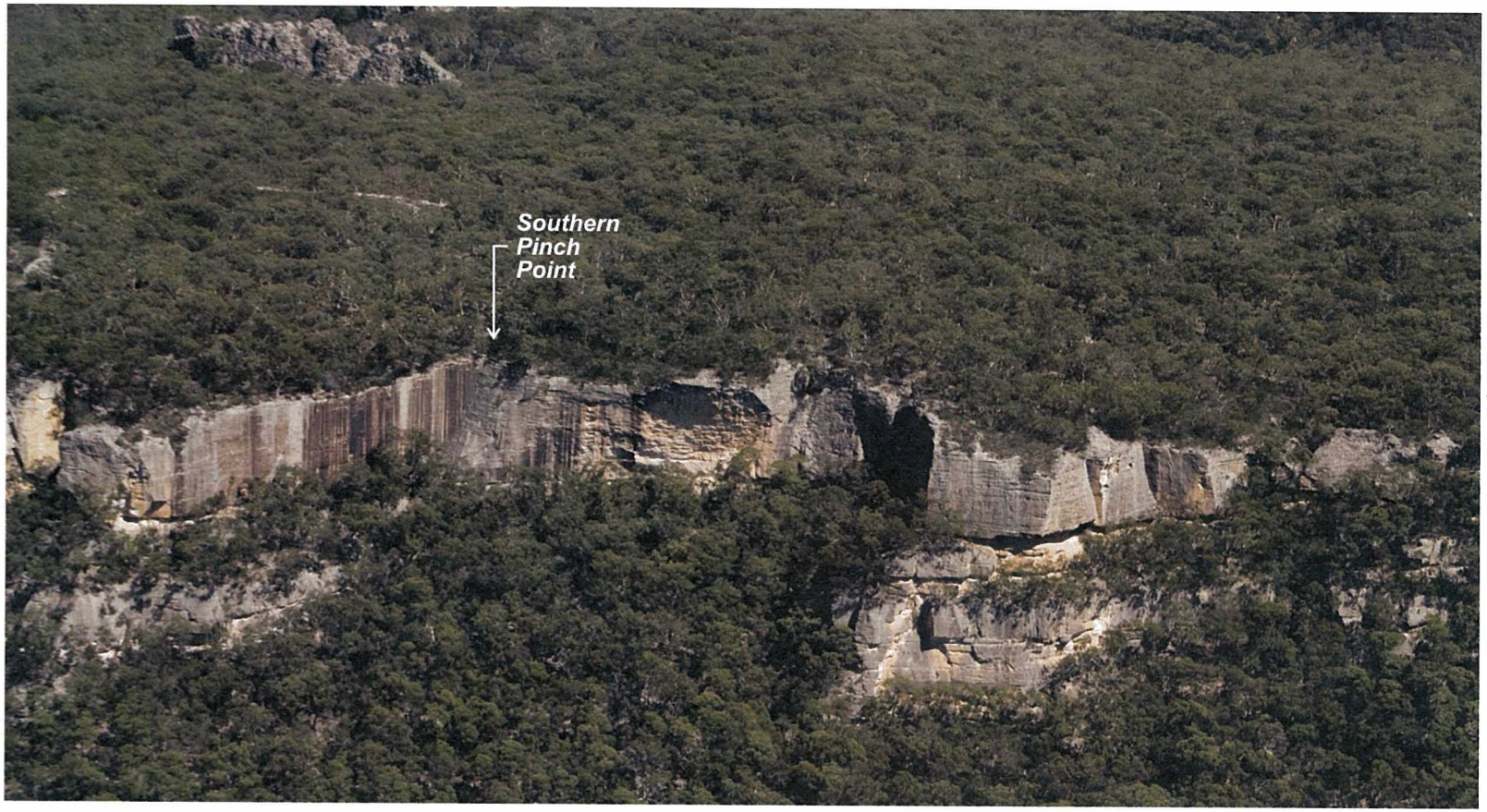


Figure 3 Oblique photo of southern pinch point.

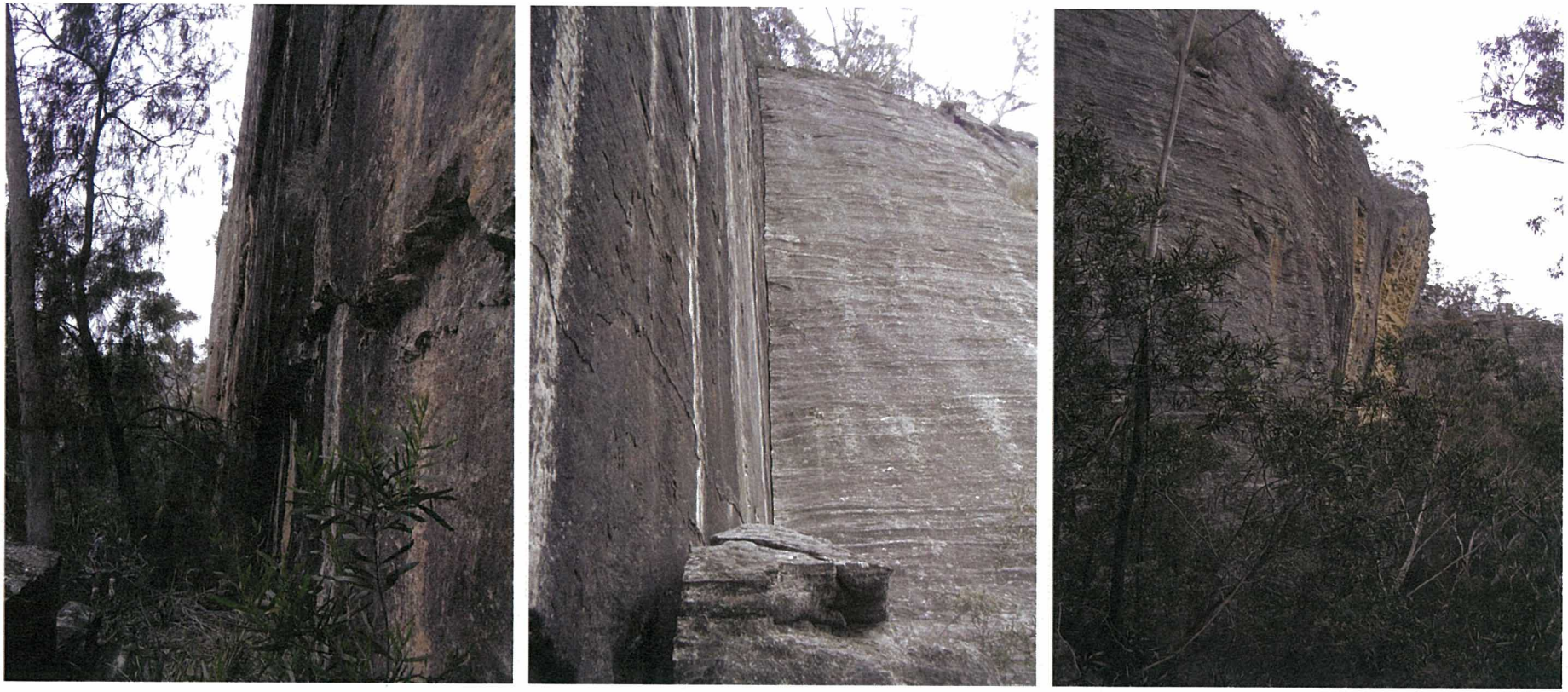


Figure 4 Photographs of southern pinch point taken from below showing intact nature of rock formations in this area.

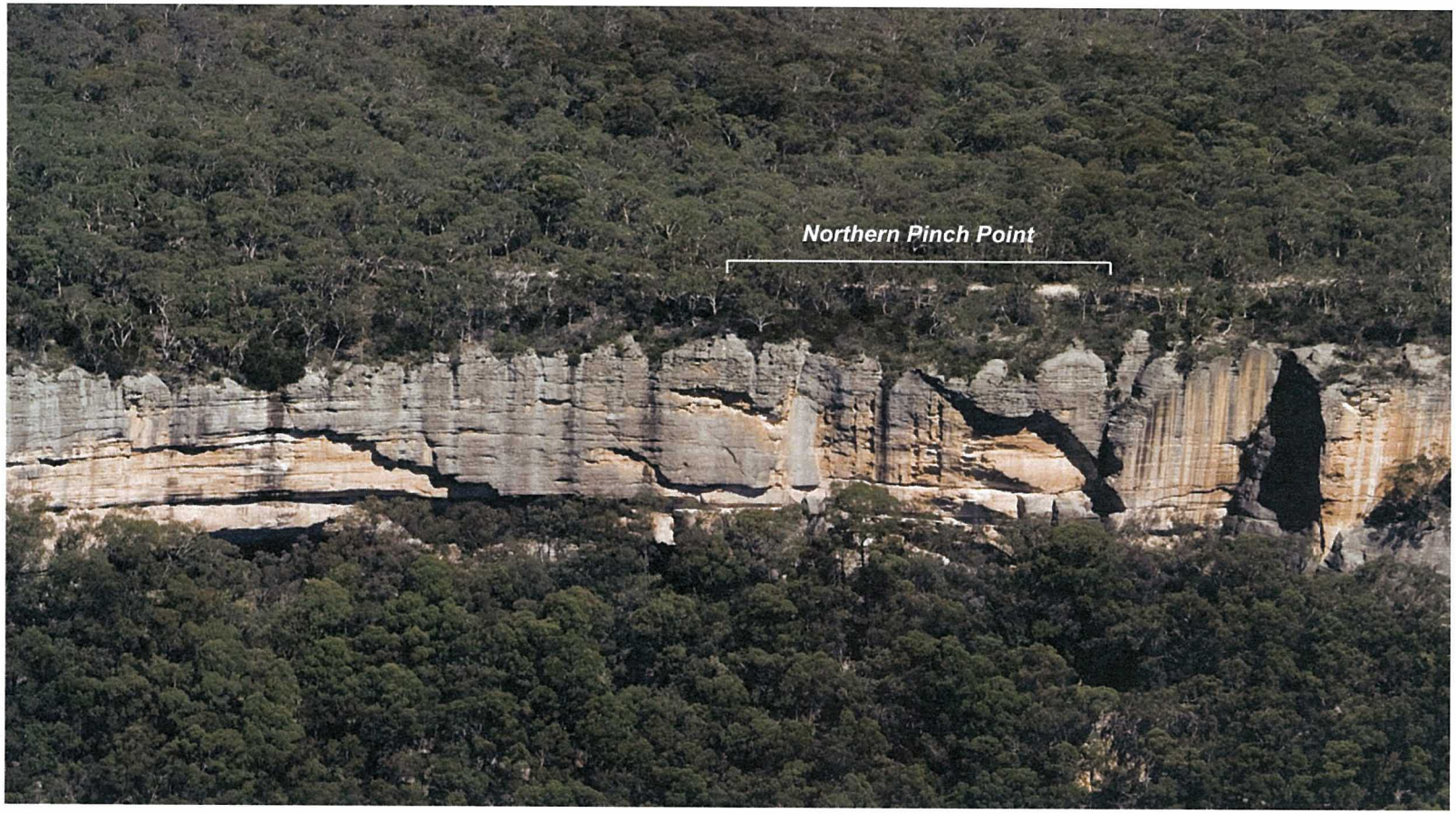


Figure 5 Oblique photo of northern pinch point.

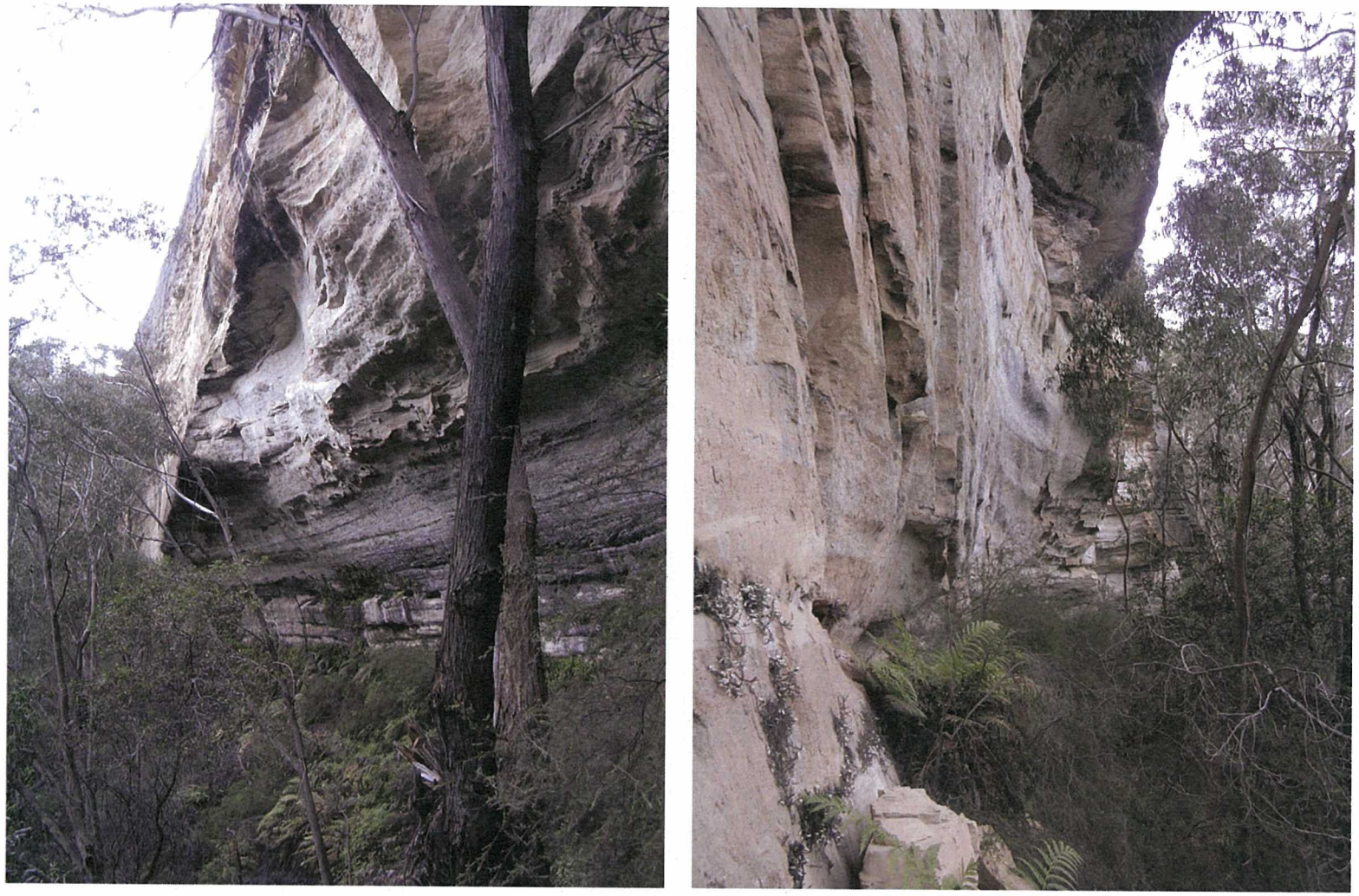


Figure 6 Photographs of northern pinch point taken from below showing overhanging nature of rock formations in this area.

The main face of the cliff comprises a number of overhanging blocks that are undercut at their base and their southern end. They appear to be joint bounded on their back surface, but remain in position suggesting that they are cantilevered from their northern end and the joints retain some cohesion. There are numerous scarps where similar blocks have become detached in the past. The general nature of this formation indicates that it is imminently unstable and likely to be sensitive to subsidence movements.

3. BACKGROUND TO LAYOUT DESIGN

SCT Report BBO3259 provides a review of the experience of mining in the vicinity of cliff formations at Baal Bone Colliery and at other sites in the Western Coalfield. This review indicates that a high level of protection is provided to the cliff formations if a protection barrier equivalent to 26.5° angle of draw (typically 100-120m) is formed between the longwall goaf edge and the sandstone cliff formations.

During the planning stage for the Southern Area, the longwall panels were aligned to minimise the potential for impacting surface rock formations in the area and to prevent any disturbance to the Wolgan Escarpment. The approach adopted was to provide a barrier equivalent to an angle of draw of 26.5° from the edge of the escarpment. The edge of the escarpment was defined in this context as the upslope edge of any rock formations that could be regarded as being associated with the escarpment proper.

In the area north of the three longwall panels, the edge of the escarpment defined this way ranged 10-70m back from the edge of sheer cliff. At the two pinch points, the nature of the formations is such that the edge of the escarpment is less than 10m back from the edge of the sheer cliff.

4. BASIS FOR ADDITIONAL PROTECTION

Full protection of escarpments against rock falls is not possible because rock falls occur naturally from time to time and may occur at any time irrespective of any mining activity. However, it is appropriate in a circumstance of high visual significance to be able to demonstrate that any rock falls that may occur coincidentally are not a result of mining subsidence. Following close inspection of the nature of the cliff formations, consideration of the results of horizontal stress monitoring from a pinch point adjacent to Longwall 26, and discussion with the Department of Primary Industries, a rational basis for the protecting the Wolgan Escarpment has been developed. This basis is discussed in this section.

4.1 Review of Mining Experience Generally

SCT Report BBO3259 reviews the experience of rock falls at Baal Bone Colliery and other sites. This review indicates that there has been no experience of mining induced rock falls beyond 26.5° angle of draw from any longwall panels in the Western Coalfield and only a very few actually outside the area directly above the panel itself (an angle of draw of 0°). The

protection afforded to the Wolgan Escarpment by an angle of draw of 26.5° is considered to provide a high level of protection.

4.2 Previous Barriers at Baal Bone Colliery

A more conservative approach than 26.5° angle of draw can be based on the local experience at Baal Bone Colliery of protection barriers successfully applied in the past to high cliff formations including the Wolgan Escarpment and the deeply incised valley at the eastern ends of Longwalls 20-22. While these barriers are recognised to be somewhat arbitrary in size relative to the sheer cliffs because they were based on a range of criteria – mining constraints in some cases, 26.5° angle of draw to the ridgeline in other cases, and 26.5° angle of draw to the upper limits of rock formations, not specifically the sheer cliffs themselves – the barriers were nevertheless successful in terms of completely protecting the cliff formations. Given that there has been no history of impacting high cliff formations using any of these barriers, a barrier based on this previous experience is considered to provide a very high level of protection to the cliffs of the Wolgan Escarpment adjacent to Longwall 31.

Figure 7 shows a plan of the Wolgan Escarpment and deeply incised valley to the east of the longwall panels at Baal Bone Colliery together with the overburden depth isopachs. The edges of the sheer cliffs that have been fully protected in the past have been located from an overlay of Orthophoto Maps produced by GeoSpectrum (2001).

Figures 8 and 9 show more detail of the location of the cliff edges and the sizes of the barriers that have been successful in terms of fully protecting the cliff formations. Table 1 summarises the effective offset distances and the overburden depth at each of the pinch points.

Table 1: Summary of Previous Protection Barriers at Baal Bone Colliery

Location	Barrier Size (m)	Depth (m)	Barrier Size Based on 26.5° Angle of Draw (m)	Additional Barrier Size (m)
LW20	185	210	105	85
LW21	140	210	105	35
LW23 (off corner)	130	210	105	25
LW24 (upper)	130	220	110	20
LW24 (main cliff)	170	220	110	50
LW25	155	210	105	50
LW26	160	210	105	55

While all these barriers were designed to protect the cliff formations, the basis for the design was either providing 26.5° angle of draw to the ridge line or to the uppermost rock formations that lead down to the high cliffs. The barrier width additional to a distance defined by 26.5° angle of draw shown in Table 1 ranges from 20m to 85m with a median of 50m.

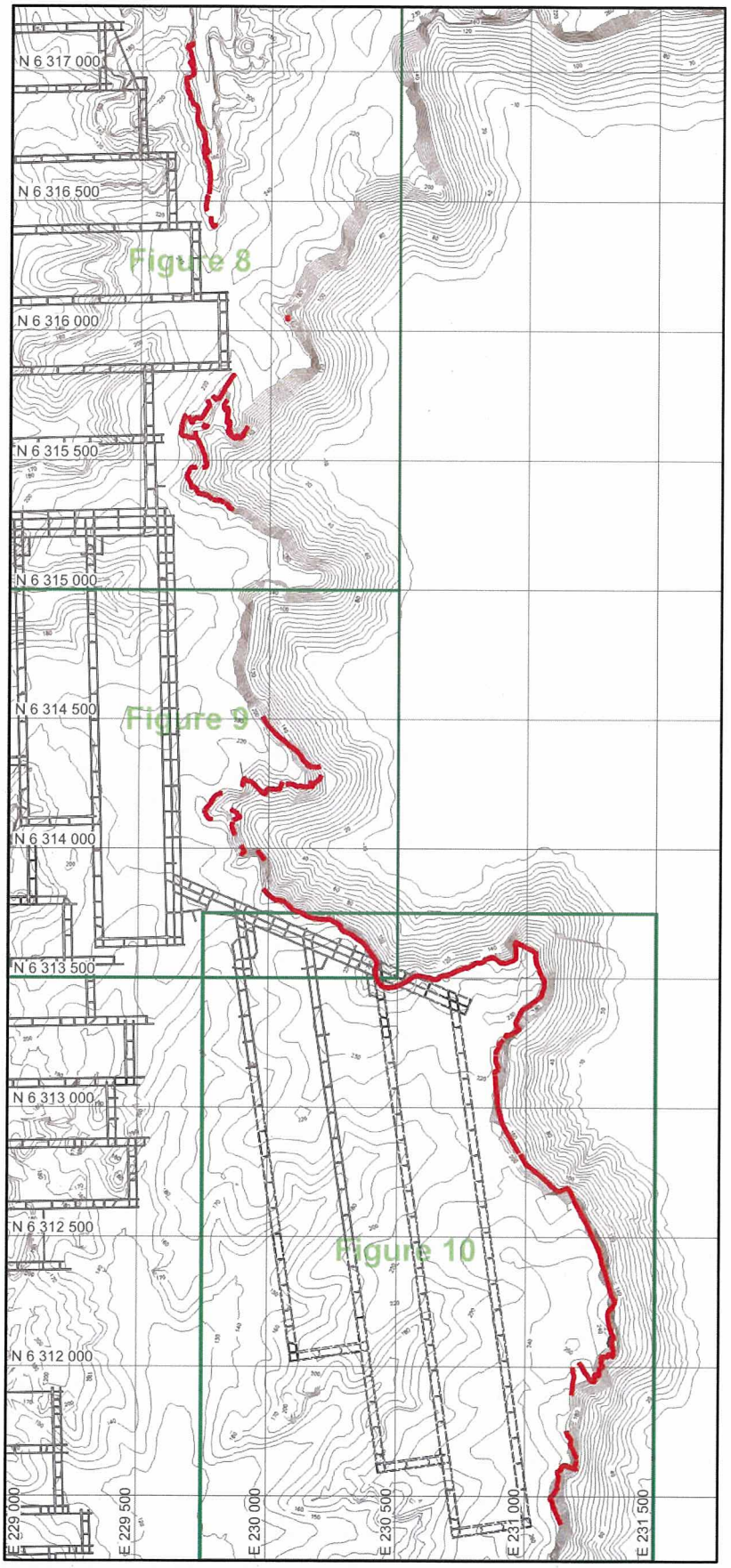


Figure 7 Plan showing eastern part of longwall panels at Baal Bone Colliery and the location of high cliff formations based on GPS and orthophotographs.

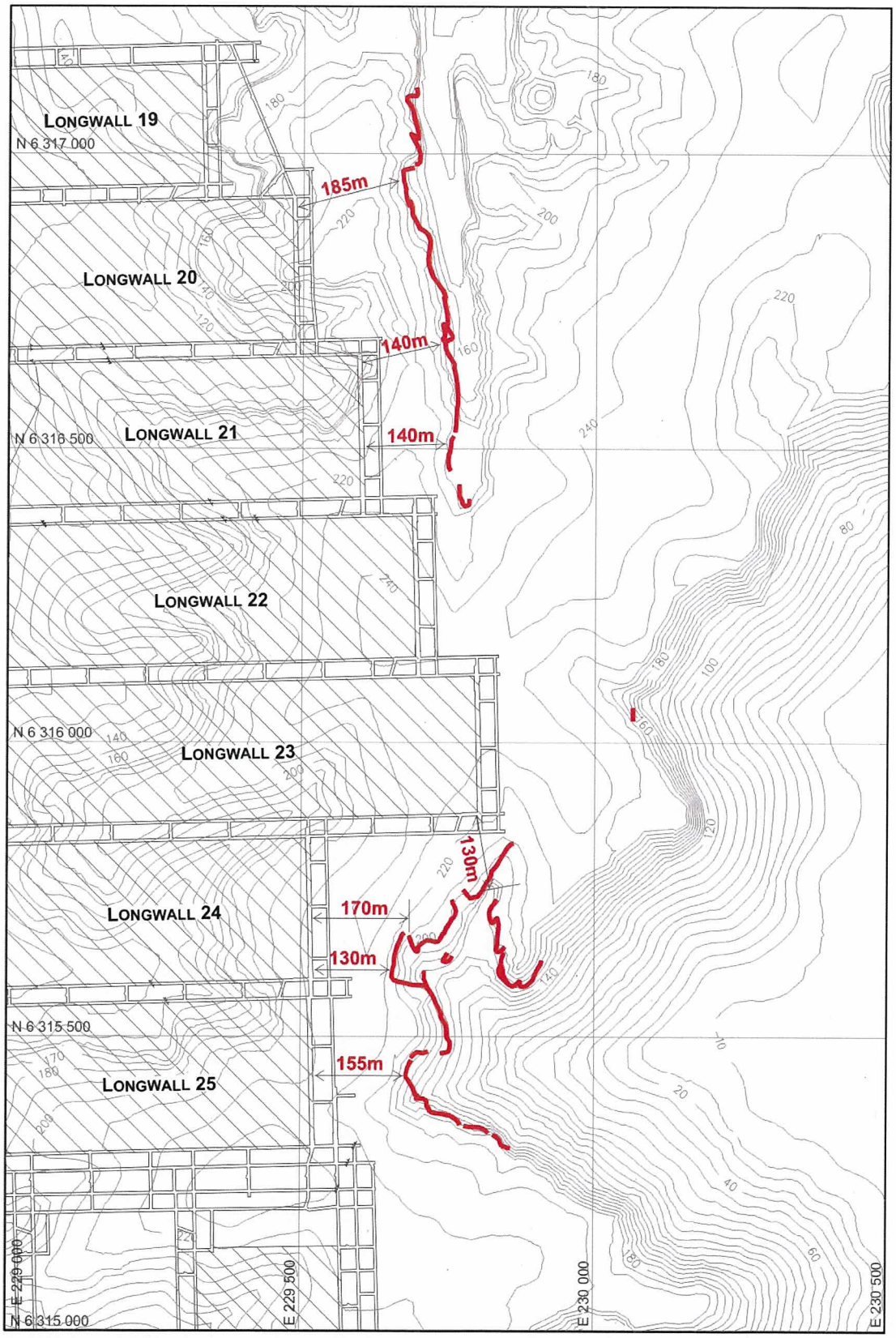


Figure 8 Overburden depth isopachs and barrier sizes to high cliffs at eastern end of Longwalls 19-25.

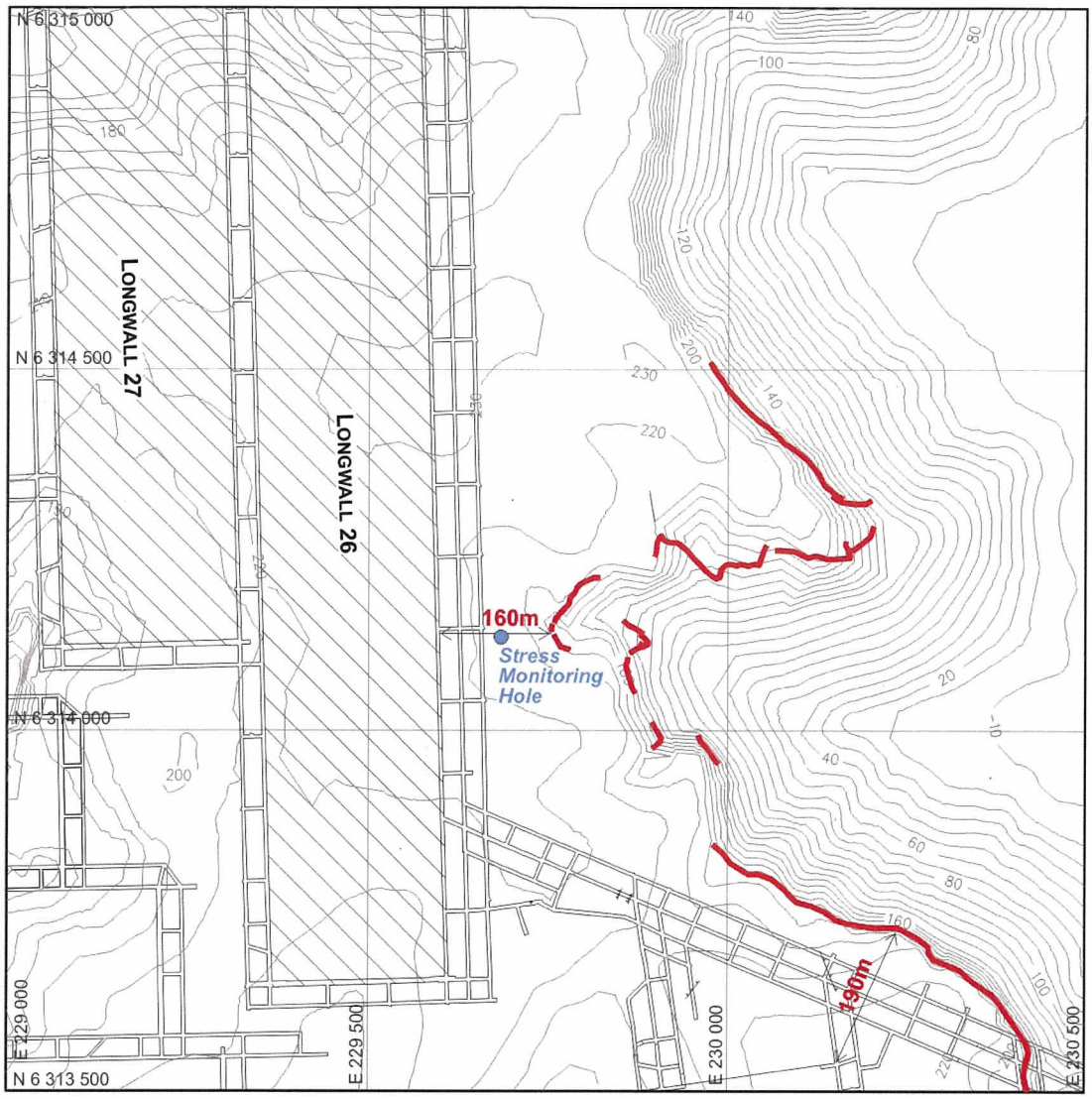


Figure 9 Overburden depth isopachs and barrier sizes to Wolgan Escarpment adjacent to Longwall 26.

This data indicates that a barrier based on an angle of draw of 26.5° plus 50m would be equal to or greater than all but two of the barriers that have been used previously and for which there has been no perceptible impact on the cliff formations.

4.3 Barrier Based on 35° Angle of Draw

An alternative approach to determine barrier size is to use an angle of draw of 35°. At overburden depths of 200m, an angle of draw of 35° is recognised in subsidence engineering to provide a very high level of protection to even very sensitive structures. At 200m overburden depth, an angle of draw of 35° is equivalent to a barrier of 26.5° plus 40m. At 250m overburden depth, an angle of draw of 35° is equivalent to a barrier of 26.5° plus 50m. The overburden depths at the two pinch points on Longwall 31 range 200-215m at the northern pinch point and 210-230m at the southern pinch point.

An angle of draw of 26.5° plus 50m is considered to provide a very conservative barrier against any potential for rock falls associated with nearby longwall mining activity.

4.4 Stress Change Monitoring Results

SCT Report BBO3252 presents the results of stress monitoring conducted within the cliff forming sandstones between Longwall 26 and the Wolgan Escarpment midway across a 190m barrier pillar. This monitoring indicated that there was horizontal stress concentration between the goaf of Longwall 26 and the Wolgan Escarpment of approximately 2MPa as well as horizontal stress relief toward the goaf of Longwall 26 of approximately 5MPa.

Subsidence monitoring at the same site indicated that the horizontal strain changes surveyed on the subsidence lines were consistent with the stress change monitoring and had a magnitude of approximately 0.1mm/m. The greater resolution of the stress monitoring instrument enabled the form and magnitude of the stress changes to be measured with more confidence than was possible by conventional surveying, but it should be recognised that the magnitude of the changes are very small by comparison with subsidence movements commonly observed directly over the panel.

To put these changes in context, the coefficient of thermal expansion for sandstone rock strata is expected to be of the order of 1×10^{-5}/°C. For a 40°C range of surface temperatures likely to be experienced as a result of natural heating and cooling, the horizontal strain experienced by the rock is likely to range up to approximately 0.4mm/m from season to season.

Any changes in horizontal stress associated with longwall mining, while perceptible with stress monitoring instruments, are small by comparison with the variation in surface temperature that occurs naturally from day to day and season to season. On this basis, with a barrier equal to 26.5° angle of draw plus 50m the horizontal stress concentrations expected to occur at

the pinch points as a result of mining Longwall 31 are expected to cause strain changes at the surface of less than 25% of the strain changes expected as a result of diurnal and seasonal temperature changes caused by natural heating and cooling cycles on the surface of the rock formations.

4.5 Barrier Size Considerations

A barrier size of 26.5° angle of draw is expected to provide a high level of protection to the cliffs of the Wolgan Escarpment based on general experience of mining close to cliff formations.

While a barrier of greater size clearly delivers a higher level of protection against mining induced rock falls, it should be recognised that the actual protection afforded is not necessarily greater once the rate of mining induced rock falls drops below the background rate of naturally occurring rock falls. These background rates are difficult to determine from the limited dataset available. General observations of rock falls on the Illawarra Escarpment indicate that over approximately 30km of escarpment at least 100m of the escarpment has experienced natural rock falls over a 20 year period. This rate is equivalent to a natural probability of 1 in 1000 of a rock fall in the 5-10 year period that a rock fall might reasonably be linked to mining activity.

A barrier based on an angle of draw of 26.5° plus 50m is consistent with the level of protection provided to high cliffs at the colliery without any impact being apparent. While somewhat arbitrary, this level of protection has nevertheless been effective in preventing any mining induced impacts in the past.

5. IMPLICATIONS FOR BARRIER SIZE

Figure 10 shows that the protection barrier originally planned between the northern pinch point and the nearest goaf edge of Longwall 31 was 125m. At 210m overburden depth, this distance is equivalent to an angle of draw of 26.5° plus 20m. To provide a level of protection to the cliffs of the Wolgan Escarpment at the northern pinch point similar to that which has been provided previously to high cliffs at Baal Bone Colliery, the barrier would need to be increased to 26.5° angle of draw plus 50m. This increase would reduce the width of Longwall 31 by 30m from 250m to 220m.

At the southern pinch point, the protection barrier was originally 115m. At an overburden depth of 230m, this barrier is equivalent to an angle of draw of 26.5° with no additional offset. The cliff formation at this southern pinch point is much more stable than at the northern pinch point. There is unlikely to be any potential for mining induced impacts on the Escarpment at a distance of 26.5° angle of draw. If Longwall 31 is reduced in width by 30m because of the northern pinch point, the barrier at the southern pinch point is also increased by 30m providing an even higher level of protection.

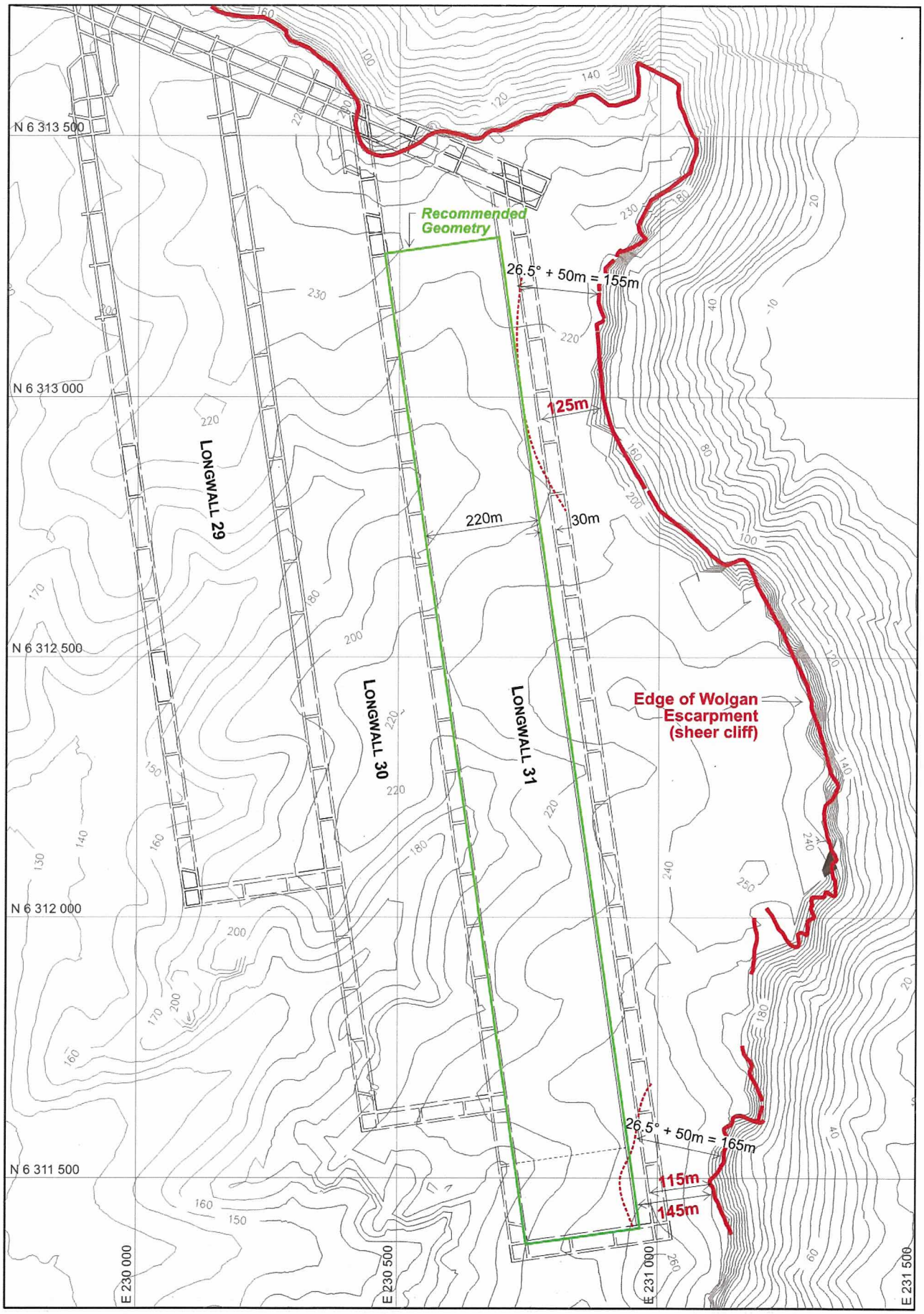


Figure 10 Overburden depth isopachs and barrier sizes to Wolgan Escarpment adjacent to Longwall 31.

If the cliff formation at the southern pinch point is required to be protected by an angle of draw of 26.5° plus 50m, Longwall 31 would need to be reduced in length by approximately 150m. But if Longwall 31 is reduced in width by 30m (to provide adequate protection to the northern pinch point) and a barrier of 26.5° plus 30m is accepted as sufficient to protect the southern pinch point, Longwall 31 could be mined full length to maximise resource recovery.

6. MONITORING STRATEGY

This section describes the monitoring strategy that is recommended for the barrier between Longwall 31 and the two pinch points on the Wolgan Escarpment. A program of work including subsidence monitoring, stress measurement, and stress change monitoring is recommended to detect any irregular movements that might provide early warning of an imminent rock fall. Figure 11 shows the geometry of the proposed subsidence and other monitoring that is proposed.

6.1 Subsidence Monitoring

The proposed subsidence monitoring program is aimed to measure the general development of subsidence over Longwalls 29-31 and, in particular, the horizontal subsidence movements in the vicinity of the two pinch points.

At the finish end of Longwall 29, a subsidence line perpendicular to the escarpment is recommended. The barrier in this area is sufficient to fully protect the escarpment so the monitoring frequency does not need to be intense. A survey when the longwall panel is 50m out, 20m out and finished would be expected to provide confirmation that no movements are occurring at the escarpment. If there is any indication of unusual movement, the frequency should be increased accordingly.

At the southern pinch point, a short cross line perpendicular to the gateroad passing through the pinch point and a second line parallel to the gateroad and located midway between the goaf edge and the Wolgan Escarpment are recommended. At the northern pinch point, the main cross line across all the panels and a second short line parallel to the gateroads located midway between the goaf edge and the Wolgan Escarpment are recommended.

It is recommended that pegs are spaced approximately 10m apart and monitored in three dimensions. An array of semi-permanent glass prisms located at approximately 20m along the edge of the escarpment and able to be surveyed from the longitudinal lines without need to approach the edge of the escarpment are recommended to provide greater detail of movement on the escarpment itself.

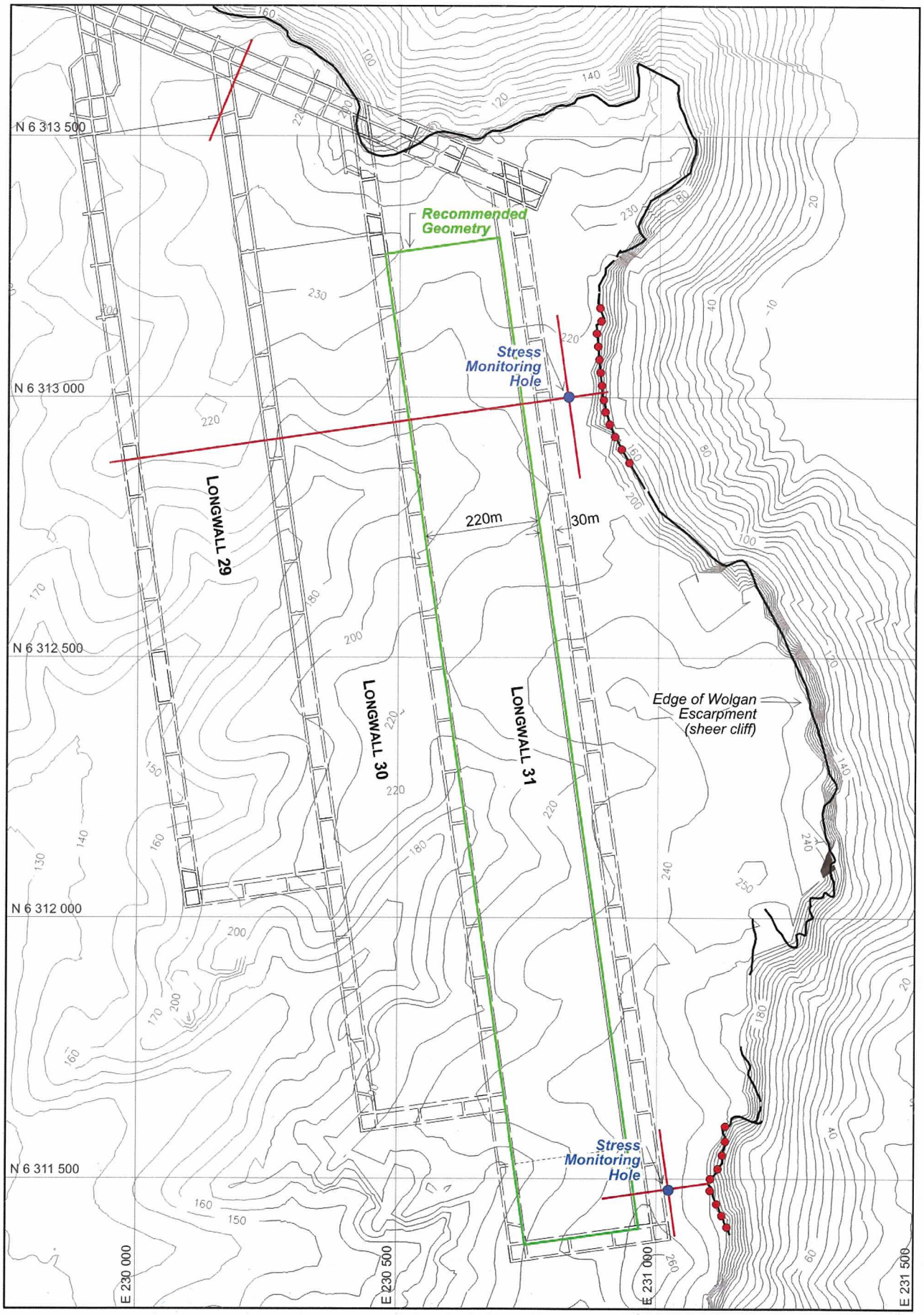


Figure 11 Subsidence monitoring proposed.

The frequency of monitoring can be based on longwall geometry. A recommended frequency involving a survey conducted approximately every 30m of longwall retreat during the period from when the longwall face is 60m from the line until the longwall face is 200m past would provide confirmation that subsidence movements are developing at a steady rate. A final survey should be conducted once the longwall face is 600m past or has finished. If there is any indication of unexpected movement, the frequency of surveying should be increased accordingly.

6.2 Stress Change Monitoring

Stress change monitoring adjacent to Longwall 26 showed that the resolution of stress monitoring is significantly greater than the resolution of conventional surveying. Given the large barriers that have been provided, stress monitoring is considered likely to be the best indicator of any mining induced changes that occur on the face of the escarpment.

A program of stress change monitoring is recommended at both pinch points, with stress change monitoring instruments located as close as practical to the Wolgan Escarpment. Recognising the limitations of drilling and not wanting to introduce water into joints that might affect the stability of the cliff formation, we recommend that the instruments are installed at a convenient distance back from the edge of the sheer cliff of at least 20m.

Ideally the instruments would be installed approximately halfway down cliff forming sandstone and would be monitored as Longwalls 29, 30 and 31 are mined.

The aim of the stress monitoring would be to show that horizontal stress changes induced by mining parallel to the longwall goaf edge are much smaller than thermal stress changes that occur naturally in a diurnal or seasonal cycle. To measure the natural diurnal and seasonal changes, an array of temperature measuring sensor is recommended. These instruments would be installed in a shallow hole in a sandstone outcrop, not necessarily on the escarpment itself but in a similar environment nearby, to measure a thermal profile and variations in it, against which the stress changes monitored within the cliff forming sandstones could be compared.

6.3 Detailed Assessment of Cliff Stability at Northern Pinch Point

A detailed assessment of the cliff stability at the northern pinch point could be undertaken, but a higher level of site characterisation would be required. This characterisation would involve measurement of the cliff geometry using a terrestrial photogrammetry system called Sirovision, measurement of the in situ stresses in the cliff forming sandstone which could be undertaken as part of the stress monitoring installation, and laboratory testing of the cliff forming sandstone strata. An analysis would be undertaken to determine the potential for overall stability given the 8m undercut and the potential for joint bounded rock falls based on the observation that previous rock falls at the site appear to be a result of cantilevered rock units becoming detached.

This detailed analysis of the cliff stability is not necessary at the southern pinch point because the rock formations have been visually assessed already and found to be stable.

Detailed analysis of the northern pinch point would provide a basis for interpreting any stress changes that may be observed in the monitoring, but it is unlikely to indicate other than that the cliff formations at the northern pinch point are in a state of imminent instability.

7. CONCLUSIONS

Our assessment indicates that reducing the width of Longwall 31 by 30m to an overall width of 220m and keeping the panel full length would ensure a high level of protection to the Wolgan Escarpment equivalent at the northern pinch point to the protection that has been provided to high escarpments at Baal Bone in the past and sufficient at the southern pinch point to prevent any potential for rock falls recognising the more stable nature of the cliff formation in this southern area.

There have been a variety of strategies used to determine the appropriate barrier to high cliffs such as the Wolgan Escarpment. An angle of draw of 26.5° is considered to be effective, but an additional barrier has typically been added for a range of reasons to do with mining geometry and cliff line geometry. At Baal Bone Colliery, previous experience indicates that the barrier has ranged from 20m to 85m with an additional barrier of 50m being the median. An angle of draw of 35° is equivalent to an angle of draw of 26.5° plus 40-50m at the pinch points on Longwall 31.

At the northern pinch point where the cliff formations of the Wolgan Escarpment are in a current state of imminent instability, a barrier equivalent to 26.5° angle of draw plus 50m is expected to be sufficient to demonstrate that any coincidental rock falls are not associated with mining activity. At the southern pinch point, the cliff formation is considered to be long term stable and a protection barrier equivalent to 26.5° angle of draw plus 30m is considered more than sufficient to protect against any potential for rock falls at this location.

It should be recognised that rock falls are a natural characteristic of the development of cliff features such as the Wolgan Escarpment, so it is not possible to fully protect against the possibility of a rock fall occurring naturally. The protection barriers proposed are considered to be more than sufficient to provide a high level of protection to the cliff formations of the Wolgan Escarpment. However, given the northern pinch point in particular is currently in a state of imminent instability, the monitoring program proposed is intended to demonstrate that Longwall 31 has an impact on the Wolgan Escarpment that is less than natural changes associated with diurnal and seasonal temperature variations.

The intention is that if a rock fall were to occur coincidentally, it could be demonstrated to be independent of any mining activity. Stress monitoring at the Longwall 26 site indicated that the changes detected were less than the thermal stress changes estimated for with diurnal and seasonal temperature variations on the surface of the cliff formation.

Short subsidence lines and permanent reflectors along the top of the cliff formations are recommended to provide confirmation of the level of subsidence movement. Stress change monitoring within the cliff forming sandstones is expected to provide a greater resolution of change than is possible with subsidence monitoring. Stress change monitoring instruments at both the northern and southern pinch points are recommended. Monitoring of thermal changes within rock formations in the vicinity of the northern pinch point is recommended to give a measure of the natural variations in temperature experienced on the Wolgan Escarpment.

A higher level of investigation and monitoring, particularly at the northern pinch point, would involve detailed measurement of the cliff geometry using airborne terrestrial photogrammetry, in situ stress measurement within the cliff forming sandstone, laboratory testing of core samples recovered from monitoring holes, and an analysis of the likely state of stability of the sandstone cliff formations at the northern pinch point. The southern pinch point has already been assessed as stable and tolerant to subsidence movements anticipated at 26.5° angle of draw from the nearest goaf edge.

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11 December 2009

Kate Tilden
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Dear Kate,

SUBSIDENCE ZONES IN REMNANT AREAS AT BAAL BONE COLLIERY

As requested, please find herein our assessment of the four areas likely to require special consideration from a subsidence impact perspective during possible future pillar extraction operations in remnant pillar areas at Baal Bone Colliery.

Our assessment indicates that there are three areas where cliff lines would be impacted and one area where Ben Bullen Creek would be mined under at an overburden depth of approximately 40m. These four areas would need special consideration in terms of extraction layout design if potential subsidence impacts on the overlying surface features are to be maintained at low levels. It is anticipated that other surface infrastructure such as access tracks and power lines could be managed with specific subsidence management plans similar to those used previously.

Similar surface features adjacent to all four areas have previously been impacted by longwall subsidence. However, the community tolerance to surface impacts has changed since these areas were longwall mined and it is anticipated that mining layouts would need to be designed to minimise surface subsidence to low levels to prevent rock falls on cliff formations and loss of surface water from Ben Bullen Creek.

Figure 1 shows a plan of the existing mine geometry at Baal Bone Colliery superimposed onto a 1:25,000 topographic series plan of the area. The remnant pillar areas are shaded. The surface features likely to be impacted by mining subsidence comprise sandstone cliff formations and Ben Bullen Creek. The subsidence protection zones required to limit subsidence impacts to imperceptible levels are based on an angle of draw of 26.5° which is equivalent to a horizontal distance equal to half overburden depth.

Maximum subsidence and surface impacts in the remnant pillar extraction areas are likely to be similar to the maximum subsidence and surface impacts experienced over adjacent longwall panels. The subsidence may be more irregular and may vary more depending on the extent and geometry of extracted pillar areas. It is anticipated that any other subsidence impacts within the remnant pillar extraction area would be able to managed by a site specific subsidence management plan.

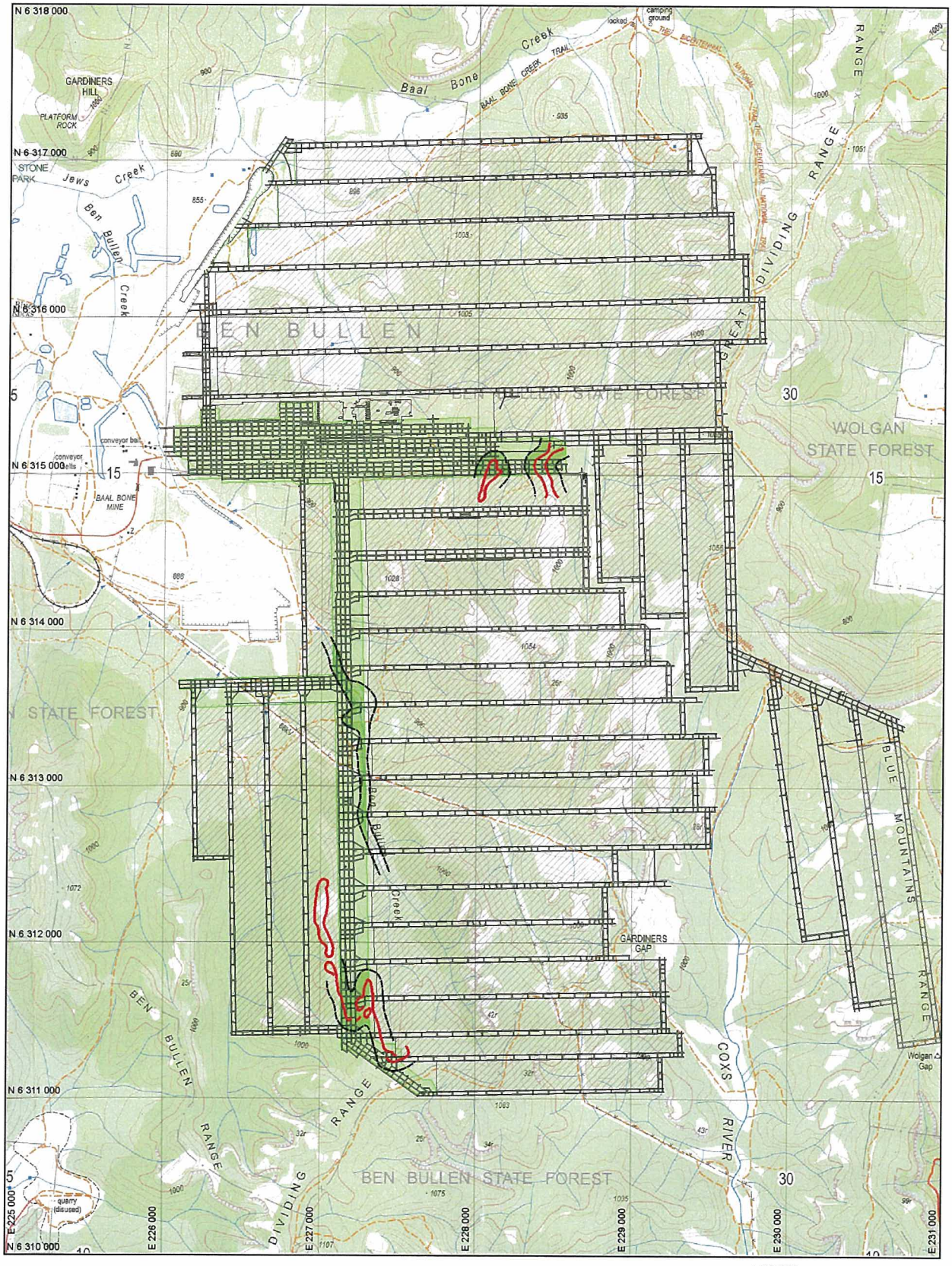


Figure 1: Plan of mine layout superimposed onto 1:25,000 topographic series map showing remnant pillar areas and areas that may require special design to limit subsidence.

Pillar extraction mining under cliff formations and Ben Bullen Creek would be expected to cause subsidence impacts similar to the subsidence impacts associated with longwall mining. Rock falls would be expected along approximately 20% of the length of cliff formations that are mined under. Perceptible cracking would be expected on approximately 70% of cliff formations that are mined under. Perceptible cracking would also be expected to a distance outside the mining area to a distance equal to 0.4 times overburden depth, but rock falls outside mining areas are unlikely.

It should be recognised that perceptible cracking and rock falls may have already occurred in the areas directly over and immediately adjacent to the proposed pillar extraction because the remnant pillar areas are located adjacent to and between previously extracted longwall panels.

Surface cracking and cracking of the overburden strata below Ben Bullen Creek is likely to have occurred during previous longwall mining and would be expected to occur again if pillar extraction occurs directly below the creek. The creek is ephemeral and only flows following heavy rain. Remediation of surface cracks is likely to be effective as a means to prevent direct ingress of surface flow, but such remediation may cause significant disturbance to the surface vegetation, particularly in the low lying swamp areas adjacent to the end of Longwalls 6 and 7. Surface cracking of Ben Bullen Creek is not expected to develop if there is no pillar extraction within an area defined by 26.5° angle of draw from the creek.

A high level of protection against subsidence impacts would be provided to the three areas of cliff formations and to Ben Bullen Creek if these features are protected from being directly mined under by an angle of draw of 26.5° or greater. The subsidence zones shown in Figure 1 are based on an angle of draw of 26.5°.

Pillar extraction operations have a high degree of flexibility in terms of the layout geometry that can be mined. While it would be possible to develop pillar extraction geometries that limit surface subsidence to low levels, the resource recovery is inevitably decreased in such designs. The design of pillar extraction geometries to limit surface subsidence is beyond the scope of this report.

If you have any queries or would like further clarification of any of these issues, please do not hesitate to contact me directly.

Regards

Ken Mills
Senior Geotechnical Engineer



APPENDIX D

Subsidence Risk Assessment

XSTRATA COAL NSW
BAAL BONE COLLIERY

LONGWALL MINING
SUBSIDENCE RISK ASSESSMENT

FINAL REPORT
DECEMBER 2006
HMS622

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XSTRATA COAL NSW
BAAL BONE COLLIERY

LONGWALL MINING
SUBSIDENCE RISK ASSESSMENT

FINAL REPORT
DECEMBER 2006

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Client: **Mr Bernie McKinnon**
Mine Manager
Baal Bone Colliery

Author: **David Swan**
Andrew Whalan
HMS Consultants Pty. Ltd.

Date: **5th December 2006**

File	Report	Prepared By	Reviewed By	Date
20061204 HMS622 - Baal Bone SMP RA.doc	Draft	A. Whalan/ D. Swan	K. Price	Jan 07
20070227 HMS622 – Baal Bone SMP RA.doc	Final	D. Swan	Mine	Feb 07

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APPENDIX A – Baal Bone Risk Matrix

APPENDIX B – Baal Bone Risk Table, October 2006

1 EXECUTIVE SUMMARY

In December 2006, Hawcroft Miller Swan Consultants Pty Ltd ("HMS") was engaged by Mr Bernie McKinnon, Mine Manager, for Baal Bone Colliery, Lithgow ("Baal Bone"), to facilitate a risk assessment to investigate the potential impacts of subsidence at Baal Bone, relating to the planned longwall mining of panels 29, 30 and 31, within Consolidated Coal Lease 749 ("CCL 749").

This report details the methods used and the recommendations resulting from the risk assessment workshop which was facilitated at Baal Bone on the 5th December 2006.

This Report will provide inputs for the development of the Baal Bone Subsidence Management Plan ("SMP").

Risk ranking was undertaken in accordance with the Australian Standard for Risk Management AS4360:2004, using the Baal Bone Risk Assessment Matrix, shown in Appendix A.

1.1 Distribution of Risks

In total, twenty-seven (27) risks were identified during the risk assessment. The identified risks have been grouped according to risk rank and are summarised in the following:

- *Table 1 - Summary of Risks by Risk Rating*
- *Chart 1 - Risk Distribution by Risk Rating*

Risk Rating	No.	%
High	nil	0%
Medium	16	59%
Low	11	41%
Total	27	100%

Table 1 - Summary of Risks by Risk Rating

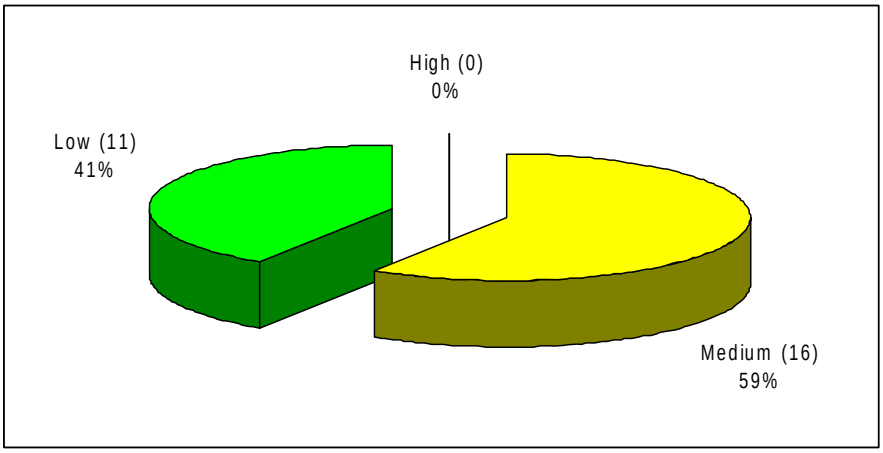


Chart 1 - Risk Distribution by Risk Rating

The lack of any potential high risk issues is mostly attributable to the proposed mine design layout where the longwall mining panels have been located between Cox's River and the Wolgan Escarpment, with evidence based angle of draw protection zones designed to minimise any impact from longwall mining operations.

This approach provides a high level of confidence that the subsidence impacts to these features from longwall mining will be minimal.

A summary of medium risk issues is shown in *Table 2 – Summary of Medium Risk Issues*, following:

A#	Aspect	C#	Consideration	R#	Risk Issue
1	Natural Features	1.01	Natural Water Courses/ Streams	1.01.01	Disruption to natural stream flow
		1.03		1.03.01	Damage to Endangered Ecological Community
		1.03		1.03.02	Damage to ecosystem
		1.05	Threatened & Protected Species	1.05.01	Partial loss of local population
		1.06	Wolgan Escarpment	1.06.01	Rock falls
		1.07	Internal Cliffs	1.07.01	
		1.07		1.07.02	Cracking
		1.08	Pagodas/ Rock Formations	1.08.01	
		1.09	State Forests/ Natural Vegetation/ Harvesting	1.09.02	Personal injury to forest workers to Forest management & fire-fighting activities in LW mining area
		1.09		1.09.03	Loss of vegetation and soil disturbance
2	Surface Improvements	2.01	Tracks / Roads	2.01.01	Damage to roads and drainage structures
		2.02	Survey Control Stations	2.02.01	Movement of Wolgan Gap survey trig.
3	Subsurface	3.01	Groundwater Resources/ Aquifer	3.01.01	Draining upper water bearing zones impacts on vegetation community
		3.01		3.01.02	Draining lower water bearing zones
		3.03	Increased mine water make	3.03.01	Increased pumping
4	Areas of Archaeological/ Heritage Significance	4.01	Aboriginal Artifacts	4.01.01	Damage/ disturbance to artifacts/ sites

Table 2 – Summary of Medium Risk Issues

1.2 Follow-up Actions

Resulting from the risk assessment process, an Action List was developed by the workshop team.

The summary list of agreed actions is shown in *Table 3 –Summary of Agreed Actions*, following;

#	Action Description	Risk Ref #	By Whom	By When
1	Finalise Aboriginal archaeological survey	4.01.01	OzArk	February 2007
2	Establish communications protocol between mine and Forests NSW	1.09.02	Environmental & Community Co-ordinator	Prior to commencement of LW29 extraction
3	Finalise flora monitoring	1.01.01	Gingra	February 2007
4	Inspections following rainfall events to be established	1.01.01	Environmental & Community Co-ordinator	Commencing August 2007
5	Mine to provide Forests NSW with mining progression plans	1.09.02	Environmental & Community Co-ordinator	Prior to commencement of LW29 extraction
6	Conduct Photographic monitoring	1.06.01, 1.07.01, 1.07.02, 1.08.01	Environmental & Community Co-ordinator	Baseline to be established a minimum of 4 months prior to extraction of each longwall
7	Proposed stress concentration monitoring program	1.06.01	SCT	Before commencement of LW29 extraction
8	Regular review and reporting of monitoring information	1.03.01, 1.03.02, 1.05.01, 3.01.01, 3.01.02	Mine Manager	Reports at four monthly intervals to relevant stakeholders
9	Rehabilitation following cessation of monitoring	1.09.03	Environmental & Community Co-ordinator	Within 3 months of cessation of monitoring
10	Remediation where required	1.01.01	Mine Manager	Following inspection and assessment with relevant authority
11	Repair/ Replace if required	2.02.01	Mine Manager	In consultation with Department of Lands
12	Review inspection frequency	2.01.01	Environmental & Community Co-ordinator	Increase during and immediately after undermining of area
13	Search of national Aboriginal heritage register	4.01.01	OzArk	Completed
14	3D survey monitoring approved by PSE DPI	1.06.01, 1.07.01	Mine Manager	In consultation with Principal Subsidence Engineer prior to commencement of each panel extraction.

Table 3 – Summary of Agreed Actions

2 INTRODUCTION

Baal Bone is one of a number of active mining operations within the Western Coalfields of New South Wales.

Baal Bone is a combination of underground and open cut operations and is located approximately 25km northwest of Lithgow and 4km north – northeast of Cullen Bullen in the Lithgow Local Government Area (LGA).

The Colliery is operated by The Wallerawang Collieries Limited.

Mining at Baal Bone commenced in the late 1940's with the operation of the Ben Bullen Open Cut mine by the NSW Mining Co Pty Ltd (a subsidiary of the Joint Coal Board). These operations consisted of shallow open box cut mining operations which ceased in 1952.

The Wallerawang Collieries Limited commenced underground mining at Baal Bone Colliery in 1982.

Coal mining operations at Baal Bone Colliery are carried out in the Lithgow seam with the underground production by longwall mining methods.

Normally production operations are carried out 24 hours per day, 5 days per week. Generally, only maintenance operations (eg stonedusting, roadway maintenance etc) are undertaken on weekends.

Export coal is washed and loaded onto trains at the site and transported to Port Kembla.

Road haulage is used for some domestic coal (Mt Piper and Wallerawang Power Stations and other minor contracts).

Baal Bone proposes to conduct "secondary workings" using longwall mining methods within CCL 749.

The proposed mining area is known as Longwall 29-31 area. This area is identified by red cross-hatching in *Diagram 1 – Longwall Panels 29 – 31 within CL749*, following:

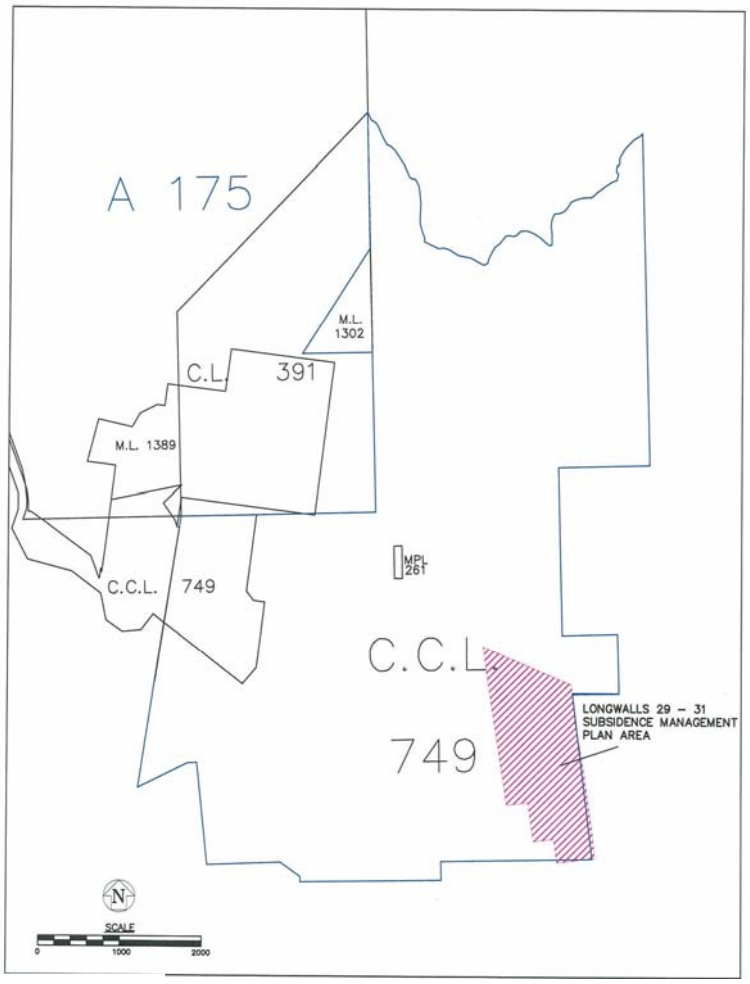


Diagram 1 – Longwall Panels 29 – 31 within CL749

The proposed longwall panels are located within CCL 749, Ben Bullen and Wolgan State Forest and Crown land to the west of the Wolgan Road and the east of Cox's River.

In developing an understanding of the approval requirements for this area and determining the appropriate approval path for this development, extensive consultation had been undertaken with Minter Ellison Lawyers. This advice has indicated that the proposed longwall mining, falls within ambit provisions of Clause 35 Schedule 1 of the Model provisions as adopted by the Lithgow City Local Environmental Plan, 1994.

A subsequent approval under the *Mining Act 1992*, in the form of the Subsidence Management Plan (SMP) is required.

2.1 The Applicant

Baal Bone is operated by The Wallerawang Collieries Limited a joint venture between Coalex Holdings (a fully owned subsidiary of Oakbridge Pty Limited) 95% and Sumitomo Corporation 5%.

2.2 Description of the Proposal

Longwall panels 29-31 are situated on a north-northwest to south-southeast axis, parallel to or at right angles to previously mined longwalls.

The panels have been located between the Cox's River and the Wolgan Escarpment and the layout has been designed, based on a combination of previous experience, monitoring results, as well as recommendations from geotechnical and subsidence engineering consultants, to maximise the efficiency of mining operations and resource recovery whilst minimising environmental impacts.

The panels have been located to avoid sensitive features, including the escarpment at the western edge of the Wolgan Valley, the Cox's River Swamp and the Cox's River Valley as well as several sensitive rock formations and faces in the Banks Wall sandstone member.

The mining section height will be in the range of 2.45 metres minimum to 2.55 metres maximum, which will include the total Lithgow seam (2.2 to 2.4 metre thickness).

The depth of cover in the extraction area ranges between 150 and 240 metres.

Based on investigations undertaken and results from previous monitoring as well as associated reviews by Strata Control Technology Operations Pty Ltd, the maximum subsidence is predicted to be in the order of 1.3 to 1.6 metres.

The theoretical maximum subsidence is 1.56 metres, based on 65% of a seam thickness of 2.4 metres.

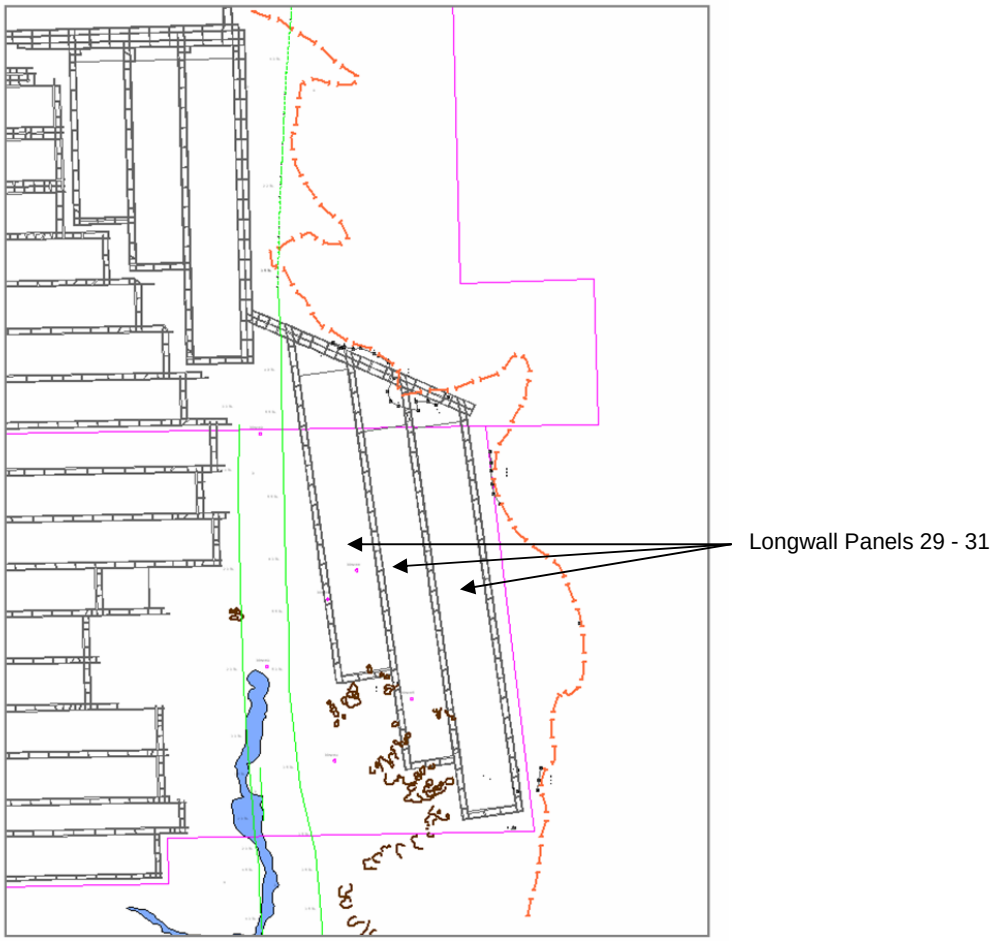
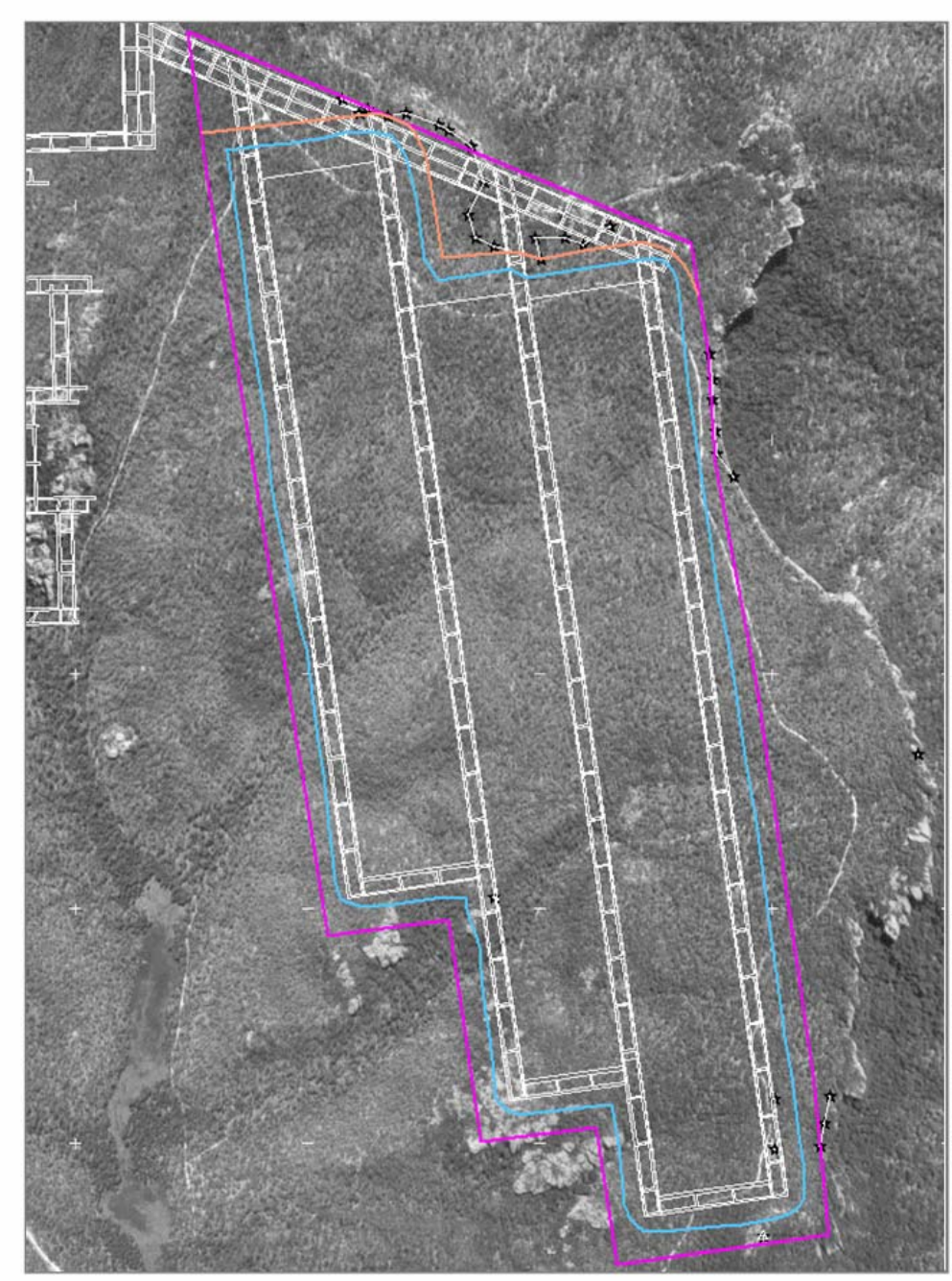


Diagram 2 – Longwall Panels 29-31

2.3 Mining Method

Longwall panels 29-31 will be extracted using the retreat longwall method of mining. This method has been successfully used for the extraction of 26 previous panels. The face equipment has been designed for mining in the proposed height range and seam.

The SMP Application Area, as well as the 17 and 26.5 degree angle of draw zones are shown in *Diagram 3 – Location of SMP Application Area,* following*;*



SMP Application Area

26.5 Degree Angle of Draw

17 Degree Angle of Draw

Diagram 3 – Location of SMP Application Area

3 CONTEXT

3.1 Scope

The Scope of this risk assessment is to identify potential subsidence risk issues associated with the planned longwall mining of panels, known as 29, 30 and 31 within CCL 749.

Risk Issues identifying a material impact to the following criteria were considered;

- Impacts on people
- Property/ Asset damage
- Environmental impacts
- Community impacts

3.2 Objectives

The Objectives of this risk assessment are to:

- Assist Baal Bone to satisfy their duty of care obligations by facilitating and documenting a risk assessment in accordance with the scope and the Australian/ New Zealand Standard for Risk Management AS/NZS 4360
- Identify and assess subsidence risk issues associated with the longwall operation
- Develop controls to reduce risks to an acceptable risk level, including assigned actions
- Identify any gaps in existing documentation
- Generate a Report consistent with the scope as well as AS4360 specifications

3.3 Assumptions

The workshop agreed to the following assumptions:

- Mine Layout Plans were accurate
- Assessment was undertaken for the “current” mine design layout and did not consider the impacts of a change to mine design
- Design Assumptions were valid
- Surface Plans were accurate

4 WORKSHOP TEAM

A key factor in the effectiveness of this exercise is the availability of relevant information and expertise. A workshop team made up of representatives of key stakeholders achieved this.

The role of team members was to provide their expertise, experience and technical knowledge, and to respect that provided by others.

Outcomes were dependent upon group consensus.

The Facilitator's role was to understand the Client's requirements and offer advice as to the best approach to meet the workshop objectives. He assisted the team by providing a systematic process and maintaining focus on the scope and objectives.

The facilitator documented the workshop process and outcomes, and will offer post-workshop feedback to the Client, if requested.

The team members are listed in *Table 4 – Risk Assessment Workshop Team*, following:

Name	Position	Company/ Site	Years Site Experience	Years Industry Experience
Roger Lembit	Ecologist	Gingra	16	25 yrs
Ken Mills	Consultant	SCT	16	25+ yrs
Ian Forster	Hydro-geologist	Connell Wagner	5	30 yrs
Tony King	Env. & Community Co-ordinator	Baal Bone	3 months	26 yrs
Jillian Wright	Mining Engineer	Xstrata	5	8 yrs
Stephanie Hutchison	Planning Forester	Forests NSW	2	4 yrs
Kevin Price	Mine Surveyor	Brunskill	10	40 yrs
Sarah Caruana	Environmental Graduate	Xstrata		1 year
David Swan	Facilitator	HMS Consultants		30 yrs
Andrew Whalan	Technical Assistant	HMS Consultants		5 yrs

Table 4 - Risk Assessment Workshop Team

5 METHOD OF APPROACH

5.1 Risk Assessment Procedure

The risk assessment process identified the risk issues associated with aspects of subsidence management of Baal Bone, longwall panels 29 -31, then assessed the risks in accordance with the Australian/ New Zealand Standard for Risk Management AS/ NZS 4360:2004 and MDG 1010 Risk Management Handbook for the Mining Industry.

This method included the following:

- A workshop team of mine management, relevant external stakeholders as well as external subsidence expertise. The name and role of each team member was recorded (see Table 4 - Risk Assessment Workshop Team)
- The Scope and Objectives of the risk assessment was clearly identified and defined by the team (§3.1 & 3.2)
- The scales for risk ranking were discussed and explained to the team using definitions which are appropriate to the operation and the company (see Appendix A)
- The processes relating to this risk assessment were identified and listed as a flow sequence. (see following section)

5.2 Process Map

Prior to commencement of the risk assessment, the group identified and documented the relevant aspects within the agreed scope of the workshop.

The aspects are shown in *Table 5 – Risk Assessment Process Areas,* following:

#	Aspect	#	Consideration
1	Natural Features	1.01	Natural Water Courses/ Streams
		1.02	River Catchments
		1.03	Swamps & Water-related Ecosystems
		1.04	Steep Slopes
		1.05	Threatened & Protected Species
		1.06	Wolgan Escarpment
		1.07	Internal Cliffs
		1.08	Pagodas/ Rock Formations
		1.09	State Forests/ Natural Vegetation/ Harvesting
2	Surface Improvements	2.01	Tracks / Roads
		2.02	Survey Control Stations
		2.03	General Public/ Recreation
3	Subsurface	3.01	Groundwater Resources/ Aquifer
		3.02	Groundwater recharge
		3.03	Increased mine water make
		3.04	Sterilisation of Coal Resources
4	Areas of Archaeological/ Heritage Significance	4.01	Aboriginal Artifacts

Table 5 - Risk Assessment Process Areas

5.3 Identification of Potential Loss Scenarios

The risk assessment workshop team systematically considered each aspect in turn, with the purpose of identifying potential loss scenarios.

The group considered scenarios relating to; health and safety (surface only), the environment, community and property damage.

These identified scenarios (risk issues) were then recorded.

5.4 Existing Controls

The risk assessment team discussed inherent and current existing control methods for each risk issue. These controls were considered when risk ranking, and recorded as part of the workshop.

5.5 Risk Evaluation

Having identified the risk issues, the Team was then directed to undertake a risk ranking exercise on the identified risk issues in consideration of the existing controls and the data quality effectiveness.

Assessment was undertaken in accordance with the Baal Bone Risk Matrix, as presented in Appendix A, recording:

- Consequence
- Likelihood

The Risk Level is then derived from the risk matrix.

The Risk Level was compared to the scale shown in Appendix A and assigned a Risk Rating, which was recorded on the risk assessment table (see Appendix B).

5.6 Post Implementation Review

It is strongly recommended that mine management undertake post implementation review at a time as appropriate, to measure the effectiveness of existing risk controls.

Xstrata Coal NSW – Baal Bone Colliery – Longwall Mine Subsidence Risk Assessment

6 MINERAL RESOURCES MDG 1014 CHECKLIST

To ensure this risk assessment complies with the Minerals Resources MDG 1010 Risk Management Handbook, the following checklist/ sign-off (MDG 1014) has been included.

Sub-sections 6.1, 6.2 and 6.3, are to be completed by Mine Management.

6.1 Report Checklist

1.	Is there a description of the operation or equipment being assessed?	(Yes) / No
2.	Is there a summary of the strategic, corporate and risk management context?	(Yes) / No
3.	Is there a list of the people involved in the risk identification step, together with their organisational roles and experience relevant to the risk assessment topic?	(Yes) / No
4.	Is there an adequately detailed outline of the approach used to identify the risks?	(Yes) / No
5.	Is there an outline of the method used for assessing the likelihood and consequences of the risks?	(Yes) / No
6.	Are there two lists of identified risks, ranked by: a) risk magnitude, and b) consequence magnitude	(Yes) / No
7.	Is there discussion of the basis for defining either the safety standard to be achieved, or the level of risk management expenditure?	(Yes) / No
8.	Is there a list of the main actions to be taken to reduce risks and to manage risks?	(Yes) / No
9.	Is there a timetable for implementing main actions?	(Yes) / No
10.	Does the report specify a requirement for a working audit required after completion of all implementation stages?	(Yes) / No

6.2 Risk Assessment Process Evaluation

How do you rate the following:		Poor			Good	
1.	The range of expertise of team which did the study	1	2	3	4	(5)
2.	The appropriateness of the degree of detail of the study	1	2	3	4	(5)
3.	The comprehensiveness of the systematic approach	1	2	3	4	(5)
4.	The identification of the key risk scenarios to be addressed	1	2	3	4	(5)
5.	The bases for deciding the required safety level or effort	1	2	3	4	(5)
6.	The method for assessing likelihood and consequences	1	2	3	4	(5)
7.	The thoroughness of consideration of planned risk reduction actions	1	2	3	4	(5)
8.	The thoroughness of consideration of existing or planned risk controls	1	2	3	4	(5)
9.	The objectivity and balance of the study (i.e. not unduly optimistic or pessimistic	1	2	3	4	(5)

6.3 Risk Assessment Process Signoff

Name: Mr Bernie McKinnon

Position: Mine Manager

Signed: _____ **Date:** 7th December, 2006

APPENDIX A – Baal Bone Risk Matrix

Xstrata Risk Matrix

Risk Matrix		Probability				
		A	B	C	D	E
Max Reasonable Consequence	1	1	2	4	7	11
	2	3	5	8	12	16
	3	6	9	13	17	20
	4	10	14	18	21	23
	5	15	19	22	24	25

Risk Groups

1-10 High
11-19 Medium
20-25 Low

Probability

A – Almost certain to happen (Everyday/ weekly event)
B – Likely to happen at some point (Once a month)
C – Possible, head of so it might happen (Yearly)
D – Unlikely, not likely to happen (Once every five years)
E – Rare, practically impossible (Once every twenty-five years)

Maximum Reasonable Consequence

	People	Property	Environmental	Community
1	Multiple fatalities. Major permanent negative health impacts on a large number of people	> $10M	Disastrous environmental impact, with long term effect, requiring major remediation, regulatory intervention or premature closure of the operation.	Public international condemnation. Major breakdown of social order in affected community
2	Single fatality. Severe irreversible disability or impairment (PDI)	$1M - $10M	Serious environmental impact with medium-term effect, requiring significant remediation or resulting in prosecution.	Loss of community's economic viability. Significant damage to reputation of the operations
3	Major injury to one or more people. Severe health impacts on a number of people	$100K - $1M	Moderate reversible environmental impact with short term effect, requiring moderate remediation such as a reportable incident not likely to result in prosecution (e.g. minor water discharge)	Significant public criticism (e.g. community complaints) NGO or Media “taking up the issue” Major negative impact on economic viability
4	Significant reportable injury (MTI or less than 5 days of RWI or LTI). Impact on health of several people	$10K - $100K	Minor, reversible environmental impact, requiring minor remediation such as non reportable environmental incident (eg. minor oil spill)	Flare up of issues in affected communities. Media criticism
5	Minor Injury. Slight negative impact on individual health.	< $10K	Negligible, reversible environmental impact, requiring very little remediation	Slight negative impact on individuals in local community

APPENDIX B – Baal Bone Risk Table, December 2006

A#	Aspect	C#	Consideration	R#	Risk Issue	Causes	Impacts	Inherent & Existing Controls	C	L	Rank	Level
1	Natural Features	1.01	Natural Water Courses/ Streams	1.01.0	Disruption to natural stream flow	- Surface Cracking - Change in land profile	Environmental	- Natural gradient is much steeper than level of tilt from subsidence - 150m+ of overburden - Cracks will naturally heal	4	B	14	M
1	Natural Features	1.01	Natural Water Courses/ Streams	1.01	Disruption to natural stream flow	- Upsidence	Environmental	- Nature/ gradient of stream flows - Ephemeral streams - Stratigraphic environment	5	C	22	L
1	Natural Features	1.02	River Catchments	1.02.0	Loss of feed water	- Cracking reducing stream flow	Environmental	- 150m+ of overburden - Cracks will naturally heal - Proportionally small catchment area impacted	5	C	22	L
1	Natural Features	1.03	Swamps & Water-related Ecosystems	1.03.01	Damage to Endangered Ecological Community	- Loss of groundwater	Environmental	- Mine layout - Cracks will naturally heal - Dip orientation - Swamps not solely reliant on groundwater - Monitoring/ Baseline surveys	2	D	12	M
1	Natural Features	1.03	Swamps & Water-related Ecosystems	1.03.02	Damage to ecosystem	- Loss of groundwater	Environmental	- Mine layout - Cracks will naturally heal - Dip orientation - Swamps not solely reliant on groundwater - Monitoring - Small area of impact	2	D	12	M
1	Natural Features	1.04	Steep Slopes	1.04.0	Slope instability	- Subsidence phenomenon	Environmental	- 150m+ of overburden - Existing topography - Extraction thickness - Stratigraphy not conducive to slumping	4	E	23	L
1	Natural Features	1.04	Steep Slopes	1.04	Increased erosion	- Surface tilt - Increased slope gradient	Environmental	- 150m+ of overburden - Existing topography - Extraction thickness	5	D	24	L
1	Natural Features	1.04	Steep Slopes	1.04.0	Personal injury	- Ground instability - Cracking	Personal Injury	- Signage - Site safety plans - Risk assessments - Generally inaccessible	4	D	21	L
1	Natural Features	1.04	Steep Slopes	1.04	Dislodging boulders	- Ground instability - Surface tilt	Environmental	- Mine design identified boulders - Limited number of rock features within the subsidence area	5	E	25	L
1	Natural Features	1.05	Threatened & Protected Species	1.05.01	Partial loss of local population	- Damage to habitat	Environmental	- 150m+ of overburden - Nature of habitat in area (i.e.. Not sensitive to subsidence) - Fauna and flora monitoring - Low habitat quality - No threatened flora species identified in area	2	E	16	M

A#	Aspect	C#	Consideration	R#	Risk Issue	Causes	Impacts	Inherent & Existing Controls	C	L	Rank	Level
1	Natural Features	1.06	Wolgan Escarpment	1.06.01	Rock falls	- Subsidence movements	Community	- Mine layout taking account of previous monitoring/ experience - Survey conducted to establish top of rock features limit associated with Wolgan escarpment - 26.5 degrees AOD from top of features associated with Wolgan escarpment - 26.5 degree AOD defining the SMP area in alignment with DPI guidelines	2	D	12	M
1	Natural Features	1.06	Wolgan Escarpment	1.06.02	Cracking	- Subsidence movements	Community	- Mine layout taking account of previous monitoring/ experience - Survey conducted to establish top of rock features limit associated with Wolgan escarpment - 26.5 degrees AOD from top of features associated with Wolgan escarpment - 26.5 degree AOD defining the SMP area in alignment with DPI guidelines	4	D	21	L
1	Natural Features	1.07	Internal Cliffs	1.07.01	Rock falls	- Subsidence movements	Community	- Mine layout taking account of previous monitoring/ experience - Orientation and geometry of cliffs relative to mine layout - No extraction directly below cliffs - Historically evidence suggests high level of protection is provided by not mining directly under cliff	3	C	13	M
1	Natural Features	1.07	Internal Cliffs	1.07.02	Cracking	- Subsidence movements	Community	- Mine layout taking account of previous monitoring/ experience - Orientation and geometry of cliffs relative to mine layout - No extraction directly below cliffs	4	B	14	M
1	Natural Features	1.08	Pagodas/ Rock Formations	1.08.01	Cracking	- Subsidence movements	Community	- Mine layout taking account of previous monitoring/ experience - Size less than 10m high - Less than 20m diameter limits potential for cracking	4	C	18	M
1	Natural Features	1.09	State Forests/ Natural Vegetation/ Harvesting	1.09.01	Restriction of commercial resource	- Limited access due to subsidence impacts	Property Value	- Limited existing harvestable resource - Previous impacts temporary only	5	D	24	L

A#	Aspect	C#	Consideration	R#	Risk Issue	Causes	Impacts	Inherent & Existing Controls	C	L	Rank	Level
1	Natural Features	1.09	State Forests/ Natural Vegetation/ Harvesting	1.09.02	Personal injury to forest workers to Forest management & fire-fighting activities in LW mining area	- Subsidence impacts - Monitoring hardware	Personal Injury	- Signage - Forests NSW Site safety plans - Safe work procedures - Informal liaison with colliery	3	D	17	M
1	Natural Features	1.09	State Forests/ Natural Vegetation/ Harvesting	1.09.03	Loss of vegetation and soil disturbance	- Clearing For monitoring activities	Environmental	- Environmental review prior to clearing - Minimisation of cleared areas - Use of existing trails where possible	4	B	14	M
2	Surface Improvements	2.01	Tracks / Roads	2.01.01	Damage to roads and drainage structures	- Change in gradient - Cracking	Property Value	- Monitoring of roads - Inspections and repairs - Road closure plan - Internal systems	4	C	18	M
2	Surface Improvements	2.01	Tracks / Roads	2.01.02	Increased sedimentation into drainage lines	- Change in gradient - Cracking	Environmental	- Monitoring of roads - Inspections and repairs - Negligible gradient changes	4	D	21	L
2	Surface Improvements	2.02	Survey Control Stations	2.02.01	Movement of Wolgan gap survey trig	- Subsidence impacts	Property Value	- Awareness - Notification - Monitoring	5	B	19	M
2	Surface Improvements	2.03	General Public/ Recreation	2.03.01	Personal injury to users, including but not limited to: motorbike rider, bushwalking, orienteering, hunting, bicentennial trail user	- Surface cracks - Rock falls - Star pickets	Personal Injury	- Signage - Newspaper advertisements - Inspections and repairs	4	D	21	L
3	Subsurface	3.01	Groundwater Resources/ Aquifer	3.01.01	Draining upper water bearing zones impacts on vegetation community	- Fracturing of overburden strata due to LW mining	Environmental	- Reduction in flow temporary and insignificant - 150m+ of overburden reduces potential for drainage - No known threatened vegetation identified in SMP area relying on ground water flows - No major identified water bearing zones in SMP area	4	C	18	M
3	Subsurface	3.01	Groundwater Resources/ Aquifer	3.01.02	Draining lower water bearing zones	- Fracturing of overburden strata due to LW mining	Environmental	- No known important water bearing zones	5	A	15	M

A#	Aspect	C#	Consideration	R#	Risk Issue	Causes	Impacts	Inherent & Existing Controls	C	L	Rank	Level
3	**Subsurface**	3.02	**Groundwater recharge**	3.02.01	**No Risks Identified**							
3	**Subsurface**	3.03	**Increased mine water make**	3.03.01	**Increased pumping**	**- Additional 0.5ML water make**	**Operational**	**- Potential to store water in North and South mine goafs** **- Relative volume small** **- Recycling stored water for use in CPP** **- Pumping plan developed for scenario** **- Sufficient pumping capacity**	**5**	**B**	**19**	**M**
3	**Subsurface**	3.04	**Sterilisation of Coal Resources**	3.04.01	**Loss of future coal resource**	**- Disruption to overlying seams caused by subsidence impacts**	**Property Value**	**- Geological investigations** **- No viable classifiable resource identified to JORC standard**	**5**	**C**	**22**	**L**
4	**Areas of Archaeological / Heritage Significance**	4.01	**Aboriginal Artifacts**	4.01.01	**Damage/ disturbance to artifacts/ sites**	**- Subsidence impacts** **- Surface cracks** **- Rock/ cliff fall**	**Community**	**- No known artifacts/ sites in application area (1992 survey)** **- Mine design avoid impact on potential areas (escarpment/ cliffs)** **- see also 1.06.01**	**2**	**D**	**12**	**M**



APPENDIX E

Noise Impact Assessment

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NOISE IMPACT ASSESSMENT
BAAL BONE COLLIERY
BEN BULLEN

39.6385.R1:CFCD3
Rev 05

Prepared for: Baal Bone Colliery
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November 2009

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1.0 INTRODUCTION

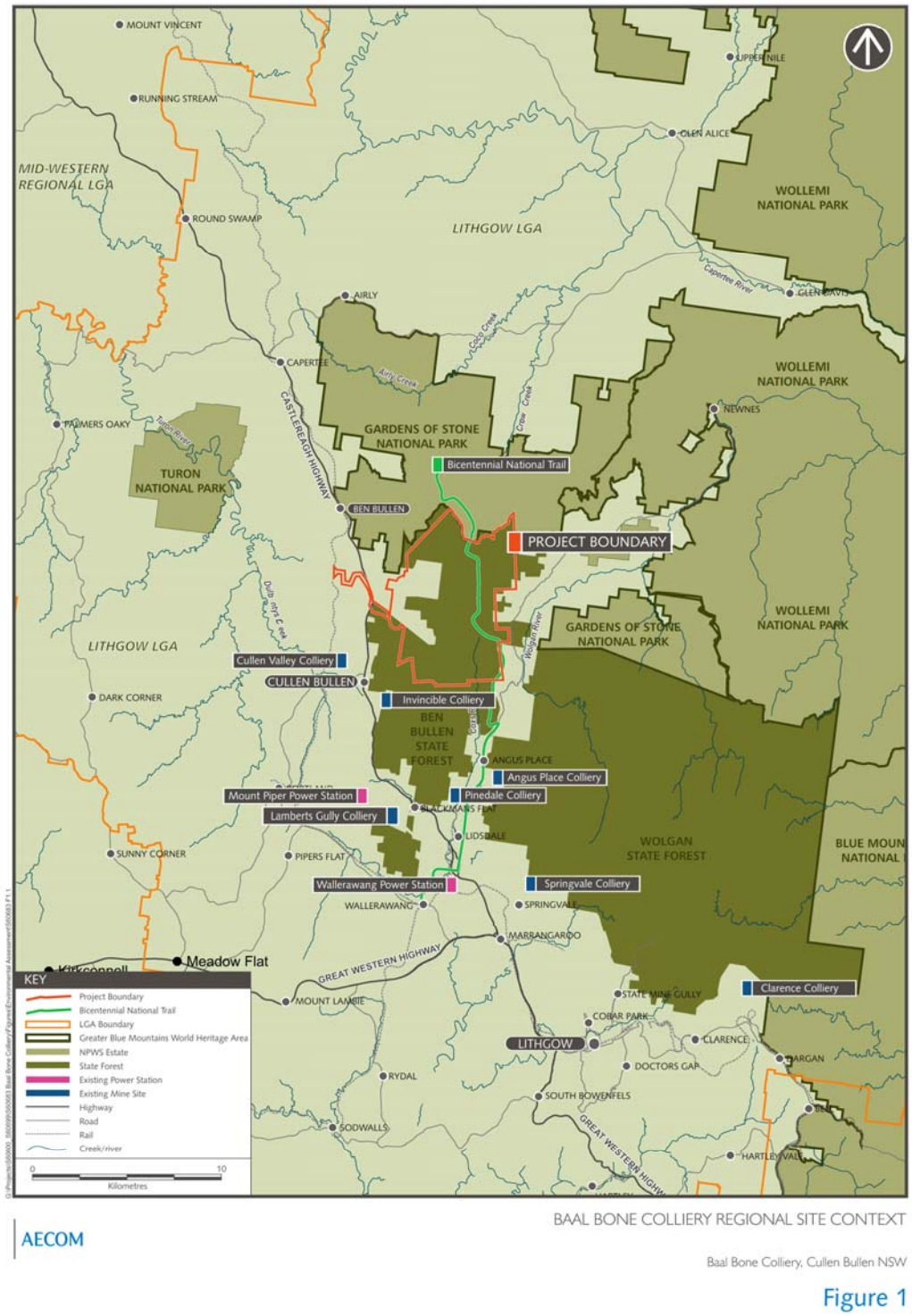
Atkins Acoustics was engaged by *AECOM* on behalf of *Baal Bone Colliery* to prepare a noise impact assessment for the continued operation of the existing colliery at Cullen Bullen. The site is located approximately 25km north-west of Lithgow, and 3km north-west of the township of Cullen Bullen (*Figure 1*) and has been operational for more than 20 years. During this time two (2) residential dwellings have been constructed within close proximity of the mine and surface infrastructure. A third dwelling was acquired from the colliery for a residence during the approval process of the original development. It is understood that there have been minimal complaints received at the colliery with respect to noise. On occasions when noise complaints have been received we have been instructed that they have been addressed and resolved.

This report presents the results and findings of the noise assessment. The methodology adopted for the assessment included:

- inspections of site and surrounds;
- site attended noise audit measurements;
- measurement and assessment of existing ambient noise levels at representative noise receiver locations;
- establishment of target noise assessment goals in accordance with the Department of Environment, Climate Change and Water *(DECCW)* Industrial Noise Policy *(INP)*; the noise Guide for Local Government *(NGLG);* and
- the prediction and assessment of operational noise levels.

The information presented in this report has been prepared for the investigation described herein, and is not intended for use in any other context or for any other purpose.

Figure 1: Site Location



2.0 THE PROPOSAL

2.1 The Site

Wallerawang Collieries Limited (*TWCL*) is currently seeking approval for the continuation of mining activities at Baal Bone. A variety of consents apply to Baal Bone dating back to 1982 that permit the mine to operate. Baal Bone has a total approved run-of-mine (ROM) production of approximately 2.8 Mtpa. Project Approval under Part 3A of the Environmental Planning and Assessment Act 1979 is required to allow continued mining operations, as mine workings will not be completed by 1 August 2010 when Clause 35 of Model Provisions will expire.

In terms of adjacent land users, three (3) residential dwellings are located north-north-west of the existing colliery surface infrastructure.

2.2 Overview of Proposal

The proposal is essentially a *'continued operation'* and does not propose changes to underground mining techniques, mining areas, capacity (2.8Mtpa) or operation of the existing surface coal handling infrastructure. Existing offices and amenities located near the mine entrance will continue to be utilised.

An aerial photo identifying the surface infrastructure, closest residences, and the noise measurement/assessment locations is presented in *Figure 2*.

Current underground mining operations at Baal Bone are by continuous miner and longwall mining methods. Longwall mining involves the extraction of panels of coal using longwall shearing machinery supported by hydraulic roof supports. A face conveyor located along the face of the panel transports ROM coal to a series of conveyors, which deliver coal to the surface ROM stockpile, coal handling and processing plant (CHPP) where it is washed, graded and stockpiled as product coal.

The mine will continue to operate twenty-four (24) hours, seven (7) days.

Historically, Baal Bone has supplied both domestic and international markets. In recent times, due to a number of market factors a majority of product coal is transported by rail to Port Kembla for export. The rail loop that services Baal Bone is a 7 km long spur line from the Wallerawang-Gwabegar line, terminating at a 200 m radius balloon loop.

Baal Bone has an existing development consent, which permits the transportation of coal via road for domestic markets. This current consent (DA 164/98) is due to expire on 31 December 2015. Baal Bone has historically supplied coal via road haulage to local power stations in accordance with development consent to transport coal via public road to domestic customers and the local Mount Piper and Wallerawang Power Stations. Due to completion of current contracts and prevailing market conditions, road transport of coal to these power stations have been minimal over the past two years, however supply of small quantities of coal via road to other domestic customers continues to occur periodically as required.

2.2.1 Plant and Equipment

The surface plant and equipment used at Baal Bone is consistent with similar coal processing and loading facilities and include:

- ventilation shafts
- dewatering facilities
- conveyors
- crushing and screening plant (Bradford Breaker)
- coal handling and preparation plant (washery)
- mobile plant – FEL and dozer

Figure 2: Aerial Photo and Receiver Locations



2.3 DECCW Noise Policy for Existing Industrial Premises

For existing industrial premises established prior to residential development, the *DECCW*, Industrial Noise Policy *(INP)* provides guidelines for assessing and managing environmental noise. The *INP* approach was developed to allow established industries to adapt to changes in noise expectations of communities while remaining economically viable. The need for industry to establish achievable target noise goals and implement noise reduction programs may be triggered by actions including:

- the site becomes the subject of serious and persistent noise complaints
- a proposal to upgrade or expand the site
- the site has no forma consent or license conditions and management wish to clarify their position
- management choose to initiate a noise reduction program

In many instances the *DECCW* will negotiate with site management to reduce noise emissions progressively to achieve specific target noise goals by specific dates. The measures required to achieve noise goals are normally set out in an agreed noise reduction program attached to a *DECCW* condition.

The process followed in the determination of target noise reduction goals generally involve negotiations with the *DECCW* and agreed achievable noise goals for the site. In the determination of the agreed target noise goals, consideration is normally given to the technical practicability and cost of the noise reduction measures. Baal Bone Colliery falls into the category of an existing industry and should be considered accordingly.

For industries established before noise sensitive development occurs in close proximity the *DECCW* recognise that the range of mitigation measures available to reduce noise from the industry may be limited and/or not feasible or practical

3.0 LOCAL ENVIRONS

Site audit noise measurements and inspections confirmed that the noise environment at potentially sensitive noise receivers is influenced by distant traffic (Castlereagh Highway / Mudgee Road), natural elements and Baal Bone Colliery.

3.1 Noise Assessment Locations

The nearest potentially affected residential dwellings are located to the north-west and north-north-west of the colliery surface activities and identified as:

- R1 – 'Muldoon' Residence (Lot 95 DP 755759, Ben Bullen); and
- R2 – 'Speirs' Residence (Lot 4 DP 734531, Ben Bullen).
- R3 – 'Desch' Residence (Lot 3 DP 734531, Ben Bullen).

Table 1 and *Figure 2* identify the receiver locations selected for noise measurement and assessment.

Table 1: Measurement and Assessment Locations

Reference	Description	Location
R1	'Muldoon' Residence	North-north-west
R2	'Speirs' Residence	North- west
R3	'Desch' Residence	North- west

3.2 Local Meteorology

The *DECCW, INP* provides procedures for evaluating the effects of meteorological condition and noise propagation. Where adverse meteorological conditions are identified and occur for more than 30% of the assessment period, the *INP* requires the conditions to be considered in the noise assessment. Meteorological data for the area was provided by *AECOM.*

3.2.1 Stability Classifications (Temperature Inversions)

Table 2 shows the frequency of occurrence (%) of the different stability classes for night hours (10pm to 7am – *INP Section 5.2*) during winter.

Table 2 Frequency of Occurrence of Stability Classes (%)

Stability Class	Percentage Frequency of Occurrence of Stability Classes (%)	Estimate ELR °C/100m	Qualitative Description
A	0	<-1.9	Lapse
B	0	-1.9 to -1.7	Lapse
C	0	-1.7 to -1.5	Lapse
D	18.7	-1.5 to -0.5	Neutral
E	35.3	-0.5 to 1.5	Weak Inversion
F	46.0	1.5 to 4.0	Moderate Inversion

The results in Table 2 show that F stability class conditions (temperature inversions) are a feature of the area. Hence the temperature inversion conditions considered the operational noise modelling is the default condition of 3°C/100m.

3.2.2 Prevailing Wind Data

Wind data compiled for annual and seasonal wind conditions for day, evening and night assessment periods (*Appendix 2*) has shown that south-westerly winds (winds blowing away from the receivers) are a feature of the area. Accordingly, noise modelling for adverse wind condition is not required for assessing noise referenced to the residential receptor locations.

4.0 EXISTING AMBIENT NOISE LEVELS

For the purpose of establishing target noise assessment goals, ambient background noise levels were monitored from Tuesday 11 November 2008 to Thursday 20 November 2008 when the CHPP was not operating. Additional monitoring was undertaken between Friday 20 February 2009 and Monday 2 March 2009 with the CHPP operating. The data collected with the CHPP operating assisted with the assessment of noise from the colliery and calibrate the computer noise model prepared for the project.

The noise monitoring locations selected (*Table 1*) to install unmanned noise loggers and undertake site attended audits are shown on *Figure 2* and are identified as:

- *M1* 'Muldoon' Residence (Lot 95 DP 755759, Ben Bullen)
- *M2* 'Speirs' Residence (Lot 4 DP 734531, Ben Bullen)

The noise monitoring instrumentation consisted of RTA Technology environmental noise loggers. The loggers were set to A-weighting, fast response and programmed to calculate and record statistical noise levels at every 15-minute interval. The instruments were calibrated before and after the measurements using a Bruel & Kjaer sound level calibrator Type 4230 and no significant drift was detected.

Table 3 presents a summary of the measurement results with a graphical presentation presented in *Appendix 1.*

Table 3: Measured RBL and L_{Aeq} Noise Levels (Baal Bone CHPP <u>not</u> Operational), dB(A) re: 20 × 10^{-6} Pa

Date	Assessment Background Level L_{A90}			Equivalent Continuous Level L_{Aeq}		
	Day	**Evening**	**Night**	**Day**	**Evening**	**Night**
November 2008						
Reference Location M1: Muldoon Residence						
Tue 11/11/08	-	35	29		43	38
Wed 12/11/08	30	32	29	44	39	37
Thu 13/11/08	28	27	28	41	37	40
Fri 14/11/08	36	34	33	*56*	45	44
Sat 15/11/08	29	36	32	44	41	40
Sun 16/11/08	29	30	39	42	42	45
Mon 17/11/08	32	31	34	46	38	43
Tue 18/11/08	28	33	28	39	42	40
Wed 19/11/08	37	30	32	*50*	45	45
Thu 20/11/08	28	30	34	42	37	40
RBL	**29**	**32**	**32**			
Ambient L_{Aeq}				**43**	**42**	**42**
Reference Location M2: Speirs Residence						
Tue 11/11/08	-	*58*	*57*	-	*60*	*59*
Wed 12/11/08	*58*	*58*	*57*	*62*	*59*	*59*
Thu 13/11/08	*59*	*58*	*58*	*61*	*60*	*60*
Fri 14/11/08	*58*	35	33	*70*	46	43
Sat 15/11/08	32	36	32	50	40	39
Sun 16/11/08	31	32	35	41	41	43
Mon 17/11/08	34	32	34	53	41	43
Tue 18/11/08	31	33	*batt*	43	43	*batt*
RBL	**32**	**33**	**33**			
Ambient L_{Aeq}				**49**	**43**	**42**

Noise levels in *Italics* excluded

batt Battery failure

NOTE: *Daytime: (7.00am to 6.00pm Monday to Saturday, 8.00am to 6.00pm Sunday and Public Holidays)*
Evening: (6.00pm to 10.00pm)
Night: (10.00pm to 7.00am Monday to Saturday, 10.00pm to 8.00am Sunday and Public Holidays)

Table 3: Measured RBL and L_{Aeq} Noise Levels (Baal Bone CHPP Operating Normally), dB(A) re: 20×10^{-6} Pa

Date	Assessment Background Level L_{A90}			Equivalent Continuous Level L_{Aeq}		
	Day	**Evening**	**Night**	**Day**	**Evening**	**Night**
February/March 2009						
Reference Location M1: Muldoon Residence						
Fri 20/2/09	-	34	29	-	*54*	36
Sat 21/2/09	30	33	32	*60*	47	37
Sun 22/2/09	31	36	37	45	48	42
Mon 23/2/09	32	29	40	45	*60*	45
Tue 24/2/09	36	32	38	*52*	49	44
Wed 25/2/09	34	39	40	*55*	47	43
Thu 26/2/09	32	39	40	44	46	45
Fri 27/2/09	31	34	33	44	42	39
Sat 28/2/09	33	30	31	*55*	45	38
Mon 1/3/09	29	29	36	44	46	45
RBL	**32**	**34**	**37**			
Ambient L_{Aeq}				**44**	**47**	**43**
Reference Location M2: Speirs Residence						
Fri 20/2/09	-	34	33	-	*51*	41
Sat 21/2/09	31	34	35	*59*	*72*	41
Sun 22/2/09	32	35	35	43	*61*	42
Mon 23/2/09	31	31	38	42	*59*	45
Tue 24/2/09	34	31	36	*53*	*59*	43
Wed 25/2/09	32	35	39	44	44	42
Thu 26/2/09	32	38	39	42	45	45
Fri 27/2/09	32	34	34	41	39	40
Sat 28/2/09	33	32	33	48	48	42
Mon 1/3/09	30	32	36	42	45	43
RBL	**32**	**34**	**36**			
Ambient L_{Aeq}				**44**	**45**	**43**

Noise levels in *Italics* excluded

NOTE: *Daytime: (7.00am to 6.00pm Monday to Saturday, 8.00am to 6.00pm Sunday and Public Holidays)*
Evening: (6.00pm to 10.00pm)
Night: (10.00pm to 7.00am Monday to Saturday, 10.00pm to 8.00am Sunday and Public Holidays)

Observations during the installation of the monitoring equipment on 20 February 2009 confirmed a north-west breeze and that the ambient noise levels were influenced by road traffic on Castlereagh Highway/Mudgee Road, natural elements and occasional domestic activities.

During retrieval of the noise monitors on 2 March 2009 conditions with an occasional light east drift the colliery noise was clearly audible, particularly with respect to a dozer operating on the product stockpile.

The results of site attended noise audits are presented in *Table 4*. Additional noise audits on Monday 6 April 2009 conducted approximately 100m south of the 'Muldoon Residence' with the dozer on the southern stockpile confirmed dozer track noise of 36-38dB(A), dozer engine 35-36dB(A) and general colliery processing and material transfer noise 34-35dB(A). Prevailing weather conditions were clear, with a light west wind drift.

Table 4: Audit Measurement Results
dB(A) re: 20 x 10^{-6} Pa

Location	Measured Statistical Noise Levels (dB(A))				Calculated Noise Contribution	Comments
	L_{Aeq}	L_{A90}	L_{A10}	L_{Amin}	$L_{Aeq,15min}$	
7.50 to 8.30am Monday 2 March 2009 (Calm to light drift)						
R1	45.8	41.4	48.6	36.6	**46**	Mine operations clearly audible, notable dozer working on product stockpile at exposed and elevated position.
R2	37.3	35.3	38.8	34.4	**37**	Dozer engine and tracks audible, also birds.

4.1 Low Frequency Noise

When a noise source contains acoustic energy within the frequency range between 20Hz and 250Hz it is described in the *INP* as 'low frequency noise'. For assessing noise impacts the *INP* recommends that where the difference between the measured/assessed C- and A- weighted sound pressure levels is 15dB or more the source noise is classified as 'low frequency'.

For the purpose of assessing noise from the CHPP site attended audits were conducted at R1 on Wednesday 18 November 2009. Weather conditions during the audit were wind north-north-west (0-0.5m/sec), temperature 17º C and no cloud cover. Audible noise sources identified included the washery, breaker, a dozer working on the product stockpile, road traffic on Castlereagh Highway/Mudgee Road and natural elements. The audit measurements confirmed that the difference between the LCeq, 15min (53.8dBC) and LAeq, 15min (39.6dBA) levels was 14.2dB and less than 15dB.

5.0 ENVIRONMENTAL NOISE ASSESSMENT GOALS

Procedures for establishing target goals for the assessing environment noise are documented in the *INP* and guidelines for assessment of potential sleep disturbance in the *NGLG*.

5.1 Operational Noise (*INP*)

Objectives of the *INP* are to protect the community from intrusive noise and preserve amenity. For industries established before a noise sensitive development occurred in close proximity, the *DECCW* recognise that the range of mitigation measures available to reduce noise from the industry to achieve the target noise goals may be limited and/or not feasible or practical. For assessment of intrusive noise, the *INP* recommends that the $L_{Aeq,15min}$ source noise should not exceed Rating Background Levels *(RBL)* by more than 5dB(A). The assessment goal for preservation of amenity requires noise levels to be within the acceptable levels for the locality and land-use. *Table 5* present a summary of the *INP* acceptable and recommended maximum amenity assessment goals.

Table 5: INP Amenity Noise Goals

Receiver Description	Indicative Noise Amenity Area	Time of Day	Recommended L_{Aeq} Noise Level dB(A)	
			Acceptable	Recommended Maximum
Residence (1)	Rural	Day	50	55
		Evening	45	50
		Night	40	45

NOTE: Daytime: (7.00am to 6.00pm Monday to Saturday, 8.00am to 6.00pm Sunday and Public Holidays)
Evening: (6.00pm to 10.00pm)
Night: (10.00pm to 7.00am Monday to Saturday, 10.00pm to 8.00am Sunday and Public Holidays)

(1) In assessing noise levels at residences, the noise is assessed at the most affected point on or within the residential property boundary or, if this is more than 30 m from the residence, at the most-affected point within 30m of the residence.

From the *INP* procedures, *Table 6* presents assessment *RBL's*, ambient L_{Aeq} noise level, the intrusive and amenity noise goals and project target noise assessment goals for a greenfield sites. For the development of target noise goals the ambient background noise measurements conducted during November 2008 in the absence of colliery noise have been adopted.

Table 6: Operational Noise Assessment Goals
dB(A) re: 20 x 10^{-6} Pa

Period (1)	Recommended $L_{Aeq,period}$ Noise Level	Existing RBL	Existing $L_{Aeq,period}$ Noise Level	Intrusive Criterion $L_{Aeq,15min}$ Noise Level	Project Assessment Goals $L_{Aeq,15min}$ Noise Level
Reference Location R1 – 'Muldoon' Residence					
Day	50	29*	43	35	**35**
Evening	45	32	42	37	**37**
Night	40	32	42	37	**37**
Reference Location R2/R3 – 'Speirs/Desch' Residences					
Day	50	32	49	37	**37**
Evening	45	33	43	38	**38**
Night	40	33	42	38	**38**

NOTE: Daytime : 7.00am to 6.00pm Monday to Saturday, 8.00am to 6.00pm Sunday and Public Holidays.
Evening : 6.00pm to 10.00pm.
Night : 10.00pm to 7.00am Monday to Saturday, 10.00pm to 8.00am Sunday and Public Holidays.
* In accordance with INP procedures (Section 3.1.2) if the RBL is<30dB(A), then it is set to 30dB(A)

The principles underpinning the establishment of noise assessment goals are that the goals are best regarded as planning tools, *"They are not mandatory, and an application for a noise-producing development is not determined purely on the basis of compliance or otherwise with the noise criteria. Numerous factors need to be taken into account in the determination. These include economic consequences, other environmental effects and the social worth of the development. The criteria help to determine consent conditions because they provide information on the likely effect of any environmental noise associated with the development."*

5.2 Night-time Disturbance (NGLG)

As the colliery operates twenty-four (24) hours a day, there is potential for noise to be emitted during night-time hours that could give rise to sleep disturbance. To avoid possible disturbance during night hours, the *NGLG* recommends that the $L_{A1,1min}$ noise levels when assessed outside a bedroom window, should not exceed the background L_{A90} noise level by more than 15dB(A).

In accordance with the *NGLG* assessment procedures and considering the background measurement results, the target assessment goals recommended for assessing intermittent noise during night-time hours (10.00pm to 7.00am) are:

- *Location R1:* 47dB(A) (L_{A90} 32 +15dB(A))
- *Location R2/R3:* 48dB(A) (L_{A90} 33 +15dB(A))

6.0 OPERATIONAL NOISE ASSESSMENT

Operational noise from the colliery infrastructure including mobile (FEL, dozer, train) and fixed plant (fans, conveyors, conveyor drive, screens breaker, transfers, water treatment pumps, train loading, coal falling, etc) has been predicted with the *ENM* environmental noise model. The model takes account of noise attenuation due to distance separation, ground effect, atmospheric absorption, shielding from intervening structures and topography. Atmospheric conditions assumed for the noise modelling included calm conditions with 20°C air temperature and 80% relative humidity. Additional weather condition considered for noise modelling included 3°C/100m temperature inversion.

Table 7 presents a summary of plant/equipment sound power levels adopted for the noise modelling. The sound power levels and octave band spectra presented have been established from site attended noise audits of the existing plant and equipment. Data for the locomotive and train loading was extracted from previous investigations and measurements.

Table 7: Plant/Equipment Sound Power Levels
L_{Aeq} re: 10^{-12} Watts

Description of Noise Source	Linear Sound Power (SWL) Spectra dB Lin										Overall SWL
	31.5	63	125	250	500	1k	2k	4k	8k	16k	dB(A)
Underground Exhaust Fans	115	114	116	114	113	106	102	97	113	108	116
Drift Conveyor Drive (North Facade)	98	112	110	110	112	109	101	97	96	89	113
Drift Conveyor Drive (West Facade)	91	105	103	103	105	102	94	90	89	82	106
Drift Conveyor Drive (South Facade)	98	112	110	110	112	109	101	97	96	89	113
Drift Conveyor Drive (East Facade)	91	105	103	103	105	102	94	90	89	82	106
Drift Conveyor Drive (Roof)	98	112	110	110	112	109	101	97	96	89	113
Stockpile Conveyor Drive (Nth Façade)	97	104	103	103	98	97	94	88	80	72	102
Stockpile Conveyor Drive (West Façade)	97	104	103	103	98	97	94	88	80	72	102
Stockpile Conveyor Drive (Sth Façade)	97	104	103	103	98	97	94	88	80	72	102
Stockpile Conveyor Drive (East Façade)	97	104	103	103	98	97	94	88	80	72	102
Stockpile Conveyor Drive (Roof)	97	104	103	103	98	97	94	88	80	72	102
Transfer Building (North Façade)	106	100	100	100	98	95	89	78	68	64	100
Transfer Building (West Façade)	106	100	100	100	98	95	89	78	68	64	100
Transfer Building (Sth Façade)	106	100	100	100	98	95	89	78	68	64	100
Transfer Building (East Façade)	106	100	100	100	98	95	89	78	68	64	100
Transfer Building (Roof)	102	96	96	96	94	91	85	74	64	60	95
Bradford Breaker	120	111	115	116	117	115	110	103	95	67	118

Table 7: Plant/Equipment Sound Power Levels (cont.)

L_{Aeq} re: 10^{-12} Watts

Description of Noise Source	Linear Sound Power (SWL) Spectra dB Lin										Overall SWL
	31.5	63	125	250	500	1k	2k	4k	8k	16k	dB(A)
Washery Building (Nth Façade)	113	112	107	105	101	98	94	87	74	68	103
Washery Building (West Façade)	112	111	106	104	100	97	93	86	73	67	102
Washery Building (Sth Façade)	113	112	107	105	101	98	94	87	74	68	103
Washery Building (East Façade)	112	111	106	104	100	97	93	86	73	67	102
Washery Building (Roof)	114	113	108	106	102	99	95	88	75	69	104
Washery Building (Open Door West)	95	94	89	87	83	80	76	69	56	50	85
Stockpile Drive Transfer (Nth Façade)	96	95	96	94	95	91	87	84	80	71	97
Stockpile Drive Transfer (West Façade)	96	95	96	94	95	91	87	84	80	71	97
Stockpile Drive Transfer (Sth Façade)	96	95	96	94	95	91	87	84	80	71	97
Stockpile Drive Transfer (East Façade)	96	95	96	94	95	91	87	84	80	71	97
Stockpile Drive Transfer (Roof)	92	91	92	90	91	87	83	80	76	67	92
Train Loader Drive (Nth Façade)	100	95	97	95	96	94	87	77	70	69	98
Train Loader Drive (West Façade)	102	97	99	97	98	96	89	79	72	71	99
Train Loader Drive (Sth Façade)	100	95	97	95	96	94	87	77	70	69	98
Train Loader Drive (East Façade)	102	97	99	97	98	96	89	79	72	71	99
Train Loader Drive (Roof)	99	94	96	94	95	93	86	76	69	68	97
Pressure Tunnel Supply Fan	102	104	100	94	91	94	89	84	79	72	97
Refuse Bin (Nth Façade)	96	96	87	86	82	83	83	83	79	67	90
Refuse Bin (East Façade)	96	96	87	86	82	83	83	83	79	67	90
Refuse Bin (Sth Façade)	96	96	87	86	82	83	83	83	79	67	90
Refuse Bin (West Façade)	96	96	87	86	82	83	83	83	79	67	90
Refuse Bin (Roof)	93	93	84	83	79	80	80	80	76	64	87
Water Treatment Plant	112	106	104	107	101	101	99	92	86	76	106
Compressor Building (Nth Façade)	90	92	94	94	87	84	81	72	64	57	91
Compressor Building (West Façade)	87	89	91	91	84	81	78	69	61	54	88
Compressor Building (Sth Façade)	90	92	94	94	87	84	81	72	64	57	91
Compressor Building (East Façade)	87	89	91	91	84	81	78	69	61	54	88
Compressor Building (Roof)	92	94	96	96	89	86	83	74	66	59	92
Substation	99	96	91	91	85	81	76	74	72	69	88
D11R Dozer	110	113	115	114	115	109	107	102	100	94	116
Conveyor ROM (run of mine)	88	99	100	95	94	94	91	87	82	77	98
Conveyor Stockpile	95	93	96	94	92	85	76	69	60	57	92
Conveyor Washery	99	95	96	92	89	85	81	75	73	67	91
Conveyor Refuse	99	93	92	90	91	90	81	72	65	62	93
Conveyor Stockpile 1	89	90	88	85	88	86	79	73	68	65	90
Conveyor Stockpile 2	86	83	82	82	88	84	77	71	67	65	88
Conveyor Stockpile 3	86	83	82	82	88	84	77	71	67	65	88
Conveyor Train Loader	98	92	95	93	93	92	84	75	68	65	95
Coal Falling ROM	110	104	105	105	108	105	105	108	111	101	115
Coal Falling Stockpile	101	95	96	96	99	96	96	99	102	92	105

For the assessment of intermittent noise during night hours the assessment considered impact noise from banging in the washery building and adopted a sound power level of 120dBA.

6.1 Noise Modelling

Table 8 presents a summary of the predicted noise levels for the assessment residential receivers with the source levels from *Table 7* the '*with*' and '*without*' the dozer operating at the product stockpile. It is understood that the dozer does not operate continuously and generally after 10.00pm.

Appendices 3 and *4* present noise contour plots at 5dB(A) intervals for calm and temperature inversion conditions. The noise contour plots are presented for illustrative purpose only. The predicted levels summarised in *Table 8* are presented for assessing noise at the residential assessment locations.

Table 8: Predicted Operational Noise Levels
$L_{Aeq(15min)}$ dB(A) re: 20 x 10^{-6} Pa

Reference Location	Description	Assessment Target Noise Goal $L_{Aeq,15min}$ (D/E/N)	Predicted $L_{Aeq,15min}$ Sound Pressure Level		Compliance	
			Without Dozer	With Dozer	Without Dozer	With Dozer
Operational Noise - Calm						
R1	'Muldoon' Residence	35/37/37	43	46	X	X
R2/R3	'Speirs/Desch' Residence	37/38/38	38	41	X	X
Operational Noise – Temperature Inversion						
R1	'Muldoon' Residence	37	48	51	X	X
R2/R3	'Speirs/Desch' Residence	38	43	46	X	X

D/E/N Day/Evening/Night
X indicates non-compliance

The modelling assumed all plant and equipment operating simultaneously. Whilst this does not occur all of the time, the noise modelling represents the likely worst-case operating scenario.

For assessing intermittent noise during night hours, the modelling considered impact noise from the washery building. The predicted $L_{A1,1min}$ levels at the referenced residential assessment locations are summarised in *Table 9*.

Table 9: Predicted Intermittent Noise Levels - Night
$L_{A1,\ 1min}$ dB(A) re: 20 x 10^{-6} Pa

Reference Location	Description	Assessment $L_{A1,1min}$ Goal	Predicted $L_{A1,1min}$ Noise Level	Compliance
Intermittent Noise - Calm				
R1	'Muldoon' Residence	47	42	√
R2/R3	'Speirs/Desch' Residence	48	39	√

√ *indicates compliance*

6.2 Assessment

The results of the noise modelling show that during calm meteorological conditions operational (L_{Aeq}) levels (*Table 8*) exceed the target noise assessment goals at the Muldoon residence. With the exception of a 1dBA technical exceedance during daytime hours the noise predictions with calm meteorological conditions for the Speirs and Desch residences show that the target noise assessment goals are satisfied without the dozer operating. With the dozer operating the predicted noise levels exceed the day/evening and night target noise assessment goals at the three residences. During adverse meteorological conditions (temperature inversions) the predicted nighttime operational (L_{Aeq}) noise levels for the Muldoon, Speirs and Desch residences (*Table 8*) exceed the target noise assessment goals.

During night-time hours the predicted $L_{A1,1min}$ noise levels (*Table 9*) satisfy the target noise assessment goals.

6.3 Operational Noise Control Recommendations and Management

The results of modelling show that noise from the existing Baal Bone surface infrastructure would need to be reduced in order to achieve the target assessment noise goals recommended for greenfield developments. As the colliery is an existing operating premises, the *INP* provides guidelines for assessing and managing environmental noise. The approach was developed by the *DECCW* to allow established

industries to adapt to changes in noise expectations of communities while remaining economically viable.

From investigations undertaken the following conceptual measures could be considered to ameliorate noise from the existing operations and incorporated into a site noise reduction program *(SNRP)*.

- close off facade openings in the Washery to Stockpile Transfer Building;
- close off facade opening in the Washery Building;
- replace damaged insulation installed in the Washery Building;
- investigations options to assess the feasibility and possibility of enclosing the Bradford breaker; and
- investigate options to replace the dozer during night hours.

Additionally the *SNRP* could include:

- procedures for residents to contact the site environmental manager in regard to noise complaints or requests for information;
- procedures to inform residents of actions implemented following receipt of noise complaints;
- a program for regular inspections of site plant including the dozer to ensure that the installed noise suppression controls are functioning and require no maintenance; and,
- regular site attended noise audits to identify additional procedures to minimise noise emissions from the site.

6.4 Discussion

Noise reduction benefits from closing openings in the Washery and Transfer Buildings and repairing the insulation in the Washery Building could be in the order of 1-2dBA and unlikely to provide a noticeable reduction to the noise at residences. If considered practical and feasible the main acoustic benefits for the residents would be achieved by treating the Bradford breaker and managing the stockpile dozer.

7.0 SUMMARY

Atkins Acoustics was engaged by AECOM on behalf of Baal Bone Colliery to prepare a noise impact assessment for the continuation of the existing longwall operations and subsequent operation of the colliery at Cullen Bullen. The colliery is located approximately 25km north-west of Lithgow, and 3km north-west of the township of Cullen Bullen (*Figure 1*).

The colliery has been operational for more than 20 years. During this time two (2) residential dwellings have been constructed within close proximity of the existing mine and surface infrastructure. A third dwelling was acquired from the colliery for a residence during the approval process of the original development.

Site audit measurements and inspections confirmed that distant traffic (Castlereagh Highway/Mudgee Road), domestic activities, natural elements and operation of the colliery surface infrastructure influence the existing noise environment at the three residences.

The residential dwellings are located to the north-north-west of the colliery surface facilities and identified as R1: ‘Muldoon’ Residence (Lot 95 DP 755759, Ben Bullen); R2: ‘Speirs’ Residence (Lot 4 DP 734531, Ben Bullen); and, R3 – 'Desch' Residence (Lot 3 DP 734531, Ben Bullen). *(Figure 2)*.

Target noise assessment goals for the evaluation of operational noise from the greenfield sites have been developed from procedures documented in the *DECCW*, Industrial Noise Policy *(INP)* and Noise Guide for Local Government *(NGLG).* The report has also addressed *DECCW* guidelines for assessing and managing noise from existing operating sites.

Noise modelling for operating scenarios representing day/evening/night conditions under calm meteorological and temperature inversion conditions are presented as noise contour plots *(Appendices 3* to *5).* The modelling represents a range of noise levels

likely to be emitted from the site with all plant and equipment operating simultaneously. Whilst these situations do not occur all of the time, the noise modelling represents a worst-case operating scenario.

The noise modelling results for calm meteorological conditions show that the operational L_{Aeq} levels (*Table 8*) exceed the target noise assessment goals at the Muldoon residence. With the exception of a 1dBA technical exceedance during daytime hours, the noise predictions with calm meteorological conditions for the Speirs and Desch residences show that the target noise assessment goals are satisfied without the dozer. With the dozer operating the predicted noise levels exceed the day/evening and night target noise assessment goals at the three residences. During adverse meteorological conditions (temperature inversions) the predicted nighttime operational L_{Aeq} noise levels at the Muldoon, Speirs and Desch residences (*Table 8*) exceed the target noise assessment goals.

Noise modelling for envisaged night-time intermittent activities has shown that the predicted $L_{A1,1min}$ noise levels (*Table 9*) satisfy the target noise assessment goals.

Site attended audit measurements for the CHPP confirmed that the difference between the LCeq, 15min (53.8dBC) and LAeq, 15min (39.6dBA) levels was 14.2dB and less than the 15dB goal recommended in the INP for assessing 'low frequency' noise.

The findings of the assessment have shown that noise levels from the existing operations would need to be reduced in order to satisfy noise assessment goals recommended for greenfield developments. As the colliery would be classified as an existing operating premises, the *INP* provides procedures and guidelines for assessing and managing environmental noise. The *DECCW* approach was developed to allow established industries to adapt to changes in noise expectations of communities while remaining economically viable.

The report presents conceptual noise control measures that could be considered to ameliorate noise from the existing surface operations and incorporated into a Site Noise Reduction Program.

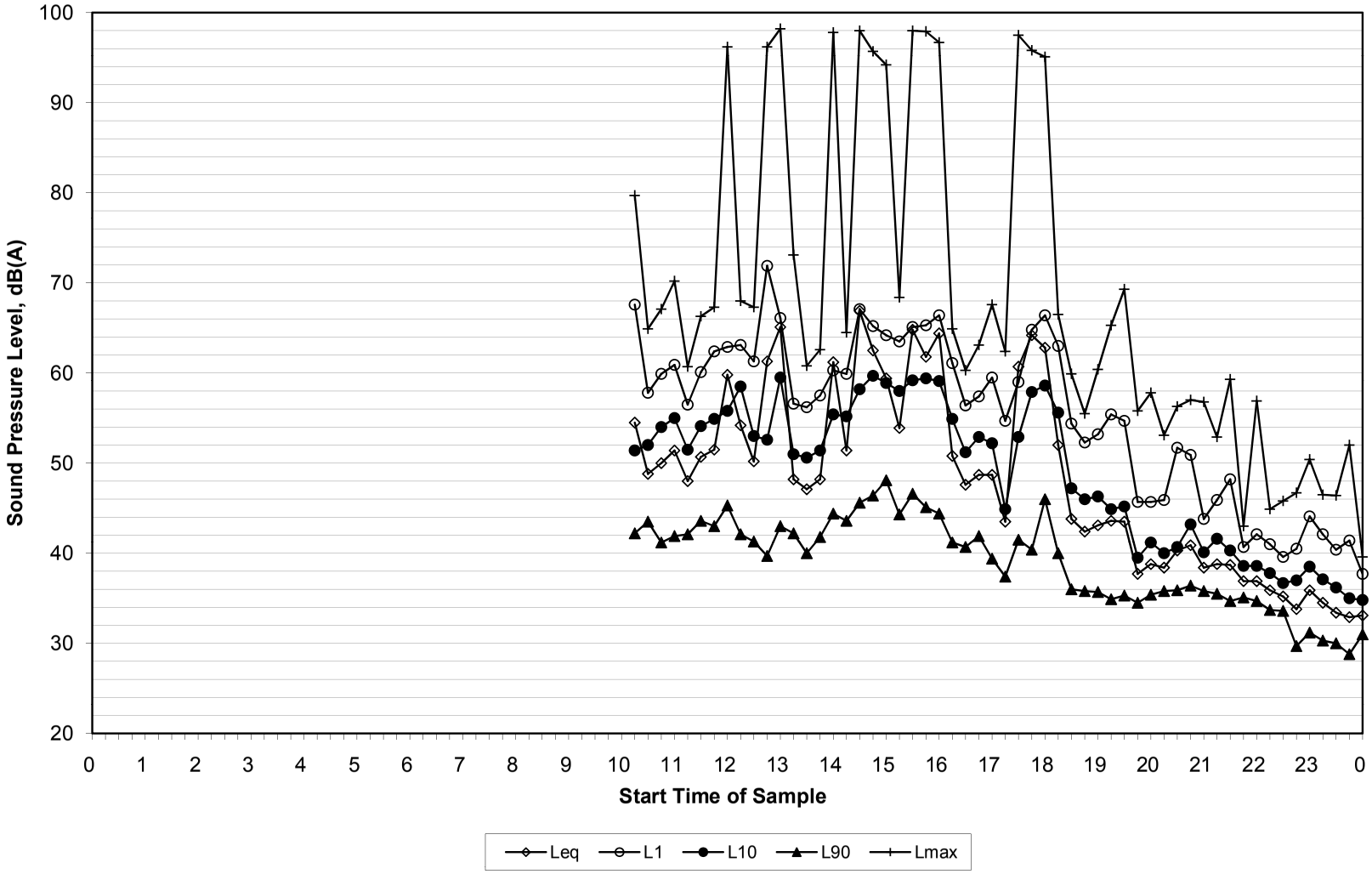
The noise reduction benefits by treating building openings and repairing acoustic insulation in the Washery Building would be in the order of 1-2dBA and unlikely to provide a noticeable reduction to the perceived noise at the residential dwellings.

The assessment has identified that noticeable noise reductions and acoustic benefits could be achieved for the residents by treating the Bradford breaker and managing the operation of the stockpile dozer.

APPENDIX 1: AMBIENT NOISE MEASUREMENT RESULTS (BAAL BONE CHPP NOT OPERATING)

Ambient Sound Pressure Levels

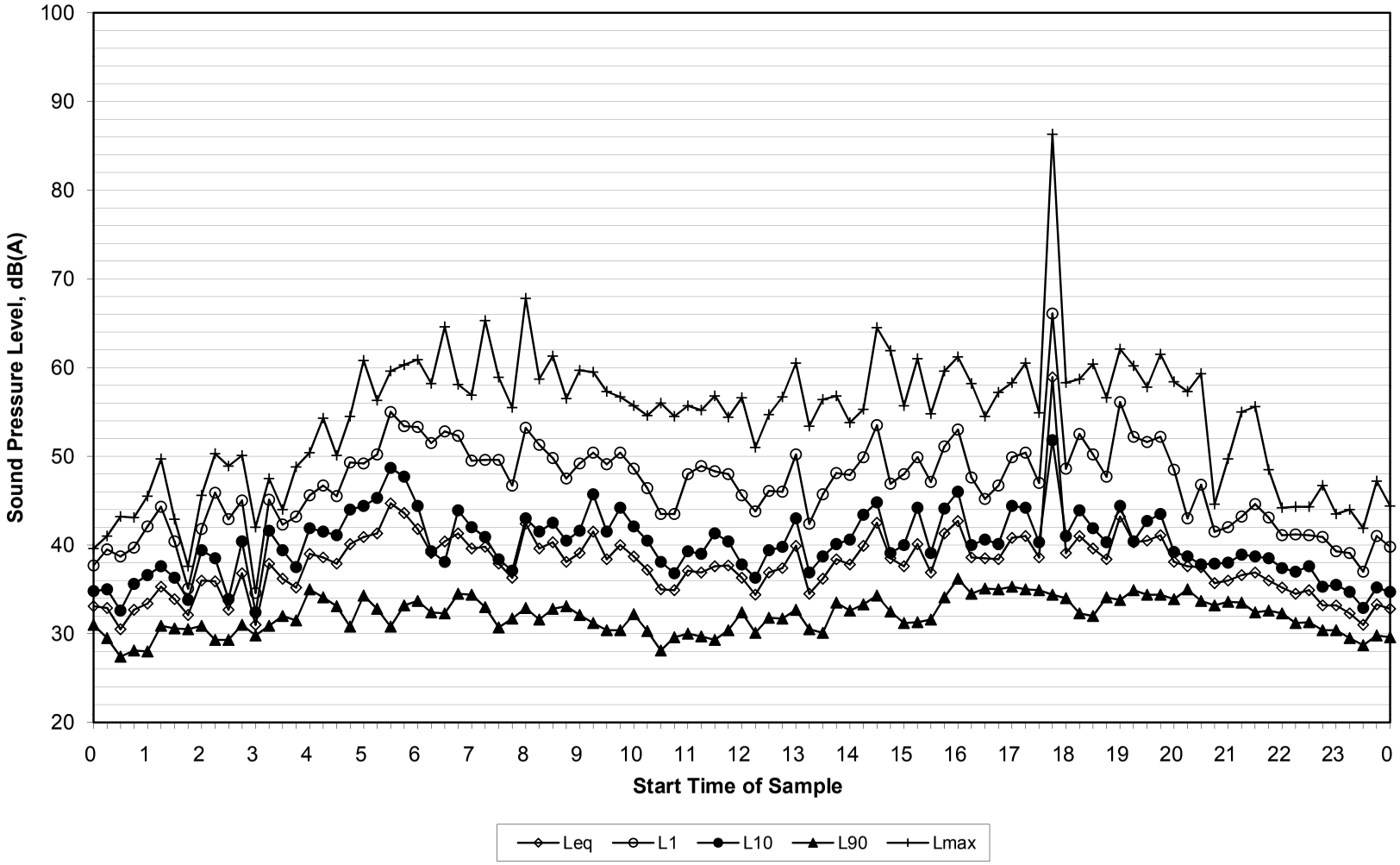
Tuesday, 11 November 2008



Location 1
Muldoon Residence

Ambient Sound Pressure Levels

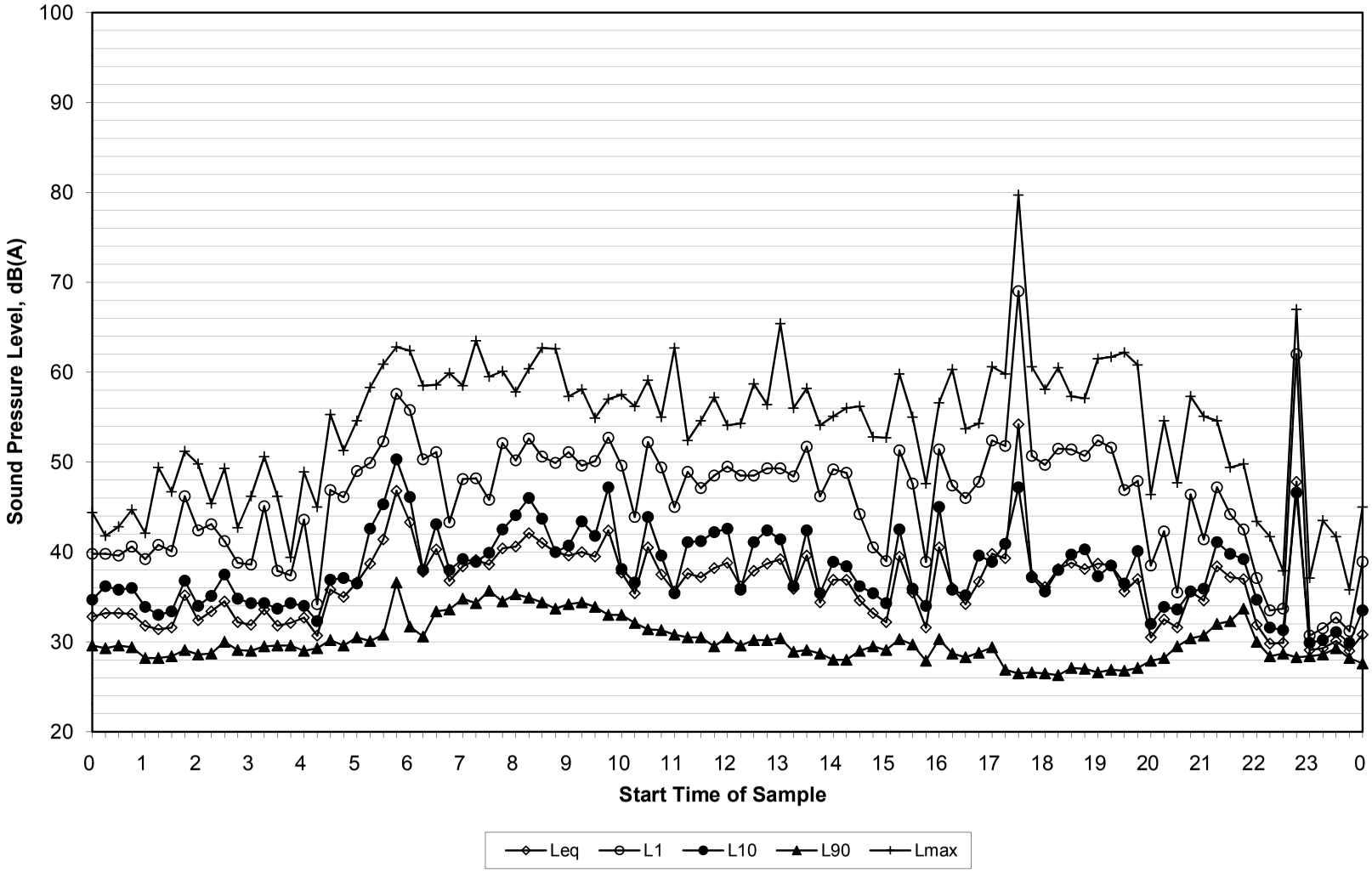
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Location 1
Muldoon Residence

Ambient Sound Pressure Levels

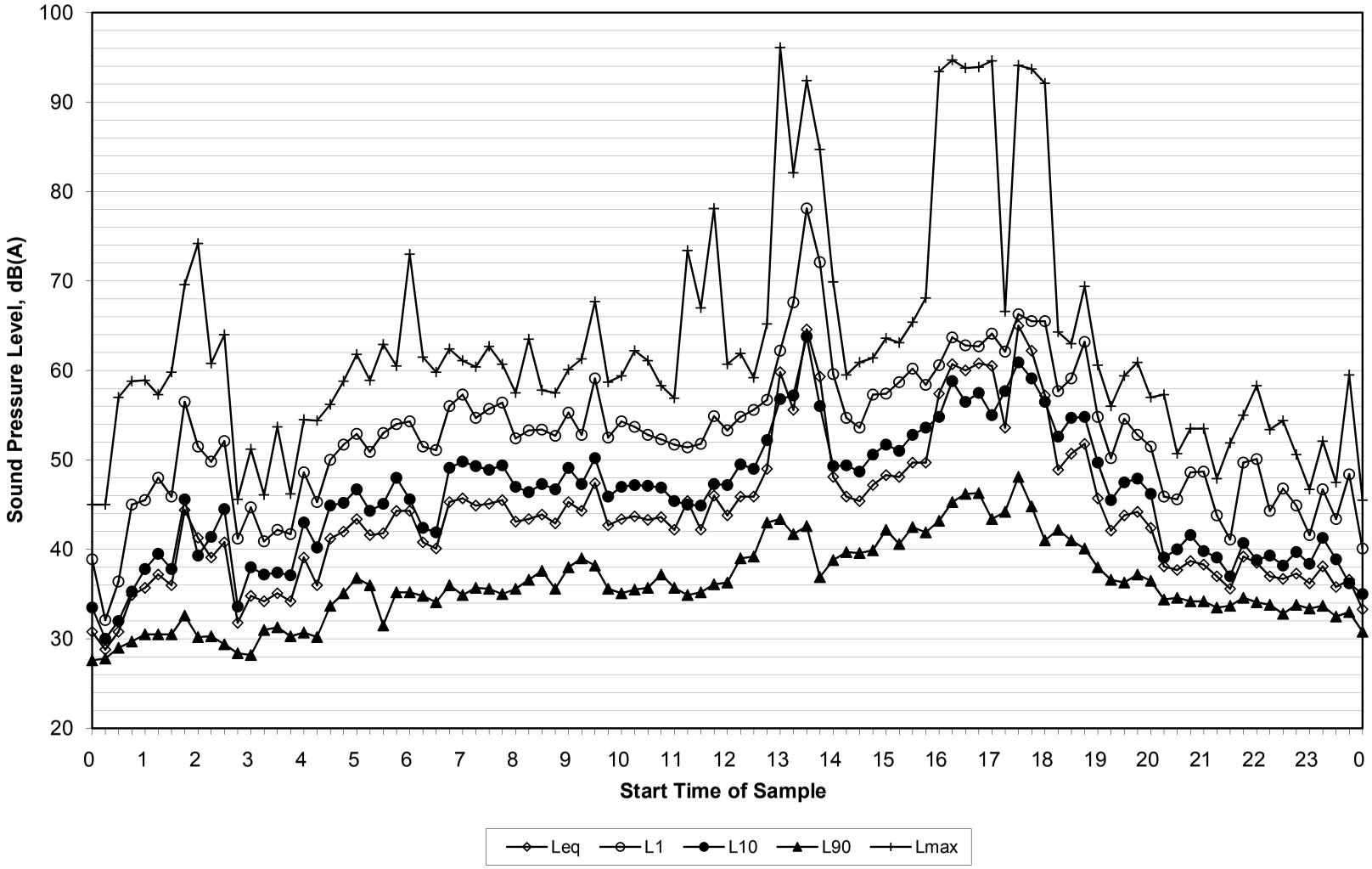
Thursday, 13 November 2008



Location 1
Muldoon Residence

Ambient Sound Pressure Levels

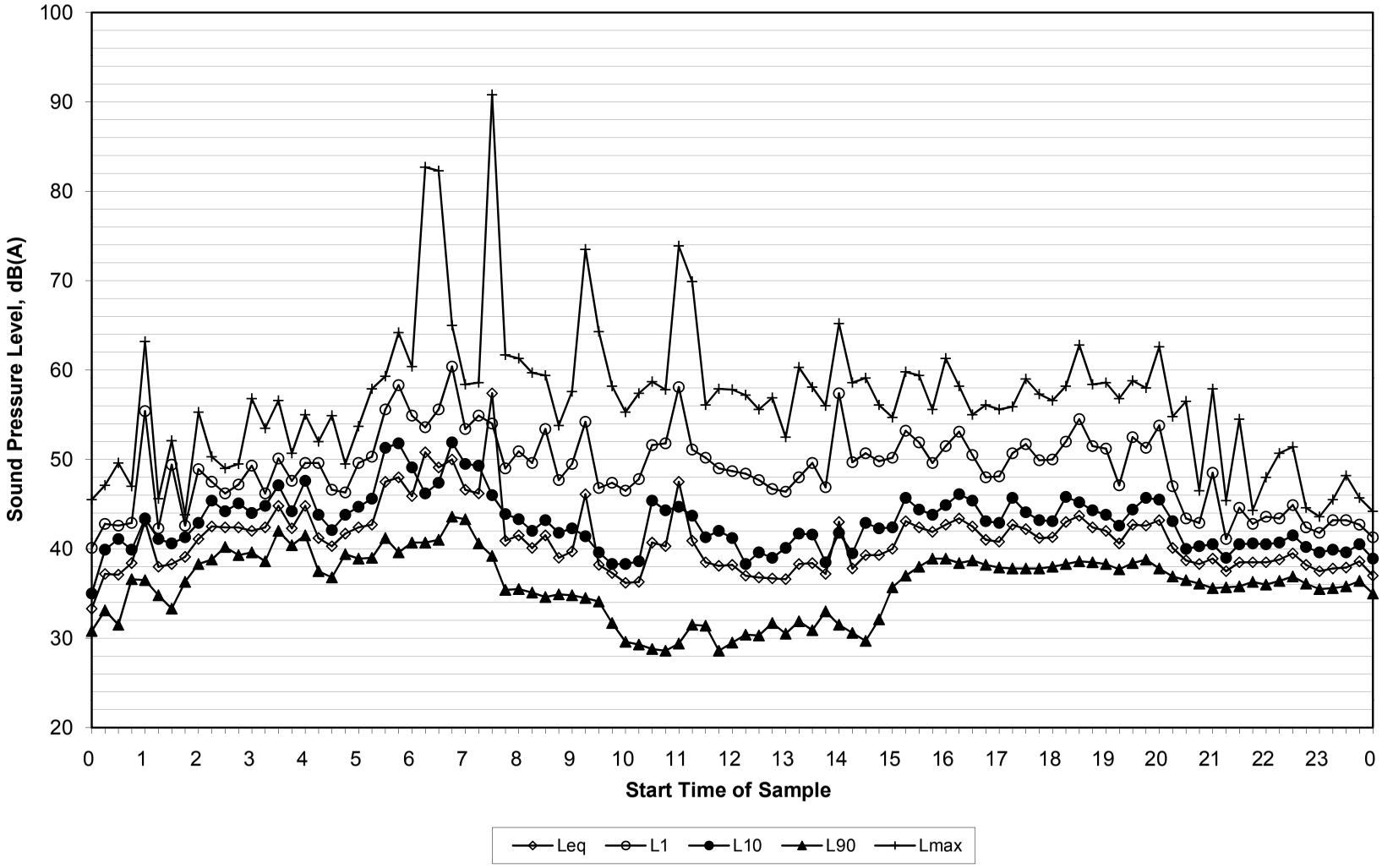
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Location 1
Muldoon Residence

Ambient Sound Pressure Levels

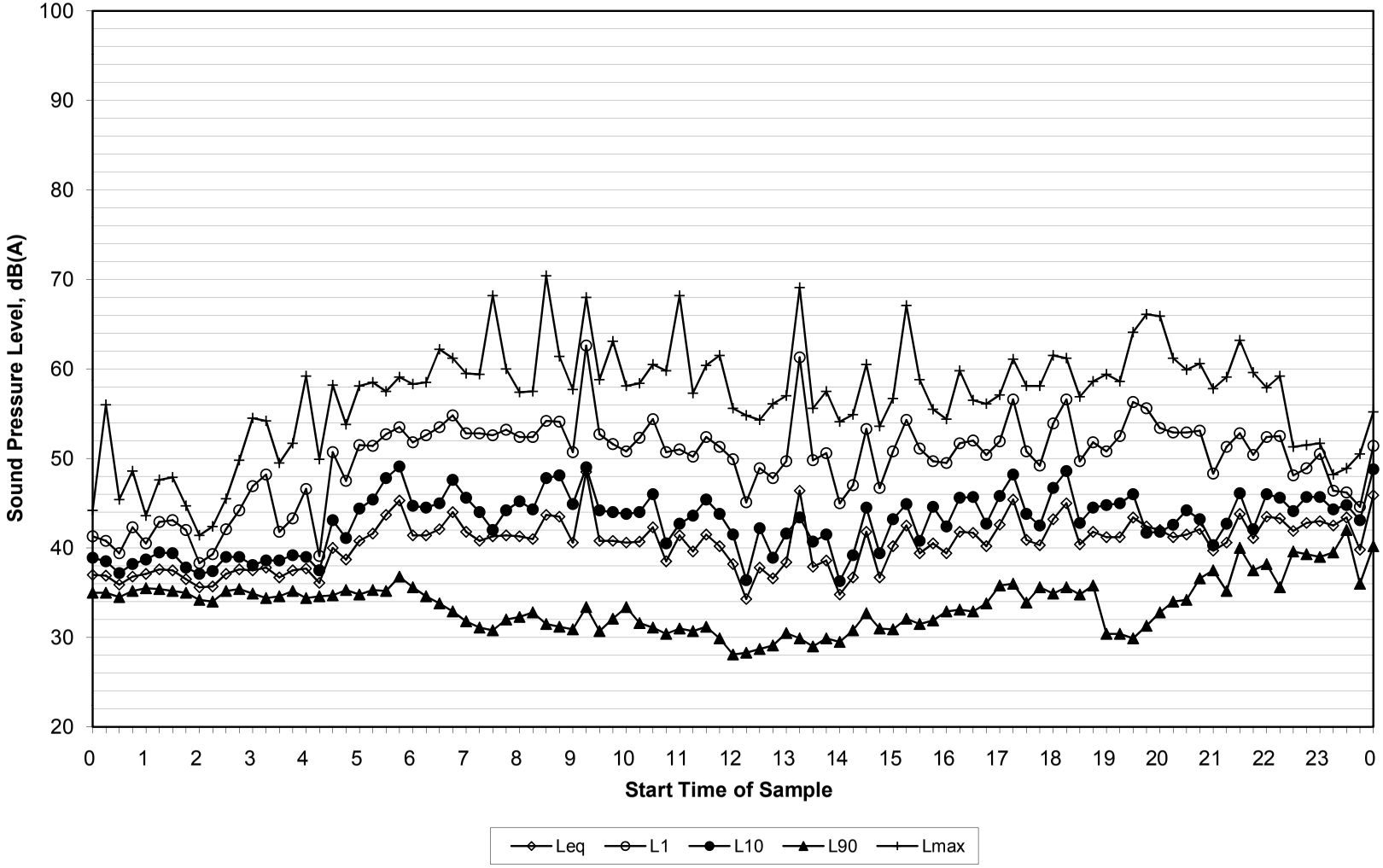
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Location 1
Muldoon Residence

Ambient Sound Pressure Levels

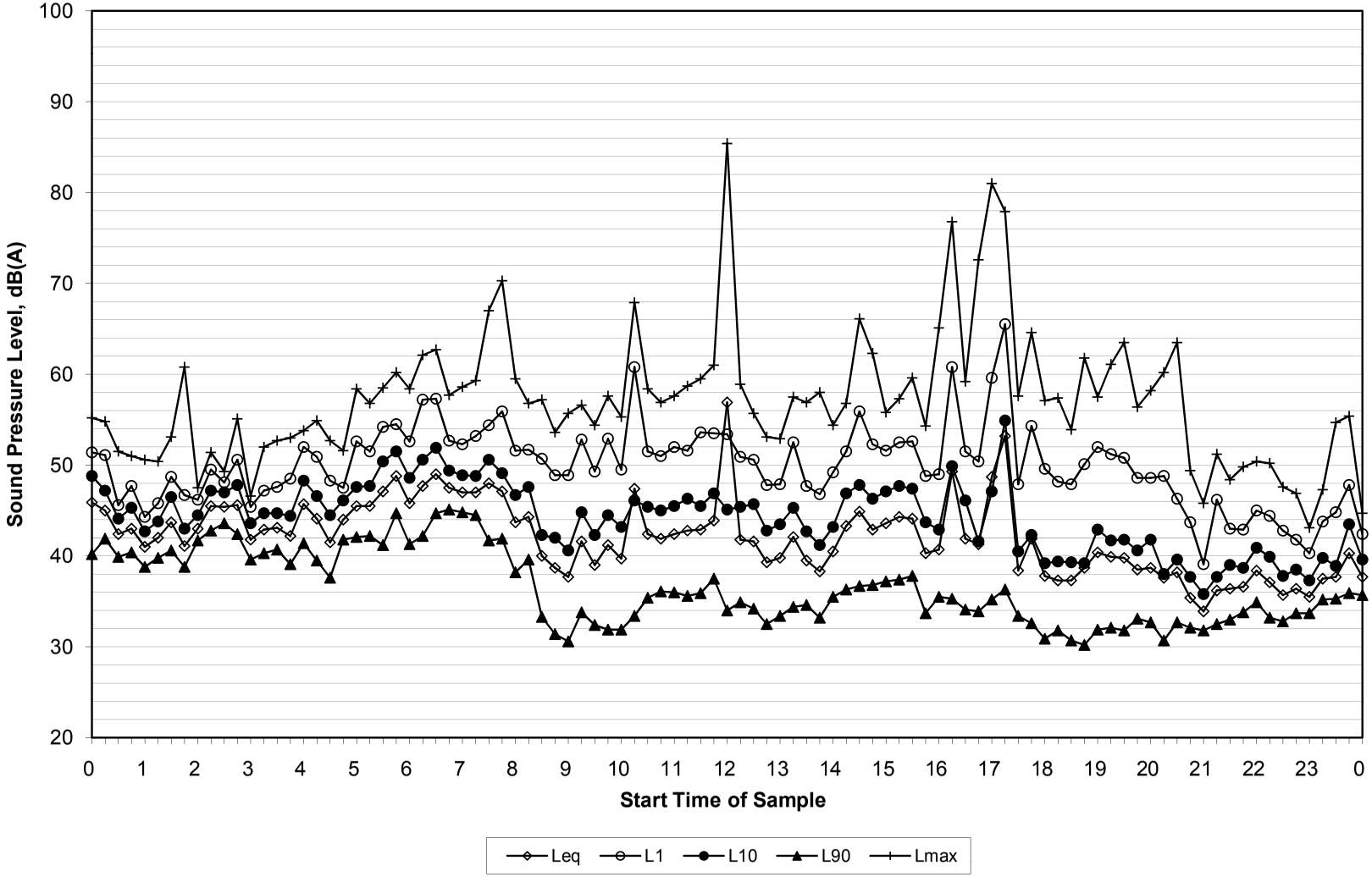
Sunday, 16 November 2008



Location 1
Muldoon Residence

Ambient Sound Pressure Levels

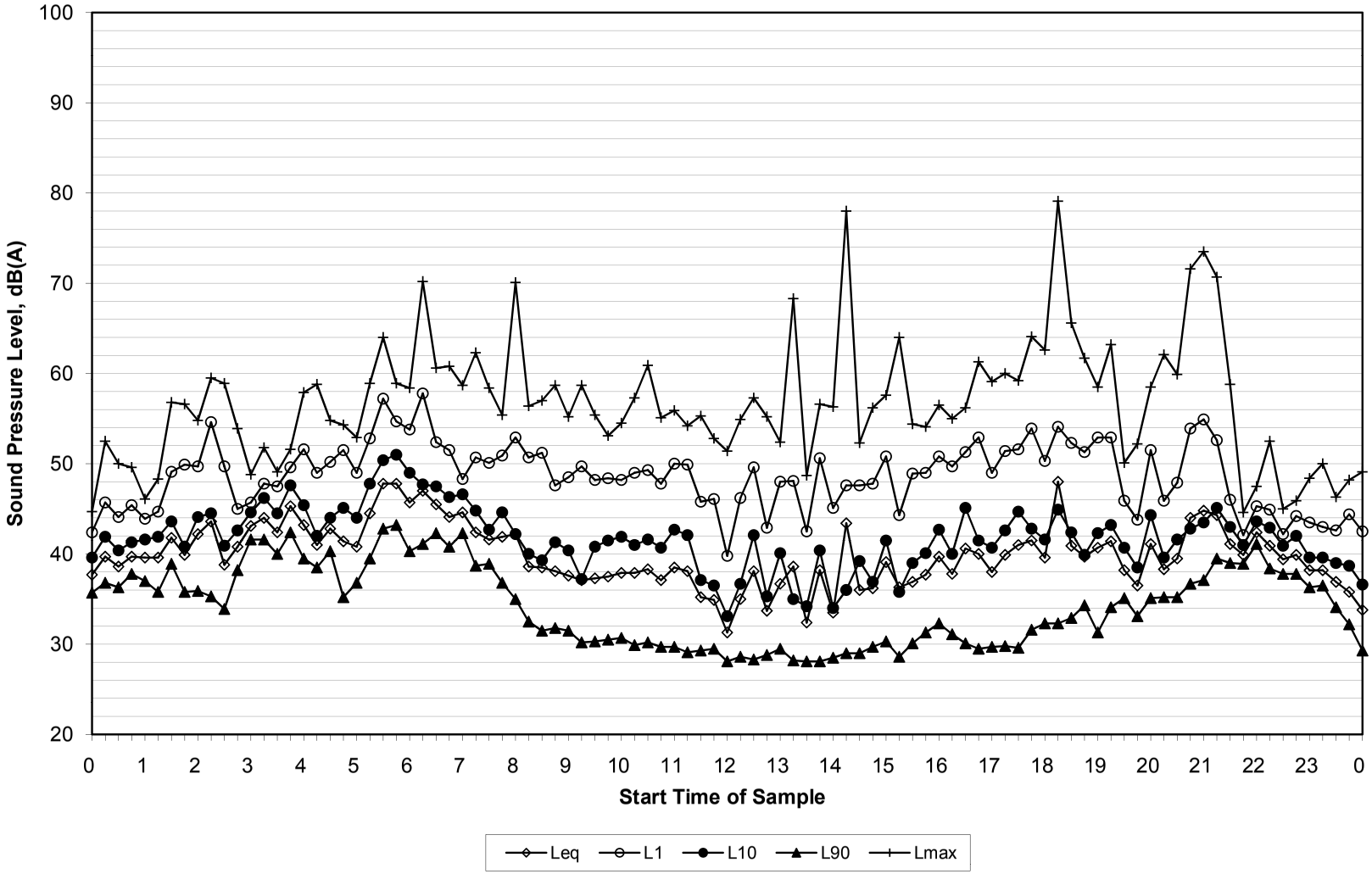
Monday, 17 November 2008



Location 1
Muldoon Residence

Ambient Sound Pressure Levels

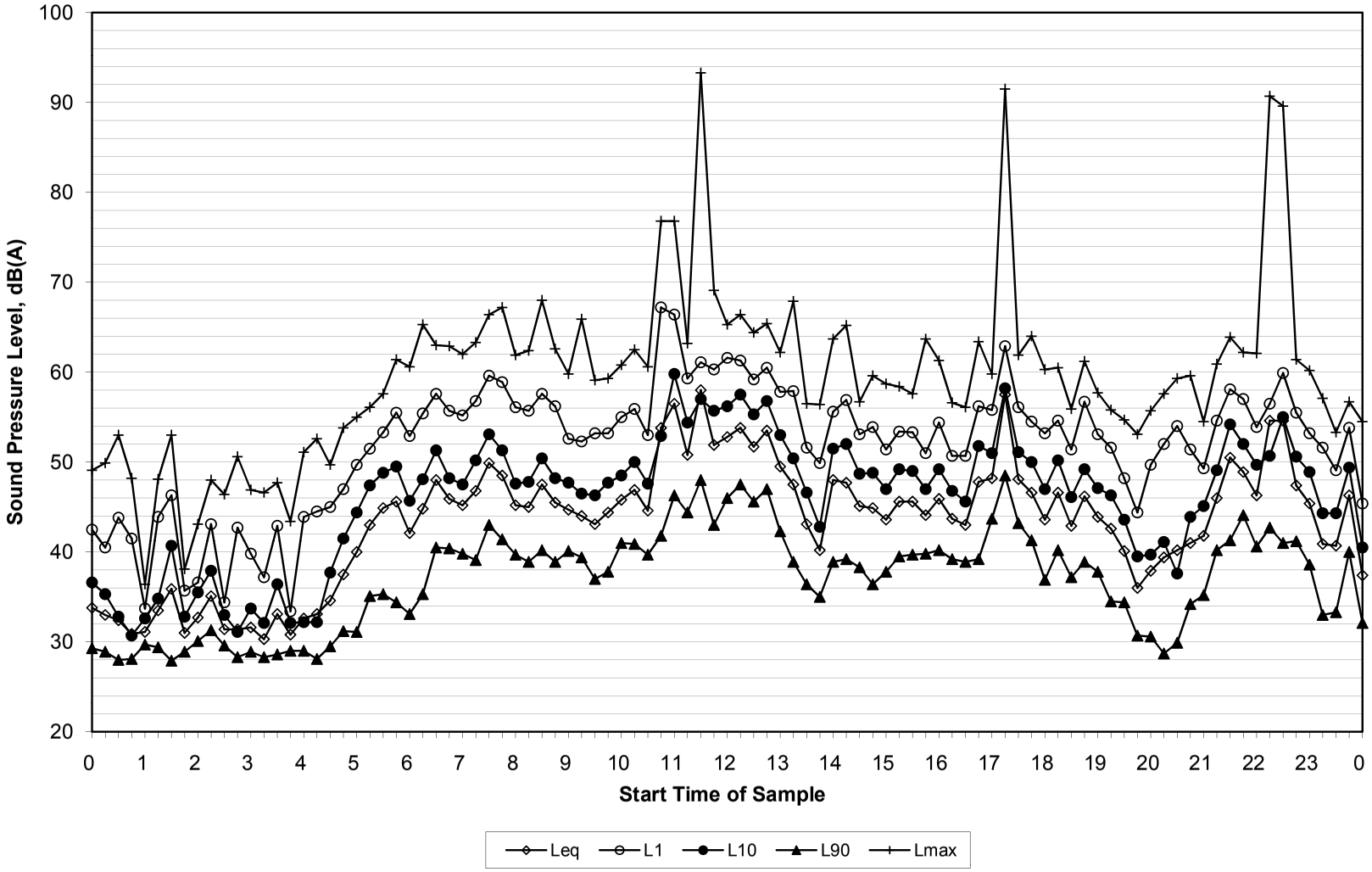
Tuesday, 18 November 2008



Location 1
Muldoon Residence

Ambient Sound Pressure Levels

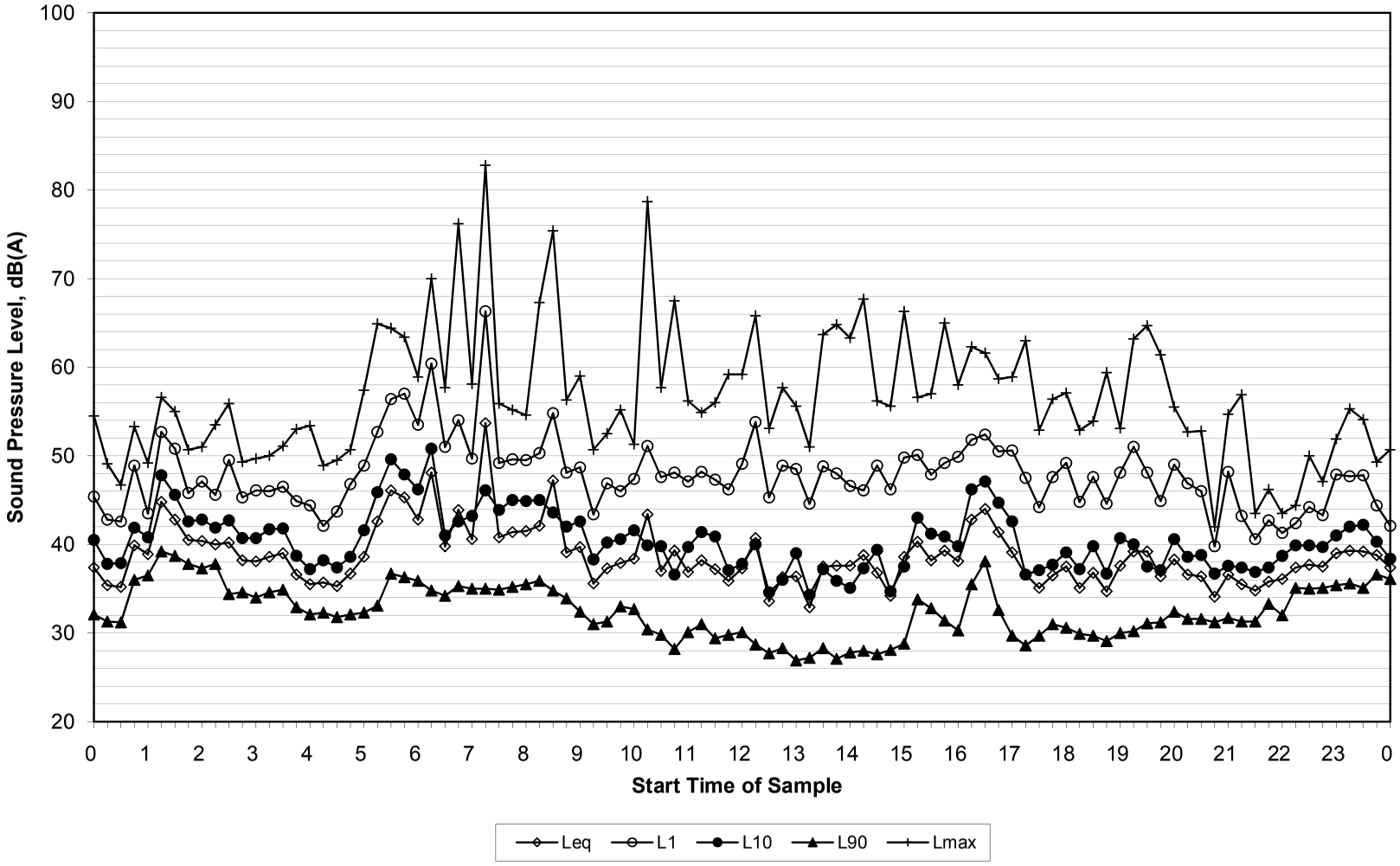
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Location 1
Muldoon Residence

Ambient Sound Pressure Levels

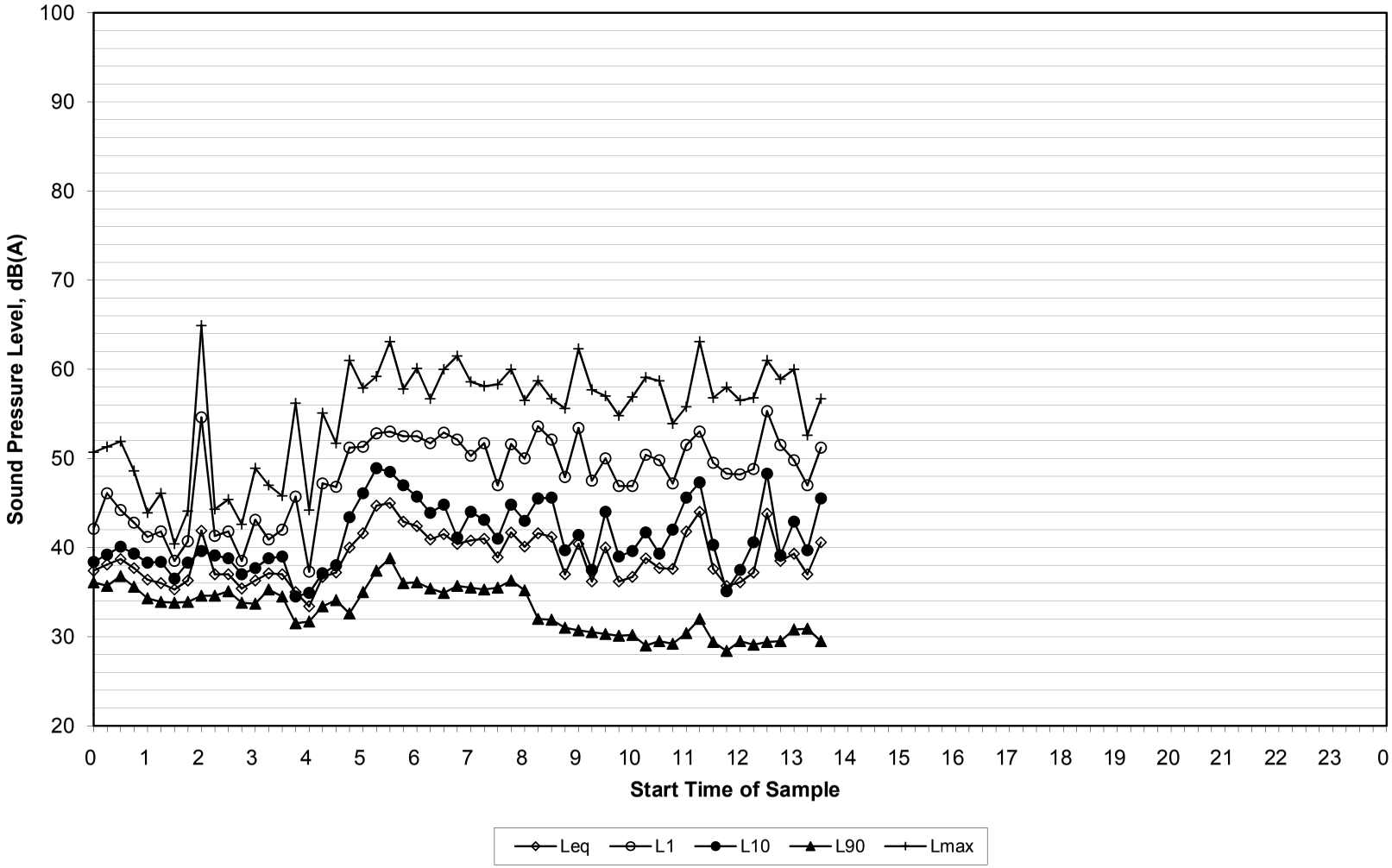
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Location 1
Muldoon Residence

Ambient Sound Pressure Levels

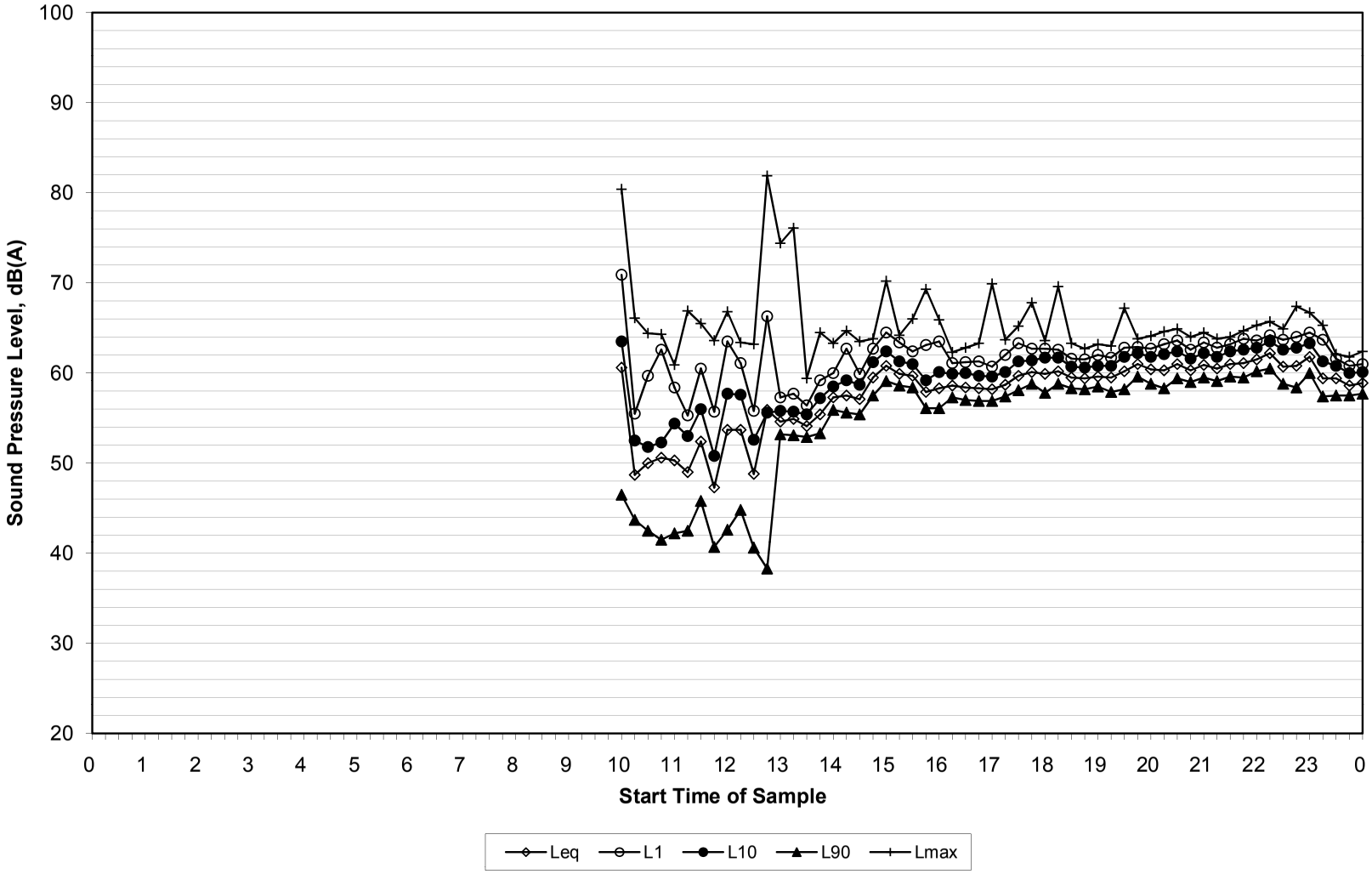
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Location 1
Muldoon Residence

Ambient Sound Pressure Levels

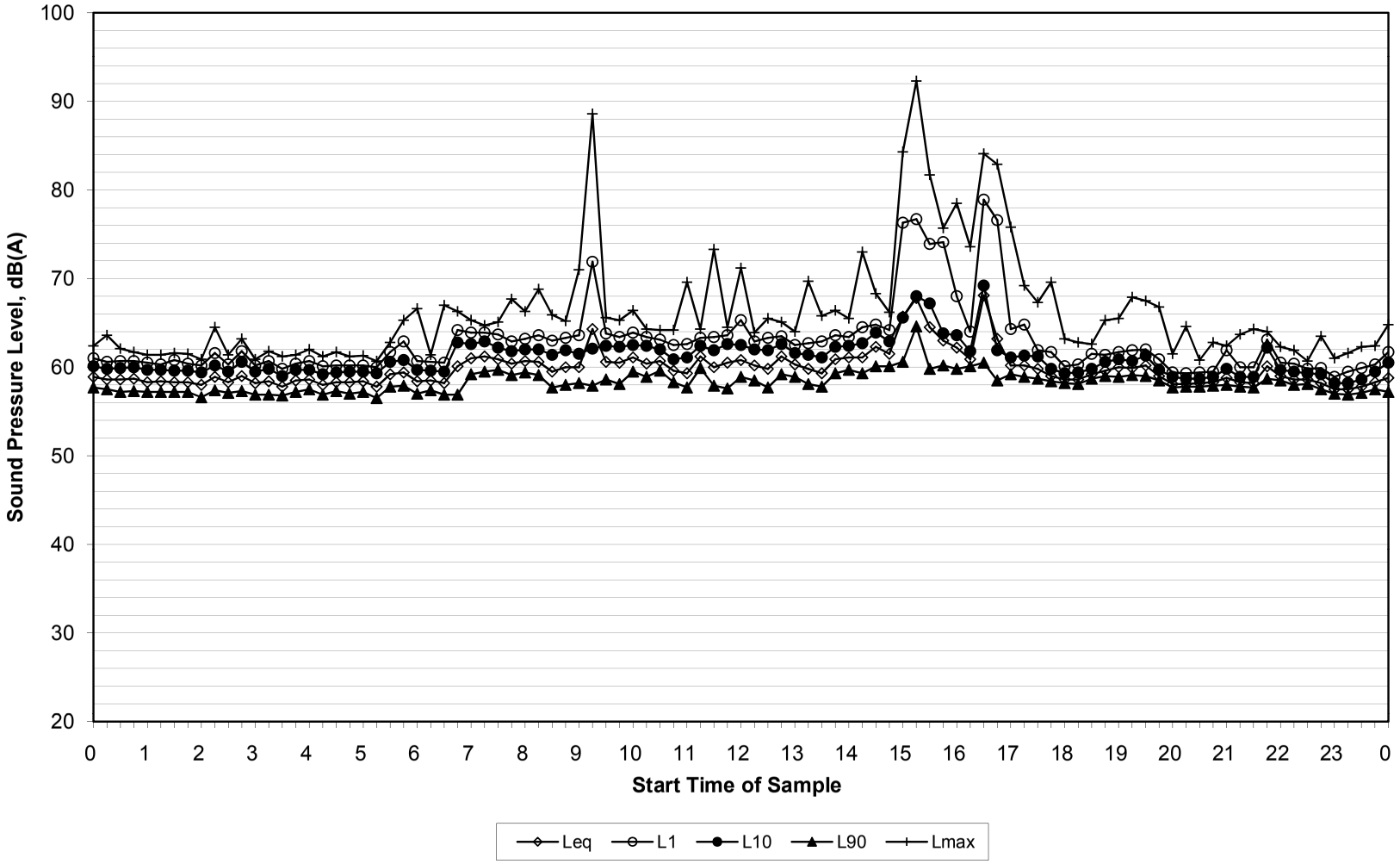
Tuesday, 11 November 2008



Location 2
Speirs Residence

Ambient Sound Pressure Levels

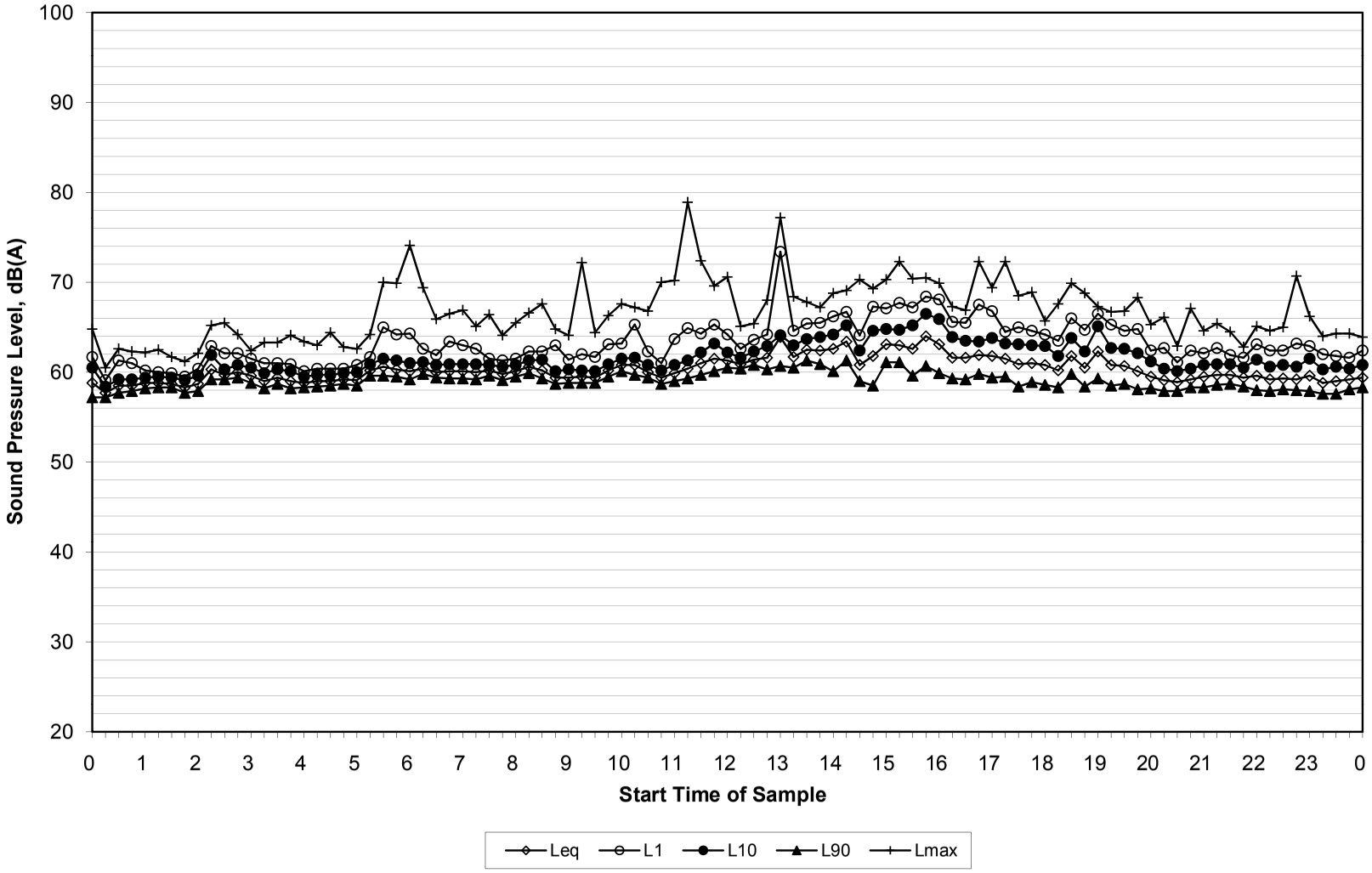
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Location 2
Speirs Residence

Ambient Sound Pressure Levels

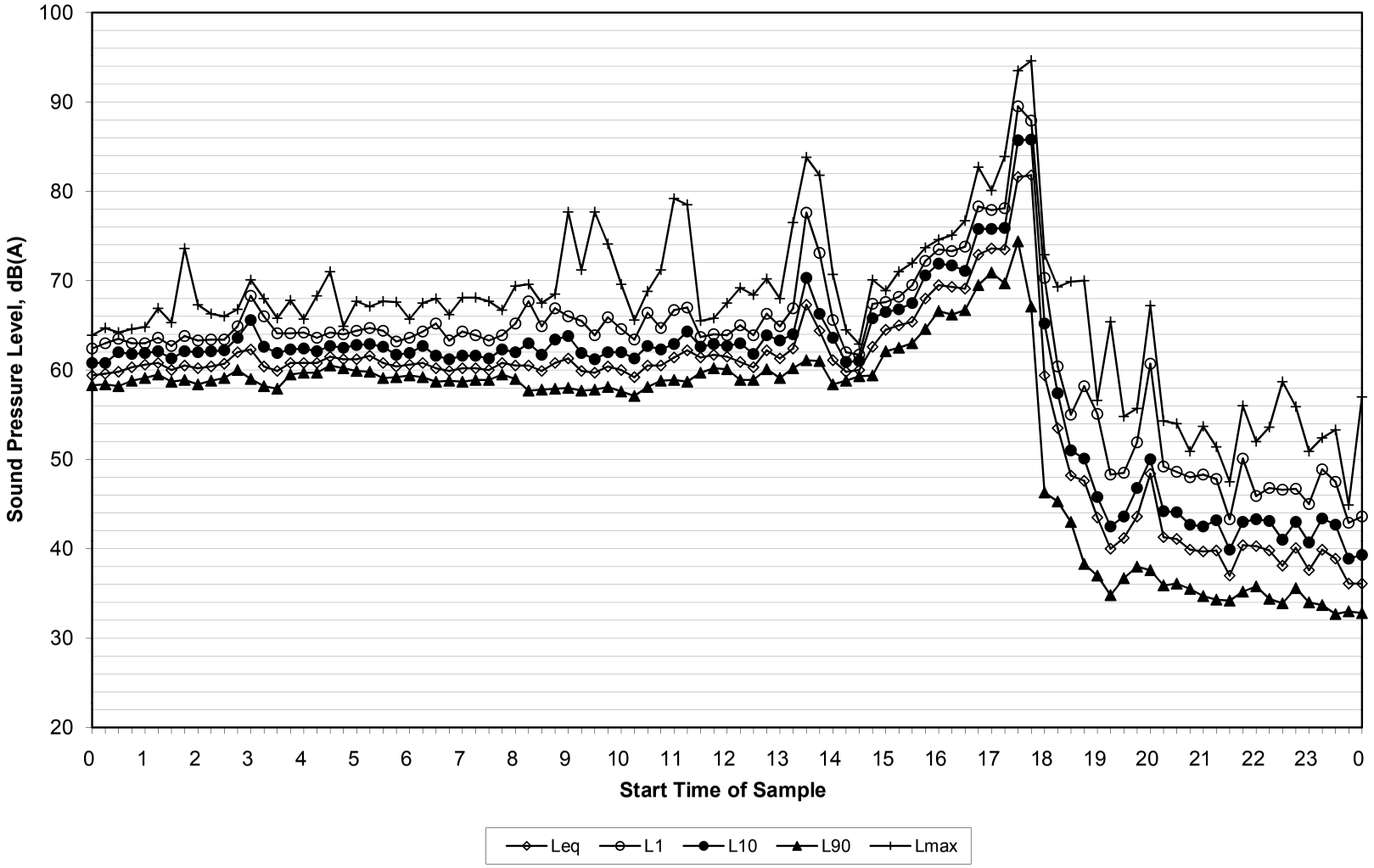
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Location 2
Speirs Residence

Ambient Sound Pressure Levels

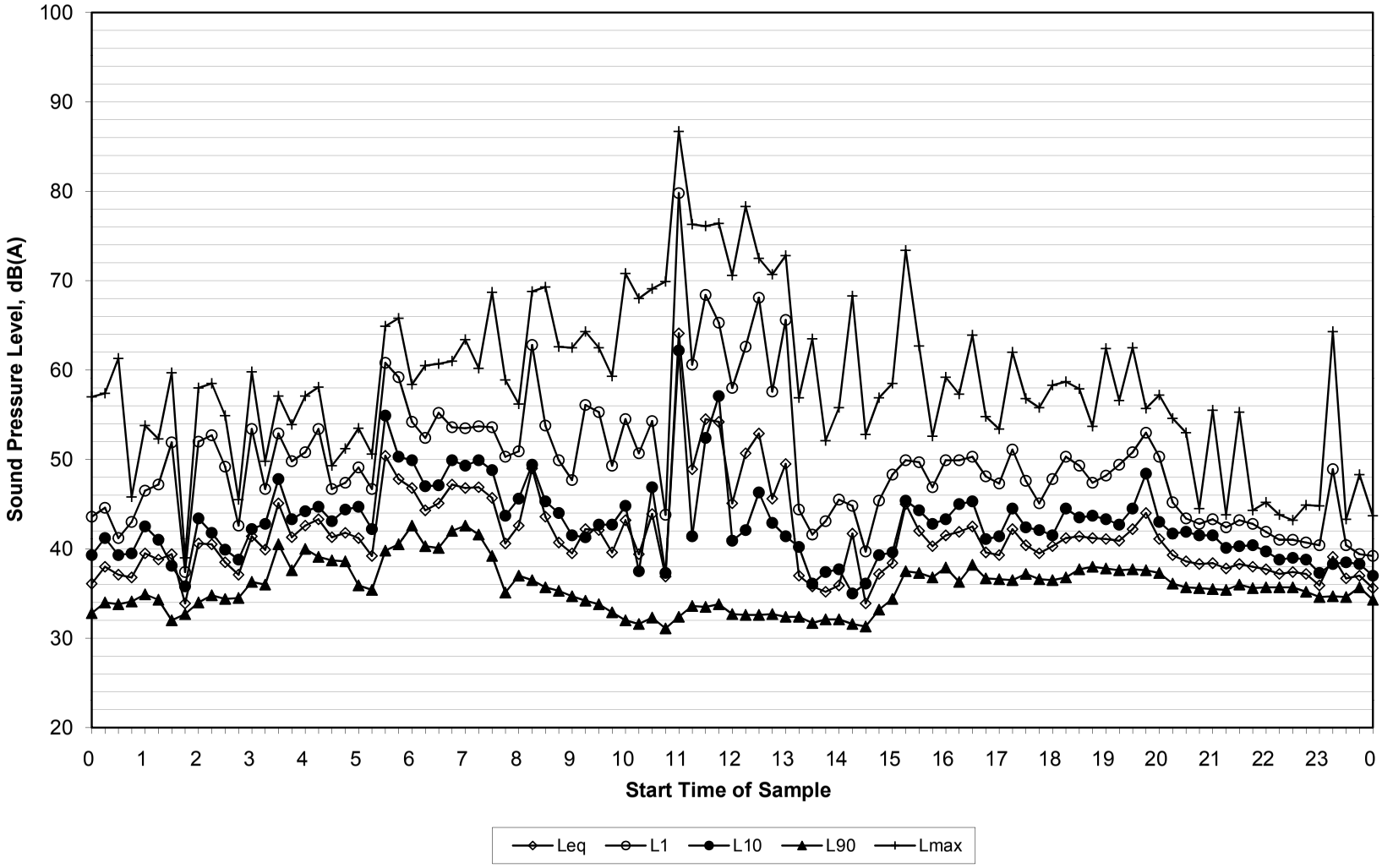
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Location 2
Speirs Residence

Ambient Sound Pressure Levels

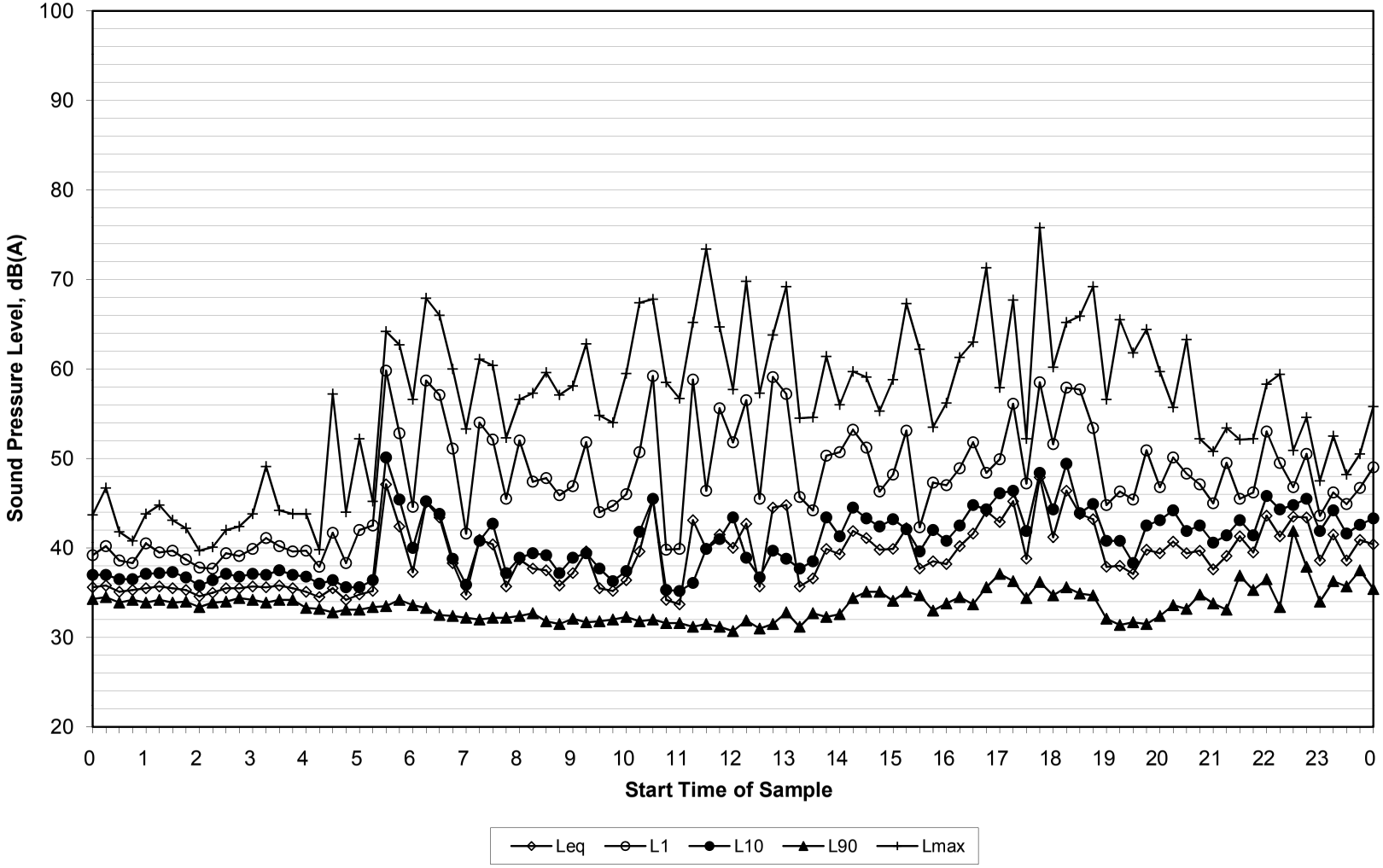
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Location 2
Speirs Residence

Ambient Sound Pressure Levels

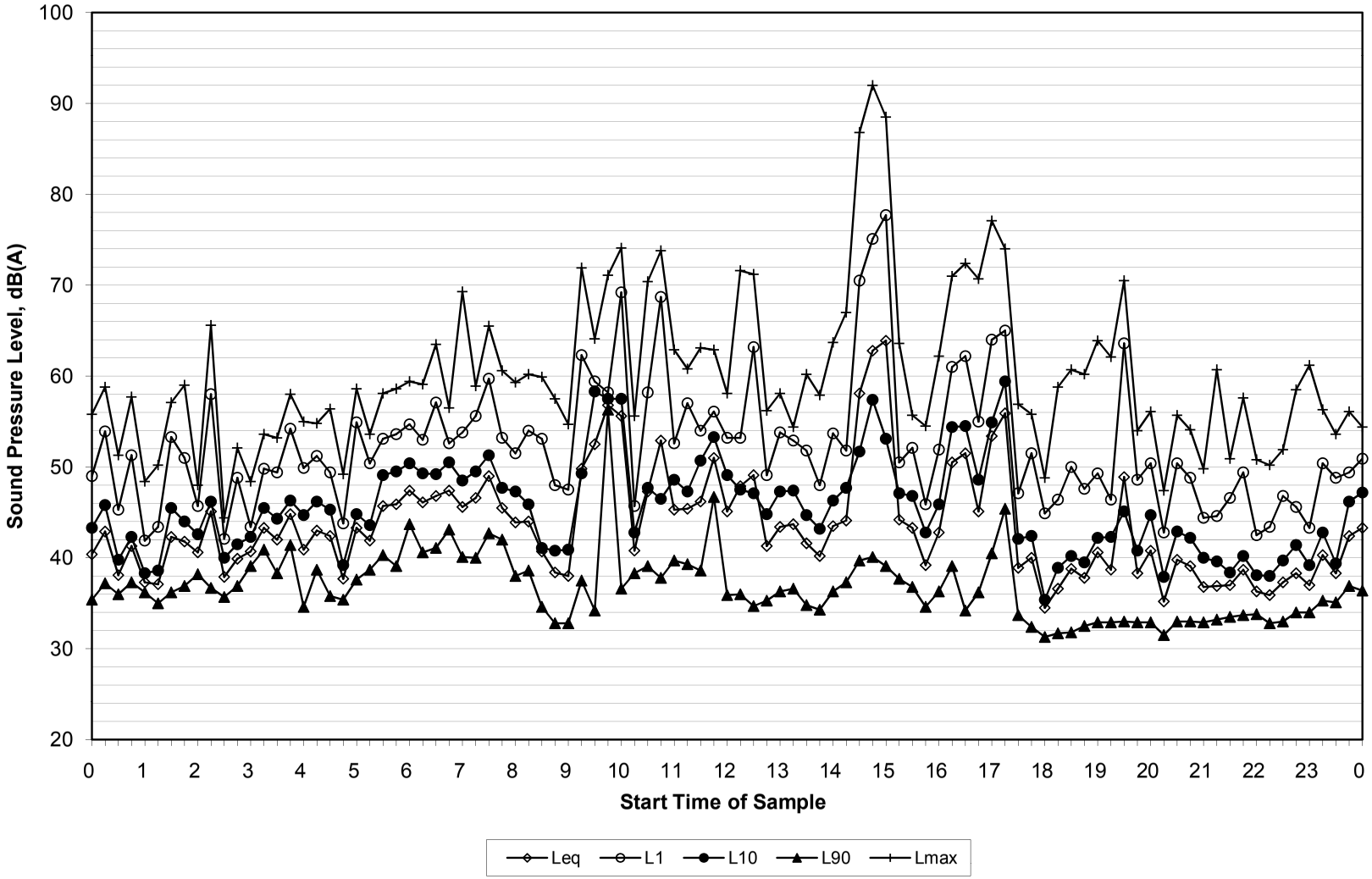
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Location 2
Speirs Residence

Ambient Sound Pressure Levels

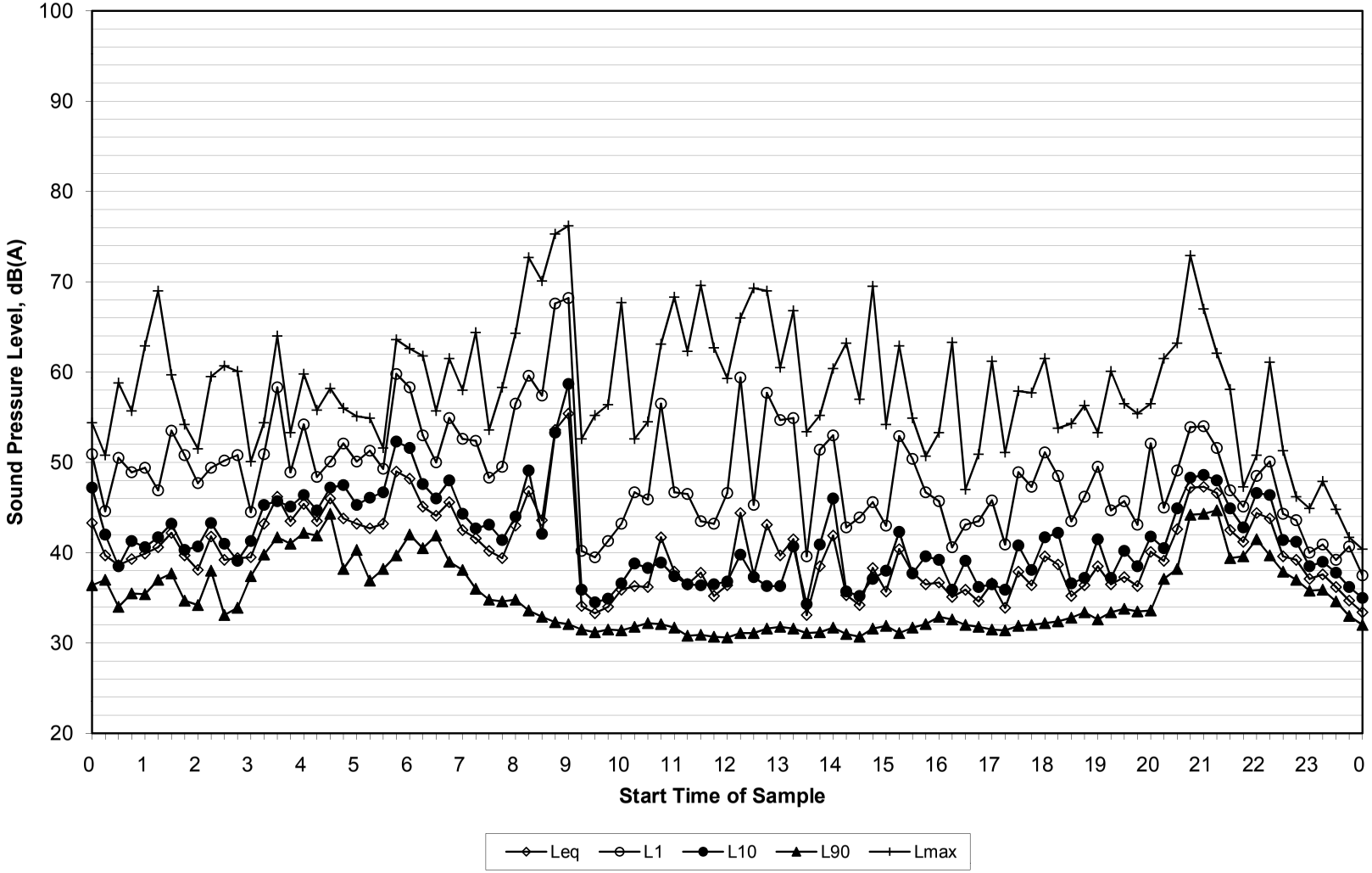
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Location 2
Speirs Residence

Ambient Sound Pressure Levels

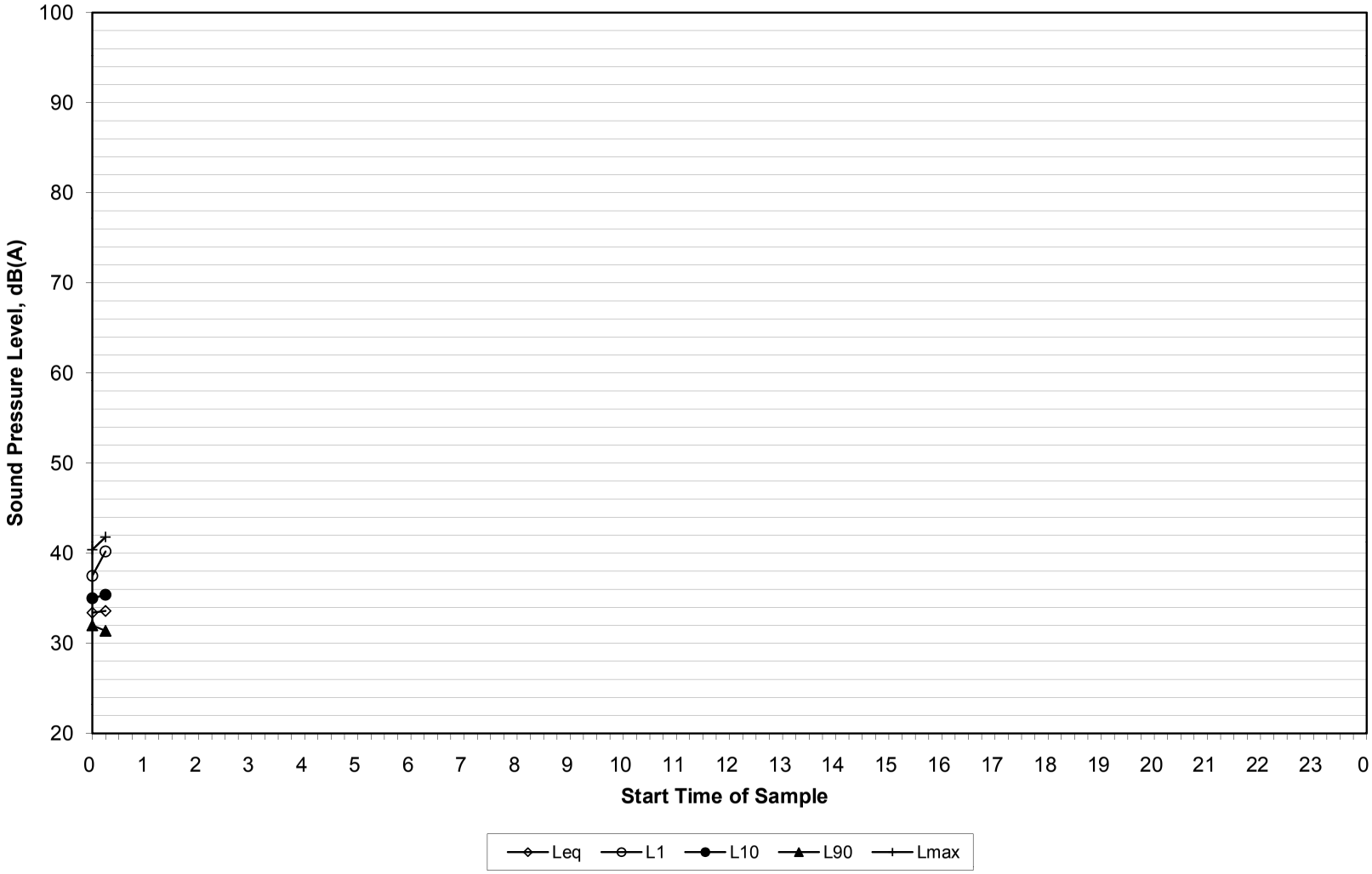
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Location 2
Speirs Residence

Ambient Sound Pressure Levels

Wednesday, 19 November 2008

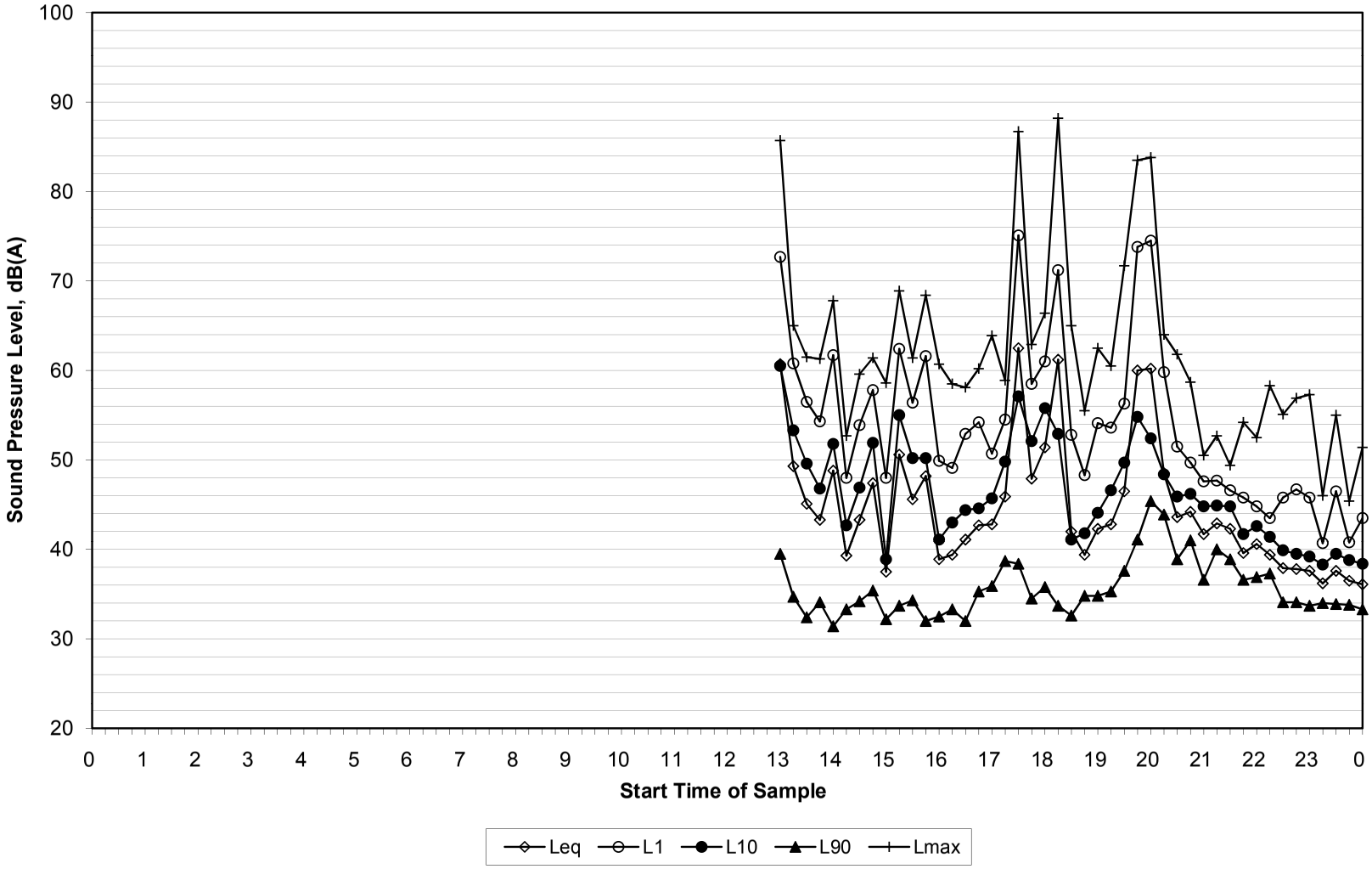


Location 2
Speirs Residence

APPENDIX 1: AMBIENT NOISE MEASUREMENT RESULTS (BAAL BONE CHPP OPERATING)

Ambient Sound Pressure Levels

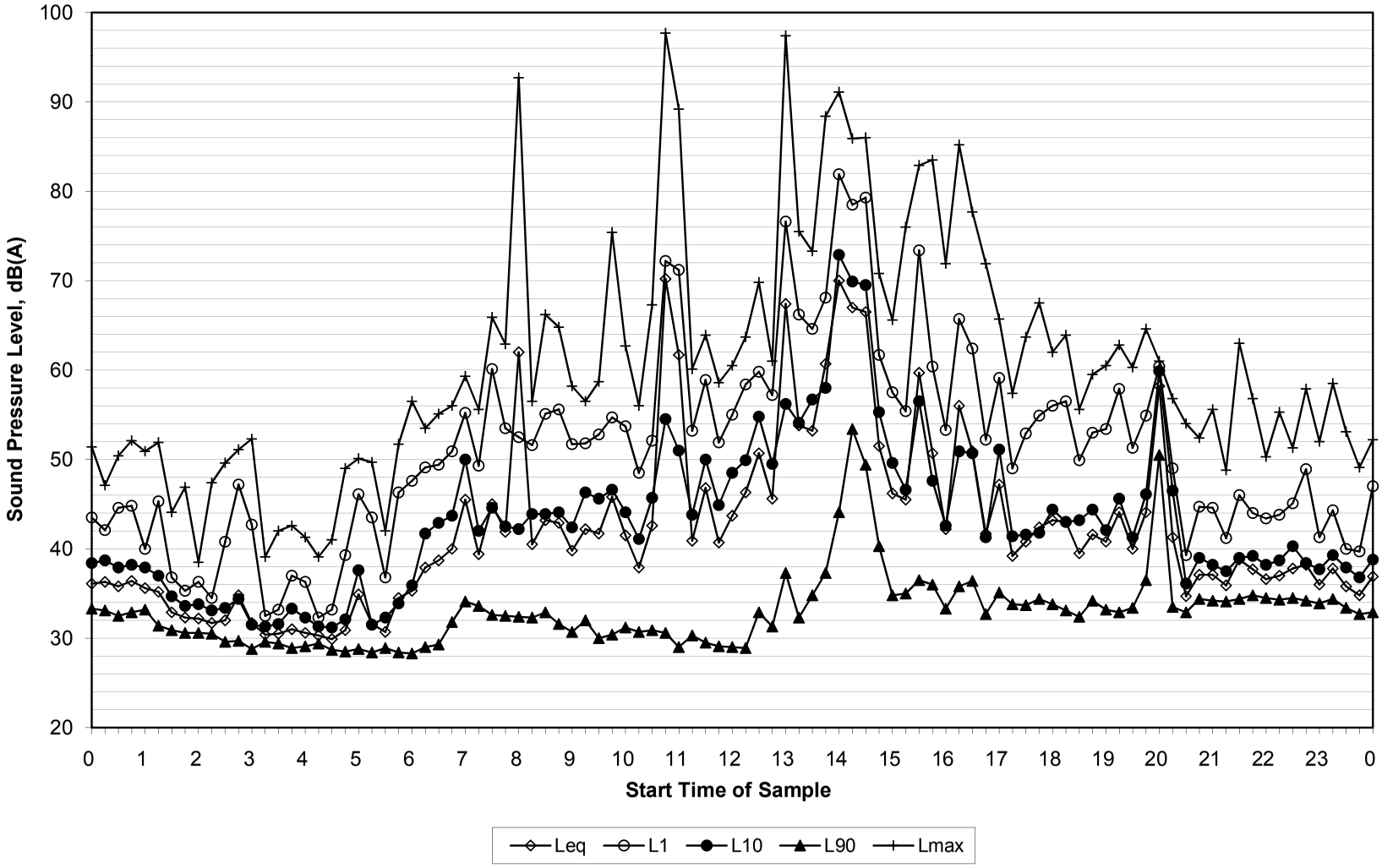
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Location 1
Muldoon Residence

Ambient Sound Pressure Levels

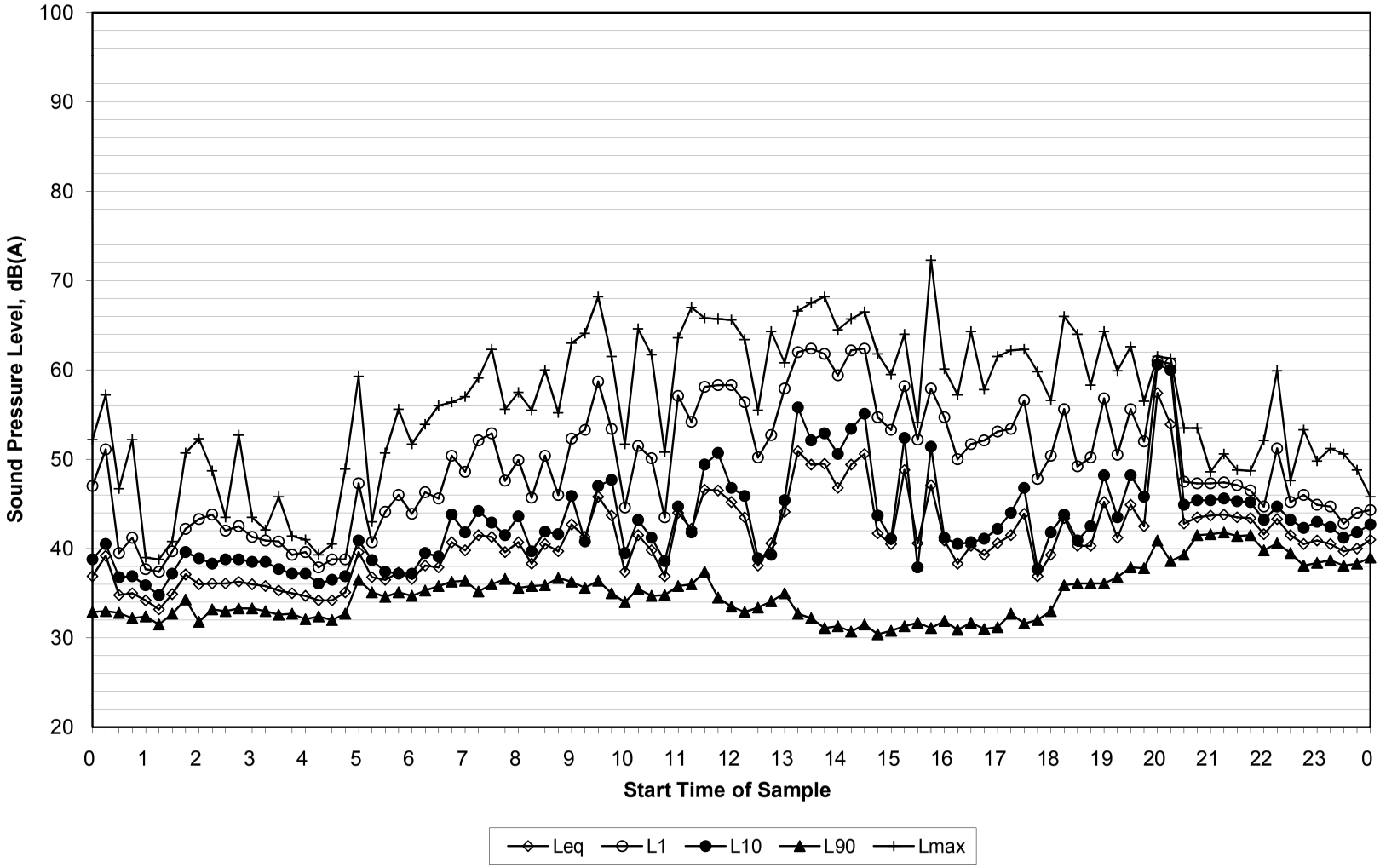
Saturday, 21 February 2009



Location 1
Muldoon Residence

Ambient Sound Pressure Levels

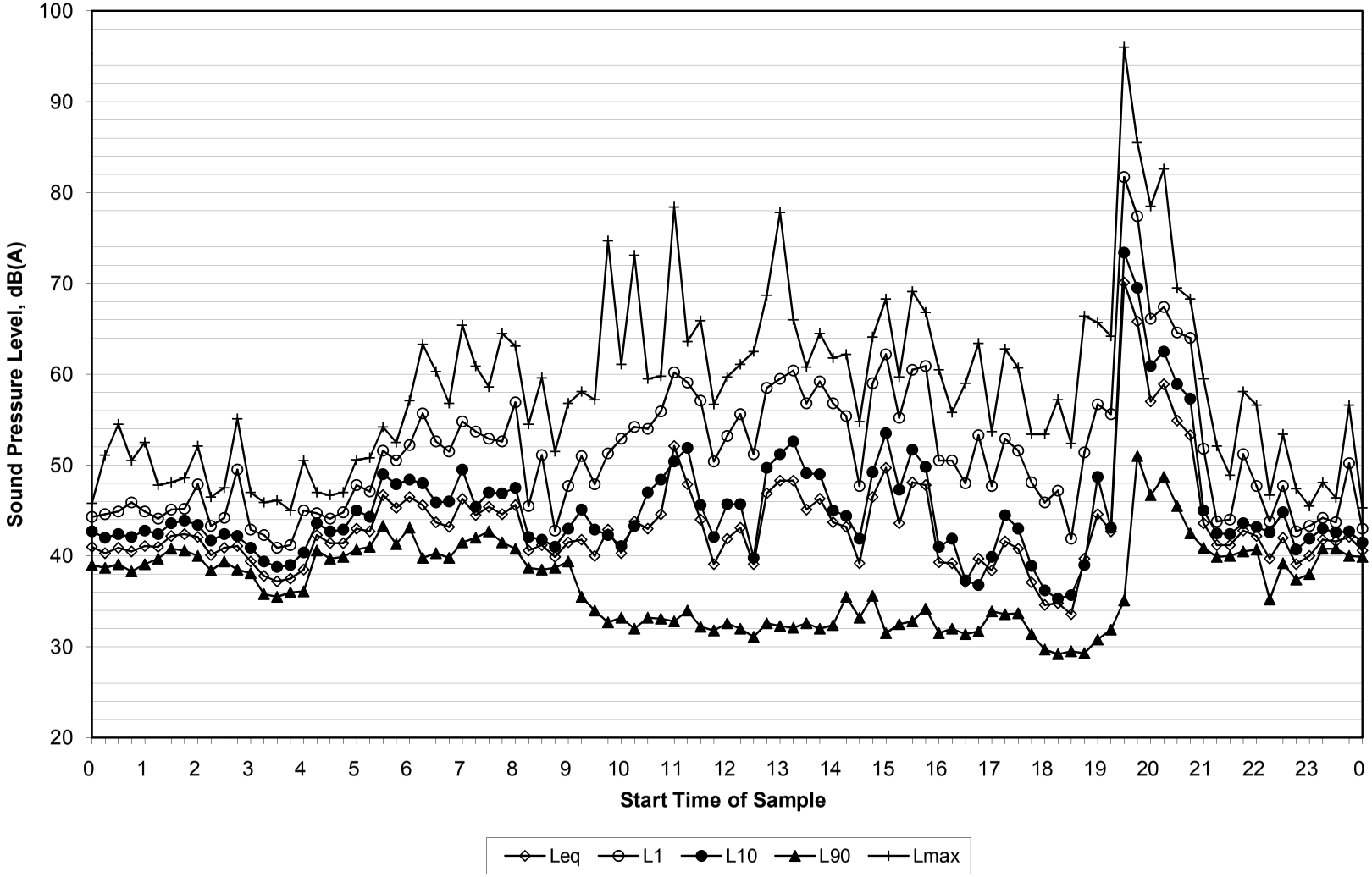
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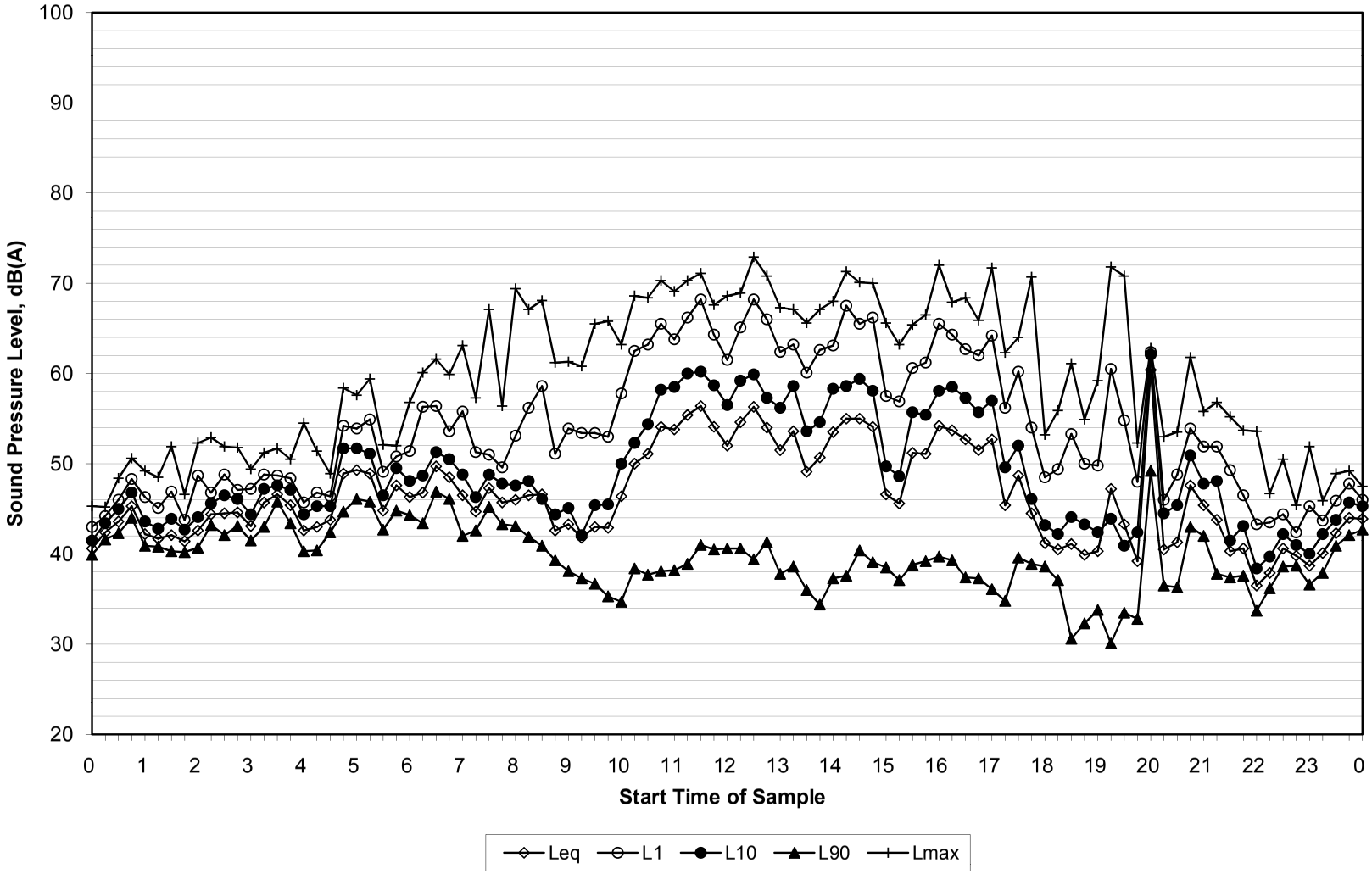
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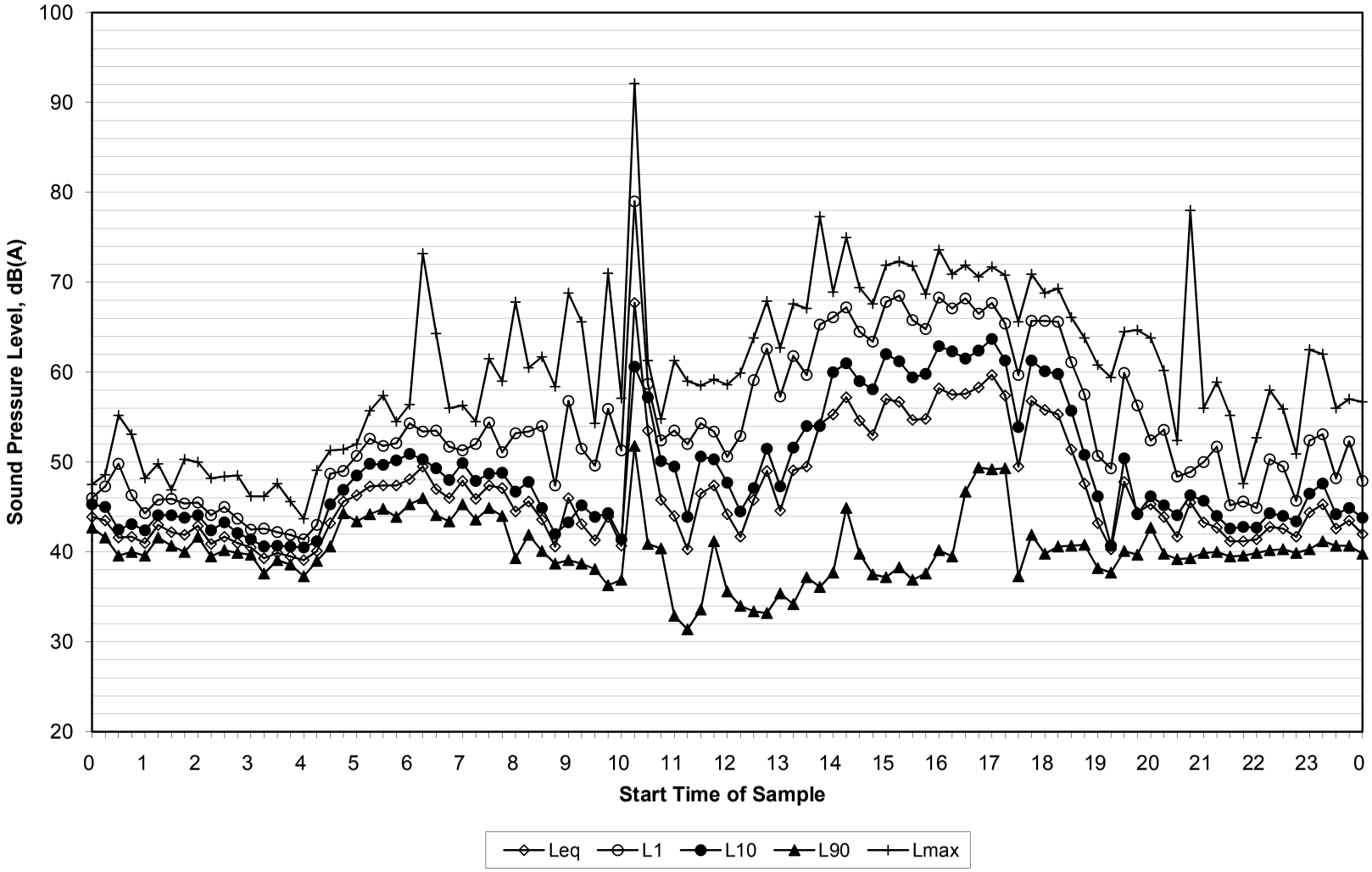
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Ambient Sound Pressure Levels

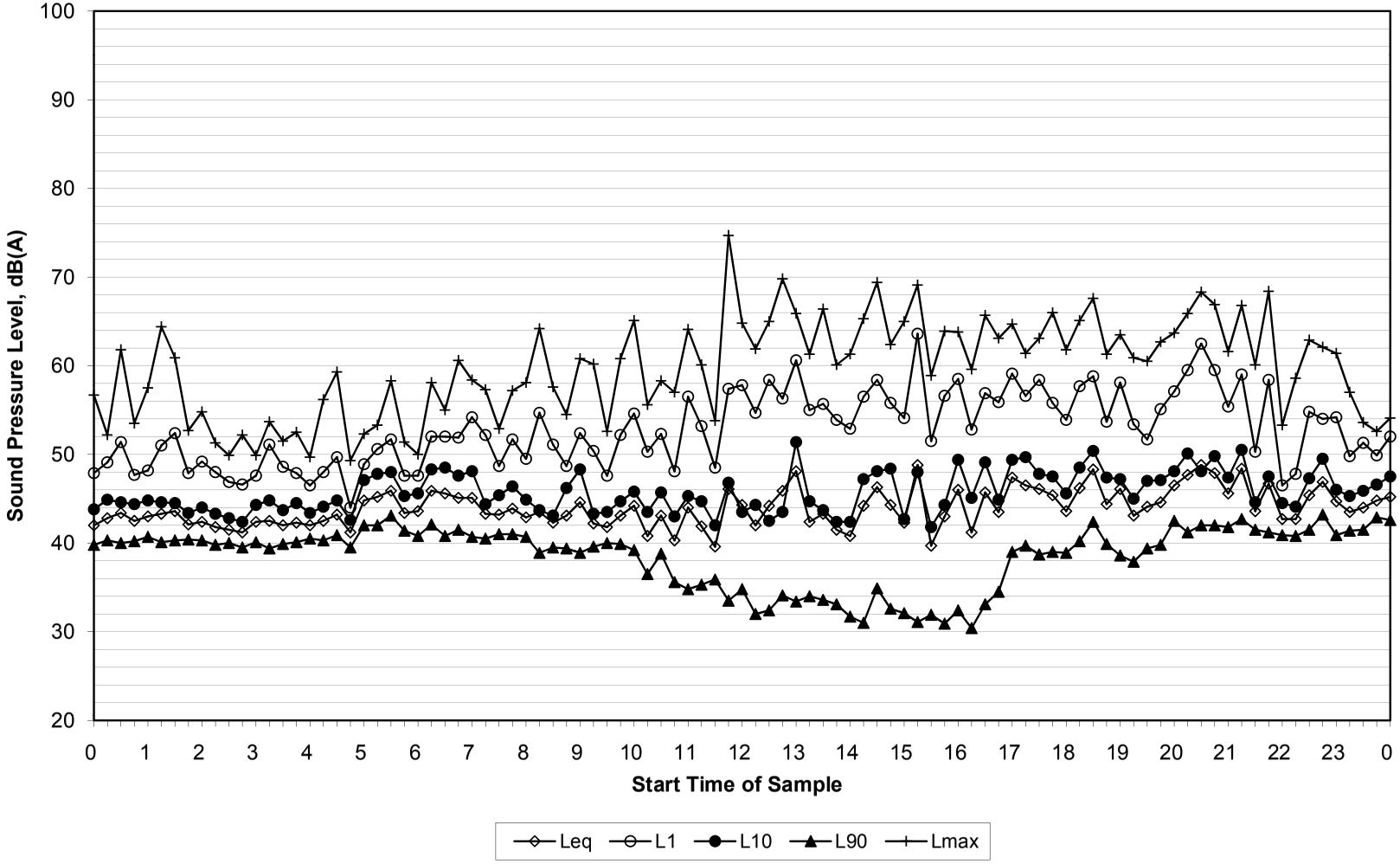
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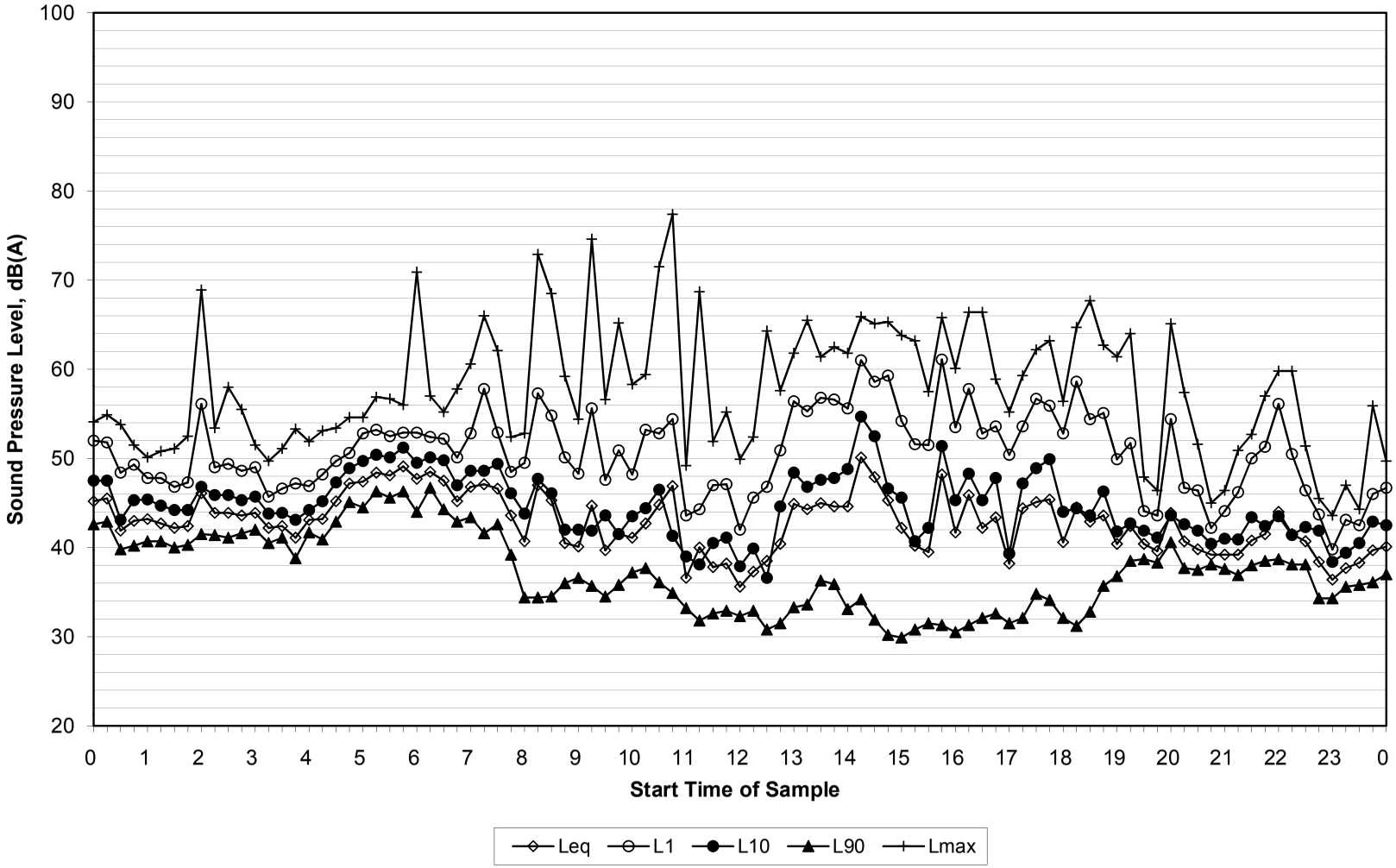
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Ambient Sound Pressure Levels

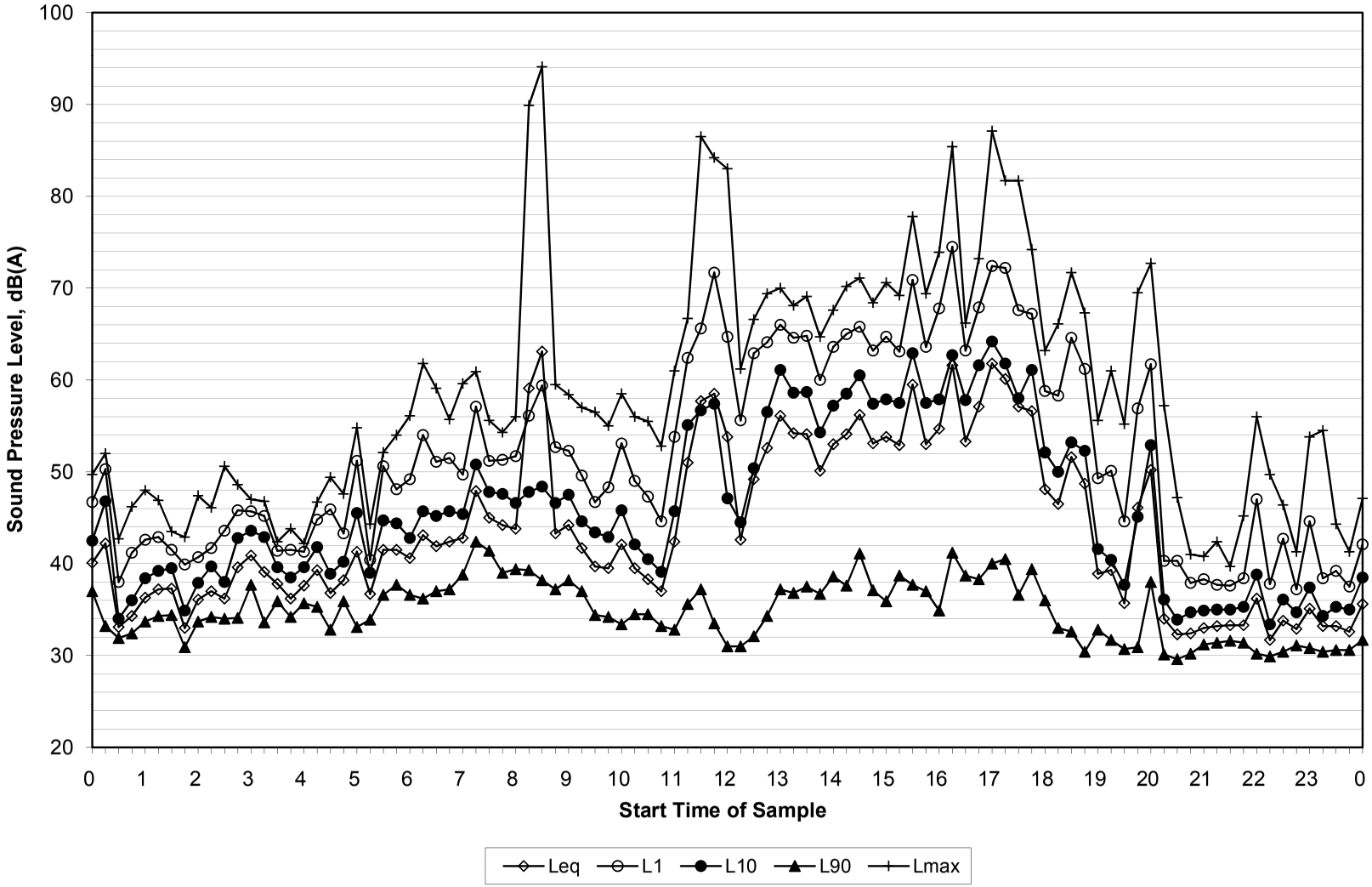
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Ambient Sound Pressure Levels

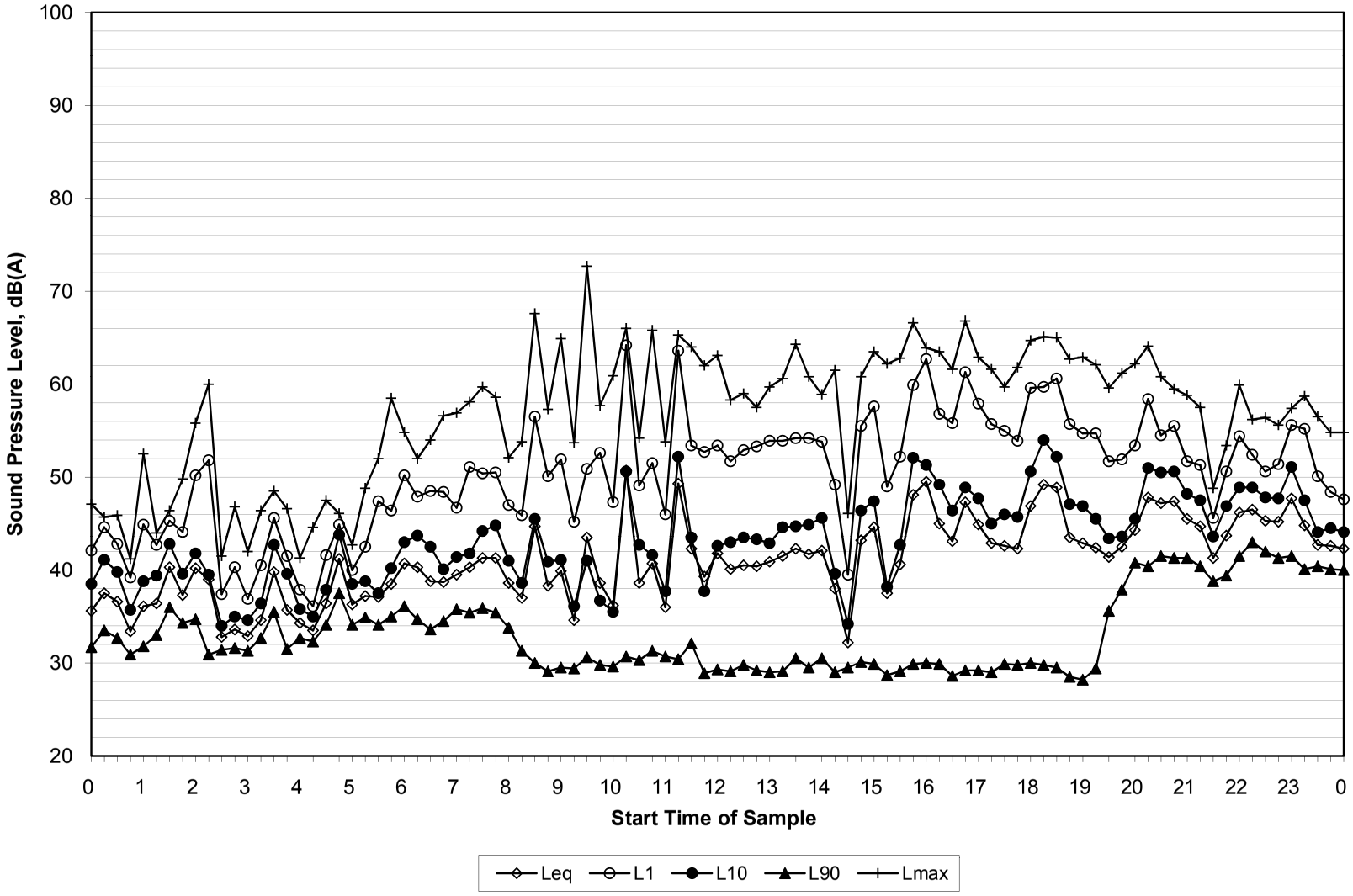
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Ambient Sound Pressure Levels

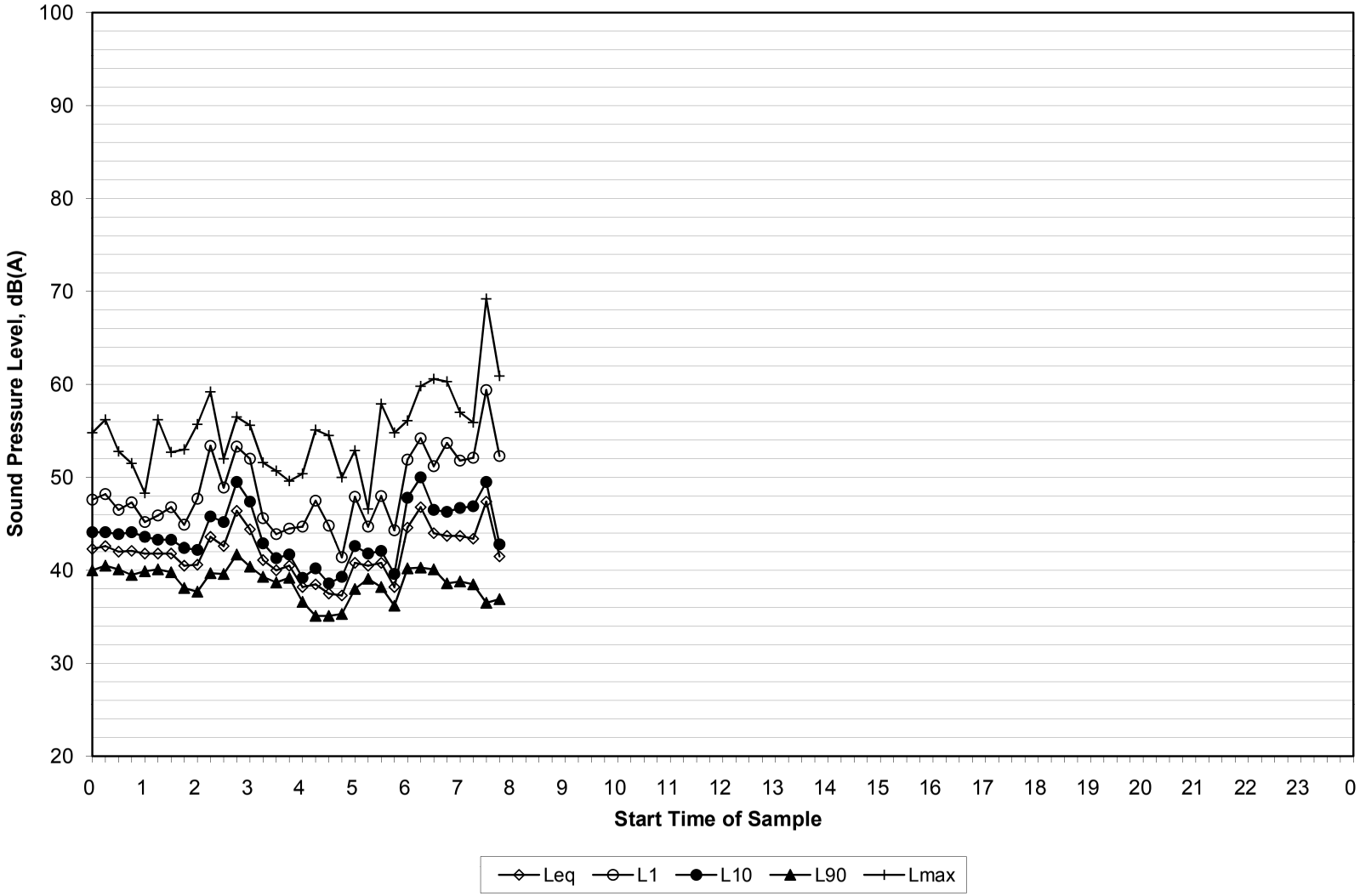
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Ambient Sound Pressure Levels

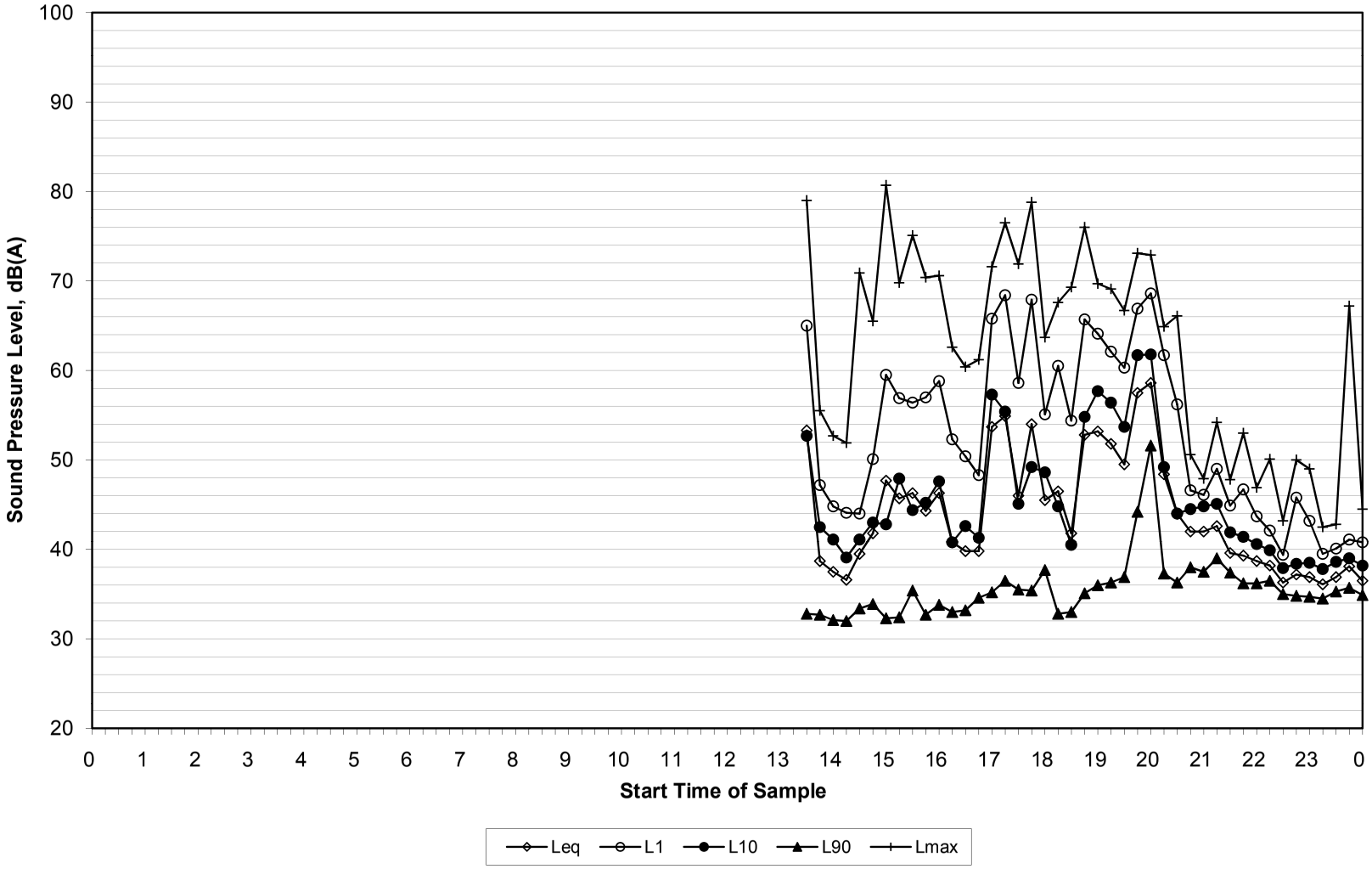
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Ambient Sound Pressure Levels

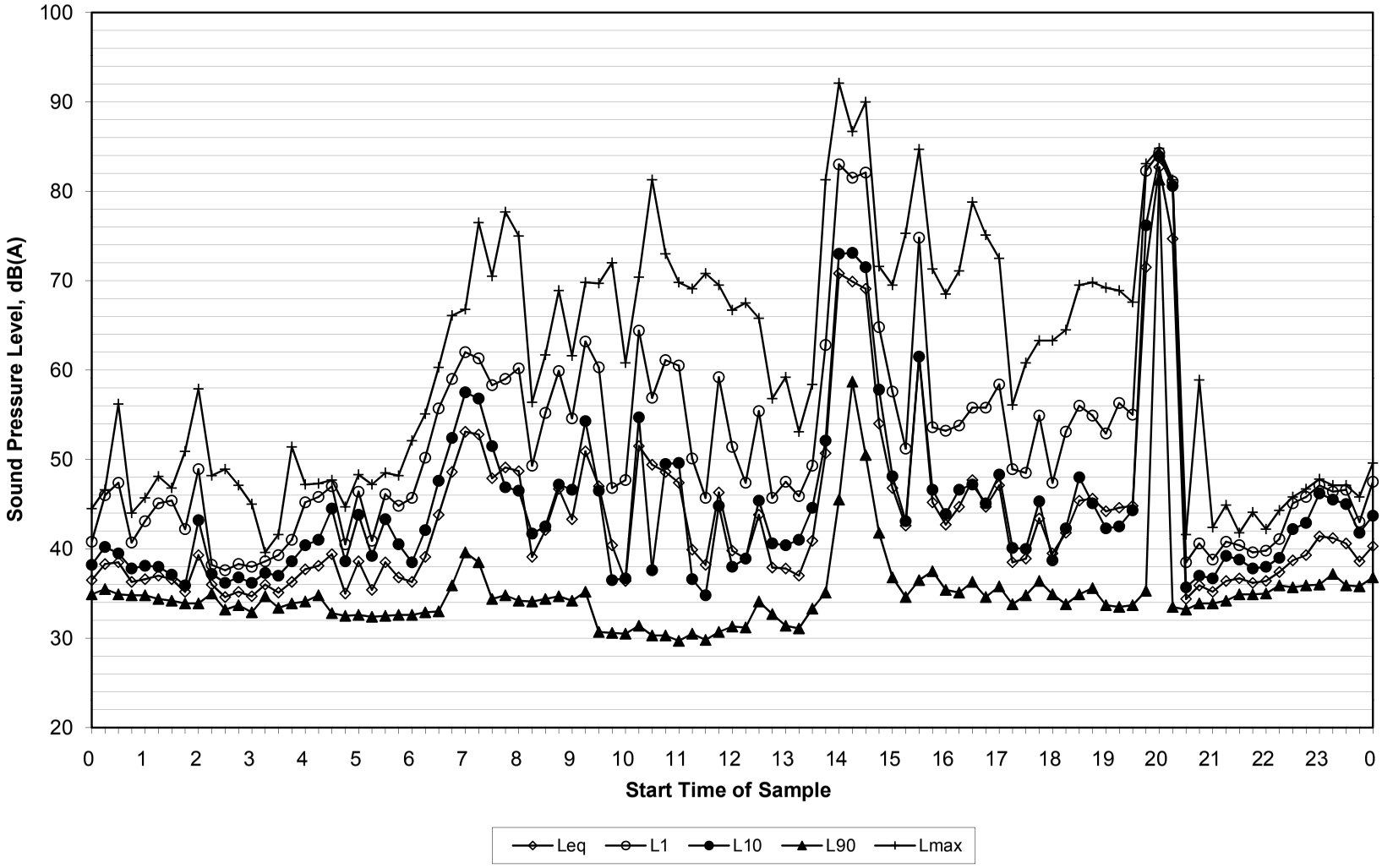
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Location 2
Speirs Residence

Ambient Sound Pressure Levels

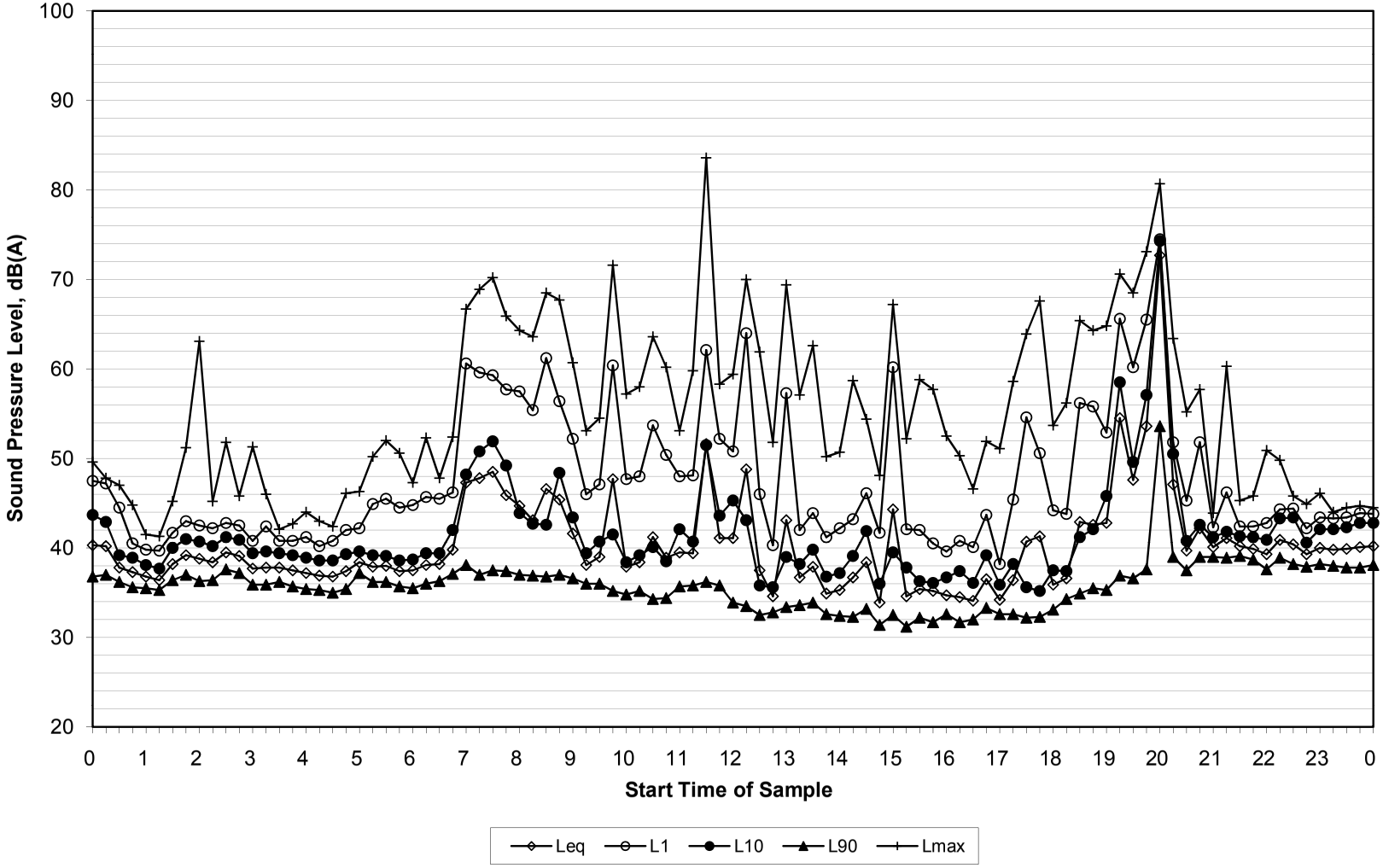
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Location 2
Speirs Residence

Ambient Sound Pressure Levels

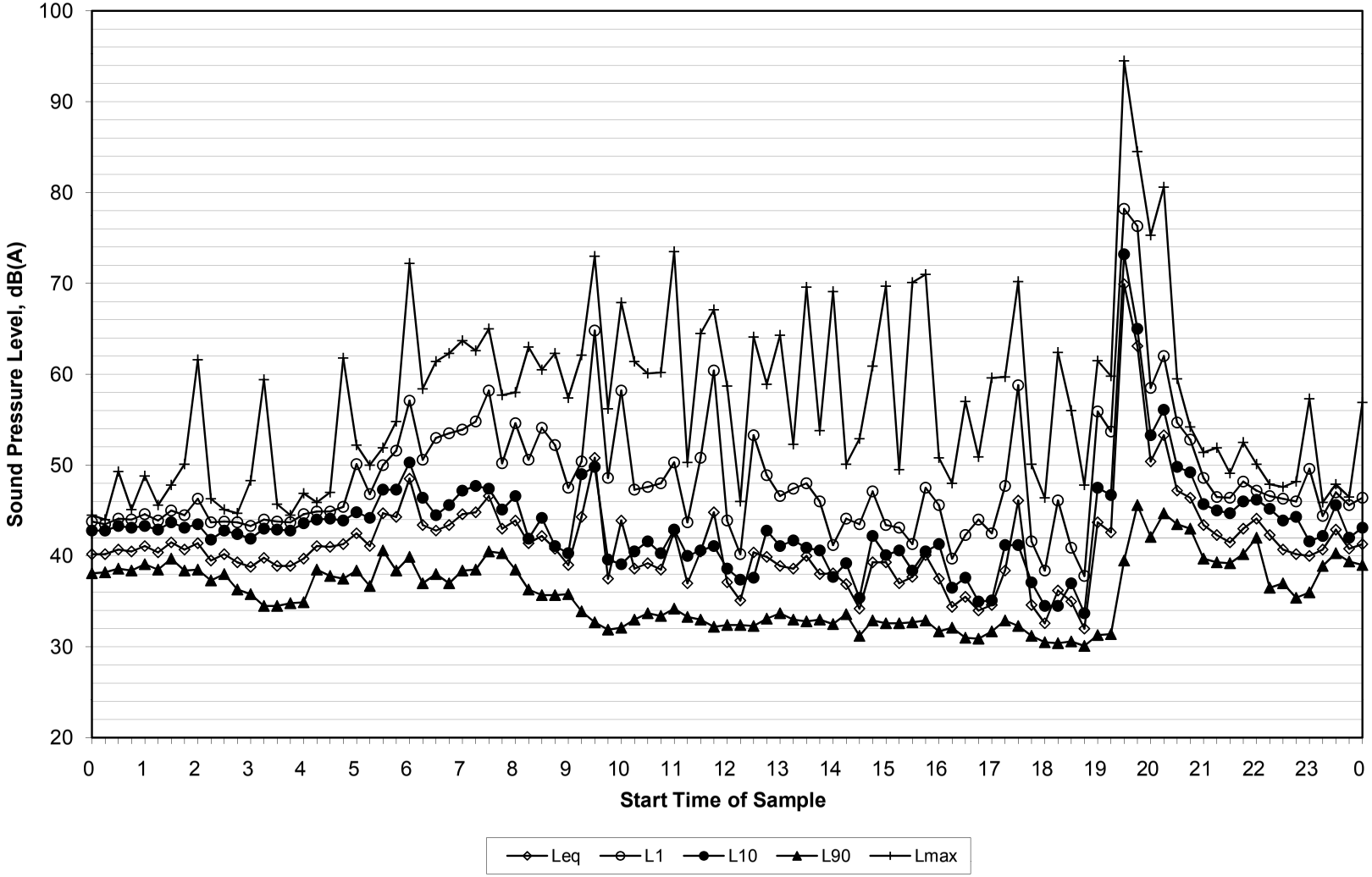
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Ambient Sound Pressure Levels

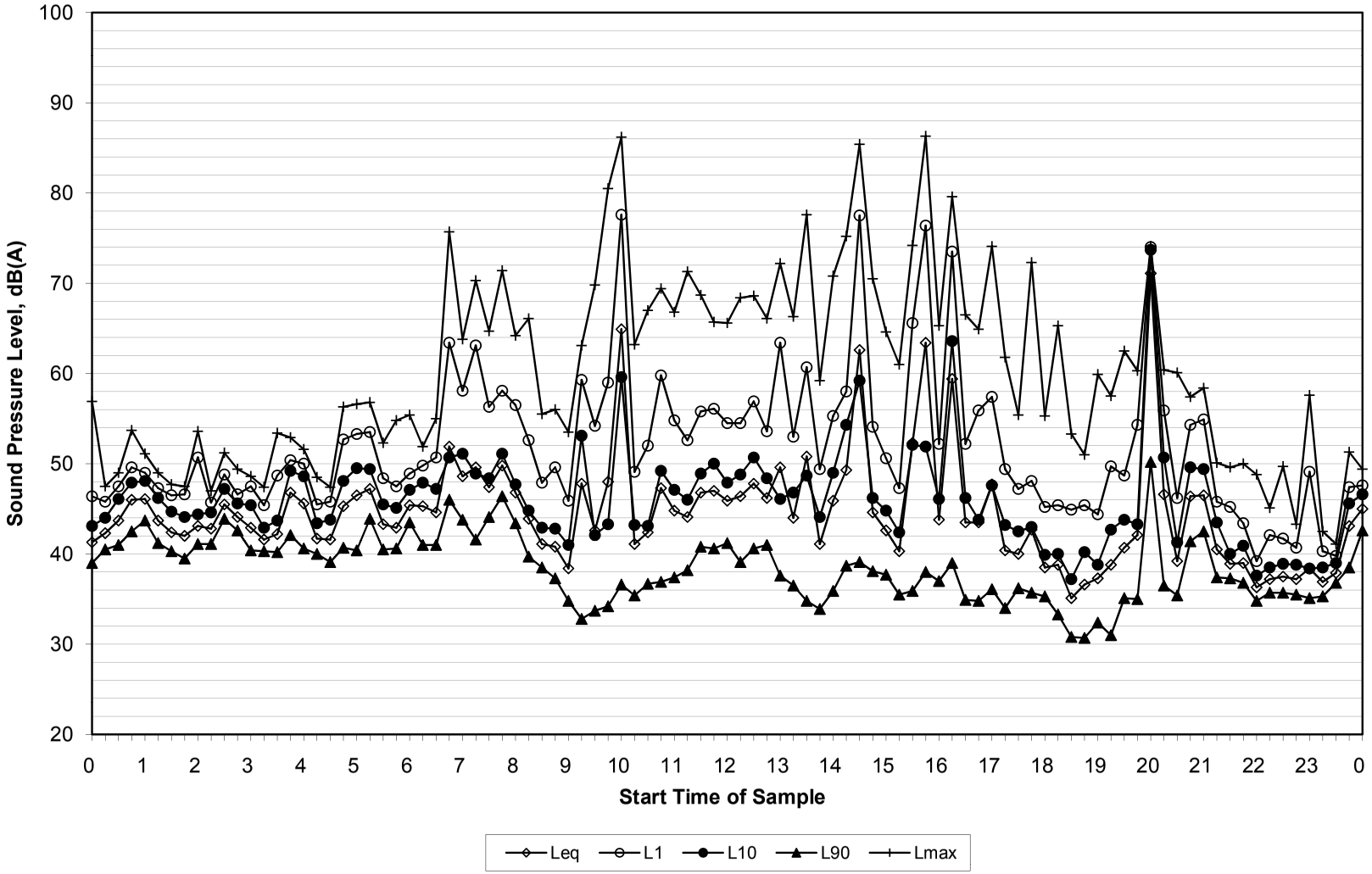
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Ambient Sound Pressure Levels

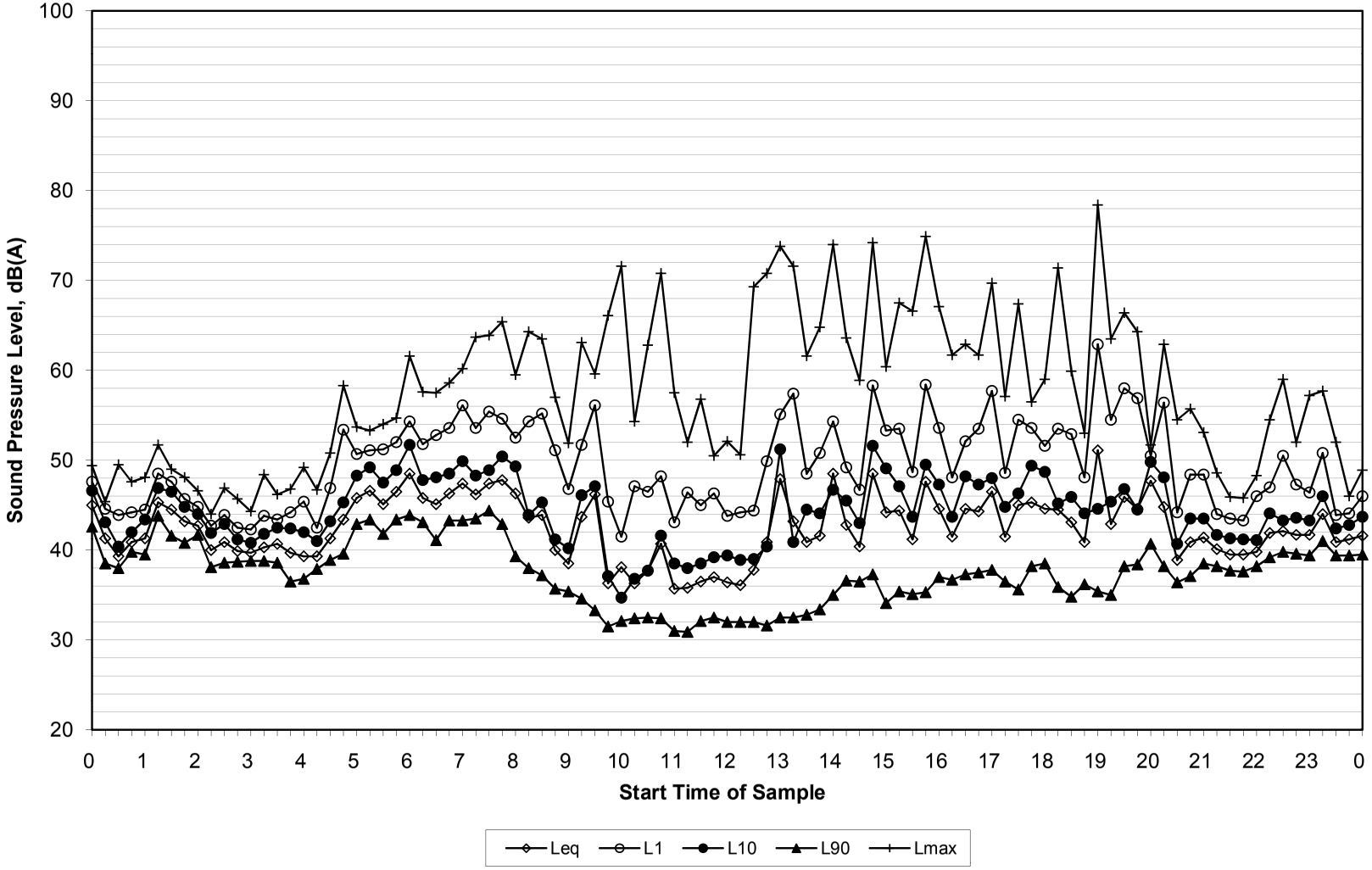
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Ambient Sound Pressure Levels

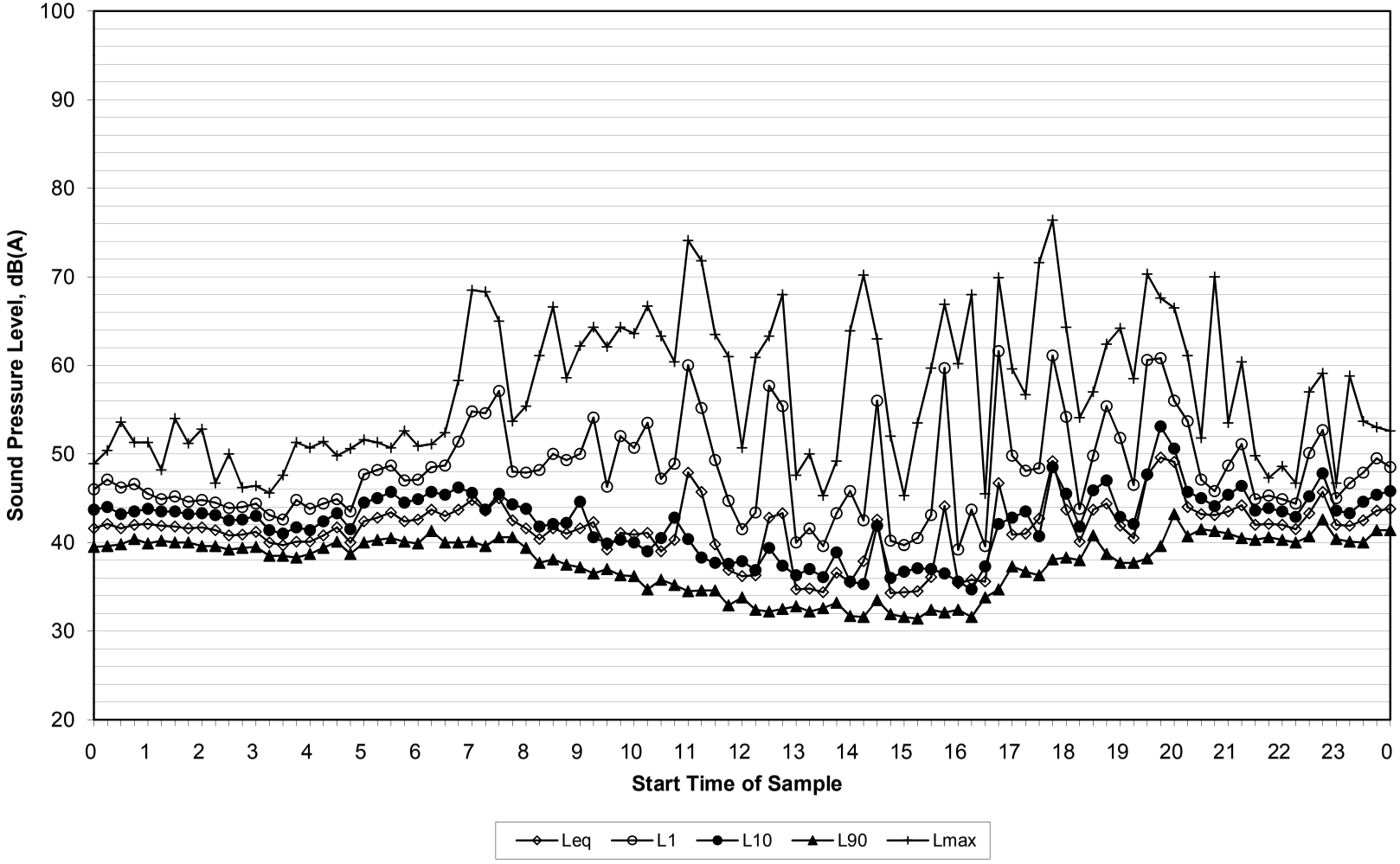
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Ambient Sound Pressure Levels

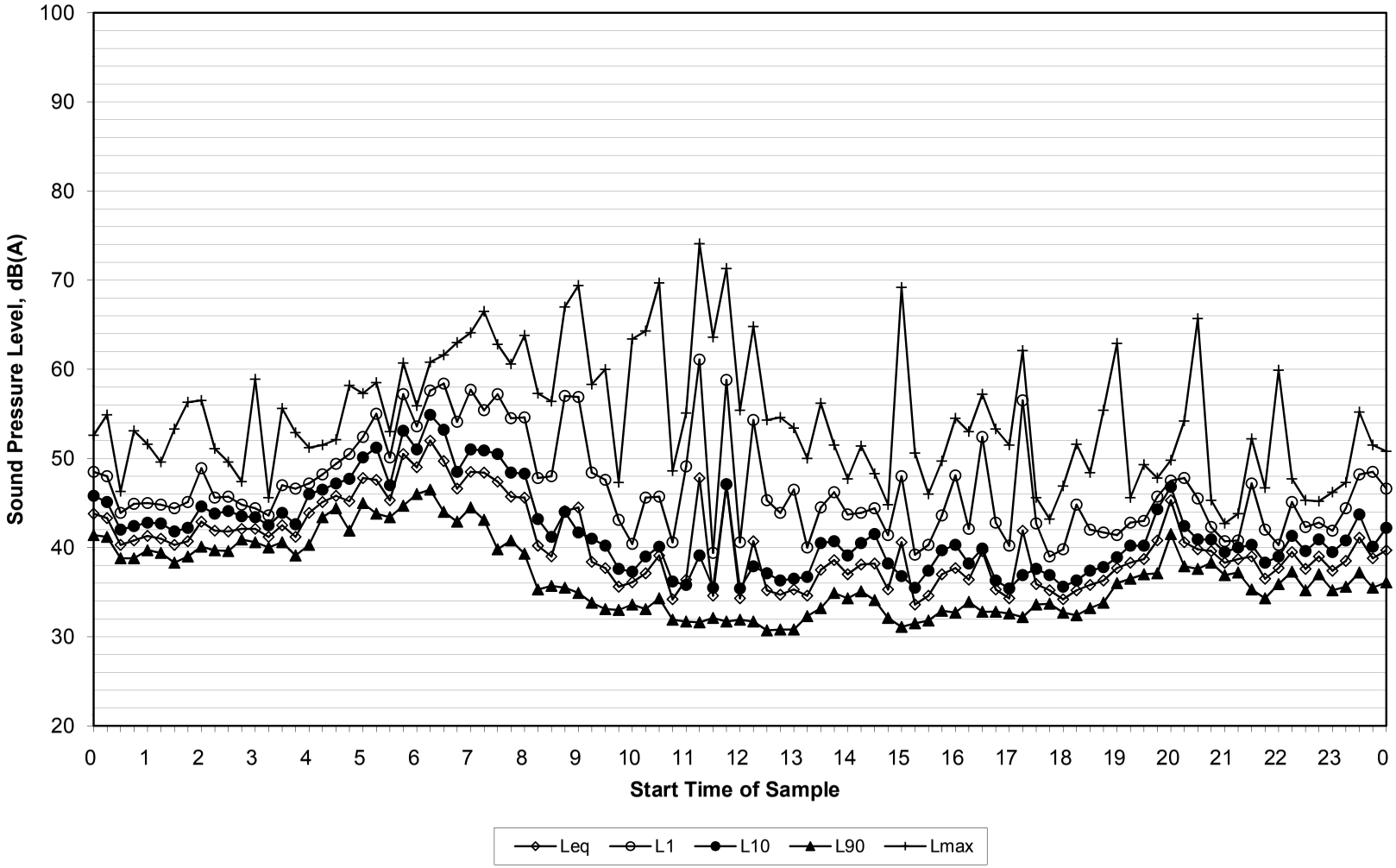
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Ambient Sound Pressure Levels

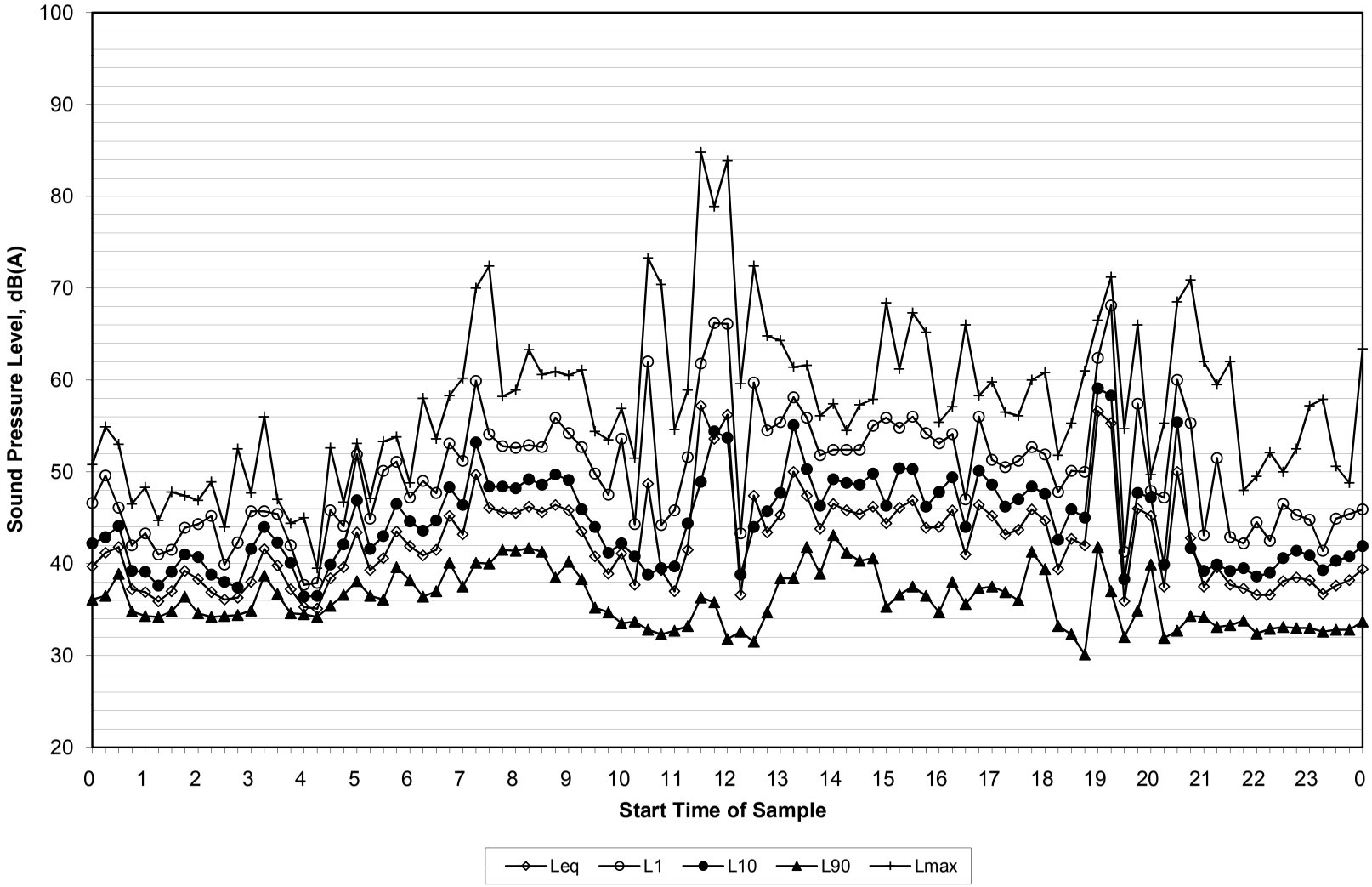
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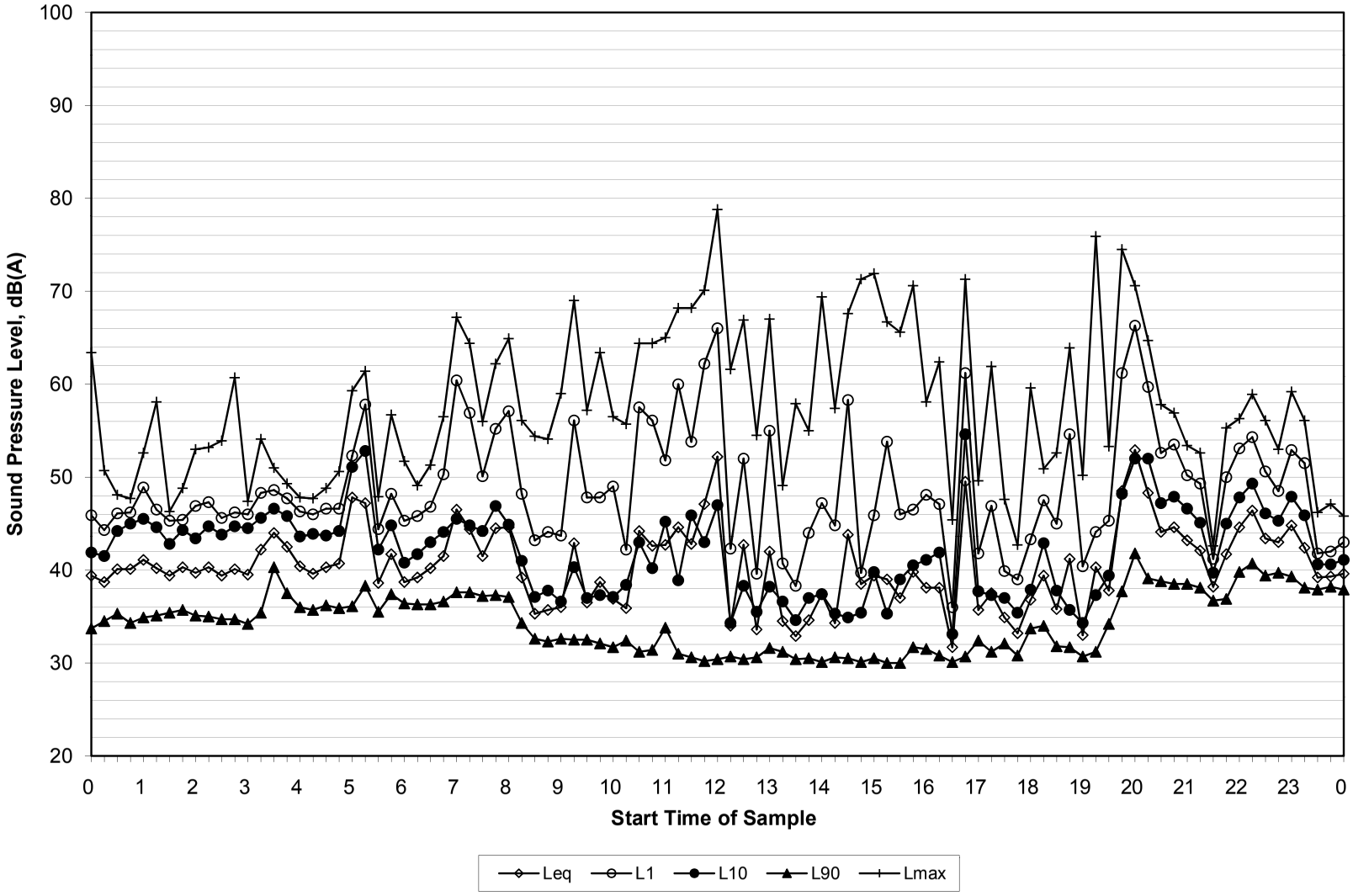
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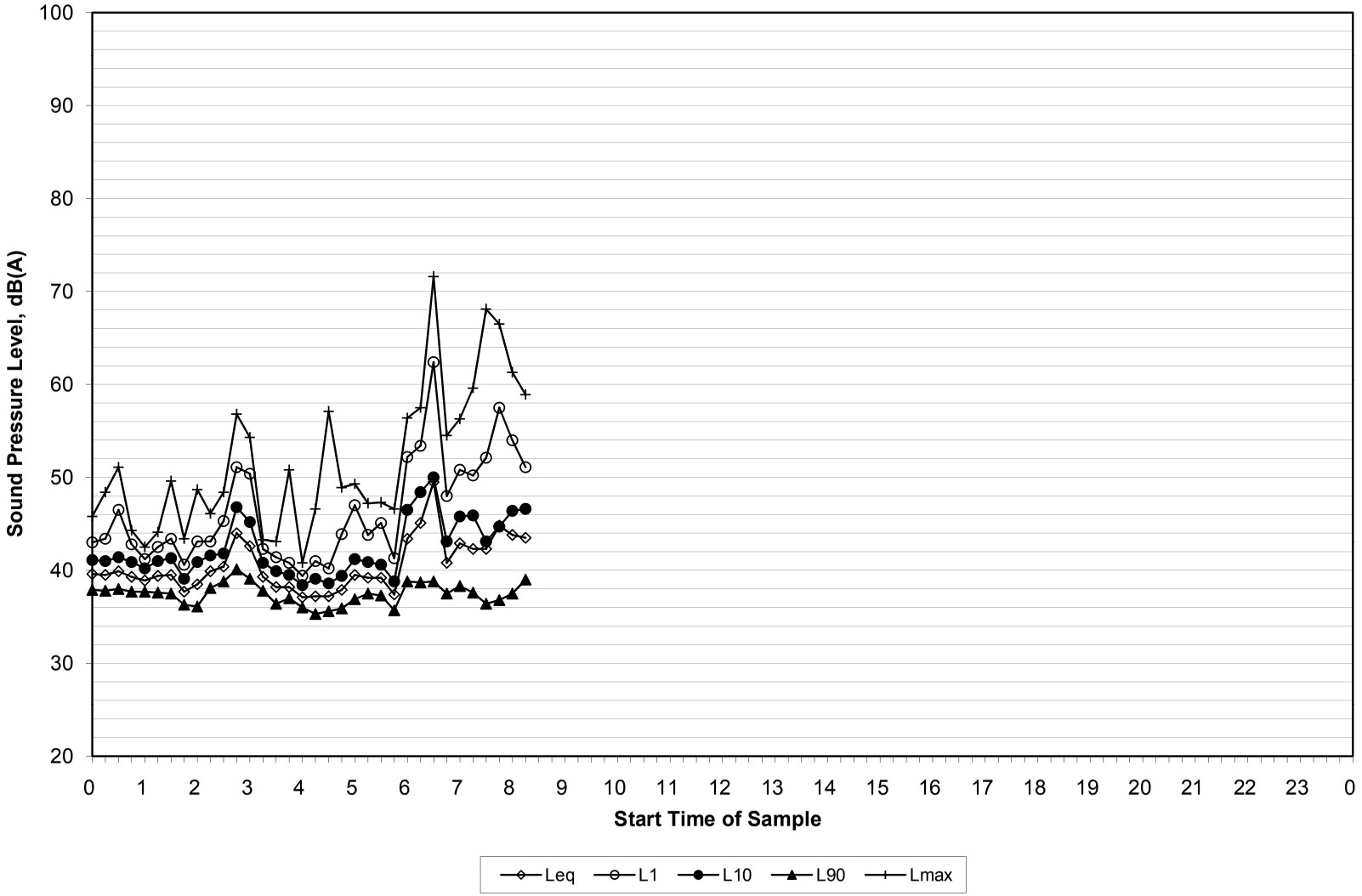
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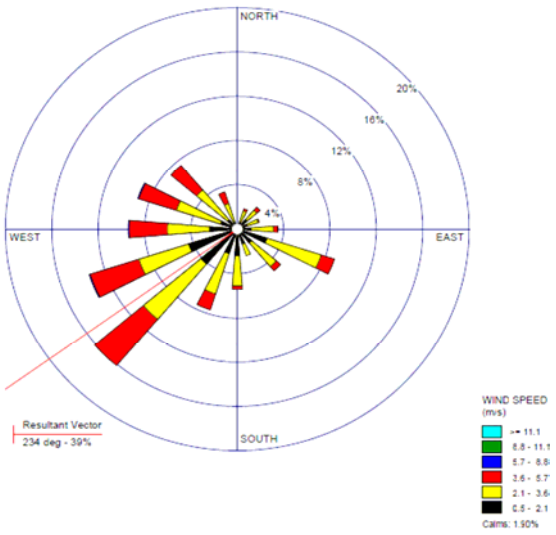
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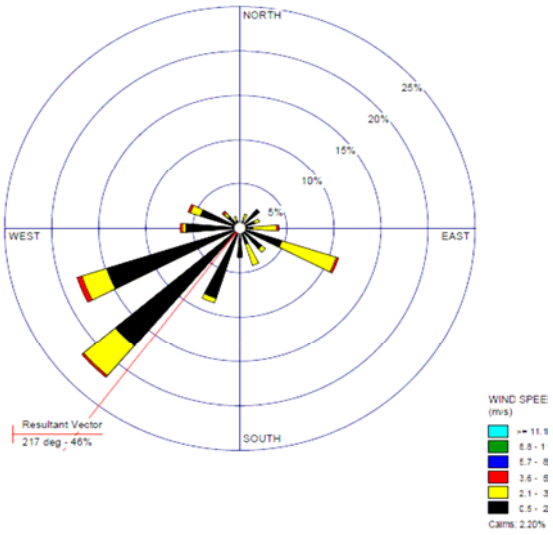


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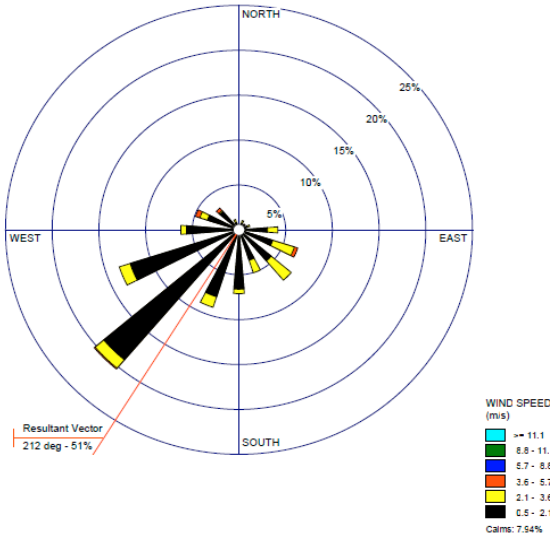
APPENDIX 2: WIND ROSES



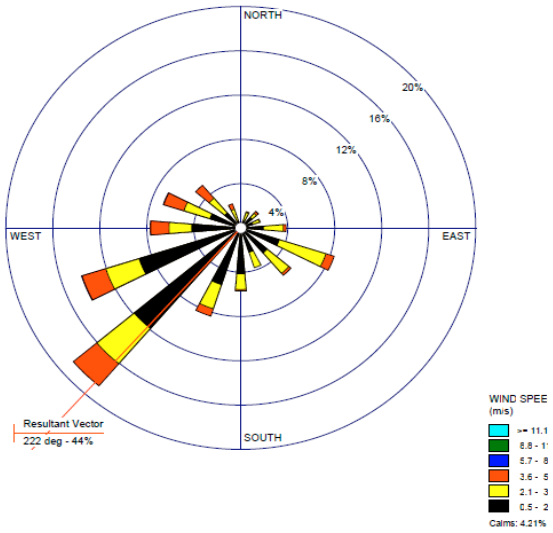
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Spring – Evening

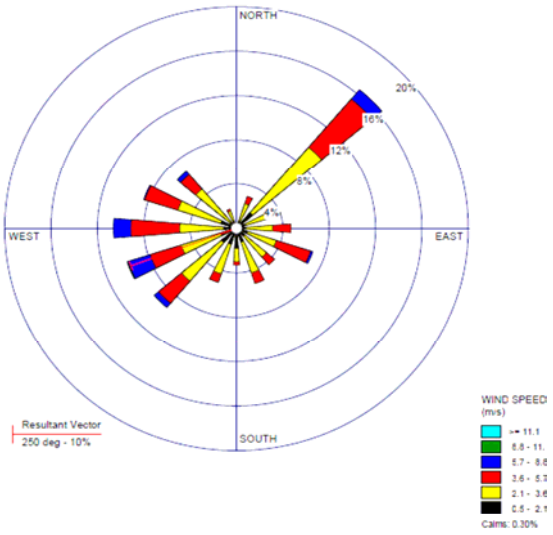


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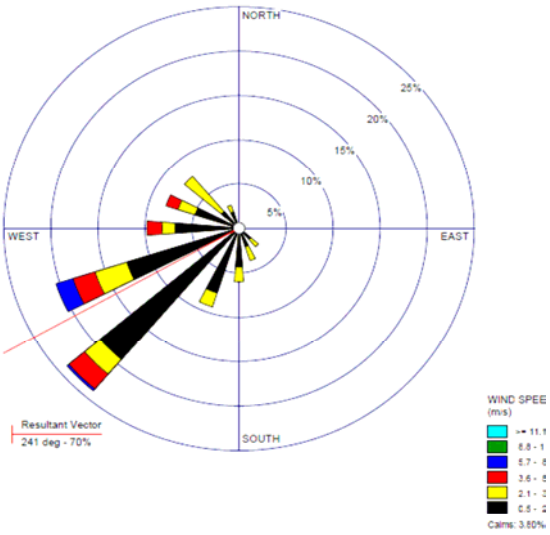


Spring – All Day

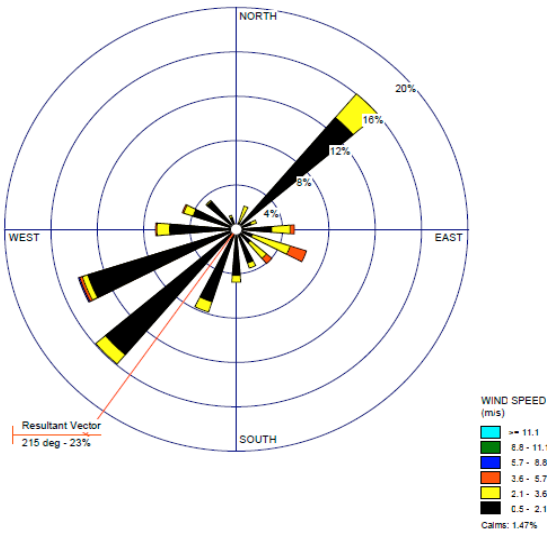
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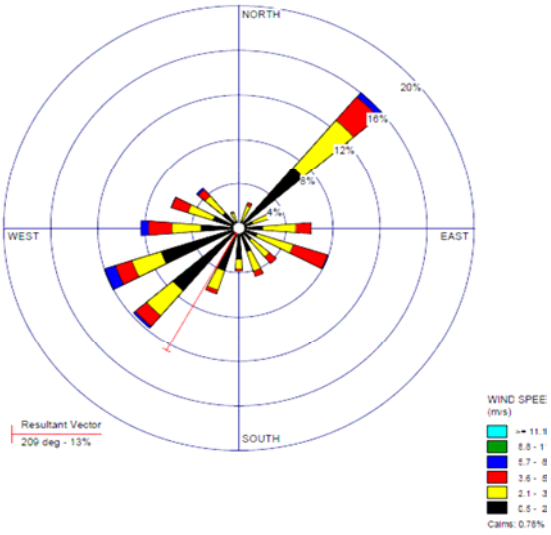
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Summer – Evening

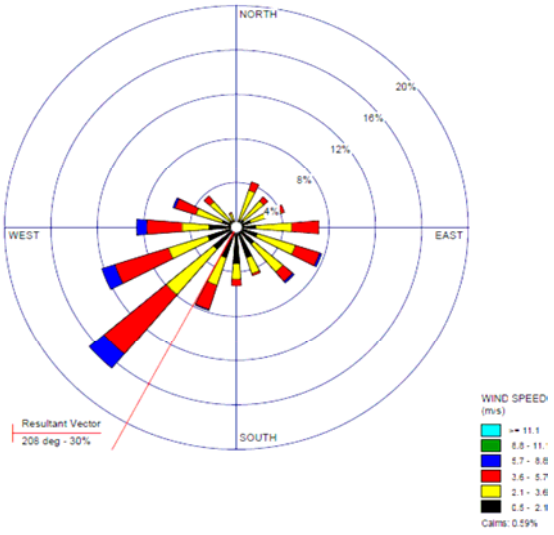


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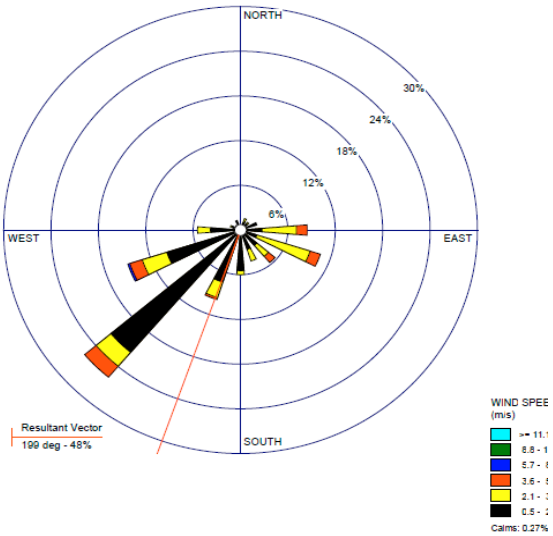


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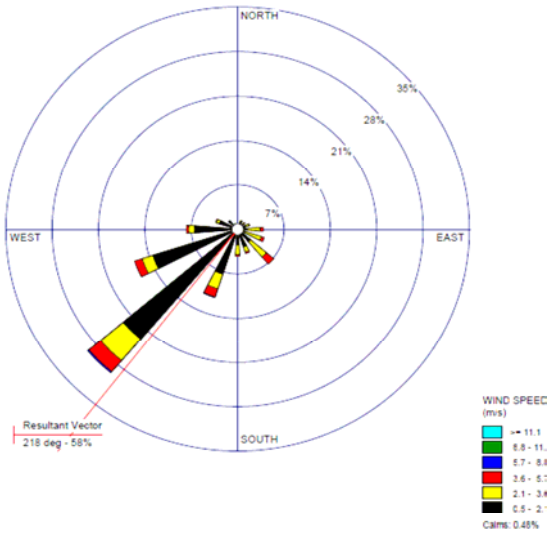
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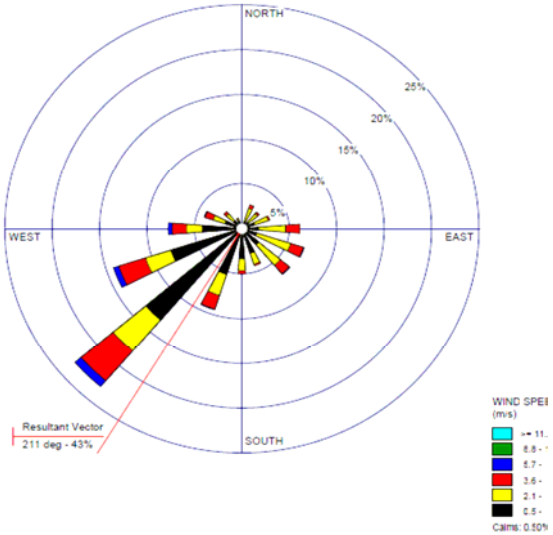
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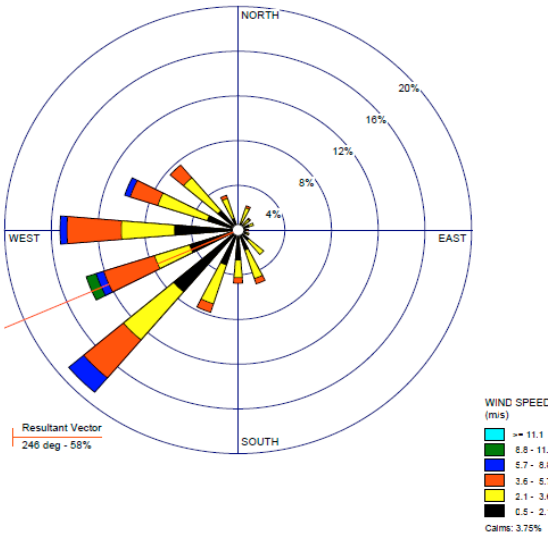


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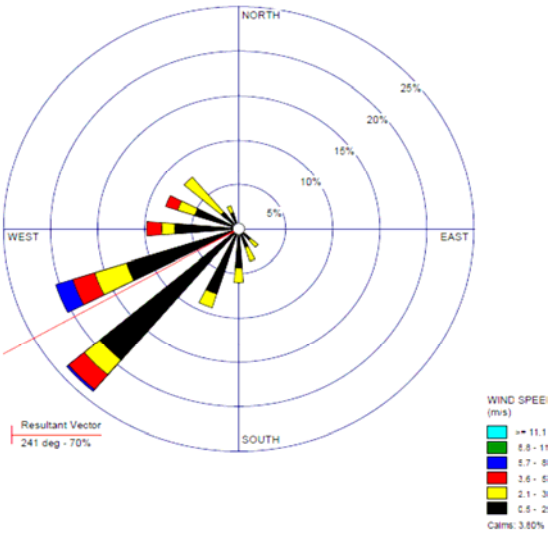


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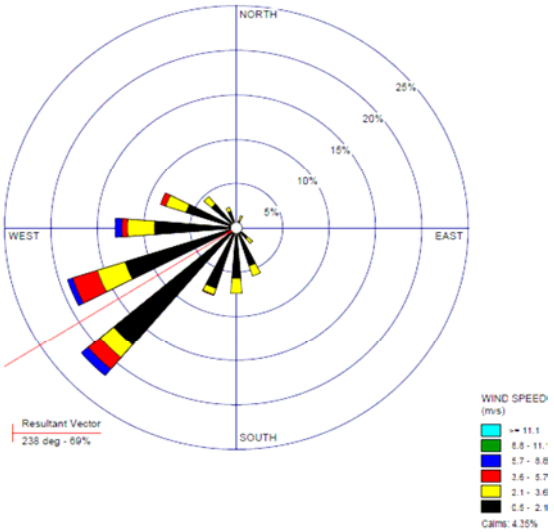
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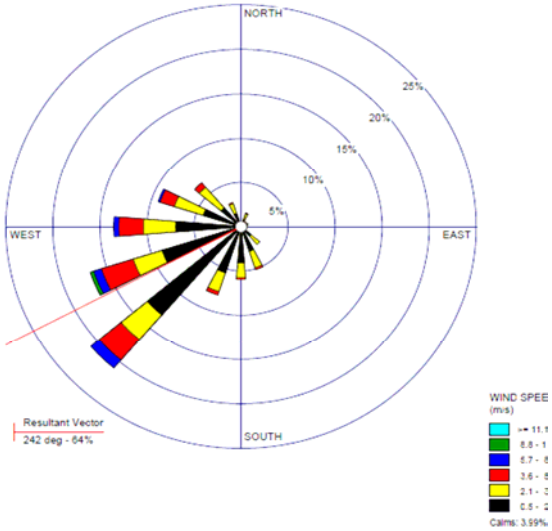
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Winter – Evening



Winter – Night

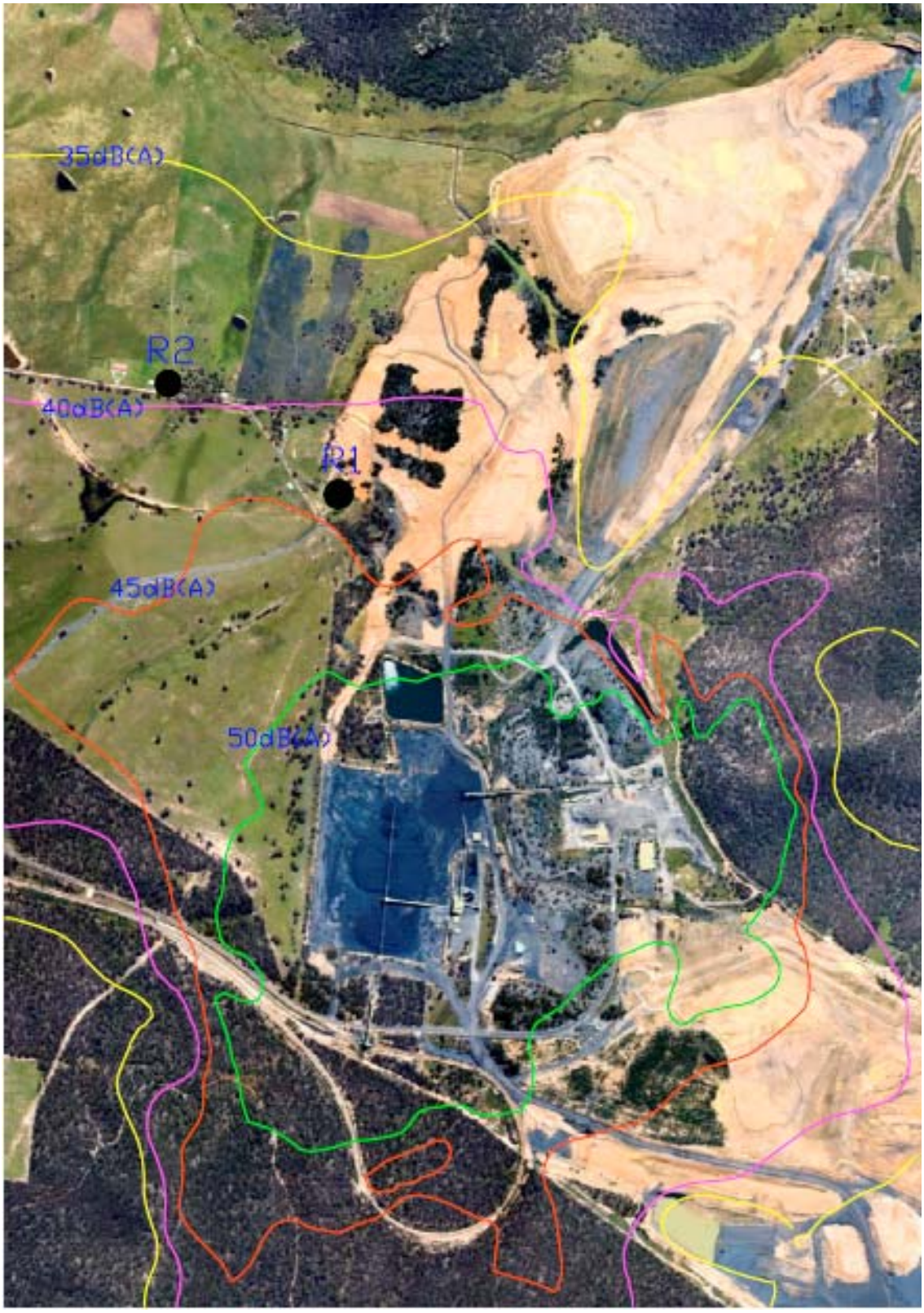


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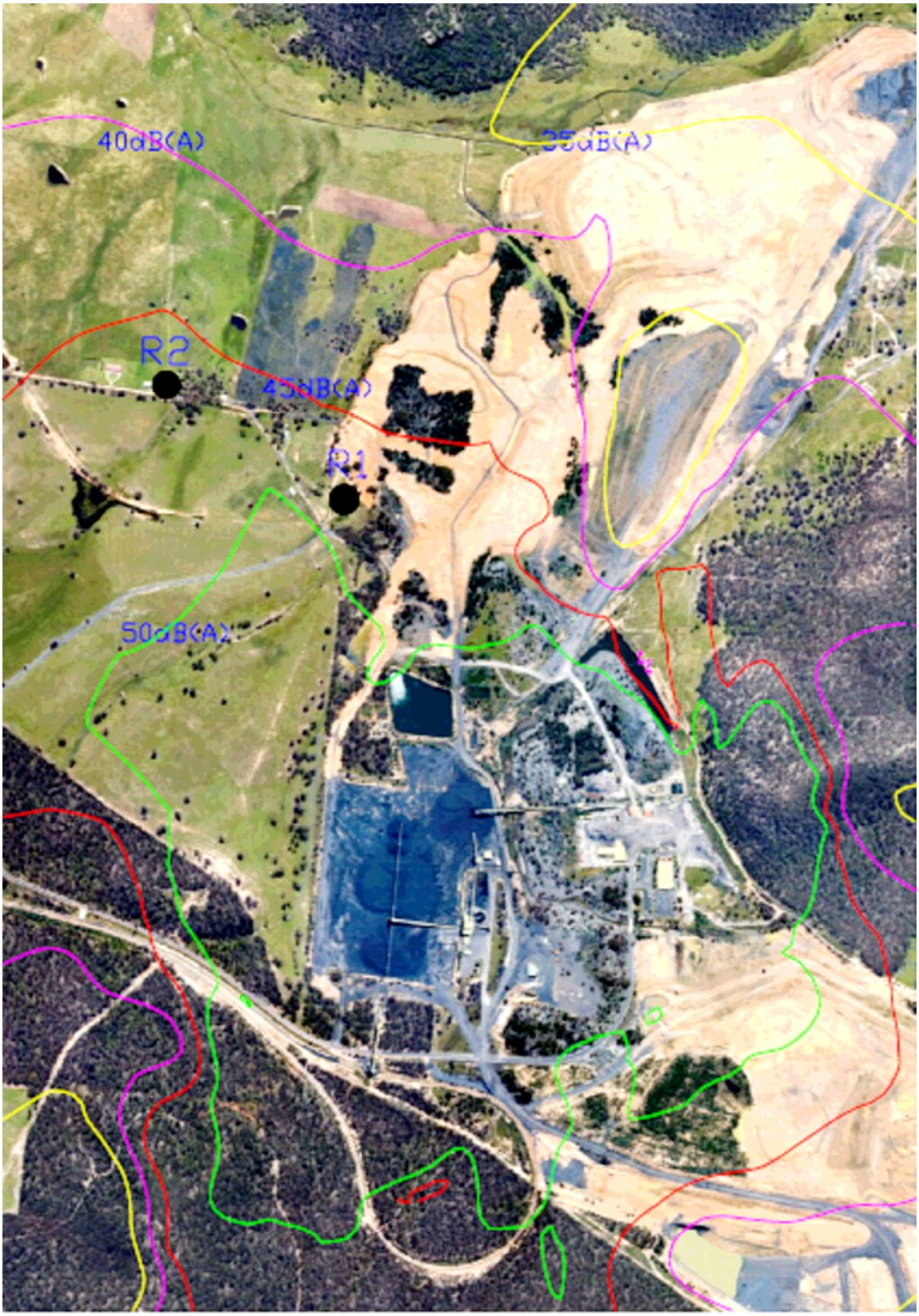
APPENDIX 3: OPERATIONAL NOISE CONTOURS (WITH DOZER) CALM



APPENDIX 4: OPERATIONAL NOISE CONTOURS (WITHOUT DOZER)CALM



APPENDIX 5: OPERATIONAL NOISE CONTOURS (WITHOUT DOZER) 3°C/100m TEMPERATURE INVERSION



APPENDIX 5: DEFINITION OF TERMS

A-Weighted: See dB(A)

Adverse weather: Weather effects that enhance noise (that is, wind and temperature inversion) that occur at a site for a significant period of time (that is, wind occurring more than 30% of the time in any assessment period in any season and/or temperature inversions occurring more that 30% of the nights in winter).

Ambient noise: The all-encompassing noise associated within a given environment. It is the composite of sounds from many sources, both near and far.

Assessment background level (ABL): The single figure background level representing each assessment period-day, evening and night (that is, three assessment background levels are determined for each 24-h period of the monitoring period). Its determination is by the tenth percentile method.

Assessment period: The period in a day over which assessments are made: day (0700-0800h), evening (1800 to 2200h) or night (2200 to 0700h).

Background Noise: The underlying level of noise present in the ambient noise, excluding the noise source under extraneous noise is removed. This is described using the L_{A90} descriptor.

Cumulative noise level: Refers to the total level of noise from all sources.

Day: The period between 0700 and 1800hrs (Monday-Saturday) and 0800-1800 (Sunday and Public Holidays).

dB: Abbreviation for decibel-a unit of sound measurement. Given sound pressure to a reference pressure.

dB(A): Unit used to measure "A-weighted" sound pressure levels. A-weighting is an adjustment made to sound level measurement to approximate the response of the human ear.

A change of 1dB(A) or dB(A) in the level of a sound is difficult to detect, whilst a 3dB(A) to 5dB(A) change corresponds to a small but noticeable change in loudness. A 10dB(A) change corresponds to an approximate doubling or halving in loudness.

The table below lists examples of typical noise levels.

Sound Pressure Level (dBA)	Typical Source	Subjective Evaluation
130	Threshold of pain	Intolerable
120 110	Heavy rock concert Grinding on steel	Very noisy
100 90	Loud car hone at 3m Construction site with pneumatic hammering	Noisy
80 70	Curbside of busy street Loud radio or TV	Loud
60 50	Department store General Office	Moderate to quiet
40 30	Inside private office Inside bedroom	Quiet to very quite
20	Unoccupied recording studio	Almost silent

Default parameters: In assessing meteorological enhancement of noise, refers to set values for weather parameters, such as wind speeds and temperature gradients, to be used in predicting source noise levels.

Equivalent Continuous Noise Levels: The level of noise equivalent to the energy average of noise levels occurring over a measurement period.

Evening: Refers to the period between 1800-2200hrs.

Extraneous Noise: Noise resulting from activities that are not typical of the area. Atypical activities may include construction, and traffic generated by holiday periods and by special events such as concerts or sporting events. Normal daily traffic is not considered to be extraneous.

Feasible and reasonable measures: Feasibility relates to engineering considerations and what is practical to build; reasonableness relates to the application of judgement in arriving at a decision, taking into account the following factors:

- noise mitigation benefits (amount of noise reduction provided, number of people protected)
- cost of mitigation (cost of mitigation versus benefits provided)
- community views (aesthetic impacts and community wishes)
- noise levels for affected land uses (existing and future levels, and changes in noise levels).

Fluctuating Noise: Noise that varies continuously and to an appreciable extent over the period of observation.

Greenfield site: Undeveloped land.

Impulsive Noise: Noise having a high peak of short duration, or a sequence of such peaks. A sequence of such peaks. A sequence of such impulses in rapid succession is termed 'repetitive impulsive noise'.

Intrusive Noise: refers to noise that intrudes above the background level by more than 5 decibels.

L_{A90}: The A-weighted sound pressure level that is exceeded for 90% of the time over which a given sound is measured. This is considered to represent the background noise.

L_{Aeq}: The equivalent continuous noise level – the level of noise equivalent to the energy average of noise levels occurring over a measurement period.

Long-term annoyance: Prolonged annoyance over months and years.

Median: The middle value in a number of values sorted in ascending or descending order. Hence, for an odd number of values, the value of the median is simply the middle value. If there is an even number of values the median is the arithmetic average of the two middle values.

Meteorological conditions: wind and temperature inversion conditions.

Most-affected locations(s): Locations that experience (or will experience) offensive noise from the noise source under consideration. In determining these locations, one needs to consider existing background levels, exact noise source locations(s), distance from source (or proposed source) to receiver, and any shielding between source and receiver.

Negotiated agreement: An agreement involving the negotiation of an achievable noise limit in cases where the project specific noise levels cannot be met. The agreement is negotiated between the proponent and the EPA or the proponent and the community. Such an agreement is reached through balancing the merits of a development, the feasibility and reasonableness of available mitigation measures and the noise impacts produced.

Night: The period between 2200 and 0700 (Monday-Saturday) and 2200-0800 (Sunday and Public Holidays)

Noise criteria: The general set of non-mandatory noise level targets for protecting against intrusive noise (for example, background noise plus 5dB) and loss of amenity (for example, noise levels for various land uses).

Non-mandatory: With reference to the proposed policy, means not required by legislation. The proposed policy specifies criteria to be strived for, but the legislation does not make these criteria compulsory. However, the policy will be used as a guide to setting statutory (legally enforceable) limits for licenses and consents.

Performed-based goals: Goals specified in terms of the outcomes/performance to be achieved, but not in terms of the means of achieving them.

Rating Background Level (RBL): the overall single-figure background level representing each assessment period (day/evening/night) over the whole monitoring period (as opposed to over each 24-h period used for the assessment background level). This is the level used for assessment purposed. It is defined as the median value of:

- all the day assessment background levels over the monitoring period for the day
- all the evening assessment background levels over the monitoring period for the evening; or
- all the night assessment background levels over the monitoring period for the night.

Receiver: The noise-sensitive land at which noise from a development can be heard.

Stationary noise sources: Sources that do not generally move from place to place, eg. industrial or commercial sources. In general, these include:

Individual stationary sources such as:

- heating, ventilating and air conditioning (HVAC) equipment,
- rotating machinery,
- impacting mechanical sources,
- other mechanical equipment and machinery such as conveyors.

Mobile sources confined to particular location such as draglines and haul trucks.

Facilities, usually comprising many sources of sound, including:

- industrial premises,
- extractive industries,
- commercial premises,
- warehousing facilities,
- maintenance and repair facilities.

(In this case, the stationary source is understood to encompass all the activities taking place within the property boundary of the facility).

Temperature inversion: An atmospheric condition where temperature increases with height above the ground.



APPENDIX F

Mine Water Balance

AECOM



Continued Operations at Baal Bone Colliery Mine Water Balance

The Wallerawang Collieries Limited

9 October 2009
Document No.: 60098124-DO-008

Mine Water Balance

Prepared for

The Wallerawang Collieries Limited

Prepared by

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ABN 20 093 846 925

9 October 2009

60098124

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Quality Information

Document Mine Water Balance

Ref 60098124

Date 9 October 2009

Prepared by Justin Watts & Chris Gagg

Reviewed by Andrew Kielniacz, Principal Engineer

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	2/07/2009	Draft	Amanda Kerr Senior Environmental Engineer	
B	24/07/2009	Draft	Amanda Kerr Senior Environmental Engineer	
C	27/08/2009	Final Draft	Amanda Kerr Senior Environmental Engineer	
D	30/09/2009	Final	Amanda Kerr Senior Environmental Engineer	
	15/12/2009	Correction on Page 16	Amanda Kerr Senior Environmental Engineer	

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Executive Summary

The Wallerawang Collieries Limited has approval to operate the Baal Bone mine up to late 2010. Baal Bone is seeking approval to complete mining of Longwalls 29 to 31 as well as the remnant areas within existing workings. These mining activities are expected to be complete within a nominal 10 to 15 years. To demonstrate that the current water management practises are sustainable (i.e. do not require large inputs of potable water or require discharges of contaminated process water off site) a mine water balance has been developed.

Several catchment areas on the site have been identified including the larger rehabilitated areas in the south and north of the site and the reject emplacement area. There are also two smaller catchments in the centre of the site, the pit top area along with the Coal Handling and Preparation Plant (CHPP) and coal stockpile areas. Runoff is collected from these operational areas of the site and used to supplement process water.

On average at least 50% of the process water used on site is recycled water recovered from the tailings through the leachate recovery process. The pit top, stockpile and CHPP areas do not provide enough runoff to supplement the remaining volumes of on-site water. The process water requirements are currently supplemented with water pumped from the operational areas of the mine (Adit No. 3 and Adit No. 5) and the Boxcut Sump. On average, approximately 63% of the total water used on site is recycled water.

A surplus of water at the mine is generated as a result of groundwater infiltration, however this water is pumped to the environment via two licensed discharge points: LD3 and LD6. Approximately 1.5GL/annum of mine water is pumped directly to Ben Bullen Creek providing environmental flows to downstream users.

The current water management strategy is sustainable if the current practises are maintained. The process water demands are expected to remain constant during the mining of Longwalls 29 to 31 and remnant areas within the existing workings including the use of all surface runoff water collected on site. The high level of water recycling on site ensures that any discharges off site are high quality. The water that leaves the site is runoff generated from rehabilitated areas and from mine dewatering. Other water collected from potentially contaminated areas is collected and used on site.

The existing license conditions allow all groundwater infiltration into the mine workings to be discharged off site via both LD3 and LD6. It is also predicted that there is sufficient mine/groundwater from both Adit No. 5 and the Box Cut Sump to supplement the process water circuit and ensure there is sufficient water for operation of the mine taking into account potential effects of future climate change.

1.0 Introduction

1.1 Project Background

The Baal Bone Mine is owned and operated by The Wallerawang Collieries Limited (TWCL) under a development approval which extends to late 2010. Baal Bone intends to continue mining remaining parts of the coal seam including the mining of Longwalls 29 to 31 as well as remnant areas within the existing workings. It is anticipated that the mining of these areas would be completed within a nominal 10 to 15 years. In order to obtain approvals to continue mining past 2010, TWCL has commissioned the preparation of an Environmental Assessment (EA) in support of an application for continued development approval and to demonstrate operations are sustainable during this period (i.e. do not require large inputs of potable water or require discharges of contaminated process water off site).

As part of this EA process it is important to demonstrate that the existing practises to manage the site water balance are sustainable during future operation. As part of this assessment, Baal Bone Colliery has engaged AECOM to review and update the site mine water balance, providing a basis to demonstrate that the current water management practises are sustainable for future operations.

1.2 Scope of Work

AECOM were engaged to review and update the mine site water balance model.

The project involved the following key tasks:

- Review existing information;
- Determine inputs, outputs and internal water use at the site;
- Develop a water balance model to demonstrate sustainable water management, including assessment of potential impacts due to climate change; and
- Provide a report which summarises key information and assumptions.

The focus of this report is on the modelling of the water balance to demonstrate that the existing water management practises are sustainable in that the ongoing operation of the site will not:

- Require large inputs of potable water; or
- Result in discharges of contaminated process water off site.

2.0 Site Characteristics

The site is located approximately 25 kilometres north west of Lithgow. The area was originally open cut mined, down to a depth of up to 15m below natural surface levels in some areas of the site. A more recent open cut void to the south of the site was reserved for the disposal of coarse reject and tailings. The remainder of the site has been rehabilitated in stages. The pit top area, CHPP and the stockpile areas are located in the centre of the site.

A layout of the site showing key features is provided as **Appendix A**.

2.1 Topography

Large areas of the site have been filled with overburden, contoured and rehabilitated with native grass and bushland species. An overview of the site showing the boundary of the mine site and the major catchment areas within the site boundary is attached in **Appendix A**. The largest catchment areas within the site are rehabilitated open cut areas and reject emplacement areas.

The pit top area, Coal Handling and Preparation Plant (CHPP), coal stockpile and the rail loading areas are located in the centre of the site. The rail loading areas form part of the area categorised as the pit top area, however runoff from some of these areas flows into Ben Bullen Creek.

Details of the seven major catchment areas identified within the mine site are summarised below in **Table 1**.

Table 1: Summary of the Characteristics of the Catchment Areas within the Baal Bone Mine Site

Description of Catchment	ID	Area
North Rehab Area (Box Cut)	A1	38.5 ha
North Rehab Area (Remainder)	A2	91.8 ha
Ben Bullen Creek Catchment	A3	49.6 ha
Stockpile/CHPP Area	A4	20 ha
Pit Top Area	A5	5.4 ha
South Rehab Area	A6	48.8 ha
Reject Emplacement Area	A7	53.4 ha

The original Ben Bullen Creek has been diverted around and through the centre of the mine site. Water can discharge from the site to Ben Bullen Creek via a constructed overflow weir and pipeline with manually operated gate valve in the Overshot Dam.

The southernmost area of the mine has been reserved for reject emplacement and drains to old open cut voids. There are also several overburden stockpiles in the area that affect local runoff patterns. Runoff from areas in the southern rehabilitation area is diverted to Ben Bullen Creek. A portion of the runoff from the northern rehabilitation area is diverted to the Ben Bullen Creek, with the remaining runoff directed to the Boxcut Sump.

Most of the infiltration from both the southern and northern rehabilitated areas migrates via subsurface flows to the Box Cut Sump.

2.1.1 Water Storages

There are four major water storages on the existing site. A description of the water storages and approximate volume is summarised below in **Table 2**. The Overshot Dam contains an overflow weir and a pipe fitted with a gate valve, which provides a controlled discharge arrangement in accordance with Baal Bone's licence under the *Water Act 1912.*

Table 2: Summary of the Site Water Storages and Approximate Volumes of Each Storage

Description	Volume (ML)
Dirty Water Dam	37
Process Water Dam	55
Leachate Dam	50 (approx)
Boxcut Sump	6.9
Overshot Dam	unknown

2.2 Potable Water Connections

Potable water is sourced from the Fish River water supply which is owned and operated by State Water. Baal Bone has two connections to the potable water supply each with individual water meters plus additional water meters to track the use of potable water on the mine site. Approximately 61 kL/day (or approx 22 ML/annum) of potable water is used at the mine site a portion of which is primarily used for drinking, showers and toilet flushing with the remainder diverted for underground use. Up to 50% of the potable water is used in the onsite amenities.

The total potable water flow to the site is measured using Flow Meter No. 8 (22 ML/annum). Flow Meter No. 10 and Flow Meter No. 12 measure the breakdown of potable water to the pit top amenities and potable water to the underground areas. Therefore the sum of Flow Meter No. 10 and Flow Meter No. 12 should be equivalent to the total potable water use on site. There is a minor discrepancy (deficit of 7 ML/annum) between the total potable water supply to the site and the sum of the potable water use in these two areas. Baal Bone is continuing investigations to identify the cause of the missing potable water but have confirmed via visual inspections that the minor discrepancy is not caused by leakage.

2.2.1 Other Water Sources

There are two existing production bores on site which can be used to supplement site water if required. The bores are 80BL136703 and 80BL135509.

Any flows to the site from upstream via Ben Bullen Creek have not been included in the site water balance. Although intercepted via the Overshot Dam, the flows to the site from Ben Bullen Creek have been ignored as they are not used on site and are allowed to discharge downstream.

2.3 Discharge Points

The discharge of excess mine water from the site is licensed under the *Protection of the Environment Operations Act 1997* by the Department of Environment and Climate Change (DECC). The details of the licensed discharge points under the Environmental Protection Licence (EPL) No. 765 are summarised in **Table 3** and **Figure 1**.

Table 3: Summary of Licensed Discharge Points for Baal Bone Colliery

EPA ID No.	Type of Discharge	Flow Limit	Description
2	Discharge To Utilisation Area	-	LD2 - Discharge from STP to transpiration bed
3	Discharge to waters	-	LD3 - South mine dewatering discharge point
6	Discharge to waters	12,000 kL/day	LD6 - North mine dewatering discharge point
11	Discharge to waters	-	LDP1 - Overshot Dam to Ben Bullen Creek

The only discharge point with a discharge flow limit is LD6.

The two main mine dewatering bores are located at Longwall 1 and Longwall 19. Water discharging from the Longwall 1 dewatering bores is piped via a surface pipeline to an aerator and settlement pond at LD3. Water discharging from Longwall 19 dewatering bore also passes through an aerator with a larger settlement/retention basin prior to discharge at LD6. An overland pipeline has been installed to redirect water from both these locations back into the colliery process water circuit during periods of water deficit.

All site discharge points eventually flow into Jews Creek downstream of the site.

Figure 1: Licensed Discharge Points



2.4 Water Quality

The quality of water discharged from points LD3 and LD6 and LDP1 is monitored on a monthly basis (during discharge). Pollution concentration limits for these monitoring points is summarised in **Table 4.**

Table 4: Pollutant Concentration Limits under EPL No. 765

Site	Oil and Grease	pH	Total Suspended Solids	Total Iron
Units:	mg/L	pH	mg/L	mg/L
LD3	10	6.5 – 8.5	50	-
LD6	-	6.5 – 8.5	50	1.0
LDP1	10	6.5 – 8.5	50	1.0

The conditions of the EPL also require that water quality monitoring be undertaken at the discharge of the STP to the transpiration bed, as summarised in **Table 5**.

Table 5: EPL Monitoring Requirements

EPL Monitoring Location	Pollutants to be Monitored
Point 2	Biological Oxygen Demand (BOD), Feacal Coliforms, Nitrogen (total) (TN), Oil and Grease, Phosphorous (total) (TP), Total Suspended Solids (TSS), pH
Point 3	Electrical Conductivity (EC), Oil and Grease, Sulfate, Total Iron, TSS, pH
Point 6	EC, Oil and Grease, Sulfate, Total Iron, TSS, pH
Point 11	EC, Oil and Grease, Sulfate, Total Iron, TSS, pH
Point 12	EC, Oil and Grease, Sulfate, Total Iron, TSS, pH

In addition to the EPL required quality monitoring, Baal Bone has implemented a comprehensive monitoring regime throughout the remainder of the site, including monthly monitoring of an additional 20 sampling points both within and external to the site, and analysis for a wider range of pollutants than required by the EPL.

3.0 Water Balance

3.1 Overview

A schematic representation of the mine water balance has been illustrated in **Appendix D.**

The mine water balance has been developed by considering the major inputs of water to the mine water cycle. The major inputs include:

- Runoff from the main catchment areas on the mine site;
- Potable water from the Fish River water supply (refer **Section 2.2**); and
- A portion of the groundwater inflow to the underground mining areas.

The focus of this investigation is on the overall management of process water at the site, therefore the key consideration in this water balance is on the process water cycle. Runoff from rehabilitated areas is diverted to the overflow point via Ben Bullen Creek. Runoff from the pit top, stockpile and CHPP areas is collected and diverted to the Dirty Water Dam after preliminary treatment (e.g. grit and oil removal). Runoff from these areas is only a relatively minor input to the total process water cycle.

3.2 Groundwater

The topography of the site means that groundwater flows from surrounding areas outside the site into the underground mining areas. It is difficult to quantify the volumes of groundwater that flow into the underground mining areas with any accuracy, however preliminary investigations suggests that it is in the order of 4 ML/day. The nature of the mine water balance is such that any groundwater flowing into the workings is generally pumped offsite directly to Ben Bullen Creek.

A portion of the groundwater that flows onto the operational areas of the mine is pumped out of the No. 5 adit to the Dirty Water Dam via a sedimentation trap and oil skimmer to ensure that any pollutants can be captured. For the purposes of the mine water balance historic flow records have been maintained which provide an average volume of mine water to be dewatered from the operational mining areas. It has been assumed that the volumes of water to be collected and dewatered from these operational areas of the mine will not change significantly as there are no major changes operational planned at the mine.

In 2008, approximately 1.5GL/annum of groundwater was pumped from the mine to Ben Bullen Creek. These environmental flows are extracted by downstream users. The management of groundwater is directly related to the underground mining activities. Some areas of the mine must be dewatered to ensure the safety of staff working in the underground areas. The volume of groundwater removed from the mine in 2008 is representative of the volume of groundwater that needs to be dewatered annually to ensure safe working conditions in the areas to be mined over the next 10 to 15 years. Therefore the 2008 records have been used as a basis for the mine water balance.

3.3 Runoff

The first step in determining the runoff from the site was to analyse the rainfall and evaporation patterns observed at the Baal Bone site.

3.3.1 Climate Information

Daily historical rainfall and evaporation data was supplied by Xstrata for the period 1st January 1889 to 4 March 2008. The data (from 1st January 1908 onwards) was analysed to determine key trends including the frequency distribution for both annual rainfall and evaporation. This data was used to model the runoff from catchment areas within the mine and assess the potential evaporation losses from free water surfaces such as the dirty water dam, process water dam and leachate dam.

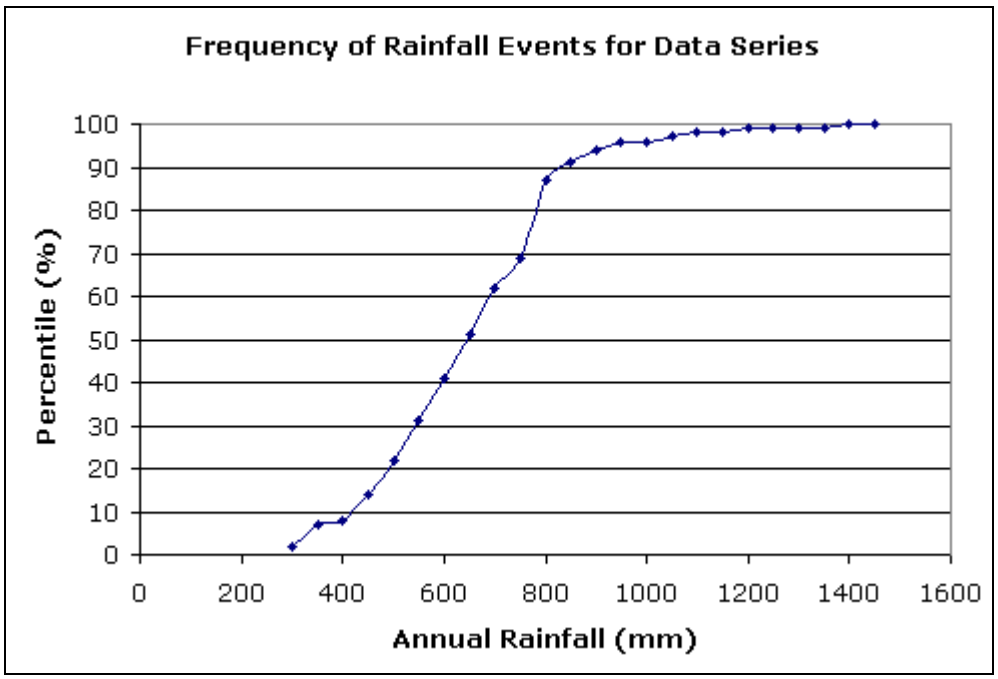
3.3.1.1 Rainfall

The climate data has been analysed to determine the annual rainfall patterns. A summary of the information presented below in **Table 6** and **Figure 2**.

Table 6: Summary of Key Statistical Values for Annual Rainfall at the Baal Bone Mine Site

Description	Value
90th Percentile	885 mm/annum
75th Percentile	819 mm/annum
Median (50th Percentile)	695 mm/annum
20th Percentile	545 mm/annum

Figure 2: Frequency Distribution of the Annual Rainfall Patterns for Baal Bone Mine Site.



Intensity-frequency-duration (IFD) data for the site was also determined which was used to assess the instantaneous rainfall patterns for the site. This data is attached in **Appendix B**.

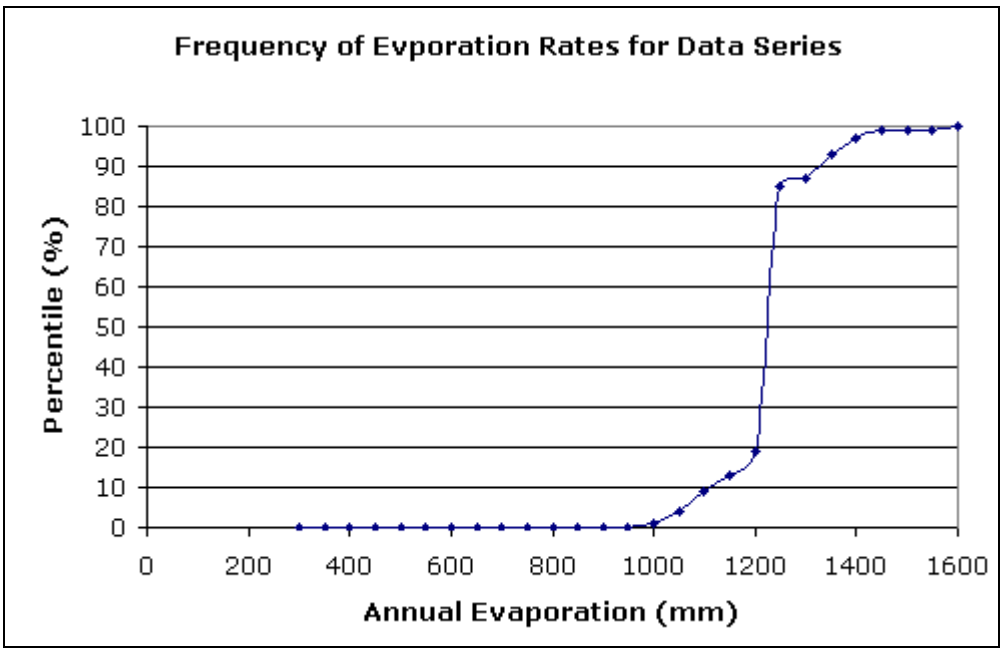
3.3.1.2 Evaporation

The climate data has been analysed to determine the annual evaporation patterns. A summary of the information presented below in **Table 7** and **Figure 3**.

Table 7: Summary of Key Statistical Values for Annual Evaporation Rates at the Baal Bone Mine Site.

Description	Value
90th Percentile	1361 mm/annum
75th Percentile	1285 mm/annum
Median (50th Percentile)	1281 mm/annum
20th Percentile	1254 mm/annum

Figure 3: Frequency Distribution of the Annual Evaporation Rates for Baal Bone Mine Site.



The average annual potential evaporation rates are higher than the average annual rainfall. Therefore, there will be a net evaporation of water from the free water surfaces. The net annual evaporation from the free water surfaces has been calculated and is not significant in comparison to the inherent errors within the water balance calculations (i.e. due to daily time step resolution, unmeasured losses/leaks etc). The total annual process water use is in the order of 650 ML/annum and the net evaporation is in the order of 30ML/annum which is less than 5% of the total annual process water use at the mine. Therefore, losses due to evaporation from free water surfaces have been ignored in this water balance, however the evaporation rates have been considered in the catchment modelling.

3.3.2 Runoff Calculations

Site rainfall data was used to estimate total annual runoff from all mine site areas. The site was segregated into seven (7) distinct areas which include:

- North rehabilitation area draining to the Boxcut Sump;
- North rehabilitation area draining to Overshot Dam;
- Ben Bullen Creek Catchment within the Mine Site;
- South rehabilitation areas (including some areas adjacent to Ben Bullen Creek);

- Reject Emplacement Areas;
- Pit top areas; and
- Stockpile and CHPP areas.

The catchment areas are shown in **Appendix A**. Runoff from each of these areas is diverted to different water storages and ultimately into different parts of the mine water cycle. Runoff from the southern rehabilitation area is diverted to Ben Bullen Creek then to the Overshot Dam. Runoff from the northern rehabilitation is diverted to either the Box Cut Sump or Ben Bullen Creek via the Overshot Dam. Runoff from the CHPP, coal stockpile and selected pit top areas is diverted to the dirty water dam via sedimentation traps.

A daily step model was used to estimate the surface water runoff from different areas of the site. The accuracy of this model is appropriate for this water balance for the follow reasons:

- The runoff areas feeding the process water cycle have relatively small catchment areas;
- The larger rehabilitated catchment areas discharge directly off site via the Ben Bullen Creek;
- The rehabilitated landscape has been designed to minimise runoff volumes; and
- The porosity of the overburden will result in low runoff volumes and high rates of infiltration.

Using this daily step model the runoff from all catchments was modelled. The inputs and assumptions in the modelling include:

- Catchment areas were calculated directly from aerial topographic site information (refer **Appendix A**);
- Maximum soil water deficit observed at the site would be in the order of 20mm for rehabilitated areas (including the reject emplacement areas) and 10mm for the pit top, stockpile and CHPP areas;
- Average runoff yield of 0.65 for pit top, CHPP and stockpile areas;
- Average runoff yield of 0.30 for rehabilitated areas; and
- Average runoff yield of 0.20 for the Reject Emplacement Areas.

The 0.65 adopted for the pit top, CHPP and stockpile areas is high but reflects the large impermeable area in the catchment which includes laydown areas, compacted roads and coal stockpiles. A runoff coefficient of 0.20 was adopted for the reject emplacement areas as these areas contain coarse reject which promotes infiltration but minimises runoff. A higher soil moisture deficit has been adopted for both the rehabilitated areas and the reject emplacement areas as the soil consists of overburden and is likely to dry out more than the pit top areas. The average annual runoff from each of the catchment areas is summarised in **Table 8**.

Table 8: Average Annual Runoff from the Individual Catchments at Baal Bone Mine:

Description	ID	Area	Median Annual Runoff
North Rehab Area (Box Cut)	A1	38.5 ha	16 ML/annum
North Rehab Area (Remainder)	A2	91.8 ha	38 ML/annum
Ben Bullen Creek Catchment	A3	49.6 ha	66 M L/annum
Stockpile/CHPP Area	A4	20 ha	26ML/annum
Pit Top Area	A5	5.4 ha	7 ML/annum
South Rehab Area	A6	48.8 ha	20 ML/annum
Reject Emplacement Area	A7	53.4 ha	11 ML/annum

3.3.3 Maximum Storage Volumes

IFD data was obtained for the geographical area which is attached in **Appendix B**. This data was used to ascertain the maximum rainfall event that could be contained by the Dirty Water Dam.

Approximate catchment peak discharge during the 24 hour duration design storm for a range of Average Recurrence Intervals (ARI) was determined using the Rational Method. It is noted that the site catchments are disturbed, and particularly in the case of the central area of the site, contain impervious areas and areas of compacted soils and roads/hardstand (adopted 60% impermeable areas). Therefore, methods of estimating runoff coefficients for disturbed/urbanised catchments as outlined in Book VIII of *Australian Rainfall and Runoff* (Pilgrim (Ed), 1998) were adopted. Total storm runoff volume was then estimated by assuming a simple hydrograph.

Results of the runoff calculations are provided in **Appendix C** and summarised in **Table 9** below.

Table 9: Approximate 24 hour design storm runoff volume to Dirty Water Dam

Average Recurrence Interval	Approximate Runoff Volume
1	8 ML
5	15 ML
10	18 ML
20	21 ML
50	26 ML
100	30 ML

The Dirty Water Dam receives runoff from catchment areas A4 and A5 (25.4ha total), and has a total capacity of 37 ML. Assuming the Dirty Water Dam is operated at a 30% level then it has the capability to contain a 1 in 50 year, 24 hour storm.

Even in a wet year, there is a deficit of runoff from the catchments A4 and A5 to the Dirty Water Dam and the water needs to be supplemented. Therefore there is very low risk of overflows from the dam unless there is a peak storm event, i.e. in this case an event exceeding a 1 in 50 year ARI, 24 hour storm event.

3.4 Mine Water Balance

Most of the pumped flows within the mine water cycle can be estimated using the flow meters that are currently installed.

The major components of the mine water cycle that have been considered as inputs are summarised as follows:

- 23 ML/annum potable water from Fish River Water Supply;
- 33 ML/annum average runoff from pit top and CHPP areas;
- 151 ML/annum average runoff from the northern and southern rehabilitation areas;
- 381 ML/annum mine dewatering from southern underground mining areas; and
- 1,168 ML/annum mine dewatering from northern underground mining areas.

This water needs to be managed by either storage, reuse/recycling within the process pant and/or discharge off-site.

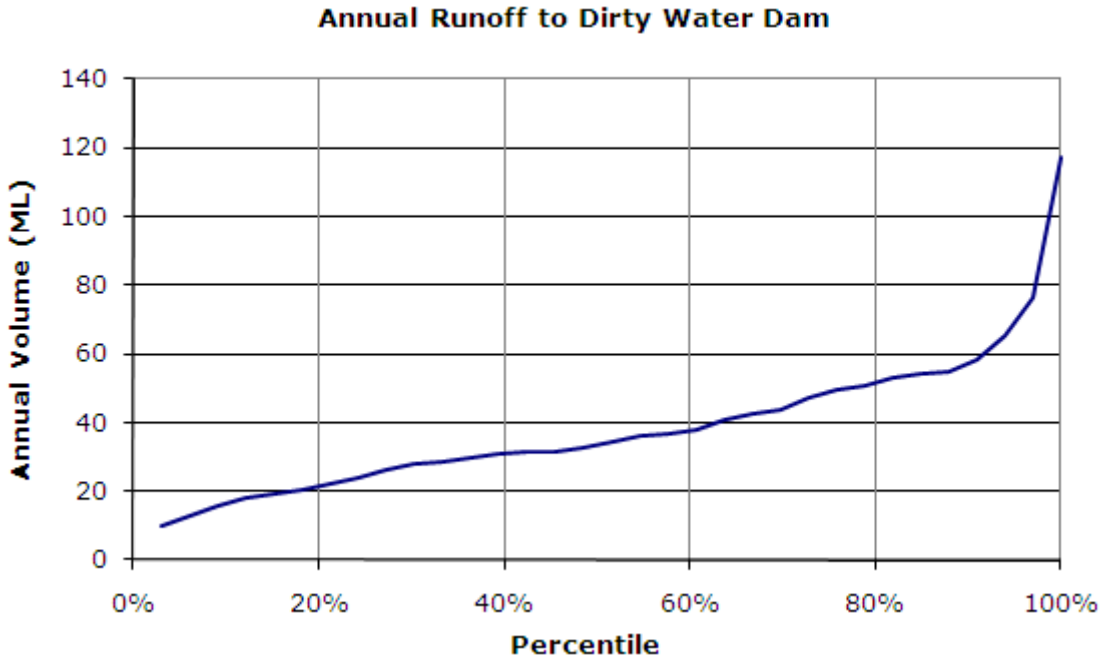
The approximate off-site discharges from the site comprise the following:

- 1,500 ML/annum groundwater that flows into the underground mining operation and is dewatered directly offsite via LD3 and LD6 to Ben Bullen Creek;
- 135 ML/annum average site overflow from the Overshot Dam (assumed to be equivalent to the runoff from the southern rehabilitation areas reject emplacement area and runoff from the northern rehabilitation areas (refer **Section 2.1**); and
- 76 ML/annum average water losses through coal washing and export of coal however could be as high as 90ML/annum.

On average, the mine uses approximately 635 ML/annum of water for potable uses, dust suppression and coal washing. However, this is recently as high as 750 ML/annum. Of this amount, approximately 610 ML/annum is used for dust suppression and process water within the CHPP. Currently approximately 50% of the CHPP demand (or 310 ML/annum) is sourced by process return water (i.e. from the Leachate Return Dam). Therefore approximately 300 ML/annum additional water is required to be sourced from surface runoff and/or mine dewatering operations.

An analysis of the potential runoff from the on-site catchments to the Dirty Water Dam has been undertaken. As illustrated in **Figure 4** below, the average annual runoff to the Dirty Water Dam is approximately 33 ML/annum which is only approximately 11% of the process water make-up requirement of 300 ML/annum. Even in extreme wet years the collection of surface runoff to the Dirty Water Dam alone is insufficient to provide enough process water for the mine operations. Only approximately 60 ML/annum of runoff is produced in the 90th percentile wet year.

Figure 4: Total Annual Runoff Diverted to the Dirty Water Dam from Onsite Catchments



As a result, water is dewatered from the mine workings via Adit No. 5 (approx 242 ML/annum) to the Dirty Water Dam which supplements the required process water demand. In addition, process make-up water may also be pumped from the Boxcut Sump (up to 365 ML/annum) to the Dirty Water Dam.

3.5 Process Water Cycle

The process water circuit allows for reuse and recycling of water used in the mining and coal preparation operations. The circuit consists of a series of leachate ponds, dams, pumps and pipelines.

3.5.1 Process Water Dam

The total outflow from the Process Water Dam is equivalent to the water transferred from the Dirty Water Dam. The difference between the inflow and the outflow of approximately 10% is within the accuracy of the water balance calculations. Some of this minor difference can be explained by minor evaporative losses from the Process Water Dam. The dam is clay lined and should have minimal losses due to infiltration.

3.5.2 Coal Handling and Preparation Plant

Process water used to wash coal in the CHPP is sourced from the Process Water Dam. The process water in turn is sourced from the Dirty Water Dam. Up to 50% of the water used in the CHPP is recycled water from the process return (leachate) water. Approximately 610 ML/annum of water is required for coal washing and dust suppression in the CHPP.

3.5.3 Dirty Water Dam

The Dirty Water Dam is used to store returned leachate water from the tailings disposal area (see **Section 3.5.4**) and also collects stormwater from the pit top area after it has passed through two grit traps and an oil separation unit to remove suspended solids, oil and grease. Runoff from the CHPP also flows into the Dirty Water Dam via a separate grit trap located adjacent to the sewage treatment plant. Water from the Dirty Water Dam is pumped into the Process Water Dam for re-use in mining and coal preparation operations.

3.5.4 Leachate Recovery

Fine tailings are pumped from the CHPP in slurry form to the tailings disposal site (Reject Emplacement Area – REA) in the southern area of the site. Excess leachate from the tailings percolates through to the Leachate Collection Pond. Leachate water is then pumped to the Dirty Water Dam and recycled to the Process Water Dam. Approximately 75% of the leachate is recovered and recycled for process water.

The coal wash water that is retained in the tailings is approximately 413 ML/annum. The leachate recovered is approximately 310 ML/annum. Therefore approximately 25% (or 103 ML/annum) of the water in the tailings is retained/trapped in the tailings voids or lost to seepage from the tailings emplacement area.

Any flow that is lost subsequently seeps to the Boxcut sump where it is collected. This water can be returned to the Dirty Water Dam to supplement the process water cycle.

3.5.5 Boxcut Sump

The Boxcut Sump collects some local runoff from the Northern mine area along with seepage from most areas of the site. Under normal circumstances, water from the Boxcut Sump flows into the northern mine workings. Approximately 780 kL/day (or 285ML/annum) is currently pumped from the Boxcut Sump to the Dirty Water Dam to supplement the process water demand. Up to 365 ML/annum is potentially available from the Box Cut Sump to supplement the process water cycle.

3.6 Recycled Water Use

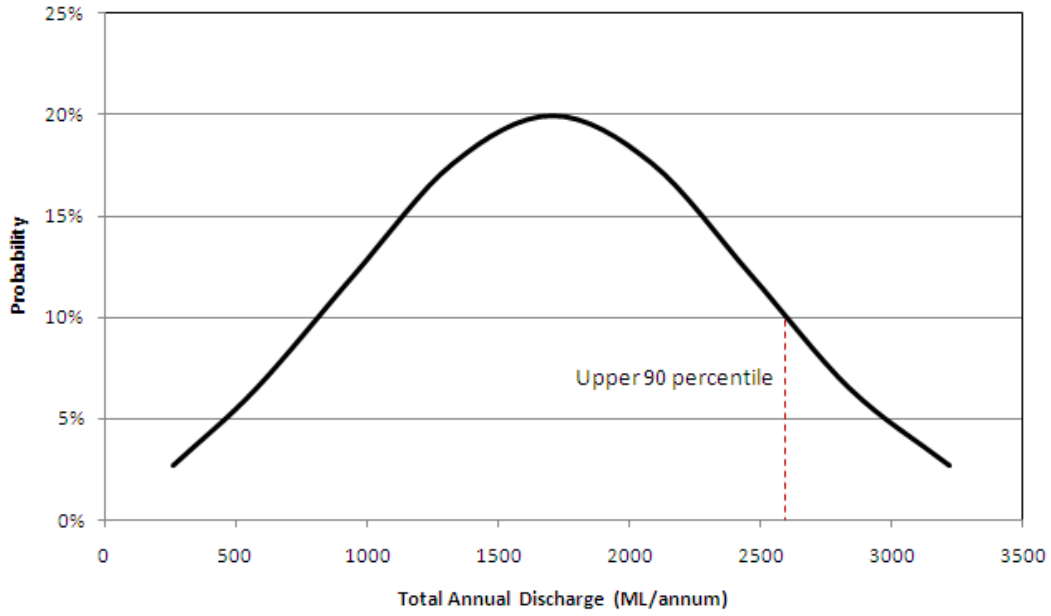
A significant amount of water is recycled on site for coal processing, dust suppression and underground workings. Approximately 63% of the total water demand on site is recycled water comprising leachate return water,water from washdown return and raw surface water (surface runoff from the pit top and the CHPP areas). Approximately 75% of the leachate is recovered and recycled for process water. This leachate recycling accounts for approximately 50% of the process water used on site.

3.7 Potential Climate Change Impacts

The primary impact of climate change in New South Wales will be the potential change in the variability and extremes of precipitation. Predictions by the CSIRO (2004) indicate that the potential for drought may increase by 35% to 70% by 2030.

A Monte Carlo style approach was used to determine the potential impact of climate change on the mine water cycle. The estimated annual volume discharged from the site has been calculated for different probability ranges. A summary of the probability discharge from the site is summarised in **Figure 5**.

Figure 5: Probability Distribution for Discharge from Baal Bone Mine Site.



The discharges from site are dominated by the raw groundwater flows discharged via LW1 and LW19 which correspond to discharges from LD3 and LD6 respectively. The estimated 90th percentile probability value (i.e. P90) for discharge from the site is in the order of 2.6 GL/annum (i.e. upper 10%ile value). The existing Environmental Protection License allows up to 12,000 kL/day or up to 4.4 GL/annum to be discharged via LD6. Therefore there is no risk that excess mine water will accumulate in the workings and prevent safe working conditions if this discharge limit is retained.

It is also important that there is sufficient water available for process water (between 610 ML/annum to 750 ML/annum). As outlined in **Section 3.4** above the water inputs to the process water circuit include:

- An average of 300 ML/annum recycled from the leachate recovery circuit;
- Between 0-120 ML/annum runoff from the pit top, stockpile and CHPP areas;
- Average of 240 ML/annum recovered from dewatering via Adit No. 5; and
- Potential for up to 365 ML/annum to be transferred from the Box Cut Sump.

In dry conditions (i.e. equivalent to a 20%ile year) less than 20 ML/annum could be available via runoff from the pit top, coal stockpile and CHPP areas. This is equivalent to a reduction of 40% of water available via runoff to the process water circuit in an average year. However the water available from mine dewatering via Adit No. 5 and the potential supplementary water from the Box Cut Sump will provide sufficient water for the process water circuit.

4.0 Conclusions

The following key points can be concluded from the mine water balance:

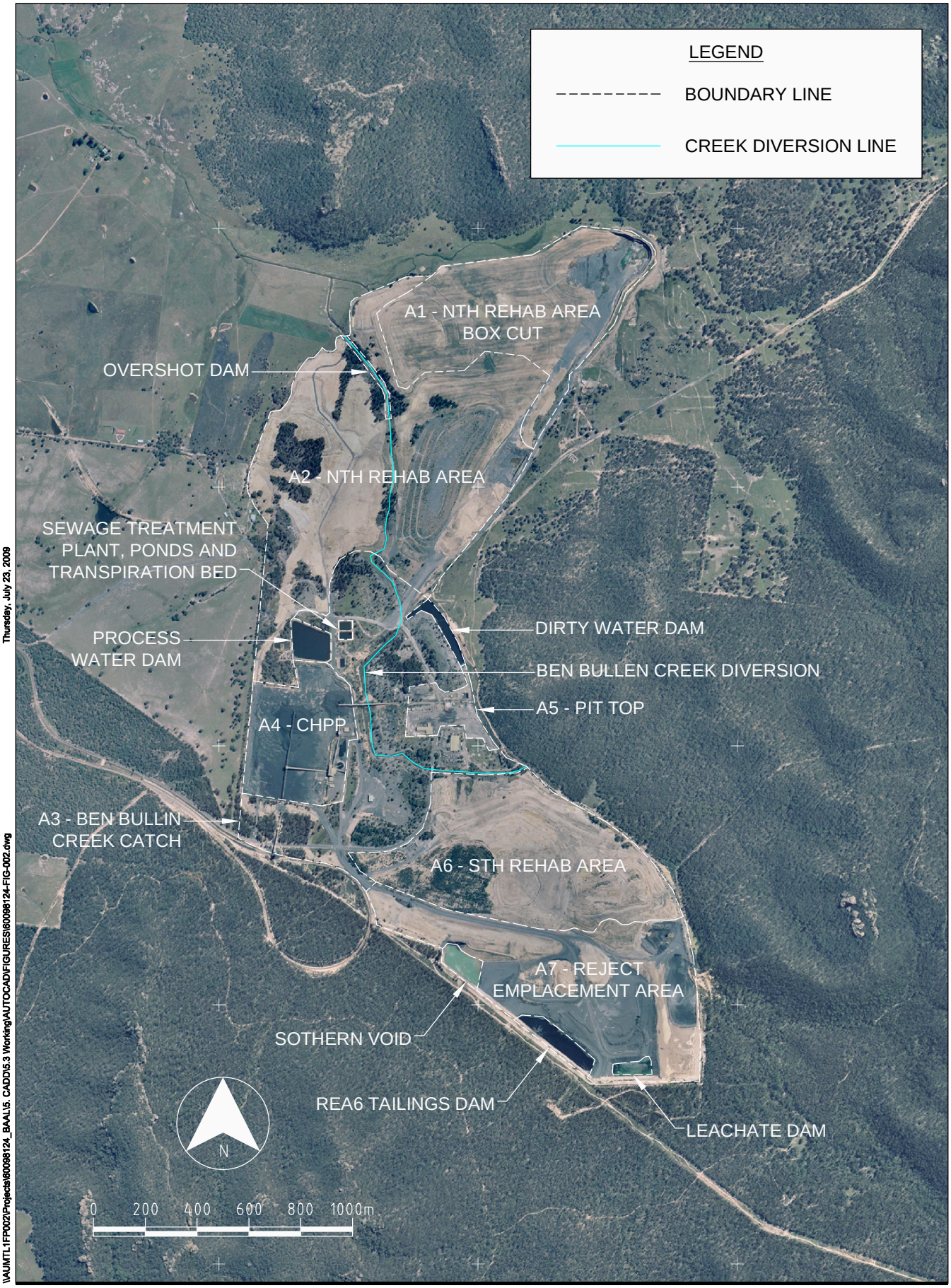
- The net water exported from the site is equivalent to approximately 1.5 GL/annum. Most of this water is generated as groundwater interception within the underground mine workings and goaf and pumped directly offsite via LD3 and LD6 to Ben Bullen Creek.
- All runoff from the pit top area, stockpile area and CHPP area is collected on site is used within the mine as process water. Site process water is supplemented with water from mine adit No. 5 dewatering and surface runoff and seepage collected from the Boxcut Sump.
- Approximately 50% of leachate is recovered from the Tailings Dam and returned to the process system.
- Approximately 63% of all process water used on site is recycled water comprising leachate return water and wash down water from the CHPP, coal stockpile and pit top areas.
- Less than 4% of water used on site is potable water.
- Even in a wet year, there is very low risk of overflows from the Dirty Water Dam unless there is a rainfall event exceeding a 1 in 50 year, 24 hour storm.

The current water management strategy is sustainable if the current practises are maintained. The process water demands are expected to remain constant for the mining of remnant areas and Longwalls 29 to 31 which provides a use for all runoff water collected on site. The high level of water recycling on site ensures that any discharges off site are high quality. The water that leaves the site is runoff generated from rehabilitated areas and from mine dewatering; other water collected from potentially contaminated areas is collected and used on site.

The existing license conditions are suitable to allow all groundwater infiltration into the mine workings to be discharged off site via both LD3 and LD6. It is also clear that there is sufficient groundwater both from Adit No. 5 and the Box Cut Sump to supplement the process water circuit and ensure there is sufficient water for operation of the mine even with the potential effects of future climate change.

Appendix A Site Layout

AECOM



Thursday, July 23, 2009

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BAAL BONE COLLIERY EXTENSION
MINE WATER BALANCE
SITE LAYOUT

Appendix B IFD Data



Appendix B IFD Data

Table 10: Intensity-Frequency-Duration Data for Baal Bone Colliery

	Average Recurrence Interval (ARI)						
Duration	1 Year	2 years	5 years	10 years	20 years	50 years	100 years
5Mins	61.4	80	105	120	141	169	192
6Mins	57.6	75	98	113	132	158	178
10Mins	46.9	60.9	79.1	90.4	105	126	142
20Mins	33.9	43.9	56.2	63.8	74	87.7	98.5
30Mins	27.5	35.5	45.1	51	58.9	69.5	77.8
1Hr	18.6	23.9	30	33.7	38.7	45.4	50.6
2Hrs	12.2	15.5	19.4	21.7	24.8	29	32.2
3Hrs	9.38	12	14.9	16.7	19	22.2	24.7
6Hrs	6	7.66	9.51	10.6	12.1	14.1	15.7
12Hrs	3.92	4.99	6.15	6.83	7.77	9.01	10
24Hrs	**2.65**	**3.35**	**4.05**	**4.45**	**5.03**	**5.77**	**6.35**
48Hrs	1.81	2.25	2.66	2.88	3.2	3.63	3.95
72Hrs	1.39	1.73	2.01	2.16	2.39	2.69	2.91

Notes: Obtained from the Bureau of Meteorology website, using site coordinates 33.275S, 150.050E.

Appendix C Design Runoff Calculations



DESIGN STORM RUNOFF VOLUME ESTIMATION				ARI	100 years	24 hour storm	
CATCHMENT	ID	AREA	C_{10} value	C_{100} value	I (mm/hr)	PEAK Q_{100} (m^3/s)	VOLUME (ML)
North Rehab Area	A1	38.5 ha	0.30	0.36	6.35	0.24	21.1
North Rehab Area (remainder)	A2	91.8 ha	0.30	0.36	6.35	0.58	50.4
Ben Bullen Creek Catchment	A3	49.6 ha	0.40	0.48	6.35	0.42	36.3
Stockpile/CHPP Area	A4	20.0 ha	**0.65**	0.78	6.35	0.28	23.8
Pit Top Area	A5	5.4 ha	**0.65**	0.78	6.35	0.07	6.4
South Rehab Area	A6	48.8 ha	0.30	0.36	6.35	0.31	26.8
Reject Emplacement Area	A7	53.4 ha	0.20	0.24	6.35	0.23	19.5

10 year 1 hour Intensity	34.8
C1-10	0.23

FREQUENCY FACTORS	
F_1	0.8
F_5	1.0
F_{10}	1.0
F_{20}	1.1
F_{50}	1.2
F_{100}	1.2

	ARI	50 years	24 hour storm	
ID	C_{50} value	I (mm/hr)	PEAK Q_{100} (m^3/s)	VOLUME (ML)
A1	0.35	5.77	0.21	18.4
A2	0.35	5.77	0.51	43.9
A3	0.46	5.77	0.37	31.6
A4	0.75	5.77	0.24	20.7
A5	0.75	5.77	0.06	5.6
A6	0.35	5.77	0.27	23.3
A7	0.23	5.77	0.20	17.0

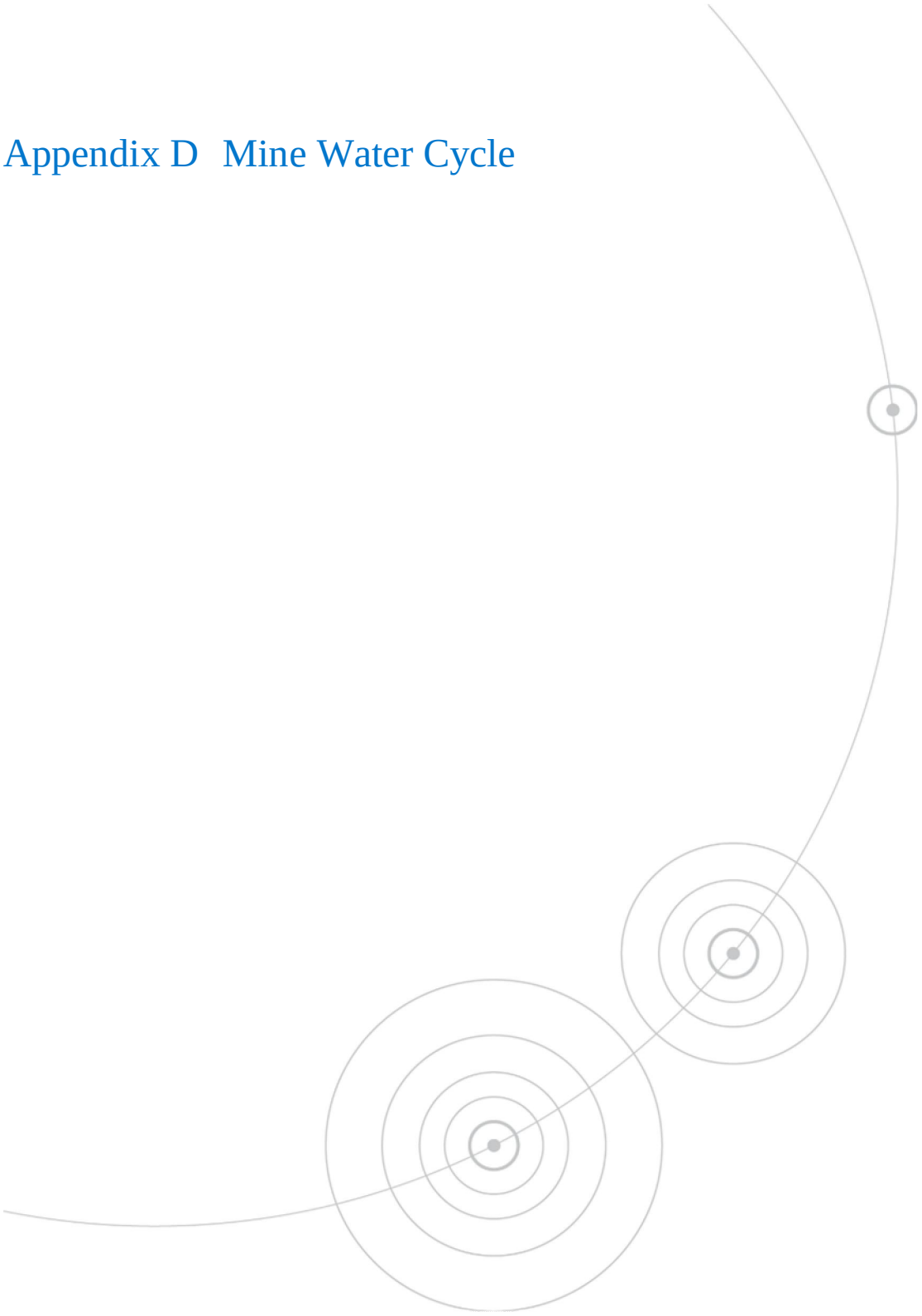
	ARI	20 years	24 hour storm	
ID	C_{20} value	I (mm/hr)	PEAK Q_{100} (m^3/s)	VOLUME (ML)
A1	0.32	5.03	0.17	14.6
A2	0.32	5.03	0.40	34.9
A3	0.42	5.03	0.29	25.1
A4	0.68	5.03	0.19	16.5
A5	0.68	5.03	0.05	4.4
A6	0.32	5.03	0.21	18.6
A7	0.21	5.03	0.16	13.5

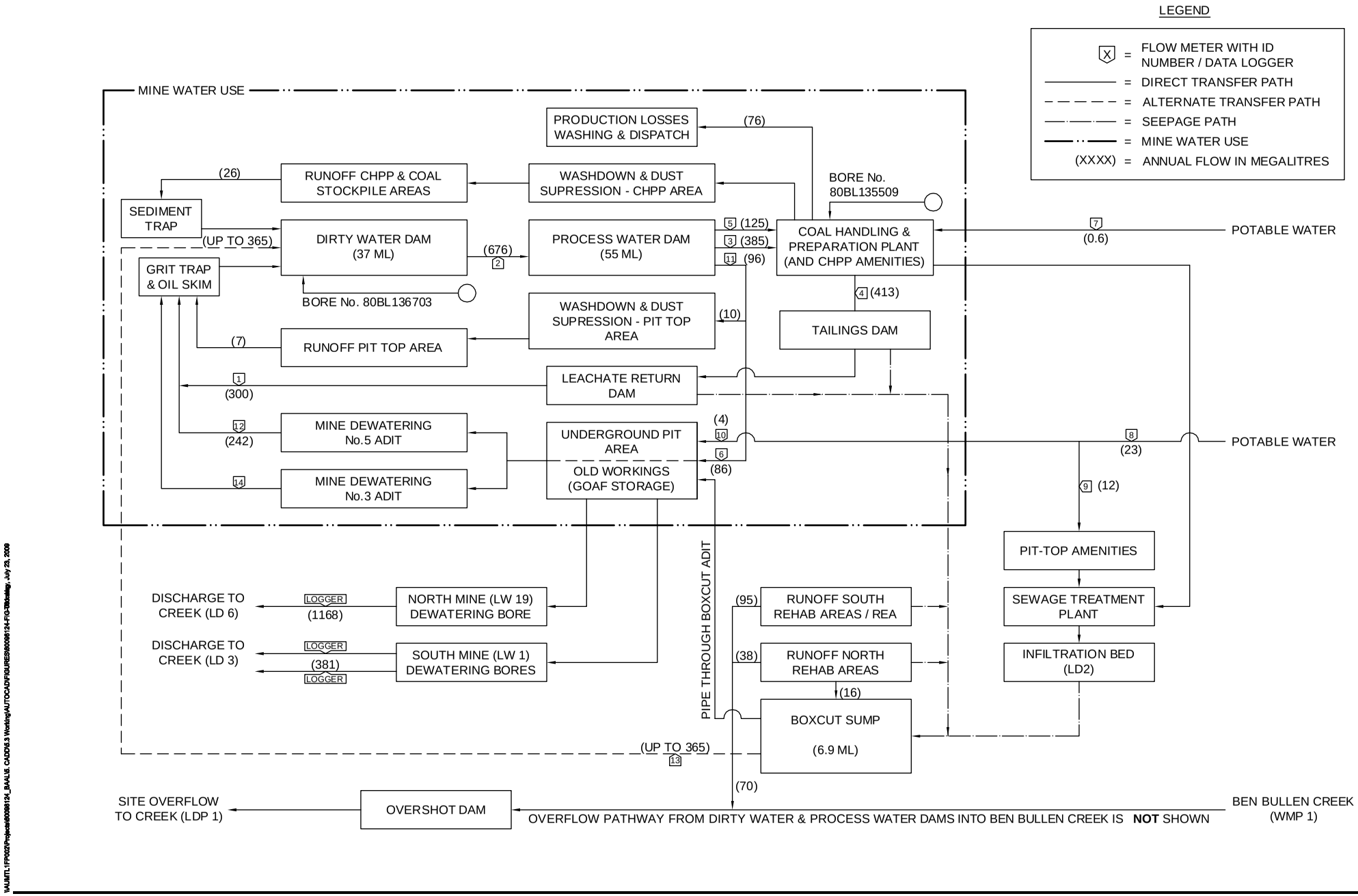
	ARI	10 years	24 hour storm	
ID	C_{10} value	I (mm/hr)	PEAK Q_{100} (m^3/s)	VOLUME (ML)
A1	0.30	4.45	0.14	12.3
A2	0.30	4.45	0.34	29.4
A3	0.40	4.45	0.25	21.2
A4	0.65	4.45	0.16	13.9
A5	0.65	4.45	0.04	3.7
A6	0.30	4.45	0.18	15.6
A7	0.20	4.45	0.13	11.4

	ARI	5 years	24 hour storm	
ID	C_5 value	I (mm/hr)	PEAK Q_{100} (m^3/s)	VOLUME (ML)
A1	0.29	4.05	0.12	10.7
A2	0.29	4.05	0.29	25.4
A3	0.38	4.05	0.21	18.3
A4	0.62	4.05	0.14	12.0
A5	0.62	4.05	0.04	3.2
A6	0.29	4.05	0.16	13.5
A7	0.19	4.05	0.11	9.9

	ARI	1 years	24 hour storm	
ID	C_1 value	I (mm/hr)	PEAK Q_{100} (m^3/s)	VOLUME (ML)
A1	0.24	2.65	0.07	5.9
A2	0.24	2.65	0.16	14.0
A3	0.32	2.65	0.12	10.1
A4	0.52	2.65	0.08	6.6
A5	0.52	2.65	0.02	1.8
A6	0.24	2.65	0.09	7.4
A7	0.16	2.65	0.06	5.4

Appendix D Mine Water Cycle





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MINE WATER CYCLE
60098124-FIG-001



APPENDIX G

Hydrogeological Assessment

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Baal Bone Colliery
Longwalls 29 to 31 SMP
Hydrogeological Assessment
Xstrata Coal

28 October 2006
Reference 24596-001
Revision 1

Connell Wagner

Document Control

Document ID: O:\24596\ENG\BBREPORT-FINAL.DOC

Rev No	Date	Revision Details	Typist	Author	Verifier	Approver
0	28 October 2006	Draft for Client comment	IF	IF	BW	LK
1	11 December 2006	Final for issue	IF	IF	BW	LK

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Appendix A
Geological logs of boreholes

1. Introduction

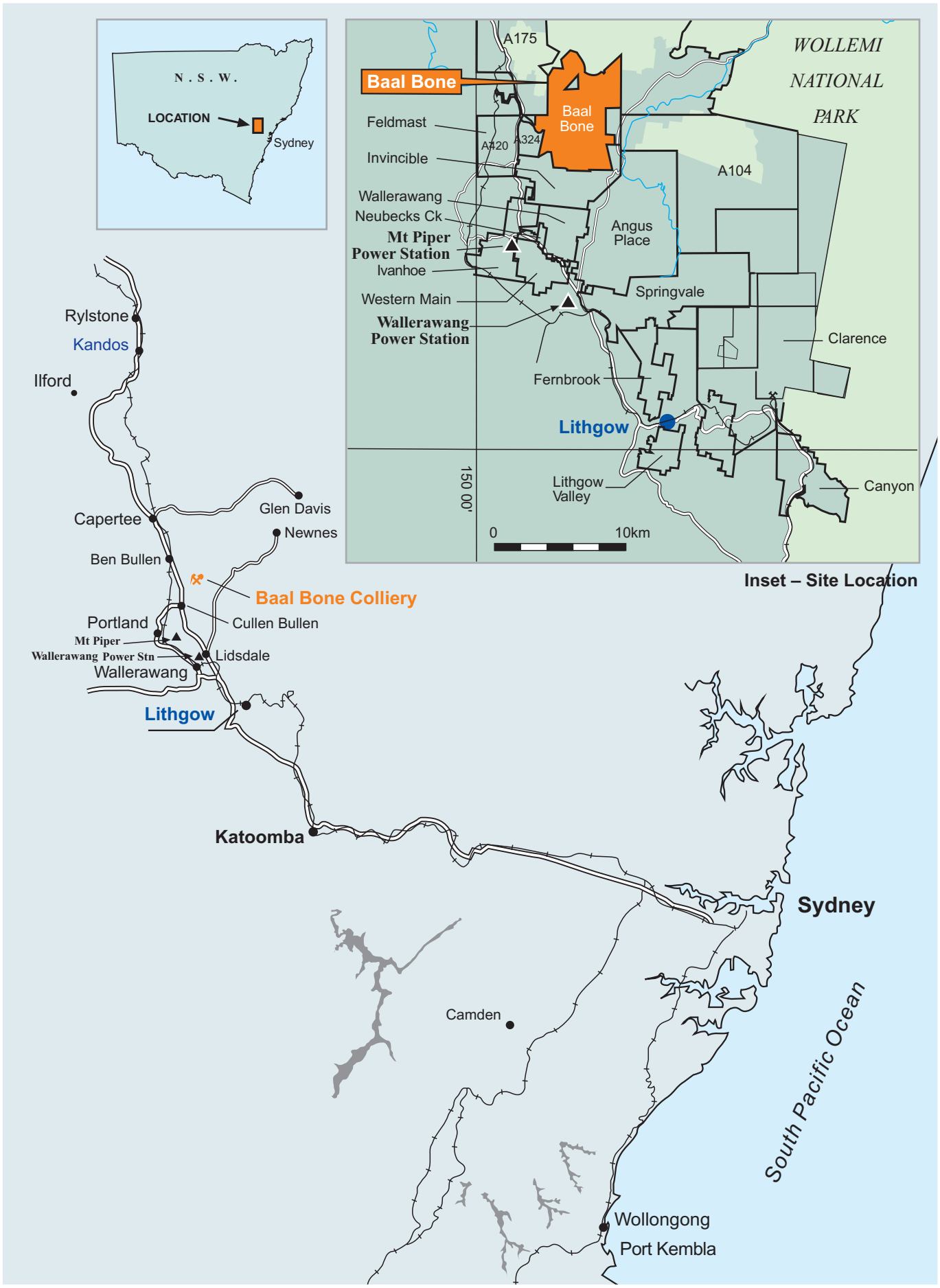
Baal Bone Colliery is located approximately 25 km north-west of Lithgow in the Central Tablelands of NSW, and extracts coal from the Lithgow Seam using longwall mining techniques (see Figure 1). The mine commenced underground operations in 1982, and has extracted a series of longwall panels in the south and north districts. Future extraction will be carried out in the south-east district in longwalls 29 to 31, beneath the Ben Bullen State Forest on the western edge of the Newnes Plateau.

In conjunction with the colliery's application to extract longwalls 29 to 31, it must prepare a Subsidence Management Plan (SMP) and seek approval for this plan from the Department of Primary Industries (DPI). The SMP is required to examine the expected impact of the subsidence caused by the proposed mining on all surface and sub-surface, natural and man-made features within the SMP application area. It must also propose measures which will mitigate any adverse impact. The SMP application for Longwalls 29 to 31 at Baal Bone Colliery, is currently being prepared and will be submitted in early 2007.

One of the major aspects which requires investigation as part of this process is the potential for any impact on the local hydrogeological regime. Preliminary investigations have highlighted two main aspects of the local hydrogeology which may be impacted. These include:

- the impact on any aquifer zones in the overburden; and
- the impact on the nearby Coxs River Swamp, a type of plant community designated an endangered ecological community. (Although the Coxs River Swamp is not strictly within the SMP application area, the proximity and importance of this feature dictates that the investigations must examine the potential for any adverse impacts).

In order to address these two issues, Baal Bone Colliery has retained the services of Connell Wagner to examine these hydrogeological aspects in detail, by drawing on all available relevant data, and to present a documented evaluation of the likely subsidence impact on the aquifers and the swamps. This report summarises the results of that evaluation. Sections 2, 3 and 4 of the report present all the relevant data and establish the baseline geological and hydrogeological conditions in the vicinity of the application area, while Section 5 to 9 attempt to pose and answer the critical questions relating to the potential impacts of the proposed mining.



Source: Robert Byrnes, IEC

BAAL BONE\24596-001\23.10.06\FM

Figure 1

Locality Plan

2. Geology

The area overlying longwall panels 29 to 31in Baal Bone Colliery forms part of the western edge of the Newnes Plateau, northwest of Lithgow. This area is well known for its unusual sandstone rock formations, and is considered to have unique environmental significance. The plateau area is cut by several deeply incised creek valleys, which drain to the north and east of the lease area and into the Wolgan valley. The application area lies on the boundary between two catchments; the Wolgan-Colo River catchment to the east and the Coxs River catchment to the west.

The underlying strata comprise mostly sandstones of the Permian Narrabeen Group, which are interbedded with shale and siltstone bands. The Narrabeen Group rocks are underlain by the Illawarra Coal Measures, which comprise interbedded sandstone, siltstone and shale. The general dip of the bedding is to the northeast at about 1 degree. The local stratigraphy is summarised in Table 1 below. The estimated height of various strata above the roof of the Lithgow Seam at Baal Bone is also shown on this table. These heights are based data from a limited number of boreholes within the application area.

Table 1 - Middle Permian to Tertiary Stratigraphy of the Western Coalfield

Period	Stratigraphy			Lithology	Dist. of Base of Rock Unit Above Seam Roof (m)
	Group	Subgroup	Formation		
Tertiary			Basalt	Basalt	
Triassic	Wiannamatta		Ashfield shale		
		Hawkesbury Sandstone			
	Narrabeen Group	Grose Subgroup	Burralow Formation		Surface 150-220 m
			Banks Wall Sandstone		
			Mt York Claystone		
			Burra –Moko Head Sandstone		112-118 m
			Caley Formation		98-100 m
Permian	Illawarra Coal Measures	Wallerawang Subgroup	Farmers Creek Formation	Coal, sandstone, claystone, siliceous claystone (includes Katoomba and Middle River Seams)	76-77 m
			Gap Sandstone	Sandstone	
		Charbon Subgroup	State Mine Creek Formation	Coal, mudstone, claystone	
			Watts Sandstone	sandstone	
			Denman Formation	Interbedded mudstone/ sandstone, claystone, mudstone	
			Glen Davis Formation	Coal and claystone bands	
			Newnes Formation	Coal, sandstone	
			Irondale Coal	Coal	27-28 m
			Long Swamp Formation	Interbedded sandstone and siltstone	
		Cullen Bullen Subgroup	**Lithgow Coal**	**Coal and claystone bands**	
			Marrangaroo Formation	Sandstone, conglomerate	
		Nile Subgroup	Gundangaroo Formation	Coal, sandstone claystone	
			Coorongooba Creek Sandstone	Sandstone	
			Mount Marsden Claystone	Claystone	
	Shoalhaven Group		Berry Siltstone		
			Snapper Point Formation		

In this area, the upper part of the Narrabeen Group has been removed by weathering, and the lower part, including the Banks Wall Sandstone, Mt York Claystone and the Burra-Moko Head Sandstone, is exposed at the surface. Ground surface slopes range from about 2 to 3% on the ridge tops to up to 50% on the flanks of the ridges in the application area. Small cliffs up to 20 metres high also occur to the south west of the application area, where the Banks Wall Sandstone is exposed. The ground surface elevation ranges from 1050 m AHD at the northern end of longwall 30, to about 980 m AHD near the southern end of longwall 29. The application area is bounded on the northern and southern sides by an escarpment up to 100 metres high above the Wolgan River, which lies up to 300 metres below the top of the plateau.

The underlying coal measures are not exposed in the application area, but the upper coal measure strata outcrop at the base of the escarpment in the Wolgan Valley to the east of the application area.

The Coxs River Lineament Fault Zone follows the valley of the Coxs River, and has been identified by seismic lines to the west of the application area. The fault zone is a north-south trending graben structure, about 250 metres wide. The displacement on the eastern structure (CR East Fault) is about 4 to 5 metres, up to the east. The western fault (CR Western Fault) shows a lesser displacement in the seismic lines of the order of 2 metres. Between these two faults, the seismic data indicates other smaller faults exist, in conjunction with brecciation of the strata.

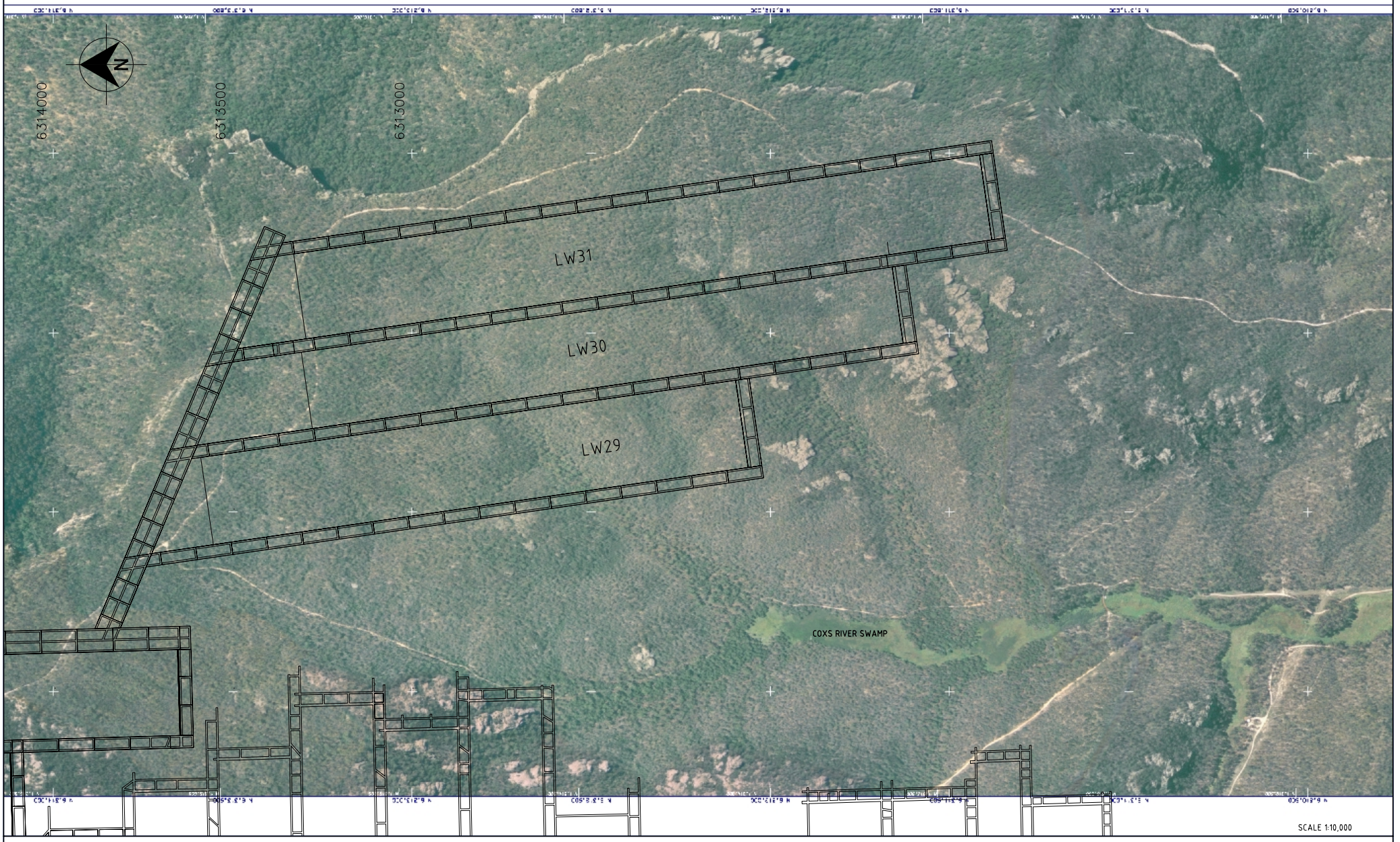
3. Proposed mining

The proposed mining in the application area involves extraction of three longwall panels in the Lithgow Seam over an area of more than one hundred hectares. Details of the proposed mining are summarised below:

Seam	Lithgow
Longwall panels	LW 29 to LW 31
Extraction thickness	2.45 metres
Depth of cover (over extraction panels)	150 to 220 metres
Panel length	1490 to 1910 metres
Pillar width (centre to centre)	30 metres
Solid pillar width	25 metres
Predicted maximum subsidence	1.3 to 1.6 m
Predicted maximum strains	+16 to -21 mm/m
Commencement date	end 2008
Completion date	early 2010

The three longwall panels have been located to avoid sensitive surface features, including the escarpment at the western edge of the Wolgan Valley, the Coxs River Swamp and the Coxs River valley, and several sensitive rock formations and rock faces in the Banks Wall Sandstone member.

The location and the layout of the longwall panels is shown on Figure 2.



BAAL BONE COLLIERY
HYDROLOGICAL STUDY
LOCATION OF LONGWALL PANELS

FIGURE 2

4. Local hydrogeological regime

In order to determine what impact, if any, the proposed mining will have on the aquifer systems, and swamps in the vicinity of the application area, it is necessary to establish a model for the local hydrogeological regime. The hydrogeological regime is defined as the occurrence of groundwater and its dynamic interaction with the local geological conditions. Unfortunately, there is little published data on the hydrogeological characteristics of the Western Coalfield strata. The following assessment is based on data gathered for the Baal Bone Colliery SMP investigations, as well as additional data acquired during other local investigations (Bish, 1999; ERM 2003; Connell Wagner, 2005a; Connell Wagner, 2005b; Connell Wagner, 2005c; Connell Wagner 2005d; Golder Associates, 2002; CSIRO, 2004; CSIRO, 2003), and local experience.

4.1 Regional hydrogeological model

In general, the sedimentary strata in the Western Coalfield comprise a non-uniform sequence of interbedded rocks of differing grainsize and strength properties. This invariably gives rise to layers of rock with a wide range of permeabilities, which form a sequence of aquifers and aquitards/aquicludes in the overburden. The term “aquifer” is generally applied to any stratum that has a high groundwater carrying capacity, relative to the surrounding rocks. It does not necessarily indicate the presence of a significant water resource within the stratum. The term “water-bearing zone” is also used in this report to describe aquifers where the continuity and permeability of the water bearing stratum has not been established.

The strata above and below the aquifer are termed either “aquicludes” or “aquitards”. Aquicludes effectively seal off the aquifer so that groundwater flow is restricted to the aquifer, while aquitards allow some minor leakage of groundwater from the aquifer either through the floor or roof. In reality, most of these layers are aquitards, as there is almost always some vertical flow, albeit extremely small. This leakage through the aquitards is largely due to the presence of vertical structures, such as joints or faults. The aquicludes/aquitards in the sequence are normally the fine-grained sedimentary rocks which have the lowest permeability.

Investigations have shown that the strata overlying the coal measures in the western Sydney Basin generally have low permeabilities ($<10^{-8}$ m/s), however there are occasional layers that have a slightly higher permeability and represent relative aquifers. The few aquifers that do occur at depth in these strata, are usually fractured rock aquifers (Bish, 1999). Fractured rock aquifers normally have permeabilities up to two orders of magnitude greater than the surrounding strata, due to their interconnecting bedding, joint or fracture patterns (hence the term fractured rock aquifer).

Previous studies have established that most of the aquifer zones in the region occur in the Banks Wall Sandstone unit, which contains multiple layered water-bearing zones and is underlain by the Mt York Claystone, a fine grained unit that forms a basal aquiclude beneath the more permeable sandstone. While the Banks Wall Sandstone unit is more than 200 metres thick to the east, in the current application area, where there is a lower depth of cover to the coal seam, it is generally less than 60 metres thick. As a result, it is likely that only the basal water-bearing zone in this formation is present in the application area, where this unit is exposed on the ridge top above the longwall panels. This water-bearing zone was intersected in a recently drilled borehole (BBN 168) to the west longwall 29 (see Figure 3, log in Appendix A). Flow from this aquifer in this borehole, was measured at 45 L/min, and its salinity recorded at 11 mg/L.



BAAL BONE COLLIERY
HYDROLOGICAL STUDY
LOCATION OF BOREHOLES

FIGURE 3

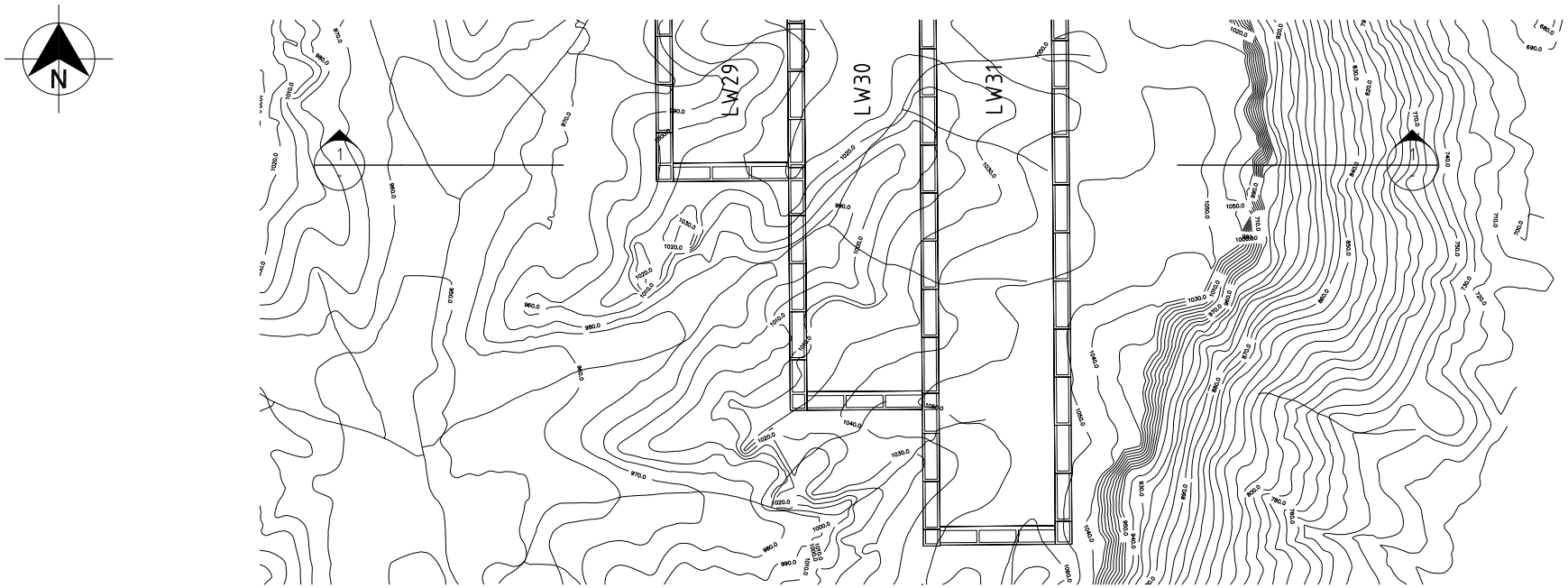
Recently drilled boreholes (see Figure 3, logs in Appendix A) also located a water-bearing zone about ten metres above the base of the Burra-Moko Head Sandstone, which underlies the Mt York Claystone. The Burra-Moko Head Sandstone is up to 30 metres thick, and is exposed around the perimeter of the ridge and beneath the Coxs River valley to the west of the application area. Flows into these bores (BBN 164, 167 and 169) ranged from 10 L/min to 90 L/min, and the salinity ranged from 11 to 35 mg/L. While the flow rates are not significant, the water quality is very good.

The water-bearing zones in both the Banks Wall Sandstone and the Burra-Moko Head Sandstone are exposed in the flanks of the Coxs River valley in the west, and in the escarpment to the east, so that the groundwater flow is heavily influenced by the topography (see Figure 4). Discharge from the water-bearing zones occurs where Coxs River valley or the escarpment intersects the water table, so that the groundwater flow direction is essentially horizontal in the Narrabeen Group Strata. Since the strata dip direction is to the north-east, and the escarpment is also in that direction, most groundwater flow is to the north-east, although since the dip is relatively flat, there will also be some local groundwater flow in a westerly direction (up-dip) into the Coxs River valley. Groundwater recharge to these near-surface sandstone strata occurs almost entirely through infiltration from the ground surface. The finer grained rocks of the basal Caley Formation (beneath the Burra-Moko Head Sandstone) limit vertical infiltration into the underlying coal measures.

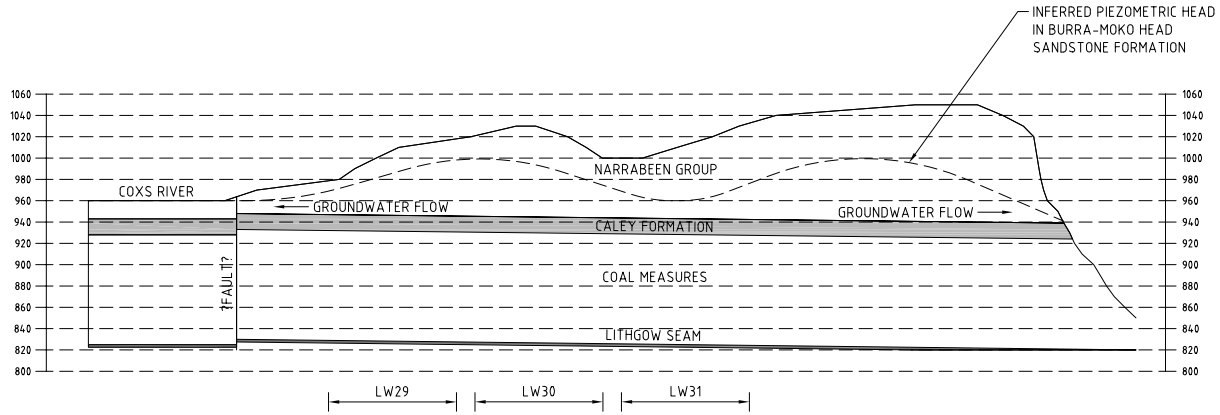
The near-surface hydrogeology may also be influenced by major geological structures, which could disrupt the normal horizontal flow regime and increase vertical flows between aquifer systems. The Coxs River Lineament Fault Zone to the west of the application area may serve as a conduit for groundwater in either the horizontal or vertical direction (see Figure 3). There are currently no data available that give any indication of the influence of this fault zone on the local hydrogeology, but its presence must be borne in mind when interpreting the impact of any future mining in its vicinity.

Although the underlying Illawarra Coal Measures rocks are essentially impermeable, some coal seams in the coal measures form aquifers, due to the fracturing and jointing in the seams. The Lithgow, Middle River and Katoomba Seams have all been identified in the past as relative aquifers, and groundwater flow in these seams is almost exclusively horizontal, since they are bounded by fine-grained sediments which act as aquicludes. A water flow of 7.5 L/min from the Middle River Seam was measured in a recently drilled borehole over longwall 30 (BBN 165). However, due to the low flow rates, the deep burial, and the high residence times, the groundwater in the coal seams is generally of a lower quality than in the near-surface sandstone aquifer zones. Recharge into these seams is largely from the west of the application area where they outcrop, although there may be a minor contribution from vertical infiltration.

Since the application area is bordered by extensive longwall extraction on the western side, and by the escarpment on the eastern side, it is likely that the piezometric head in the coal measure aquifers is drawn down significantly, and the groundwater largely depleted. Prior to mining taking place at Baal Bone, the Katoomba Seam, Middle River Seam and other coal seam aquifers in the upper coal measures would have drained towards the escarpment to the east of the application area where they are exposed at the base of the cliff face. Previous studies have shown that the Lithgow Seam, which has been mined extensively in the region, is largely drained of groundwater, although flow in this seam too would normally be towards the east.



PLAN
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SECTION 1
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BAAL BONE COLLIERY
HYDROLOGICAL STUDY
SECTION 1

FIGURE 4

Although essentially depleted, the groundwater flow in the Lithgow Seam in the application area will be influenced to a large degree by the volume of water in the adjacent south mine area goaf. Continuous pumping has lowered the water level in this area to RL 827 m, which is near the level of the Lithgow Seam in the application area, so that excess flows through the seam into the application area are not likely. However, if the pumping ceases and the water level in the south mine goaf rises, groundwater flow in the seam will recommence in a north easterly direction, down dip towards longwalls 29 to 31.

Groundwater is currently pumped from the south mine area of the Baal Bone Colliery at a rate of about 2.4 ML/day. While some of this groundwater originates from the Lithgow Seam, the major proportion flows from overlying strata, which have been fractured by the formation of the goaf above the extracted longwall panels. Although the exact source of this groundwater is uncertain, it is likely that it drains from coal seam aquifers in the upper coal measure strata, with a lesser contribution due to infiltration from higher up in the sequence. The greater than average inflows are due to the fact that the workings are shallower, and closer to the recharge zone.

4.2 Interaction with swamps and watercourses

In most hydrogeological regimes, the groundwater and the surface water systems are interconnected and inter-dependant. Consequently, in order to determine if there will be any impact on any swamps and watercourses due to the proposed mining, it is necessary to understand the hydrogeological conditions that affect them, and the relationship between the groundwater and surface water systems. Figure 5 presents, in a simplified diagrammatic form, the perceived hydrogeological regime as it relates to the swamps in the Newnes Plateau area. This has been derived based on numerous previous investigations in the region.

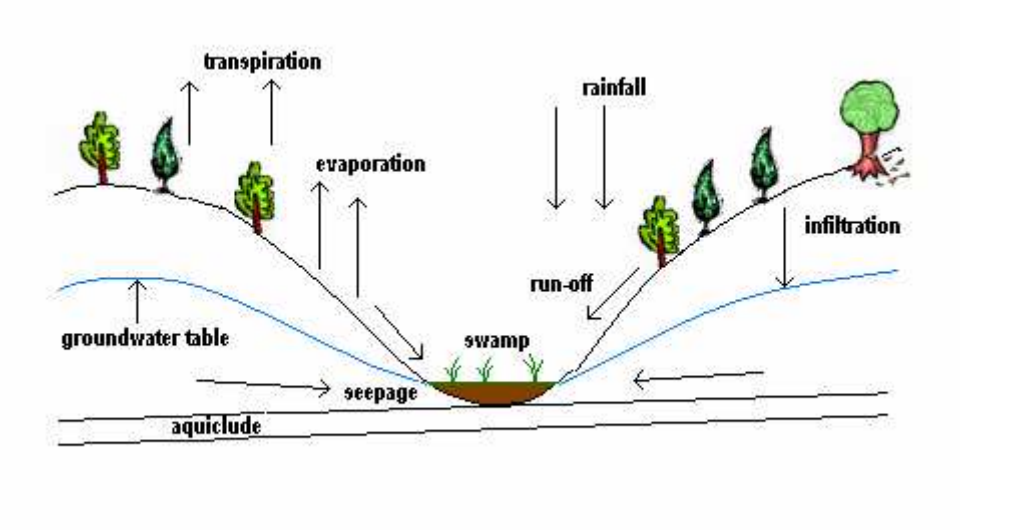


FIGURE 5 – Hydrogeological conditions surrounding swamps on the Newnes Plateau

Generally, the swamps in this region have developed at altitudes in excess of 800 metres, in valleys underlain by Narrabeen Group strata. The swamps develop in areas that are subject to a constant supply of water - both groundwater and surface runoff.

The groundwater source is initiated when rainfall infiltrates the sandy soils and the sandstone on the adjacent ridges. At various depths in the sandstone are thin layers of claystone, or tightly cemented sandstone, which are relatively impervious to vertical groundwater percolation and form aquitards. The groundwater, when it meets one of these impermeable barriers, travels

laterally until it reaches the edge of the impervious layer, which has been exposed by geological erosion in an adjacent valley. In conjunction with rainfall runoff, this may produce a condition of constant moisture, which allows a range of plant species to gradually colonise these sites over long periods of time, forming a specialised plant community.

The constant saturation of the valley floor creates anaerobic (oxygen starved) conditions in the soil, which inhibit the microbial breakdown and decomposition of dead plant material. This organic matter accumulates in a partly decomposed state as peat. Peat has an extraordinary ability to absorb water, and so the swamp soil acts as a sponge, retaining much rainwater for later slow release. The peat is generally mixed with sand derived from the weathering of the soft sandstone on the ridges, which is washed into the valley by rainfall run-off.

Since the swamps are supplied by two water sources (rainfall runoff and groundwater), and they store large quantities of water, they are resistant to some extent to natural variations in supply from either of the water sources (eg drought conditions will reduce runoff). Previous studies have shown that not all swamps in the region are the same, with some swamps apparently showing a greater dependence on groundwater than others. In general though, rainfall runoff provides the greatest water volume to most of the swamps. Normally, between 20% and 30% of the total rainfall in the area runs off the ground surface and into the swamps. When this occurs, any voids in the dry peat at the surface soak up the water, and any excess runoff flows down the creek channel and into the downstream tributary.

In contrast, less than 5% of rainfall infiltrates the ground surface and enters the groundwater system. Most of this water then enters the swamp by seepage at the margins, although a small proportion leaks through the aquitard and into the underlying strata. Unlike rainfall, the seepage into the swamps is generally continuous, and is proportional to the hydraulic head in the aquifer beneath the flanking ridges. During droughts, the seepage from the aquifer may provide a continuous source of groundwater for the swamp, albeit at a reduced flow rate, so that under normal climatic conditions, the plants are continuously supplied with water.

Field reconnaissance, has shown that there are no swamps, springs, or permanent streams within the application area. It follows then that the proposed mining will have no impact on such features. Nevertheless, the most important swamp in the area is the swamp at the head of the Coxs River, immediately west of the application area, and known as the Coxs River Swamp (Figure 3). This swamp is approximately 150 metres across at its widest, and more than 2 kilometres long. At the time of the field reconnaissance, there was no water discharge from the swamp, but this was following an extended period of below average rainfall. During periods of more normal climatic conditions, it has been reported that free water discharges from the swamp and contributes to the flow in the Coxs River.

Reference to Figure 4 suggests that the swamp has formed due to the presence, near the surface, of the Caley Formation, which forms an underlying aquitard. Groundwater flow to the swamp is likely to come from the aquifer zone in the overlying sandstone units including the Burra-Moko Head Formation. Since this aquifer may potentially be affected by the proposed mining, it is important that the impact on the Coxs River Swamp be examined, even though it is not within the application area. Figure 4 also shows the location of the Coxs River Lineament Fault Zone, which may also influence the hydrogeological conditions in the swamp, and needs to be taken into account.

5. How will longwall mining affect the overburden?

In order to determine the impact of the proposed mining on the aquifers in the application area (and any consequent impact on the Coxs River swamp), there is a need to understand the mechanics of deformation of the overburden strata above a longwall mining operation. In other words, how will the longwall mining affect the overburden? These deformations can be broadly classified into two categories: surface and sub-surface deformations. Both types of deformation are described below, and their potential impacts on the hydrogeological system summarised for the benefit of persons unfamiliar with the deformation process.

5.1 Surface deformations

Surface deformations resulting from coal extraction have been observed and measured on a routine basis at most underground coal mines for many years. In addition to the more obvious impacts on surface structures, these deformations have the potential to impact on shallow unconfined aquifers and surface waters. The deformations most commonly observed include subsidence, surface strains, surface tilts and valley bulging. Since the surface impacts are largely limited to the area above and immediately adjacent to the longwall panels, they are unlikely to have any significant impact on the Coxs River swamp. However, for completeness, the potential impacts on local groundwater and surface water systems that can result from these phenomena, are described briefly below.

Subsidence (vertical ground surface movement).
The formation of a subsidence trough over a longwall panel can lead to ponding of surface waters and disruption to stream flows if the subsidence is of sufficient magnitude

Surface strains (horizontal ground surface movement).
Of the two main types of strain (compressional and tensile), tensile strain is more likely to impact on surface and groundwater systems. For high subsidence values, the tensile strains may be large enough to cause cracks in the ground surface, which may divert surface water flows or drain the near-surface unconfined aquifer. Compressional strains at the surface may give rise to ground heaving or shearing. Surface strains may also concentrate at major geological structures, resulting abnormally high ground movements and cracking.

Surface tilting (change in slope of the ground surface).
Where surface streams have very low gradients, mining-induced tilting may either disrupt the stream flow, cause ponding or increase the discharge, so that erosion may occur in the stream bed. Similarly, disruption to groundwater flow could be experienced in a near surface aquifer, where the tilt is sufficiently large and the hydraulic gradient in the aquifer is sufficiently low.

Valley bulging and valley closure (uplift in valley floors and inward movements of valley sides).
Where valley bulging is significant, it may give rise to cracking in the valley floor, which in turn may temporarily disrupt the stream flow. In such cases, some or all of the stream flow is diverted into shallow underground cracks, sometimes leaving the stream bed dry. Generally, the stream flow reappears downstream of the area affected by the mining, where there is no cracking.

5.2 Sub-surface deformations

In addition to the near-surface deformations described above, sub-surface deformations may also impact on deeper aquifer systems and, to a lesser extent, surface waters. An understanding of this phenomenon is therefore necessary in order to determine the potential for any adverse impact on the local hydrogeology from this source. A discussion of the sub-surface deformation process and its potential impacts follows.

When the void created by extraction of a coal seam becomes sufficiently large, the unsupported roof of the seam fractures and falls into the void. Collapse of the roof continues upwards until the void is filled by broken rock, forming a goaf. This caved material supports the overlying strata, which sag downward. Significant fracturing occurs in the sagging strata immediately overlying the void, but this decreases in intensity higher up in the overburden. Where large areas are extracted, the sagging extends up to the ground surface forming a subsidence trough, and fracturing will occur to some extent through the full overburden height. Importantly, the fractures induced in the sagging strata lower down in the sequence near the goaf may interconnect. If the mine is at a shallow depth below an aquifer, these interconnecting fractures will provide a seepage path between the aquifer and the mine. Where the aquifer is at a greater height above the mine, the interconnected fractures may not reach the aquifer zone, and it will remain intact and relatively unaffected, although the fracturing may result in some temporary impacts.

Many previous studies both in Australia and overseas have examined the mechanics of strata deformation in order to understand the behaviour of the overburden strata above underground mines. Most studies have recognised four separate deformation zones in the overburden strata (Forster & Enever, 1992). Although there is some variation in the definition of these zones between the studies, a general description of each zone has been compiled and is given below.

Caved or Collapsed Zone (Some authors note primary and secondary caved zones.)
This zone comprises loose blocks of rock detached from the roof and occupying the cavity formed by mining. It can also contain large voids. Large increases in bulk permeability occur in this zone.

Fractured or Disturbed Zone
This zone comprises in-situ material lying immediately above the Caved Zone, which has sagged downwards and consequently suffered bending, significant fracturing, joint opening and bed separation. These beds rest on the underlying caved material causing it to compact. The Fractured Zone displays a significant increase in horizontal and vertical permeability, due to the interconnection of the fractures induced in the strata, and as such, the hydrogeological regime is permanently and completely altered.

Constrained or Aquiclude Zone
The Constrained Zone comprises confined rock strata above the fractured zone that have sagged slightly, but, because they are constrained and the imposed strains are lower than in the Fractured Zone, the degree of fracturing and dislocation of the strata is limited. Some horizontal bed separation or slippage is generally present, as well as discontinuous vertical cracking (usually on the underside of thick strong beds). Increases in horizontal permeability occur but no significant increase in vertical permeability is likely. Because of the occurrence of fracturing and dislocation in this zone, there may be some minor or temporary alteration to the hydrogeological regime.

Surface Zone
The surface zone comprises unconfined strata at the ground surface, in which mining induced tensile and compressive strains may result in the formation of cracks or ground heaving. Vertical permeability will increase in this zone, and the hydrogeological regime will show some changes.

These zones are shown diagrammatically in Figure 6.

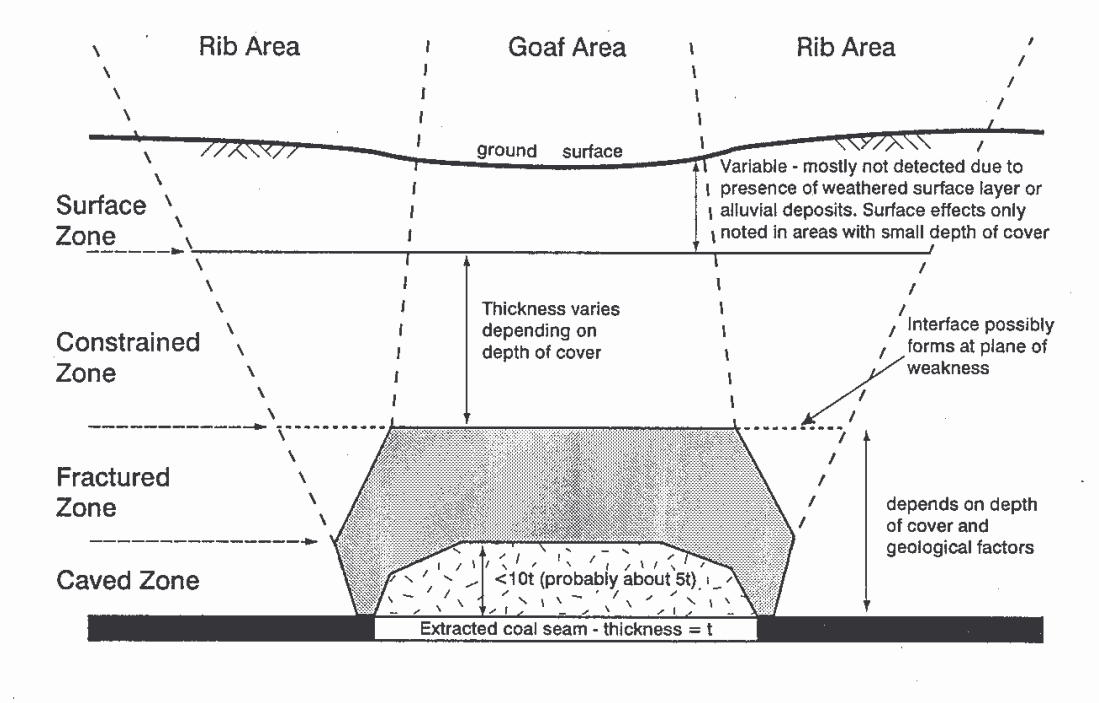


FIGURE 6 – Overburden deformation zones

The thickness of each of the deformation zones listed above is influenced by many factors. The most significant of these is the size of the mine opening. As this opening widens, the degree of deformation in the overburden strata increases. Initially, caving occurs in the roof strata, followed by formation of the fractured zone above the caved material. At greater extraction widths, the extent of the fractured zone increases and deformations at the ground surface become apparent. The maximum degree of deformation occurs when the mine opening reaches its critical width. Previous studies indicate that this critical width is about 1.4 times the depth of cover (Holla, 1991). For extraction widths greater than the critical width (supercritical extraction), there is no increase in the vertical extent of the deformation zones. Studies have shown, that for any given coal seam extraction width and orientation, the extent of each of the strata deformation zones in the overburden is dependent on the seam extraction height, depth of cover and the physical properties of the overburden strata (Forster, 1995).

If there are only minimal quantities of groundwater contained in the overburden strata, then the strata disturbance and increased permeabilities described above will have little impact on mining activities or the groundwater regime. It is only when mining is planned under extensive aquifers (or surface water bodies), that the nature and extent of the strata deformation zones must be considered.

It is evident that the caved and fractured zones would normally experience an increase in vertical permeability and would therefore tend to drain groundwater from any aquifers which occur in these zones. However, the constrained zone, since it contains few interconnecting fractures, has the potential to prevent a significant vertical hydraulic connection between the mine and any overlying aquifer, provided the initial permeability of the rock in this zone is low. Therefore, provided the initial permeability of the overburden strata is low, and there are no major aquifers within the caved or fractured zones above the mine, then there is limited potential for disruption to the groundwater regime or for groundwater inflows into the mine workings from the upper overburden. This does not mean that there will be no groundwater flow

at all between the constrained material and the fractured zone below, just that any flow will be insufficient to cause a significant disruption to the groundwater regime.

Therefore, in order to determine the impact of the proposed future mining on the aquifers and shrub swamps, the height of the fractured zone above the proposed mine workings needs to be estimated. This is defined as the height of interconnected fracturing that could transmit water from the strata to the mine opening. Since there is no quantitative method of estimating this height prior to mining, it must be established based on previous experience, incorporating a qualitative evaluation of local geological and mining conditions. This is not a simple task; since the height of the fractured zone is dependant on many variables including seam thickness, rock type, rock strength and deformation properties, jointing, bedding and depth of cover.

Previous studies in the Newcastle Coal Measures (ECNSW, 1987, Forster & Enever, 1992) have suggested that the fractured zone extends to a height of between 20 and 33 times the coal extraction thickness above supercritical extraction areas. These findings have not been tested in the Western Coalfield, although it is expected that the height of fracturing may be slightly greater due to differences in the rock properties.

Several previous field studies have been carried out at various locations to investigate the extent of the overburden deformation zones above underground coal mines, and in particular to determine the height of the fractured zone. Using either piezometric or microseismic monitoring during mining, these studies have measured a height for the fractured zone of between 40 and 120 m, over a range in cover depths of 80 to 500 metres, and seam heights of 1.9 to 3.2 m (ECNSW, 1987, Forster & Enever, 1992, Seedsman & Kerr, 2001, Kelly et al, 1998). These case studies are summarised in Table 2 below.

Table 2 – Fractured Zone Heights above Various Coal Seams

Colliery	Panel No.	Seam	Seam Height (m)	Depth of Cover (m)	Fractured Zone Height (m)	Investigation Method
Cooranbong	North B	Gt Northern	3.2	80	58	piezometric
Appin	LW 28	Bulli	2.3	500	90	microseismic
Wyee	LW 11	Gt Northern	1.9	180	40	piezometric
Wyee	3D Panel	Gt Northern	1.9	185	63	piezometric
Gordonstone	LW 103	German Ck	3.0	235	120	microseismic
Bellambi West	LW 514	Bulli	2.7	400	90	microseismic

Due to the lack of relevant field data in the Western Coalfield, no rigorous assessment has been made of the likely fractured zone height above longwalls 29 to 31. If the Newcastle Coal Measure data is used to estimate the fractured zone height, it would be expected to be of the order of 80 metres (assuming an extraction thickness of 2.45 metres). Based on this, a conservative figure of about 100 metres will be assumed for the fracture zone height in the current assessment. As a result, the fractured zone is likely to be restricted to the strata in the Illawarra Coal Measures, which extend approximately 95 to 105 metres above the Lithgow Seam, up to the base of the Narrabeen strata. Although strata fracturing and hydrogeological changes will be experienced in the Narrabeen strata above this zone, these changes will not be significant and/or permanent.

6. How will longwall mining affect the aquifers?

6.1 Impact of mining on aquifer systems

In Section 4, it was demonstrated that there were water-bearing horizons in the Narrabeen Group strata including the Banks Wall Sandstone and the Burra-Moko Head Sandstone, which contributed to the water supply to the Coxs River Swamp. It is therefore necessary to examine the potential impact of mining in greater detail, and determine how the expected overburden deformations will affect these aquifers. This will allow an understanding of the reasons for any impact or lack of impact, so that monitoring systems can be put in place to check that the conclusions are valid.

In Section 5 above, it was inferred (conservatively) that the fractured zone above the longwall panels could extend up to the base of the Narrabeen strata. If this were the case, then any aquifers in the coal measures would be drained into the mine opening. The volume of groundwater currently being pumped from the mine suggests that this is already occurring, and the coal seam aquifers above the Lithgow Seam probably contribute a large proportion of the groundwater inflow to the current mine workings. It follows then that most of the aquifers in the coal measures will be drained as a result of the proposed longwall extraction.

The situation for the aquifers in the Narrabeen strata is significantly different. The lowest aquifer is located towards the base of the Burra-Moko Head Sandstone Formation, and is above the overburden fractured zone. The underlying Caley Formation, which comprises fine grained sedimentary rocks, acts as an aquitard and, since it is not significantly fractured by the mining, will continue to limit any drainage downwards into the mine. This is because the base of this aquitard is located at a height of about 100 metres above the seam (Table 1), where the degree of deformation in the overburden would be insufficient to induce any significant vertical fracturing, which could drain the aquifer. Consequently, any impact on this aquifer should be limited to that caused by changes in gradient resulting from subsidence or opening of bedding partings. Since the maximum sub-surface tilts are likely to be less than 3%, any change in gradient will be insignificant, and any impact on the aquifer from this source should be negligible. Opening of bedding partings during mining may produce a temporary loss of pressure, which will recover with time.

While these conclusions are well-founded, there are currently no local data to support them, since there have been no previous hydrogeological investigations at Baal Bone. Nevertheless, there is a body of supportive data from other nearby collieries, which may be relevant, although the Lithgow seam thickness at Baal Bone is less than at other mines and the depth of cover shallower. Although these two aspects are favourable and would normally serve to reduce the fracture zone height, monitoring is recommended during coal extraction to confirm these findings.

6.2 Regional impact

Once the likely impact of the mining on the aquifer systems has been established, it is necessary to evaluate any regional consequences. Since the aquifers in the Narrabeen Group are unlikely to suffer any significant long-lasting impacts due to the mining, the regional consequences on these aquifers outside the application area are judged to be negligible. Nevertheless, the Coxs River Swamp and Coxs River rely on these aquifers for a source of water, and so this issue is examined separately in Section 7 below.

In Section 6.1, it was determined that the coal measure aquifers would almost certainly be drained into the goaf. It therefore needs to be established that this will not have any wide-ranging impacts on a regional scale. Searches have shown that there are no domestic,

industrial or agricultural users of the groundwater resources in these aquifers in the area surrounding the Baal Bone Colliery, probably due to their depth and relatively low yield. Consequently, there will be no immediate impact from the mining, but the long-term impacts must also be assessed.

It has already been concluded that the drawdown in these aquifers is significant in the vicinity of the mine and the application area (Section 4.1), and extraction of longwalls 29 to 31 will probably drain the groundwater completely from the aquifers. While these aquifers currently drain towards the escarpment on the eastern side of the application area, and would normally contribute to the flow in the Wolgan River, this contribution would be negligible, due to the relatively low permeability of the strata. In addition, this contribution would have been further reduced due to the impact of the existing mine workings, which have effectively cut off most recharge to these aquifers in the application area. Therefore any incremental impact on this water source from the extraction of longwalls 29 to 31 will be miniscule.

Once mining is completed, and pumping from the pit ceases, the strata will re-pressurise as the mine fills with water. Previous experience has shown that the pre-mining hydrogeological conditions will eventually re-establish following mining. This has been demonstrated at the Lithgow State Mine adjacent to Springvale Colliery, which ceased extracting coal in 1964. Since that time, the workings have completely filled with water, and the water head at seam level has been measured at 129 metres (CSIRO, 2003). This is very close to what the pre-mining level would have been. Other abandoned mines in the vicinity have also filled with water since mining activities ceased, including Newcom and Fernbrook Collieries.

Based on these facts, it is concluded that the incremental impact on the regional hydrogeological regime at Baal Bone due to the extraction of longwalls 29 to 31 will be minimal. The pre-mining regime will be restored in the long term after mining ceases, even though it may take several decades to re-establish.

Also on a regional scale, it has occasionally been suggested that there may be very slow drainage of the important upper aquifers in the Narrabeen Group into the lower aquifers in the Coal Measures over a period of decades, with resulting impacts on the overlying swamps. For this to occur there would need to be a reasonable hydraulic connection between the upper and lower aquifers. Based on the available data this is not considered to be a valid proposition. Pumping tests carried out at Clarence Colliery were designed to examine precisely this issue (ERM, 2003). The Katoomba Seam was pumped out and the near-surface aquifer zone monitored for any resultant drop in pressure. The testing showed that there was no measurable impact on the upper aquifers.

7. How will longwall mining affect the swamp?

Section 4.2 described the means by which the Coxs River Swamp was formed, and its dependence on surface water flows and groundwater flow from the water-bearing zones in the sandstone strata. This model suggests that, if either the surface water flow or the groundwater supply from the water-bearing zones were to be cut off or disrupted, there may be some deleterious impact on the swamp. It is therefore desirable that the proposed mining does not impact these water sources to any major degree.

There are essentially only three means by which it is possible that surface water or groundwater flow to the swamps could be disrupted or altered by longwall mining. These are:

1. Subsidence effects such as tilting, strains and uplift, if they are of sufficient magnitude, have the potential to alter the flow direction and/or volume of surface water or groundwater;

2. Sub-surface deformations may cause bed separation or possibly rupturing of the aquitard that supports the aquifer (Caley Formation), resulting in drainage of the aquifer; and

3. Surface strains may concentrate on the faults in the Coxs River Lineament Fault Zone and result in surface cracking and possible drainage of groundwater from the swamp.

While all of these effects are theoretically possible given the right circumstances, the risk of any of them causing significant changes to the groundwater regime in the vicinity of the Coxs River Swamp is considered to be extremely low for the following reasons:

- Groundwater probably supplies only a small percentage of the total water input to the swamp, so that any changes in groundwater flow will have a negligible impact.

- It is probable that bed separation will occur in parts of the Narrabeen strata due to the passage of the longwalls. Nevertheless, bedding separations do not drain any water vertically, but create a narrow horizontal cavity. Generally, these cavities close to some degree with the passage of the adjacent longwall, although it is probable that there will be some residual bedding separations in the overburden. Fortunately, any bedding opening which forms in an aquifer should be filled with groundwater relatively quickly, and normal flows should resume shortly afterwards. As a result, it is unlikely that lateral groundwater flow towards the swamp will be disrupted by bed separation.

- Since the aquitard beneath the Burra-Moko Head Sandstone lies almost 100 metres above the Lithgow Seam, it is unlikely that the fractured zone will intersect it. As a result, the integrity of the overlying aquifer will be maintained, and groundwater flows will continue to be largely horizontal and not vertical. While the extraction will result in tilting and the formation of a subsidence trough in the overlying strata, including the aquifers, the ground level at the escarpment and the Coxs River valley will not be affected. Because of this, there will be minimal impact on the flow rates from the aquifers, since they are confined, and should quickly re-pressurise to their pre-mining head after any subsidence event.

- The surface strains at the fault zone will be unmeasurable, based on the current predictions, so that any opening of the faults or other movement due to mining will be negligible.

- The Coxs River Swamp and the creek valley are outside the zone affected by subsidence, so that there will be no surface strains, tilts or valley effects at the swamp. As a result, surface deformation will not be a source of disruption to water flows in the swamp.

- The extracted longwall panels in the south mine area are closer to the swamp than the proposed extraction in longwalls 29 to 31, and there did not appear to be any identifiable deleterious impacts due to the extraction of those longwalls, or in the intervening period after the completion of mining.

Given the available data and previous experience, there can be a high level of confidence that the Coxs River Swamp will suffer no long-term adverse impacts from the proposed mining. At worst there may be minor unmeasurable transient changes to groundwater flow, which should result in negligible short-term impacts. Should any unforseen impacts eventuate, normal rainfall and runoff should replace any temporary shortfall in the groundwater flow to the swamps. This shortfall will be made up from excess runoff that currently discharges down the creek channel and into the Coxs River. Alternatively, temporary remedial measures may be required (see Section 9).

8. What monitoring is required?

A detailed monitoring program should be established at the swamp to monitor the local hydrogeological conditions and check for any impacts due to the potential effects of subsidence at the surface. Piezometers and groundwater holes should be included in this monitoring program to monitor the aquifers and swamps for any change in groundwater level.

The monitoring program should include the following:

- Two groundwater monitoring bores (approximately 500 metres apart) should be installed in the Coxs River Swamp to allow the monitoring of groundwater levels and give an indication of the impact of any subsidence-induced longitudinal changes in the watercourse gradient and the groundwater gradient.

- Four groundwater monitoring boreholes should be drilled to the base of the Burra-Moko Head sandstone to intersect the aquifer zone near the base of this unit. These bores should include one each on the eastern and western sides of the swamp, one at the head of the swamp and one upstream of the swamp, between the swamp and the proposed longwall panels. Monitoring of groundwater in these bores will give an indication of the impact of mining on the piezometric head in the aquifer that feeds the swamp, and will allow any mining-induced changes in the lateral groundwater gradient to be detected. This is important, since it is the lateral gradient that determines the magnitude of the seepage from the aquifer into the swamps

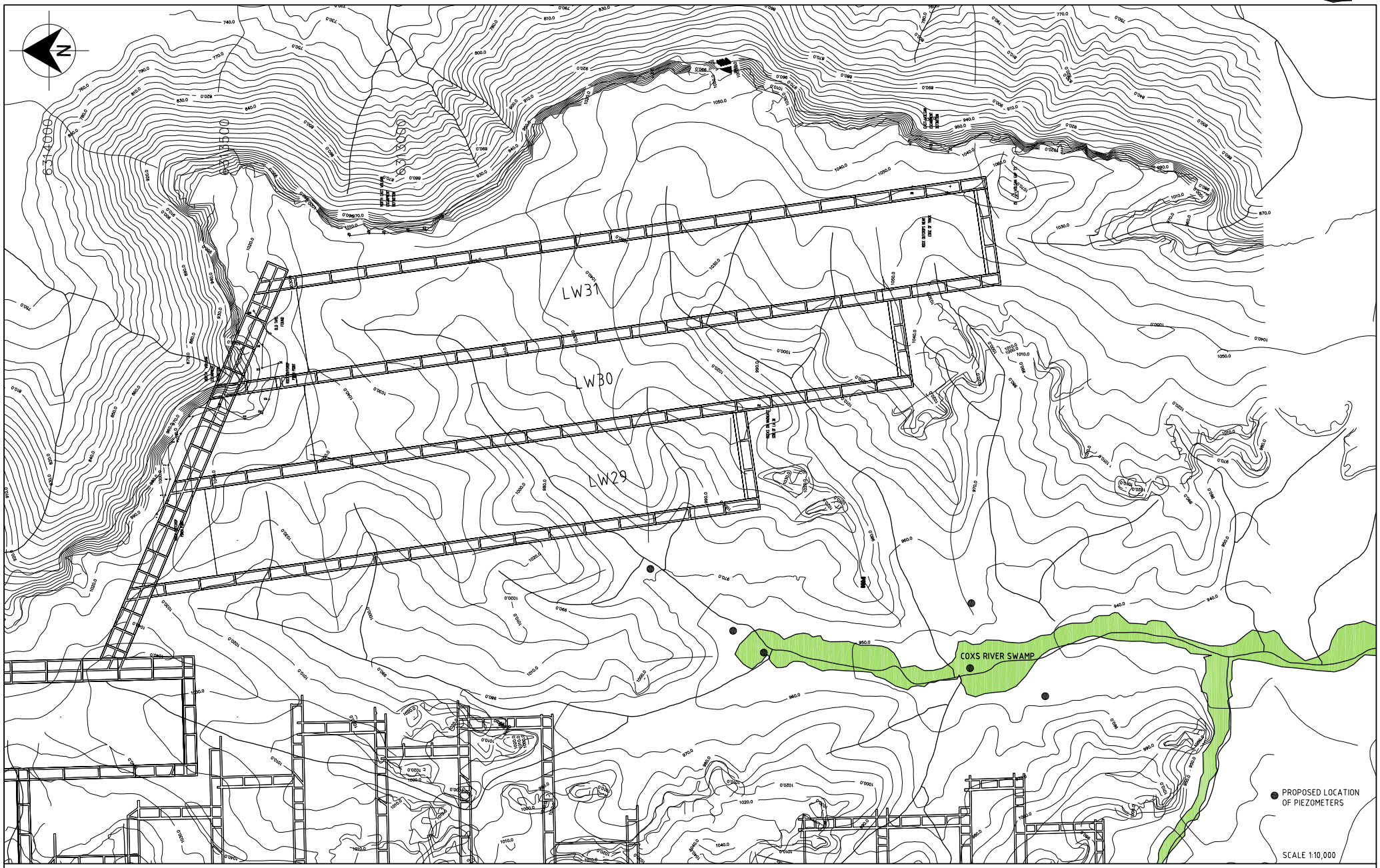
- All six groundwater observation bores should be cased with polypipe and fitted with continuous water level monitoring and logging instrumentation. Data should be downloaded at regular intervals, corrected for barometric pressure fluctuations and plotted in graphic form. Daily rainfall data should also be plotted with the water level data to give an indication of the response of the swamp and aquifer to rainfall.

The suggested locations of the proposed groundwater holes are shown in Figure 7.

In the period before and during coal extraction, the groundwater monitoring activities should include the following aspects:

- Continuous monitoring of water levels in the swamps and the groundwater monitoring holes on the flanking ridges;
- Regular review of the monitoring results (two monthly) in order to identify any abnormal trends in the data; and
- Reporting on the impact of mining following the passage of each longwall.

It is recommended that contingency actions be documented for reference in the event that the monitoring program detects any abnormal impacts. Suggested actions are provided in Section 9 below.



BAAL BONE COLLIERY
HYDROLOGICAL STUDY
LOCATION OF PIEZOMETERS

FIGURE 7

9. What if the predictions are wrong?

During the current study, every effort has been made to evaluate the potential impact of mining accurately and, where uncertainty exists, with some conservatism. The level of mining experience in this area gives confidence that the predictions are as accurate as conditions allow. Nevertheless, there will always be a minimal risk of an adverse outcome, no matter how intensive the investigation and evaluation has been. This risk must be evaluated, and any necessary measures enacted to reduce the risk to an acceptable level.

Based on the results of a risk assessment carried out at Baal Bone on 5th December 2006, the risk to the Coxs River Swamp was determined to be medium. This rating takes into account the environmental significance of the swamp, as well as the fact that the swamp is located outside of the area affected by subsidence. In addition, the contribution of flow to the swamp from groundwater most likely represents only a small proportion of the total inflow. Runoff provides the bulk of the water used by the swamp, and (except in drought conditions) any shortfall in groundwater would be wholly or partially made up by excess runoff that would otherwise have discharged down the stream channel. In effect, any peat deposits deprived of groundwater seepage would soak up excess runoff during major storm events.

For medium risks, control measures are often recommended to reduce the level of risk. These control measures will typically include monitoring of certain parameters to detect any unexpected or unusual impacts. The risk assessment concluded that, with the recommended monitoring program in place (see Section 8), the risk to the swamp was acceptable. The only additional control measure recommended was to carry out a regular revision of all the monitoring data, and report any abnormal behaviour.

Where monitoring is undertaken, it is advisable to establish contingency measures to be carried out in the event that the monitoring detects any abnormal impacts. These contingency measures should include the following actions:

1. If the monitoring highlights any anomalous groundwater behaviour in the vicinity of the swamp, a field inspection should be carried out at the swamp by a hydrogeologist accompanied by Xstrata staff. Anomalous behaviour is defined as any fluctuation or change in the hydrogeological conditions that cannot be explained by climatic fluctuations or the established hydrogeological model (as detailed in Section 4 of this report). The field inspection should be targeted at determining if there have been any adverse consequences at the swamp resulting from the anomalous condition.

2. Following the field inspection, a full evaluation, should be carried out in order to determine the cause of the anomalous behaviour if possible. The evaluation should take account of all available monitoring data, including piezometer data, pumping data and subsidence data, as well as the results of the field inspection.

3. The evaluation should attempt to determine whether the observed anomaly represents a temporary or permanent disruption to the hydrogeological regime, and the likely impact, both short-term and long-term, on the affected swamp. The evaluation should also assess whether any impact is localised or widespread.

4. Following the evaluation, recommendations should be made for any additional monitoring measures that may be necessary in order to determine the cause and/or impact of the anomalous condition. Such monitoring may include (but should not be limited to), detailed subsidence surveys, installation of additional groundwater observation bores or piezometers, or flora and fauna surveys. The type and extent of monitoring will depend on the nature and severity of the anomalous condition.

5. If the anomalous condition has resulted in a significant loss of groundwater or surface water flow to the swamp, it may be necessary to divert part of the discharge from the mine into the valley upstream of the head of the swamp to replace the lost flows. While this is not considered to be a permanent solution, it should provide an acceptable solution while the problem is rectified or investigated.

6. If the anomalous condition prevails, and the condition is judged to be deleterious to the swamp in the long term, recommendations will be made for any remedial measures to mitigate the adverse impacts. Depending on the nature of the condition, such measures may be necessary prior to the passage of the subsequent longwall panel. The type and extent of remedial measures implemented will depend largely on the nature of abnormal condition and its potential impact on the swamp. Such measures may range from continued monitoring and evaluation to physical measures including grouting or earthworks.

10. References

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Appendix A

Geological logs of boreholes

BAAL BONE COLLIERY
LITHOLOGY LOG

BBN 164

Location:	South East Resource Block
Site No.:	D4
Co-ordinates:	(GDA)
E: 230076.23	N: 6311636.68 R.L.: 961.50
Logged by:	J. Bryan
Commenced:	6.03.06
Completed:	8.03.06
T.D.:	138m
Hole Type:	Open Hole/Down Hole Hammer
Hole cemented?:	Yes, to surface
Contractor:	Country to Coast Drilling
Driller:	Shane Mills
Rig:	Mole Pioneer B40
Casing:	PVC – 10m
Precision Energy Down Hole Logging:	DD6
Ground Water Flows:	Minor Flows at 8m to 10m; less than 10 litres/minute

---

BBN 164

Depth To Floor (m)	Thickness (m)	Lithology	Comments
3.0	3.0	Sand, soil clay	
5.0	2.0	Gravel and clayey sand	
8.0	3.0	Sandstone, orange/brown, weathered	Minor water inflow at 10m
22.5	14.5	Sandstone, light grey to white, quartzose.	
36.10	13.6	Siltstone, light to mid grey	
43.50	7.4	Coal, carbonaceous claystone, claystone	KA
45.95	2.45	Siltstone, mid grey	
46.60	0.65	Coal and claystone	Band
51.45	4.85	Siltstone, mid to light grey	
57.70	6.25	Coal and carbonaceous claystone	MR
62.50	4.80	Siltstone, mid grey	
62.90	0.40	Coal, undiff.	Band
64.65	1.75	Siltstone and claystone, light grey	
66.15	1.50	Coal and carbonaceous claystone	OS
92.70	26.55	Siltstone, mid grey	
93.20	0.50	Coal, undiff.	GDU
93.70	0.50	Claystone, light grey/brown (tuff)	TF3
93.95	0.25	Coal, undiff.	
98.20	4.25	Siltstone and claystone	

BBN 164 Continued

Depth To Floor (m)	Thickness (m)	Lithology	Comments
99.40	1.20	Coal, undiff.	GDL
103.15	3.75	Siltstone, mid grey, minor claystone	
104.70	1.55	Coal, undiff. And claystone	IR
128.75	24.05	Sandstone and siltstone, light to mid grey	
129.25	0.50	Claystone, white	TF1
131.15	1.90	Siltstone, mid grey	
133.40	2.25	Coal, undiff.	LITH
138.0	4.60	Sandstone/siltstone, grey, minor pebbles	T.D.

BAAL BONE COLLIERY
LITHOLOGY LOG

BBN 165

Location:	South East Resource Block	
Site No.:	D5	
Co-ordinates:	(GDA)	
E: 230462.64	N: 6311946.53	R.L.: 983.02
Logged by:	J. Bryan	
Commenced:	4.04.06	
Completed:	7.04.06	
T.D.:	168m	
Hole Type:	Open Hole/Down Hole Hammer	
Hole cemented?:	Yes, to surface	
Contractor:	Ultra Drilling	
Driller:	Peter Davidson	
Rig	Mole Pioneer B40	
Casing:	24m PVC	
Precision Energy Down Hole Logging: DD6, verticality, sonics		
Ground Water Flows:	7.5 litres/minute between 90m and 95m	

BBN165

Depth To Floor (m)	Thickness (m)	Lithology	Comments
3.0	3.0	Sand and clay	
12.0	9.0	Sand, weathered sandstone?	
21.0	9.0	Sandstone, light grey, coarse, slightly weathered	
41.5	20.5	Sandstone and siltstone, light grey, hard	
59.30	17.80	Siltstone, mid grey	
67.25	7.95	Coal, undiff. And claystone	KA
69.70	2.45	Claystone, grey	
70.15	0.45	Coal, undiff	BAND
76.50	6.35	Siltstone and claystone	
81.75	5.25	Coal, and claystone	MR
91.75	10.00	Silstone, mid-grey	
93.20	1.45	Coal, undiff.	OS
119.75	26.55	Siltstone, mid grey with minor claystone	
120.25	0.50	Coal,undiff.	GDU
120.80	0.55	Claystone, light grey/brown, tuff.	TF3
121.05	0.25	Coal, undiff.	GDU
125.00	3.95	Siltstone, mid grey	
125.50	0.50	Coal, undiff	GDL
130.30	4.80	Siltstone and sandstone, grey	

BBN 165 Continued

Depth To Floor (m)	Thickness (m)	Lithology	Comments
131.80	1.50	Coal, undiff and claystone	IR
157.00	25.20	Sandstone and siltstone, grey	
157.50	0.50	Claystone, grey/brown, tuff.	TF1
159.35	1.85	Siltstone, light grey	
161.65	2.30	Coal, undiff.	LITH
168.00	6.35	Sandstone, light grey	T.D.

BAAL BONE COLLIERY
LITHOLOGY LOG
BBN 166

Location:	South East Resource Block	
Site No.:	D2	
Co-ordinates:	(GDA)	
E: 230187.12	N: 6312588.15	R.L.: 980.13
Logged by:	J. Bryan	
Commenced:	10.04.06	
Completed:	11.04.06	
T.D.:	168m	
Hole Type:	Open Hole/Down Hole Hammer	
Hole cemented?:	Yes, to surface	
Contractor:	Ultra Drilling	
Driller:	Peter Davidson	
Rig	Mole Pioneer B40	
Casing:	7m PVC	
Precision Energy Down Hole Logging:	DD6	
Ground Water Flows:	Dry hole	

BBN 166

Depth To Floor (m)	Thickness (m)	Lithology	Comments
6.0	6.0	Sand, gravel, clay	
21.0	15.0	Sandstone, light grey, partly weathered	
40.0	19.0	Sandstone and siltstone, light grey	
55.30	15.3	Siltstone, grey/brown	
62.70	7.4	Coal, undiff. And claystone	KA
72.40	9.7	Claystone and siltstone, mid grey	
78.70	6.3	Coal, undiff. And claystone	MR
87.55	8.85	Siltstone and claystone, grey	
88.85	1.30	Coal, undiff	OS
114.10	25.25	Siltstone, mid grey	
114.60	0.50	Coal, undiff.	GDU
115.15	0.55	Claystone, brown, (Tuff)	TF3
115.45	0.30	Coal, undiff	GDU
119.80	4.35	Siltstone, mid-grey	
120.15	0.35	Coal, undiff.	GDL
125.65	5.50	Siltstone and claystone, grey	
127.25	1.60	Coal, undiff. and claystone	IR
152.30	25.05	Sandstone, siltstone and minor claystone	
153.00	0.70	Claystone, light grey/brown (Tuff)	TF1
154.70	1.70	Siltstone and claystone	
157.10	2.40	Coal, undiff.	LITH
168.00	10.90	Sandstone, siltstone, grey/brown, pebbly in part.	T.D.

BAAL BONE COLLIERY
LITHOLOGY LOG

BBN 167

Location: South East Resource Block
Site No.: D1
Co-ordinates: (GDA)
E: 230038.99 N: 6312443.69 R.L.: 968.70

Logged by: J. Bryan
Commenced: 12.04.06
Completed: 13.04.06
T.D.:
Hole Type: Open Hole/Down Hole Hammer
Hole cemented?: Yes, to surface
Contractor: Ultra Drilling
Driller: Peter Davidson
Rig Mole Pioneer B40
Casing: 7m PVC
Precision Energy Down Hole Logging: DD6
Ground Water Flows: 90 litres/minute from aquifer between 15m and 21m; 35ppm total salt.

BBN 167

Depth To Floor (m)	Thickness (m)	Lithology	Comments
6.0	6.00	Sand with clay	
15.0	9.00	Sandstone, light grey/brown – weathered	BOW
28.00	13.00	Sandstone and siltstone, light grey, includes aquifer	1.5 litres/sec flow of water (35 ppm salt)
42.10	14.10	Siltstone, mid to dark grey	15-21m: Aquifer
49.10	7.00	Coal and claystone	KA
57.60	8.50		
63.75	6.15	Coal and claystone	MR
73.40	9.65	Siltstone, grey	
74.60	1.20	Coal, undiff.	OS
99.75	25.15	Siltstone and claystone, mid-grey	
100.30	0.55	Coal, undiff	GDU
100.90	0.60	Claystone, brown/grey – Tuff	TF3
101.10	0.20	Coal, undiff	GDU
105.40	4.30	Siltstone, mid grey	
105.85	0.45	Coal, undiff	GDL
111.15	5.30	Siltstone and claystone, grey	
112.65	1.50	Coal, undiff	IR
137.50	24.85	Sandstone and siltstone, grey	

BBN 167 Continued

Depth To Floor (m)	Thickness (m)	Lithology	Comments
138.10	0.60	Claystone, light grey/brown	TF1
140.05	1.95	Siltstone and claystone	
142.35	2.30	Coal, undiff.	LITH
150.00	7.65	Sandstone & siltstone grey/brown, hard	T.D. at 150m

BAAL BONE COLLIERY
LITHOLOGY LOG

BBN 168

Location:	South East Resource Block	
Site No.:	D8	
Co-ordinates:	(GDA)	
E: 229701.37	N: 6313269.45	R.L.: 994.98
Logged by:	J. Bryan	
Commenced:	18.04.06	
Completed:	21.04.06	
T.D.:	186m	
Hole Type:	Open Hole/Down Hole Hammer	
Hole cemented?:	Yes, to surface	
Contractor:	Ultra Drilling	
Driller:	Peter Davidson	
Rig	Mole Pioneer B40	
Casing:	48m PVC	

Precision Energy Down Hole Logging: DD6, verticality, sonics

Ground Water Flows: 45 litres/minute from aquifer at 18m to 20m; 11ppm total salts.

BBN 168

Depth To Floor (m)	Thickness (m)	Lithology	Comments
6.0	6.0	Gravel and sand	
14.0	8.0	Sandstone, white, weathered	
40.0	26.00	Sandstone, light grey, hard	0.8 litres per sec water from aquifer at 16m-18m
42.0	2.0	Claystone, red/brown	
55.0	13.0	Sandstone, grey, coarse	
70.0	15.0	Siltstone, mid grey	
76.25	6.25	Coal (undiff.) and claystone	KA
85.75	9.50	Siltstone, mid grey	
93.35	7.60	Coal, (undiff.) and claystone	MR
104.70	11.35	Silstone, mid-grey, hard	
106.00	1.30	Coal, undiff.	OS
131.35			
131.80	0.45	Coal, undiff	GDU
132.40	0.60	Claystone, light grey (Tuff)	TF3
132.65	0.25	Coal, undiff.	GDU
136.85	4.20	Siltstone and claystone	
137.35	0.50	Coal, undiff.	GDL
144.50	7.15	Siltstone and claystone	

BBN 168 Continued

Depth To Floor (m)	Thickness (m)	Lithology	Comments
146.65	2.15	Coal, undiff.	IR
169.90	23.25	Sandstone and siltstone	
170.40	0.50	Claystone, brown/light grey (Tuff)	TF1
172.35	1.95	Siltstone, light grey	
174.65	2.30	Coal, undiff.	LITH
186.00	11.35	Sandstone, pebbly and siltstone	T.D. at 186m

BAAL BONE COLLIERY
LITHOLOGY LOG

BBN 169

Location: South East Resource Block
Site No.: D12
Co-ordinates: (GDA)
E: 229734.55 N: 6312105.64 R.L.: 955.91
Logged by: J. Bryan
Commenced: 26.4.06
Completed: 27.4.06
T.D.: 138m
Hole Type: Open Hole/Down Hole Hammer
Hole cemented?: Yes, to surface
Contractor: Ultra Drilling
Driller: Peter Davidson
Rig Mole Pioneer B40
Casing: 30m PVC
Precision Energy Down Hole Logging: DD6, verticality
Ground Water Flows: 15 litres per minute from aquifer 10m to 20m

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BBN 169

Depth To Floor (m)	Thickness (m)	Lithology	Comments
7.0	7.0	Gravel and sand	
13.0	6.0	Sandstone, brown/grey, slightly weathered	0.3 litres/sec water at 25m
27.0	14.0	Siltstone, light grey to brown with minor sandstone – slightly weathered.	
29.20	2.20	Siltstone, mid-grey	
36.50	7.30	Coal & claystone	KA
46.80	10.30	Siltstone, mid grey	
52.80	6.00	Coal and claystone	MR
61.65	8.85	Siltstone, mid grey	
62.75	1.10	Coal, undiff	OS
88.80			
89.35	0.55	Coal, undiff.	GDU
89.85	0.50	Claystone, light grey (Tuff)	TF3
90.10	0.25	Coal, undiff.	
94.10	4.00	Siltstone and claystone	
94.55	0.45	Coal, undiff.	GDL
99.25	4.70	Siltstone, mid-grey	
100.80	1.55	Coal, undiff. And claystone	IR
125.60	24.80	Sandstone and siltstone, mid-grey	

BBN 169 Continued

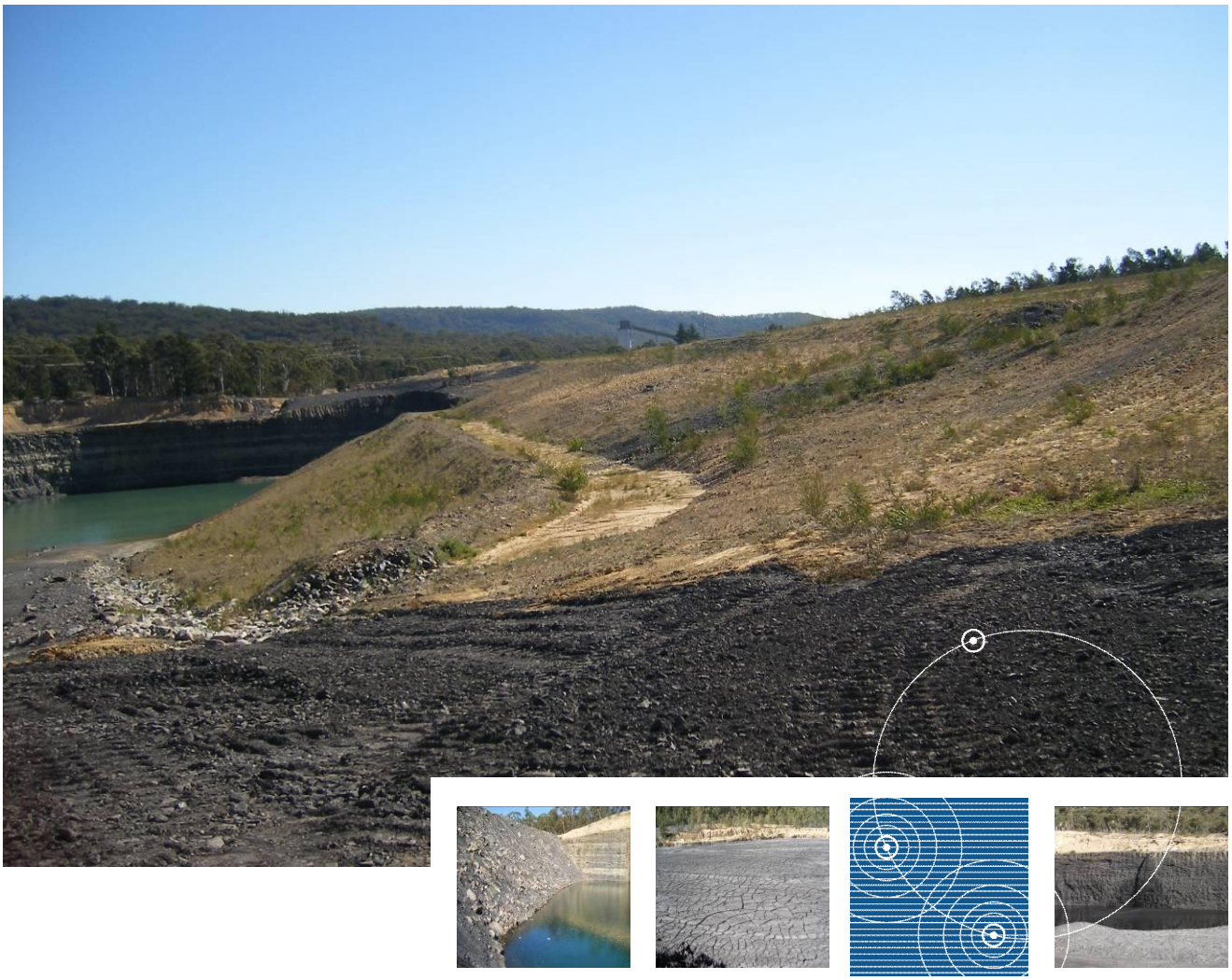
Depth To Floor (m)	Thickness (m)	Lithology	Comments
126.20	0.60	Claystone, light grey	TF1
127.80	1.60	Siltstone, mid to light grey	
130.25	2.45	Coal, undiff.	LITH
138.0	7.75	Sandstone, grey/brown, pebbly	T.D. at 138.0m



APPENDIX H

Tailings Capacity Assessment

AECOM



Continued Operations at Baal Bone Colliery Tailings Capacity Assessment

The Wallerawang Collieries Limited

9 October 2009
Document No.: 60098124-DO-009

Tailings Capacity Assessment

Prepared for

The Wallerawang Collieries Limited

Prepared by

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Quality Information

Document Tailings Capacity Assessment

Ref 60098124

Date 9 October 2009

Prepared by James Kelly

Reviewed by Amanda Kerr

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	12/05/2009	Draft	Amanda Kerr Senior Environmental Engineer	
B	01/07/2009	Draft	Amanda Kerr Senior Environmental Engineer	
C	27/08/2009	Final Draft	Amanda Kerr Senior Environmental Engineer	
D	09/10/2009	Final	Amanda Kerr Senior Environmental Engineer	

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Executive Summary

Baal Bone Colliery requires an assessment of the remaining tailings storage capacity currently on site.

The Baal Bone Colliery site was investigated with the goal of determining the capacity of existing and potential rejects emplacement areas (REA).

The Baal Bone Colliery site has previously operated a number of reject emplacement areas. REA 6 is currently in use. Recent survey data was analysed by AECOM and it was found that sufficient capacity remains in REA 6 (Cell 1 and 2) to service the process plant until mid 2012.

A further area, the Southern Void, was also identified as a potential reject emplacement area. Recent survey showed that this area has sufficient capacity to service the mine from approximately mid 2012 (following completion of REA6) to the end of 2015.

If the mine intends to extend operations beyond 2015, and continues to produce tailings and course reject at the current rate, further investigation will be required into future suitable emplacement areas.

1.0 Introduction

1.1 Project Background

The Baal Bone Colliery operated by The Wallerawang Collieries Limited (TWCL) under a development approval which expires in 2010. TWCL intends to continue mining beyond 2010 and needs to obtain approval to continue current operations on this site. In order to obtain approvals to continue mining past 2010, TWCL is preparing an Environmental Assessment (EA) in support of an application for continued development approval and to demonstrate operations are sustainable for another 10 to 15 years.

As part of this EA process it is important to demonstrate that the existing practises to manage the site are sustainable during future operation. As part of this assessment, Baal Bone Colliery has engaged AECOM to prepare an assessment of the remaining tailings and coarse reject storage capacity currently on site.

This report outlines the assessment of the remaining storage available in REA 6 and investigation into other areas available on site. This document relates to above-ground storage of tailings and coarse reject only.

1.2 Background Review

A background review was undertaken based on the available information that was provided by the client. This includes:

- Survey data collected on 22 May 2009 by Craven, Elliston & Hayes Pty Ltd of the south eastern corner of the site (DWG No BBREH09);
- Report titled: *Construction and Operation of Reject Emplacement Area 6 (REA6) at Baal Bone Colliery* (Umwelt 2008);
- Report titled: Construction and Operation of Reject Emplacement Area 5 (REA5) at Baal Bone Colliery dated September 2005; and
- Xstrata Tailings Storage Management, HSEC STD 8.1.

1.3 Site Overview

The site is located approximately 25km north west of Lithgow. A section of the mine area was originally open cut mined in the 1950s, down to a depth of up to 15 m below natural surface levels in some areas of the site. An area of a more recent open cut pit to the south of the site was reserved for the disposal of tailings. The remainder of the site has been rehabilitated in stages. The pit top area, the coal handling and the stockpile areas are located in the centre of the site.

A layout of the site showing relevant features is provided as **Figure 1**.

Figure 1 – Baal Bone Colliery



2.0 Tailings Capacity Assessment

2.1 Tailings Operations and Characteristics

Product from Baal Bone is largely thermal coal for export and the Coal Handling and Preparation Plant (CHPP) has a recovery rate of approximately 75%, with the residual reject material consisting of 7% fines and 18% coarse material.

The CHPP has a maximum design processing rate of 2.6 million tonnes per annum (Mtpa), resulting in an annual production of 114,000m^3 of fine reject material and 360,000m^3 coarse reject material. Fine reject material is pumped as 20 to 25% slurry to the reject emplacement area (REA).

REA 6 is constructed in the void of the former open cut workings in the southern extent of the site. It is bounded by the high wall to the south, and consists of two cells separated by an embankment. The embankment between the cells and the walls are constructed of coarse reject. The base of the cell is the excavated coal seam floor and the top embankment level of REA 6 is 878 m AHD. REA 6 has a capacity of approximately 352,000m^3 (refer to **Section 2.2**) and has been used for approximately the last year. The location of REA 6 and surrounding contours is shown in **Figure 3**.

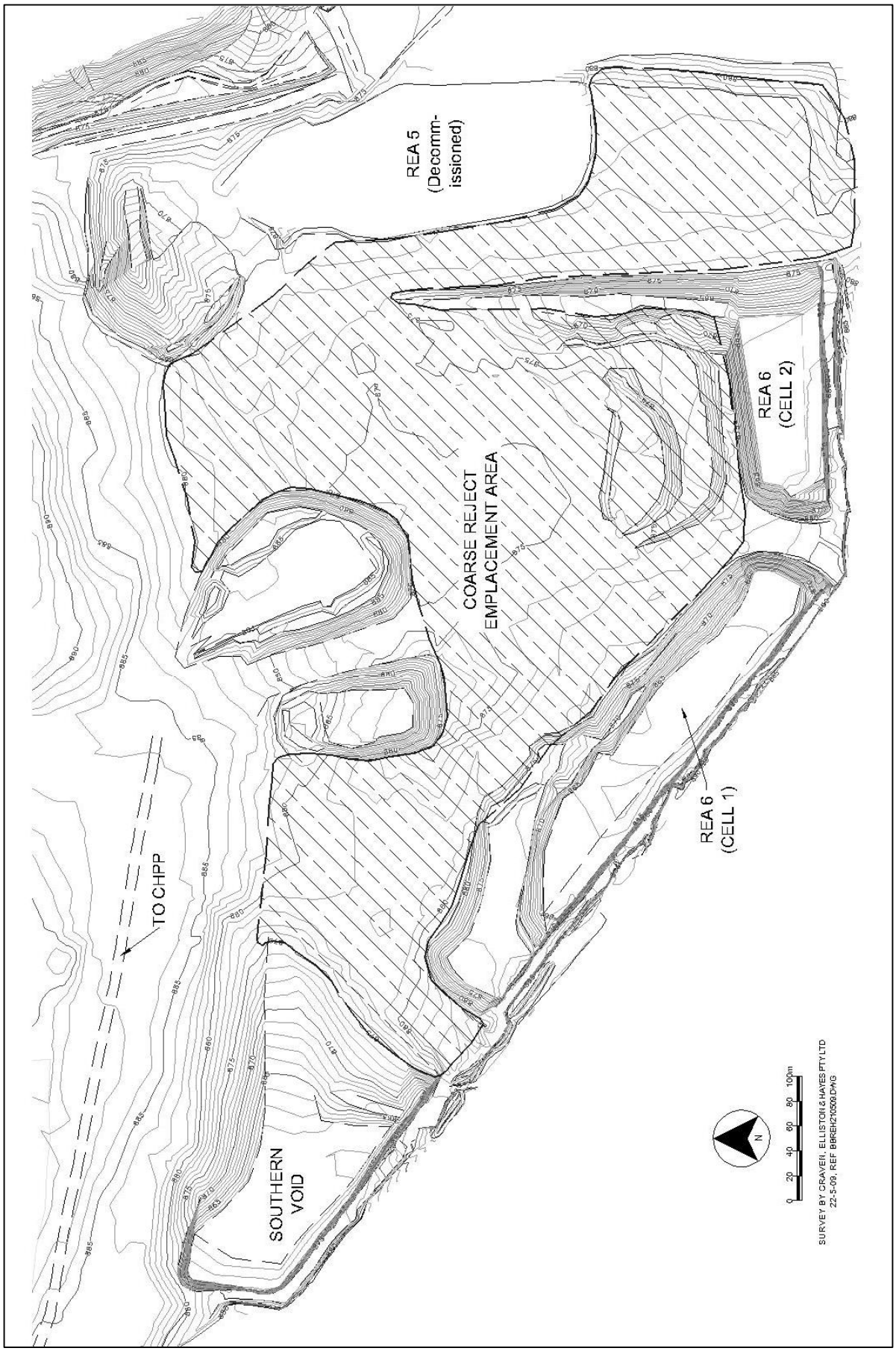
Tailings slurry is pumped from the CHPP and discharged into Cell 1. Leachate water is then allowed to decant through the embankment wall by percolation through the wall and also via a decant pipe to Cell 2.

Discussions with site staff indicated that the fine rejects slurry is rapidly self-dewatering, usually only requiring two weeks for a crust to form on cessation of deposition. **Figure 2** shows an existing rejects deposition area with cracks in the crust evident.

Figure 2 – REA 5 showing zero surface water and a crust forming



Figure 3 – Reject Emplacement Areas



At completion of REA 6, Cell 1 will then be dewatered and capped with a minimum thickness of 2.5 metres coarse reject material, overlain by 1.0m of clay loam. The final design of the rehabilitated emplacement area will be in accordance with the current Baal Bone Open Cut Mining Operations Plan.

2.2 Remaining Tailings Disposal Capacity

Currently the only emplacement area in use is REA 6 (**Figure 5**). The other above ground emplacement on site, REA 2 and 5, have been filled to capacity.

Based on recent survey data for the site it was calculated that REA 6 has a total capacity of approximately 352,000m^3 for tailings emplacement (Cell 1) and 102,000m^3 for leachate collection and storage (Cell 2). At the maximum emplacement rate of 114,000m^3 per year, this area can provide approximately 3.2 years of total storage. Given that this storage area has been used for the last year, it is estimated that REA 6 (Cell 1) will provide storage for a further 2.2 years, or to the middle of 2011.

Following completion of Cell 1, Cell 2 can be used to accept tailings, thereby providing an additional 0.9 years of storage capacity.

The following graph (**Figure 4**) shows the volume of the Cell 1 against elevation (RL). The volume of the REA was calculated from recent survey work (Baal Bone Colliery Rehabilitation Survey, May 2009, drawing number BBREH09, dated 22/5/09) by taking the volume of a slice at each RL and adding them to give a total volume. Survey was provided at 1m contours. The bottom and top of the pit are at 862mAHD and 878mAHD respectively.

Figure 4 – Storage Volume versus Elevation (REA6)

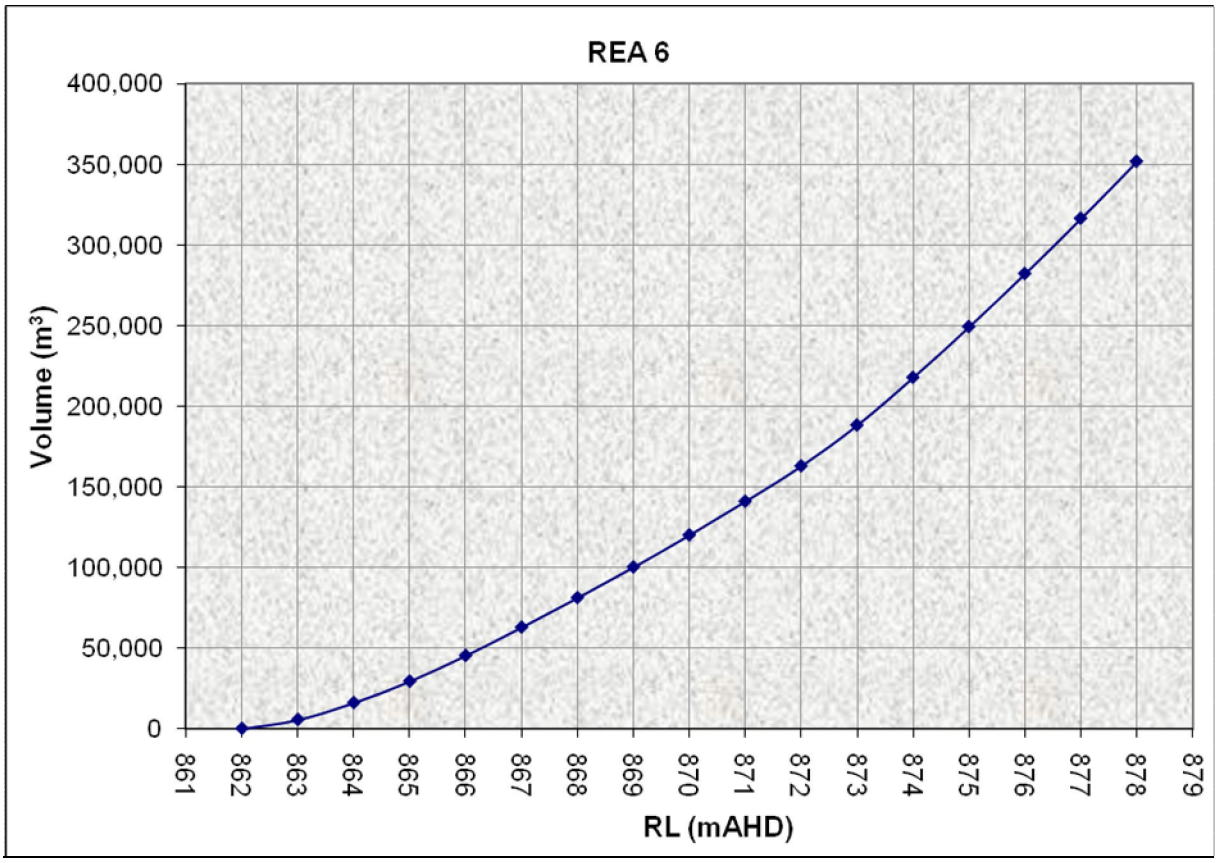


Figure 5 – REA 6, looking South West, showing current deposition level and coarse reject emplacement



Other considerations in determining the storage capacity of each rejects emplacement areas include:

- Allowance for flood events. It is expected that a 1 in 100 year ARI, 72 hour storm event will produce in excess of 200mm of rainfall and that the catchment area is the area of the dam only;
- Allowance for capping in accordance with the mine's tailings management plan; and
- Allowance for free water above the tailings surface at emplacement.

Due to the historical evidence that suggests that Baal Bone Colliery fine rejects freely dewater and the existing dams can be filled to near capacity, minimal allowance of the above has been made in this assessment.

2.3 Future Emplacement Areas

An alternative emplacement area has been identified at the Baal Bone Colliery site for deposition of fine tailings slurry. This area is a remnant open cut void currently referred to as the Southern Void (refer to **Figure 6**). The Southern Void is located north west of REA 6 and, based on recent survey data, has a total volume of approximately 383,000m^3. At the maximum emplacement rate of 114,000m^3/year, the Southern Void can provide tailings storage for approximately 3.3 years, or from about the middle of 2012 to the end of 2015.

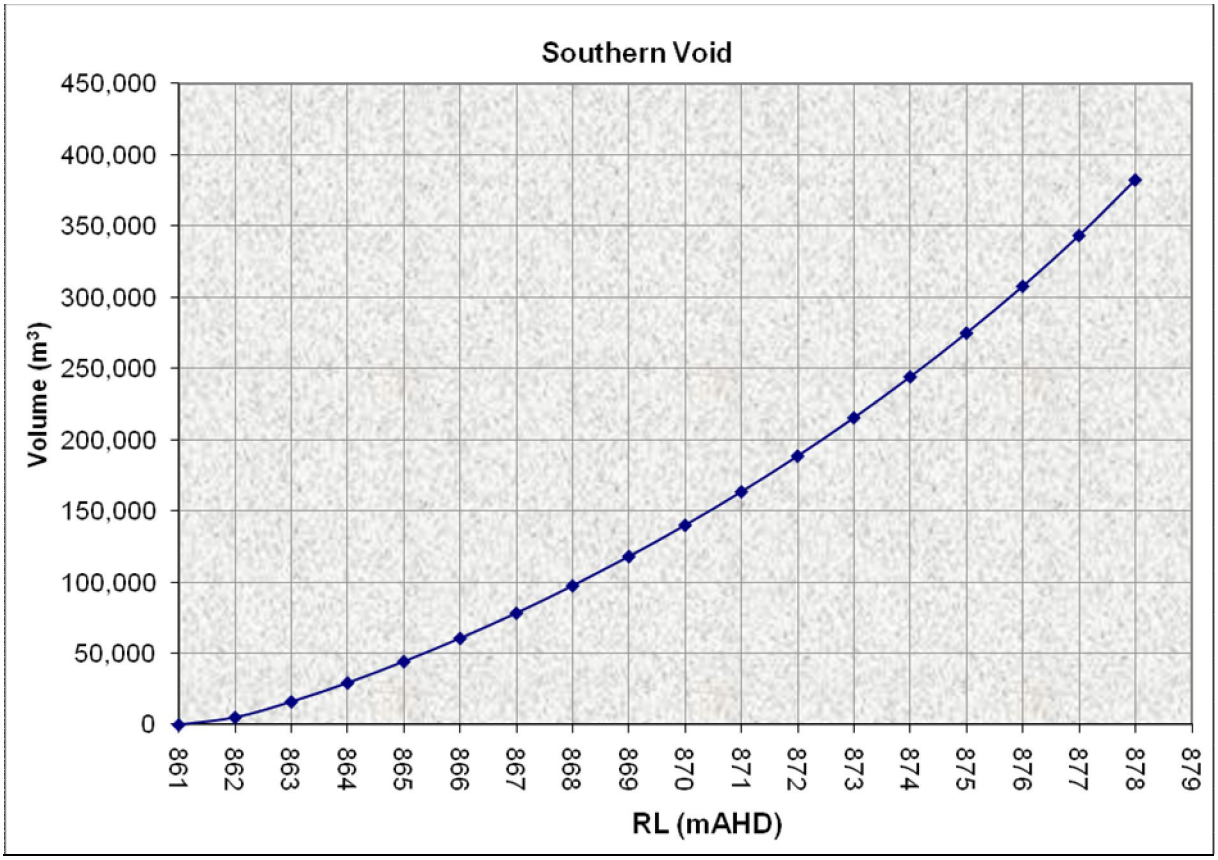
The following graph (**Figure 7**) shows the volume of the Southern Void against RL. The volume of the REA was calculated from the recent survey work (Baal Bone Colliery Rehabilitation Survey, May 2009, drawing number BBREH09, dated 22/5/09) by taking the volume of a slice at each RL and adding them to give a total volume. Survey was provided at 1m contours. The bottom and top of the pit are at 861mRL and 878mRL respectively.

Figure 3 shows the existing rejects emplacement areas in relation to the new proposed emplacement in the Southern Void.

Figure 6 – Southern Void, Looking North West



Figure 7 – Storage Volume versus Elevation (Southern Void)



2.4 Tailings Storage Timeline

The total remaining above ground tailings storage capacity at the Baal Bone Colliery is made up of the remaining volume in REA 6 and the unused open cut pit referred to as the Southern Void (refer Figure 3). The usable volume of REA 6 is 352,000m^3 and the Southern Void is 383,000m^3. Together, at the current emplacement rate, these dams can provide rejects emplacement area until at least the end of 2015.

Table 1 – Tailings Storage Timeline

Rejects Emplacement Area	Volume	Timeline
REA 6 (Cell 1)	352,000 m^3	Present – mid 2011
REA 6 (Cell 2)	102,000 m^3	Mid 2011 – mid 2012
Southern Void	383,000 m^3	Mid 2012 – End 2015

3.0 Conclusion

The Baal Bone Colliery site was investigated for potential rejects emplacement areas with the goal of determining the capacity of existing potential storage areas.

The volume of REA 6 was analysed based on recent survey data and it was found that sufficient capacity remains in it to service the process plant until mid 2012.

A further area, the Southern Void, was also identified as a rejects emplacement area. This was found to have sufficient capacity to service the mine to approximately the end of 2015.

If the mine intends to extend operations beyond 2014, and continues to produce tailings at the current rate, further investigation will be required into future suitable emplacement areas.

References

- Craven Elliston & Hayes (22 May 2009) *Baal Bone Colliery Rehabilitation Survey*, May 2009 (drawing number BBREH09)
- Umwelt (January 2008) *Construction and Operation of Reject Emplacement Area 6 (REA6) at Baal Bone Colliery*
- Umwelt (September 2005) *Construction and Operation of Reject Emplacement Area 5 (REA5) at Baal Bone Colliery*
- Xstrata Tailings Storage Management, HSEC STD 8.1



APPENDIX I

Road Assessment

Wallerawang Collieries Limited

17 December 2009

Baal Bone Colliery

Road Assessment



Baal Bone Colliery

Road Assessment

Prepared for

Wallerawang Collieries Limited

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Quality Information

Document	Baal Bone Colliery
	60104064
Ref	k:\60104064_boral_quarry\8. issued docs\8.1 reports\baal bone colliery_ra_091217.docx
Date	17 December 2009
Prepared by	Erika Garbayo
Reviewed by	Richard Merrett

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	23-Nov-2009	Draft Report	Sara Rollason Principal Consultant	Original signed
B	25-Nov-2009	Draft Report	Sara Rollason Principal Consultant	Original signed
C	17-Dec-2009	Final Report	Sara Rollason Principal Consultant	

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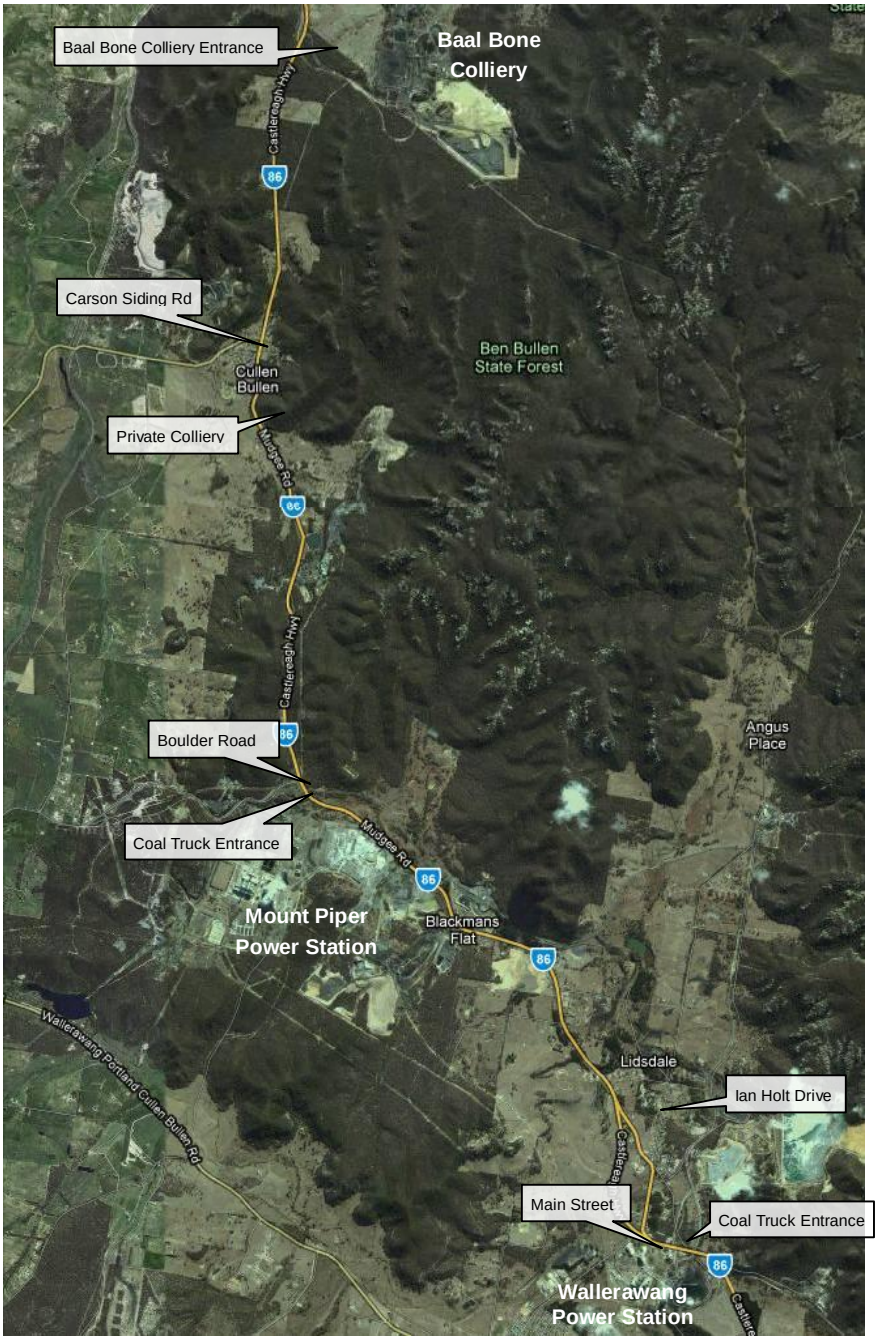
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1.0 Introduction

1.1 Background

AECOM has been commissioned by Wallerawang Collieries Limited to undertake a road safety assessment for continuation of existing coal haulage using the public roads between Baal Bone Colliery and Delta Electricity's Mount Piper and Wallerawang Power Stations. The scope of the assessment is limited to the road corridor from Baal Bone Colliery, south to Mount Piper Station coal receival entrance on Boulder Road and from Baal Bone Colliery to Wallerawang Power Station coal receival entry, located 18.3km south of Baal Bone on Castlereagh Highway. The study area illustrating key features along the corridor is illustrated in **Figure 1**.

Figure 1 Study Area Extent



The Castlereagh Highway (State Route 86) is the currently approved road transport route between Baal Bone and Mount Piper and Wallerawang Power Stations under the terms of the development consent (DA164/98). Road transport of up to 900,000 tonnes per annum of coal via this route is approved until 31 December 2015, subject to detailed reviews of alternative coal haulage options every three years produced by Baal Bone and submitted to the Department of Planning.

In recent years, road transportation of coal has tapered off significantly, operating at 3,000 tonnes per annum in 2008. Whilst coal haulage by road from Baal Bone to Delta Electricity has ceased in recent times, there is the potential for contracts to be renewed in the future, which would result in the resumption of road haulage of coal from Baal Bone up to approved levels.

At the time of inspection minimal volume of coal haulage was observed on the road transport corridor under assessment. The assessment has considered the safety implications associated with an increase in coal haulage to approved levels, under the existing road corridor.

1.2 Scope of Assessment

This report provides an assessment of existing conditions on 16 November 2009. The purpose is to identify potential safety issues under the existing network related to coal haulage between Baal Bone Colliery and Delta Electricity Power Stations: Mount Piper and Wallerawang.

This assessment responds to the Director General's Environmental Assessment Requirement and considers forecast increase in traffic volumes and school bus routes.

Various elements of the road environment such as line marking and delineation, directional signage, road alignment, visibility, speed limits, presence of overtaking lanes and intersection layout have been included in the assessment. The assessment is based on observation only and has been undertaken during day time conditions. The weather was warm, dry and sunny with 100% visibility.

2.0 Existing Conditions

2.1 Site Appraisal

2.1.1 Road Network

Castlereagh Highway is generally a two lane two way arterial road providing connection between the Great Western Highway to the south and the Golden Highway to the north. It services towns including Cullen Bullen and Mudgee, and has strategic importance servicing the transportation of freight and services such as coal between local industries to ports.

Castlereagh Highway is a relatively high speed corridor with reduced speed limits at Cullen Bullen village. It is signposted at 100km/h for the majority of the corridor, with reduced speed limits surrounding the Cullen Bullen village centre and the private colliery immediately south (50km/h and including a 40km/h school zone) and a speed limit of 80km/h from Duncan Street (Brays Lane) to immediately south of the Wallerawang Power Station coal truck entrance.

It is noted that the road corridor alignment includes steep grades such that fully laden trucks can be observed to reduce speed to approximately 30km/h.

Overtaking lanes exist along the corridor, with acceleration and deceleration lanes provided on some access points.

2.1.2 Traffic volumes and road capacity

The roadway capacity of the Castlereagh Highway is estimated to be approximately 8,700 vehicles per day (RTA, 2002), which is based on a conservative assumption of a 15% contribution from heavy vehicles, a desired operational Level of Service C and peak hour flows represent 10% of the daily traffic volumes.

The Annual Average Daily Traffic (AADT) count was obtained from the RTA at the traffic stations located in the vicinity of Baal Bone, and along the transport route. The traffic count locations on the Castlereagh Highway are shown in **Table 1,** including the estimated percentage of traffic generated from Baal Bone, shown in parentheses.

Table 1 AADT Volumes (Axle Pairs)

Station No.	Location	AADT (Percentage from Baal Bone)			
		1996	1999	2002	2005
Castlereagh Highway					
99182	Ben Bullen Rail Crossing	2,039	2,116	2,008	1,959
99254	North of Boulder Road	2,652	3,512	3,028	3,011
99253	South of Boulder Road	3,571	N/A	N/A	N/A
99889	Lidsdale, north of Newnes Road	3,864	4,447	3,526	3,717
Great Western Highway					
99024	Marrangaroo, 0.3 km east of Castlereagh Highway	13,547	14,411	N/A	N/A

Castlereagh Highway traffic volumes are relatively low, with traffic growth rates indicating a decrease in background traffic. Only station 99254 indicates an increase in traffic volumes, between 1996 and 2005 this traffic growth rate (including heavy vehicles) was equivalent to approximately 1.4% per annum.

2.1.3 Walking and Cycling

A cycle lane is provided on the west side of the Castlereagh Highway carriageway, in the hard shoulder south of Main Street. The cycle lane continues south of the Wallerawang Power Station Coal Truck entrance. North of Main Street, the cycle lane is not continuous and irregular shoulder widths would require cyclists to utilise the available traffic lanes.

Reduced speed zones are provided within the Cullen Bullen village centre at 50km/h. A school zone is also provided reducing speeds to 40km/h during school peak periods between 8am to 9.30am and 2.30pm to 4pm.

2.1.4 Public Transport

Public bus services along the route include the Lithgow to Mudgee Coonabarabran and Baradine, operated by Countrylink (two services per day).

Bus shelters were observed within the Cullen Bullen village centre adjacent to the Cullen Bullen Public School. A bus shelter is also provided adjacent to a private colliery entrance towards the south of Blackmans Village.

School bus routes are serviced by Jones Bros and include Route 1015 and Route 1014.

Route 1015 services schools located within Lithgow, originating at Capertee and travelling to Lidsdale on the Castlereagh Highway via Cullen Bullen, Ben Bullen and Blackmans Flat. It collects students from View Street and then turns into Ian Holt Drive through Lidsdale, rejoining the Castlereagh Highway via Wogan Road and continues south to the Great Western Highway.

Route 1014 services schools located within Portland, Capertee and Cullen Bullen. The route travels between Portland and Capertee via Portland Cullen Bullen Road, Carson Siding Road and then north via the Castlereagh Highway.

For both routes, students are collected at property gates and at designated bus shelters within Capertee, Ben Bullen and Cullen Bullen.

School and bus services within the study area would be exposed to issues identified for general traffic.

2.2 Coal Transportation from Baal Bone

2.2.1 Coal Haulage Traffic Generation

Since 1997, Baal Bone has modified its development consent with respect to coal haulage by road. These consents have been modified due to the volume of coal required by the nearby power stations. A summary of the consents for road haulage by Baal Bone is provided in **Table 2**.

Table 2 Summary of Approvals for Road Haulage

Year	Consent	Approval for road haulage up to
1982 – 1992	Original DA	1Mt per annum, up to 30/09/1985
1992 – 1997	Original DA, Modification 31/12/1992	0.15Mt per annum
1997 – 1999	DA 197/97	0.50Mt per annum for domestic markets
1999 – 2000	DA 164/98, 19/08/1999	1.5Mt per annum to Mount Piper and Wallerawang Power Stations Max daily rate of 6000t, up to 30/12/2000
2000 – 2003	DA 164/198, Modification 25/08/2000	0.9Mt per annum to Mount Piper and Wallerawang Power Stations Max daily rate of 6000t, up to 31/12/2003
2003 – 2015	DA 164/98, Modification 23/12/2003	0.9Mt per annum to Mount Piper and Wallerawang Power Stations Max daily rate of 6000t, up to 31/12/2015

The amount of coal transported by road has varied over the years, with contracts between Baal Bone and local power stations the main determinant.

Table 3 provides a summary of recent levels of coal transportation by road from Baal Bone.

Table 3 Road Coal Transportation Summary (2003 to 2008)

Financial Year	Road Haulage (Mt)[1]
2003	0.808
2004	0.482
2005	0.767
2006	0.628
2007	0.044
2008	0.003

1. Includes road haulage to the power stations as well as small haulage contract to other domestic locations

While road transportation of coal currently operates well under approved limits, there is potential for contracts to be renewed in the future and therefore the resumption of road haulage from Baal Bone.

2.2.1.1 Site Access and Transportation Route

The transportation route for road haulage of coal from Baal Bone requires that all trucks travel from the Coal Preparation and Handling Plant, where they are loaded, along the private Colliery access road to the intersection with the Castlereagh Highway. The trucks then turn left (towards the south) and travel along Castlereagh Highway to Boulder Road (for coal deliveries to Mount Piper Power Station, 9.9 km from Baal Bone) or directly to the Wallerawang Power Station coal receival entry (18.3 km from Baal Bone). A minor quantity of coal is periodically transported to other domestic destinations by road beyond the power stations.

There is an acceleration/deceleration lane on the Castlereagh Highway from both approaches at the intersection with the Baal Bone Colliery access road. The Baal Bone Colliery access road comprises a 7.5 m wide sealed pavement with double centre lines.

2.2.1.2 Traffic Composition

The composition of trucks transporting coal from Baal Bone to the local power stations comprises approximately 50% truck and dog, 45% semi trailer and 5% B-double (TWCL[1],2003). These trucks on average carry a load of 25t of coal.

For the approved 0.9Mt road haulage, this would equate to approximately 198 truck movements (including return trips) per day.

2.2.1.3 Hours of Operation

Coal haulage is approved from 7am to 7pm, with coal loading for trucks occurring between 7.30am and 2.45pm and then from 3.30pm to 5.30pm Monday to Friday, in accordance with the Truck Management Plan.

Under the approved 0.9Mt road haulage (approximately 198 truck movements per day) this would equate to approximately one truck movement every 7-8 minutes in each direction during the hours of operation.

[1] The Wallerawang Collieries Limited

2.2.2 Employee Traffic Generation

Baal Bone currently employs approximately 190 full time equivalent staff, including contractors. As Baal Bone is not serviced by a public transport network, it is assumed that all employees would travel to and from work in private vehicles in three shifts per day, Monday to Friday. Typical shift times are detailed in **Table 4** and **Table 5**.

Table 4 Baal Bone Employee Shift Times (weekday)

Shift	Monday to Thursday	Monday to Friday	Total staff per shift
Day Shift	7 am to 4 pm	7 am to 3 pm	85
Afternoon Shift	3 pm to 12 am	3 pm to 11 pm	60
Night Shift	11 pm to 8 am	11 pm to 7 am	50

Table 5 Baal Bone Employee Shift Times (weekend)

Shift	Saturday	Sunday	Total staff per shift
Day Shift	6 am to 6 pm	6 am to 6 pm	< 30
Late Evening Shift	6 pm to Sunday 6 am	6 pm to 11 pm	< 30

Note: These are the typical shift times at Baal Bone, however are subject to change depending on operational requirements.

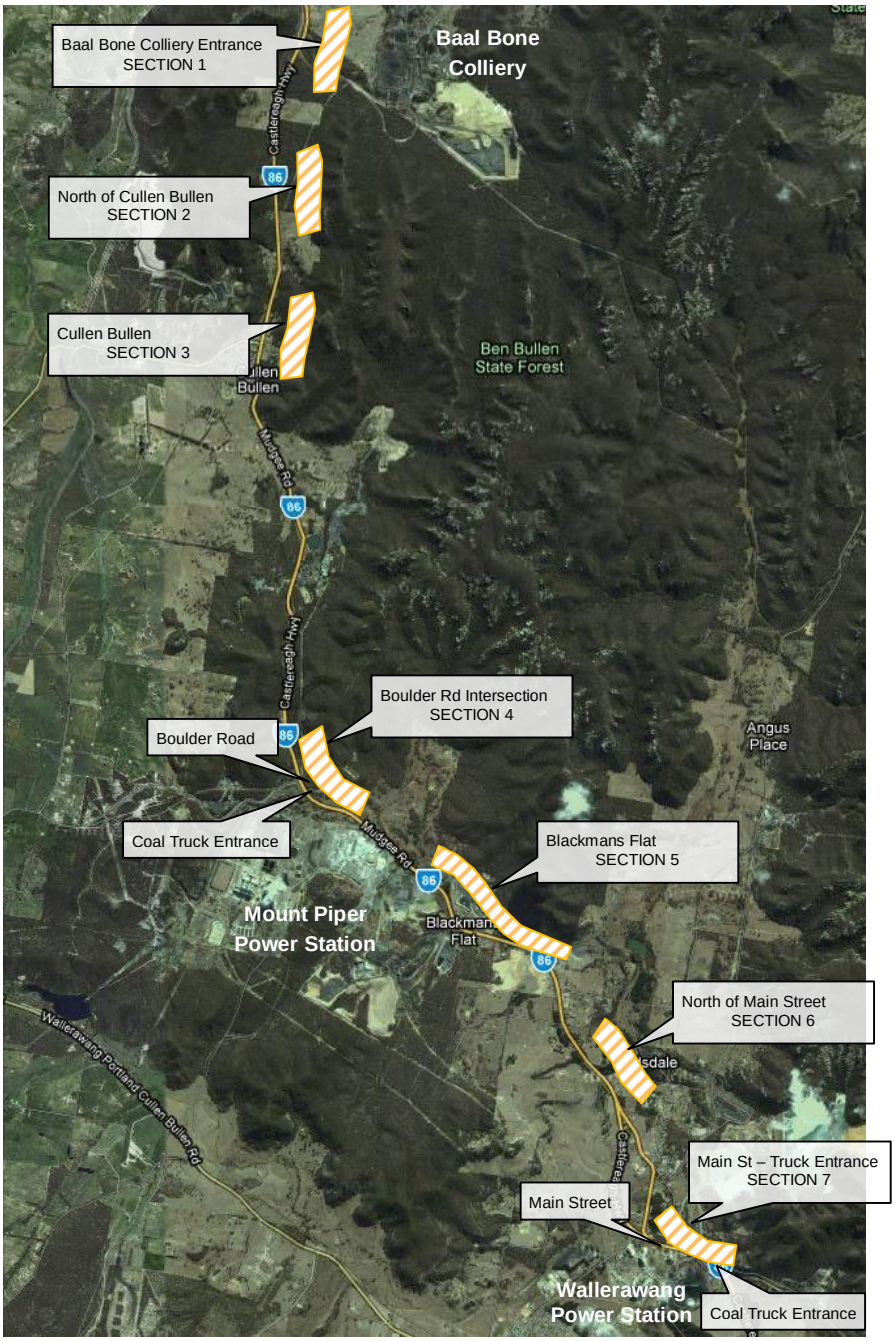
Traffic movements are predominantly generated in the half hour prior to the commencement of a shift and in the half hour following a shift. Therefore it is expected that 135 vehicle movements are currently generated between 6.30 am and 8.30 am, 145 vehicle movements between 2.30 pm and 4.30 pm, and 110 vehicle movements between 10.30 pm and 11.30 pm, Monday to Friday.

3.0 Crash Analysis

3.1 Introduction

An analysis of historical crash rates on Castlereagh Highway near Baal Bone Colliery has been undertaken based on historic crash data provided by NSW Roads and Traffic Authority (RTA) Western Region. Crash data relating to all types of crashes on Castlereagh Highway between Marrangaroo and Ben Bullen was reviewed. The data included crash statistics between 1996 and 2008, and was assessed using GIS. Seven key sections were identified for analysis from review of the available crash data; these are illustrated in **Figure 2**.

Figure 2 Crash Cluster Areas



3.2 RTA Network Measures for Safety

The RTA uses performance measures to enable assessment of current and future performance levels of network corridors.

Performance benchmarks enable the RTA to focus on progressively working toward achieving its network objectives. Benchmarks are calculated for each road 'class' and are defined as the average value for each measure over all roads contained in that class. Castlereagh Highway is classified as class 2R in the rural network hierarchy, which is defined as follows:

Class 2R[2]
(Average Annual Daily Traffic – 1,500[3]*, Heavy Vehicles – 250, Speed Limit – 60km/h – 110km/h)*
Class 2R roads provide inter-regional and intra-regional connectivity and strategic needs of freight. They are typified by low levels of traffic volumes including freight, commercial vehicle and public transport travel. They provide a reasonable standard of travel and serve intra-regional and inter-regional functions. Typically they have undivided carriageways with 2 lanes.

In assessing the safety of rural road networks, casualty crashes per kilometre per year are measured and averaged over a five year period. This is then compared against the average casualty crash rate for that road class. The average casualty crashes per kilometre per year (2001-05) for a class 2R road is 0.16.

3.3 Crash Analysis

Crash analysis on Castlereagh Highway has been undertaken for two five year analysis periods. The first is during between years 1999 and 2003 (Baal Bone road haulage of up to 1.5Mt per annum) and the second 2004 to 2008 (Baal Bone road haulage of 0.003 to maximum of 0.767Mt per annum).

The seven key crash areas assessed are identified in Figure 2, with each section selected according to location of crash clusters and ranging between 1 km and 2km in length. **Table 6** details the average casualty crash rates for the five year periods, before and after 2003.

Table 6 Average casualty crash rates

Section	Length (km)	No. of Casualty Crashes		Average Crash Rates	
		pre 2003	post 2003	pre 2003	post 2003
Baal Bone Colliery Entrance	1	1	0	0.20	0.00
North of Cullen Bullen	1.2	1	0	0.17	0.00
Cullen Bullen	1.5	0	1	0.00	0.13
Boulder Rd / Castlereagh Hwy	1	0	4	0.00	0.80
Blackmans Flat	2	5	2	0.50	0.20
North of Main Street	1	1	2	0.20	0.40
Main Street / Castlereagh Hwy	1	1	1	0.20	0.20

Analysis indicates that all sections experience casualty crash rates comparable to the national average (0.16) for a class 2R road, with the exception of Blackmans Flat where five crashes were recorded during the five year period. It is noted, that a high incidence of crashes has been recorded at the Boulder Road / Castlereagh Highway intersection during reduced operations at Baal Bone. This indicates that this area is prone to collisions, independent of operations Baal Bone. The average casualty crash rate near Boulder Rd / Castlereagh Hwy intersection reaches 0.8 in the post 2003 period.

[2] RTA, Network and Corridor Planning Practice Notes, 2008

[3] While the Network and Corridor Planning Practice Notes identifies the Castlereagh Highway as Class 2R (Figure 3.2), the increased AADT on the corridor indicates that it may also follow characteristics of a road class 3R (with 4,500 AADT). The average casualty crashes per kilometre per year (2001-05) for a class 3R road is 0.37.

From the above statistics, it can be seen that when measuring discrete areas ranging between 1 and 2km, only one crash within a kilometre within a five year period will trigger excess of the class average. Ideally this measure should be assessed on the corridor as a whole. Review of the complete study area, reveals a total of 10 casualty crashes in the five year period 1998 to 2003, and 12 casualty crashes in the five year period 2004-2008. Over a corridor of 19.4km, this equates to average annual casualty crash rates of 0.10 and 0.12 casualty crashes per kilometre per year for the two time periods respectively.

It follows, that along the corridor, the casualty crash rates per kilometre per year is below that of the state average of 0.16 for the 2R road class.

During the five year analysis period under full operation of the Baal Bone Colliery (pre 2003), one crash was recorded at the Colliery entrance. This collision involved a right turning vehicle (sedan) into the colliery, and semi-trailer following in the same northbound lane. No southbound collisions were reported at this location.

A summary of all casualty crash types recorded within the key areas is provided in **Table 7** for information.

Table 7 DCA Crash Codes per section

Section / Type of Crash	Pre 2003	Post 2003
Baal Bone Colliery Entrance	**1**	
Same direction - Rear right	1	
North of Cullen Bullen	**1**	
Left off carriageway into object	1	
Cullen Bullen		**1**
Opposing direction - Right-thru		1
Boulder Rd / Castlereagh Hwy		**4**
Adjacent - Right-thru from right		2
On path - Hit animal		1
Opposing direction - Head on		1
Blackmans Flat	**5**	**2**
Off carriageway right bend	2	
Off left bend into obj	1	1
Off carriageway left bend	1	
Same direction - Rear left		1
Opposing direction - Head on	1	
North of Main Street	**1**	**2**
On path - Hit animal	1	
Opposing direction - Head on		2
Main Street / Castlereagh Hwy	**1**	**1**
Out of control on carriageway	1	
Overtaking - Head on		1

Data analysis indicates a several head-on collisions, and off-carriageway collisions surrounding Blackmans Flat.

Within the Blackmans Flat cluster, the majority of collisions involve class 1 vehicles (car, 4WD, station wagon) comprising 82% of all vehicle units. This trend continues through the corridor. It is noted more casualty crashes, and vehicle units were recorded after 2003. **Table 8** summarises the vehicle units involved in historical crashes within the corridor.

Table 8 Vehicle units involved in study area crashes

Vehicle type	Pre 2003		Post 2003	
	Unit Numbers	Percentage	Unit Numbers	Percentage
Other (cars, 2WD, motorcycle)	8	67%	18	72%
Light truck	1	8%	4	16%
Semi-trailer	2	17%	3	12%
Utility	1	8%	0	0%
Total:	**12**	**100%**	**25**	**100%**

4.0 Risk Classification Methodology

4.1 Risk Assessment System

In carrying out this assessment a similar strategy to the risk identification for Road Safety Audits was followed; the level of importance assigned to identified issues being undertaken in accordance with the RTA Accident Reduction Guide, Part 2: Road Safety Audits (August 2005). The methodology utilised is summarised in the following.

4.2 Crash Frequency

The probable frequency of crash occurrence, resulting for identified safety issues is assessed from the options presented in **Table 9**.

Table 9 Crash Frequency

Frequency	Description
Highly probable	It is likely that a number of these crashes of this type occur within one year.
Occasional	It is likely that one crash of this type could occur within one year.
Improbable	It is likely that one crash of this type could occur every three years

It is recommended that accident statistics be reviewed before considering implementation of any treatments.

4.3 Crash Severity

The severity of the crash resulting from the identified safety issue is rated from the choices presented in **Table 10**.

Table 10 Crash Severity

Severity	Description	Examples
Major	The crash is likely to result in death or serious injuries	High/ medium speed vehicle collision High/ medium speed collision with a fixed object Pedestrian struck at high speed Cyclist hit by car
Moderate	The crash is likely to result in minor injuries or large scale property damage	Some slow speed vehicle collisions Cyclist falls Rear end crashes
Minor	The crash is likely to result in minor property damage or many near miss crash events	Some slow speed collisions Pedestrian walks into object (No head injury) Car reverses into post

4.4 Level of Risk

Deficiencies were then rated for their importance according to a three-tiered system, based on the following matrix, as summarised in **Table 11**.

Table 11 Resultant Level of Importance

Severity	Highly Probable	Occasional	Improbable
Major	High	High	Medium
Moderate	High	Medium	Low
Minor	Medium	Low	Low

4.5 Treatment Approach

Following identification of risk level, treatments are typically recommended according to the result and risk level. **Table 12** summarises treatment approach according to the resultant level of risk as applied during Road Safety Audits. This table is provided for guidance and consideration against the assessment findings only.

Table 12 Treatment Approach

Risk	Treatment
High	Should be corrected or the risk significantly reduced even if the treatment cost is high
Medium	Should be corrected or the risk significantly reduced if the treatment cost is medium but not high
Low	Should be treated or the risk reduced if the treatment cost is low

5.0 Road Assessment Findings

5.1 Introduction

An assessment of the road corridor has been undertaken on the coal haulage routes between Baal Bone Colliery and Delta Electricity Power Stations Mount Piper and Wallerawang. This assessment does not constitute a comprehensive road safety audit, but a general overview of potential safety issues identified throughout the corridor is provided.

Only one issue was found to be specifically related to an increase in road haulage from the Baal Bone Colliery (**Section 5.2**). The remaining findings are associated with pre-existing conditions along the corridor, which may be impacted by an increase in coal haulage traffic. A general overview of the remaining safety issues identified throughout the corridor is provided in **Section 5.3**, followed by specific observations identified at key areas within the study area.

An indicative chainage has been provided against key areas for reference. The key provides an approximate distance from Baal Bone Colliery as measured from Google Earth.

5.2 Baal Bone Colliery

5.2.1 Potential conflict between exiting trucks and high speed vehicles on the Castlereagh Highway

(Baal Bone Colliery Entry, CH 0)

No acceleration lane for southbound trucks exiting the Baal Bone Colliery. This exit is located on an upgrade which would result in increased time for a fully laden truck to accelerate to a 100km/h speed environment. Trucks are required to merge directly into the single lane 100km/h carriageway.

Minimal signage exists at the colliery notifying the presence of entering truck movements. This may contribute to limited driver appreciation on the highway (See **Figure 3**). This may lead to rear end collisions or vehicles running off the road in order to avoid collisions.

Figure 3 Southbound exit from Baal Bone Colliery



Frequency: Occasional
Severity: Major
Level of Risk: High

Note: The access intersection for Baal Bone Colliery allows storage for up to four B-Double vehicles within the northbound right turning bay. Dramatic increase in truck demand entering the colliery may result in vehicles queuing beyond the storage length. This would result in potential rear end collisions with through traffic.

5.3 General Observations through study area

5.3.1 Poor lane discipline associated with deteriorating road conditions

Deteriorating road conditions may lead to poor lane discipline or potential errant vehicles. This is exacerbated by the changing horizontal and vertical alignment throughout the corridor.

Deteriorating road conditions observed throughout the study include: worn line markings and redundant pavement markings. Substandard hard shoulders with irregular widths are also prevalent through the corridor. Skid marks on the carriageway may indicate that drivers have lost control or do not appreciate the road environment, particularly during night time conditions.

Figure 4 Skid marks on carriageway



Figure 5 Castlereagh Hwy / View St (old pavement marking)



5.3.2 Drivers unaware of exiting and decelerating truck movements, leading to potential rear end and intersection type collisions

Access and egress from a number of colliery sites is available throughout the study area.

Limited signage is located along the corridor to warn drivers of trucks decelerating in order to enter the site accesses available. A number of these access points require trucks to undertake 90 manoeuvres requiring slow speeds. With the changing horizontal and vertical alignment of the corridor, and limited appreciation of upcoming access points, drivers may collide with decelerating vehicles.

Similarly, trucks are required to egress from colliery sites and enter the high speed environment of Castlereagh Highway. Slow turning manoeuvres and acceleration time for trucks to the sign posted speed may result in collision with vehicles due to driver appreciation of differential speed and presence of entering trucks.

5.3.3 Debris on the carriageway together with loose chippings on the shoulder

Loose debris on the carriageway presents a hazard to cyclists, motorcyclist and vehicle wind screens, which could cause injury or driver to lose control while travelling on the high speed environment.

Figure 6 Coal debris on carriageway



5.3.4 Risk of errant vehicles colliding with hazards within the clear zone

Telegraph poles within the clear zone present a hazard to vehicles as a hard fixed object. Telegraph poles are located within the clear zone for a high speed environment[4] throughout the corridor.

At Blackmans Flat an unprotected drain is located within the clear zone within the west side of the carriageway.

Informal roadside goods selling was also identified within the carriageway clear zone.

Figure 7 Proximity of Telegraph post to carriageway (facing south)



5.3.5 Risk of drivers accelerating up driveway gradients and protruding into the northbound carriageway, risk of collision with vehicles on Castlereagh Highway

During the site visit, it was noted that there is a significant difference in grade levels with a number of private properties. It follows that if the driveways are constructed so that drivers are required to accelerate uphill to the carriageway without levelling out beforehand, they may overrun into the carriageway and collide with oncoming vehicles.

[4] For a 100km/h speed zone, clear zone range between 9m to 11m dependant on the embankment or cutting slope.

5.3.6 Limited visibility associated with fog

General fog warning signs indicate the presence of fog in the surrounding environment within these areas.

5.3.7 Potential conflict between right turning vehicles entering the garbage tip and northbound vehicles on the Castlereagh Highway

(Garbage Tip, CH 1.8km)

The entry to the garbage tip is located on a crest. Southbound drivers entering the tip are required to right turn from the single lane carriageway with limited appreciation of opposing traffic associated with restricted visibility (See **Figure 8**).

No right turning bay, nor shoulder, is available to assist the turning manoeuvre. There is potential for rear end collisions if drivers brake abruptly due to delayed awareness of opposing traffic stream.

Figure 8 Southbound visibility for right turning vehicles



5.3.8 Potential for errant vehicles to travel off island and overturn, vehicle / pedestrian conflict

(Cullen Bullen CH 4km)

Lack of guard railing and island drop off may result in errant vehicles dropping off the carriageway and into local retail stores. This is potentially severe with the increase in heavy vehicles on the carriageway (**Figure 7**).

Reduced visibility associated with vertical curvature (crest) may contribute to delayed driver reaction to pedestrians or hazards on the carriageway (see **Figure 8**).

The reduced speed environment within the town centre may reduce the likelihood of errant vehicles.

Figure 9 Cullen Bullen Town Centre (north facing)



Figure 10 Cullen Bullen Town Centre (south facing)



5.3.9 Potential for poor lane discipline and limited appreciation of road geometry, leading to rear end collisions or drivers over correcting

(Intersection of Castlereagh Highway / Ian Holt Drive, CH 15.5km)

Drivers travelling southbound along Castlereagh Drive experience a discrete change in horizontal curve alignment adjacent to the intersection of Castlereagh Highway with Ian Holt Drive. The horizontal curve radius may be difficult for drivers to appreciate during adverse weather conditions or during night time (refer to **Figure 9**).

In addition a short overtaking lane is provided to allow vehicles to overtake right turning vehicles into Ian Holt Drive (**Figure 10**). Limited appreciation of decelerating vehicles into the right turning bay may result in rear end collisions at this intersection during night time conditions as no street lighting is provided.

Figure 11 Intersection of Ian Holt Dr / Castlereagh Hwy (dog leg)



Figure 12 Ian Holt Dr / Castlereagh Hwy (north facing)



The intersection of Brays Lane / Castlereagh Highway (CH 17km) also contains a short overtaking bay against a right turning lane (with no lane marking).

Figure 13 Brays Lane / Castlereagh Highway right turning auxiliary lane



5.3.10 Potential rear end collision should right turning queues extend beyond available storage

The assessment has not included analysis of the intersection storage requirements for vehicles entering and exiting Baal Bone Colliery, Mount Piper Power Station and Wallerawang Power Station. Based on historical growth, vehicle volumes on Castlereagh Highway are unlikely to increase. However, it is recommended that queue lengths are monitored if the coal haulage operates at full capacity, with extension of the available short turn bays should vehicles queue beyond the available storage length.

5.4 Cullen Bullen Town Centre

5.4.1 Rear end collisions with protruding vehicles from short right turn bay

(Seagull intersection providing access to the Private Colliery, approximate CH 5km)

The storage capacity of the right turning bay into the private colliery south of Cullen Bullen is equivalent to one vehicle. Should the queue length entering this colliery exceed one vehicle, the resultant queue would protrude into southbound carriageway, potentially causing rear end collisions.

Figure 14 Access to Private Colliery south of Cullen Bullen Town Centre (south facing)



Frequency: Improbable
Severity: Medium
Level of Risk: Low

Note: An acceleration lane is not provided for exiting northbound vehicles. This would require truck movements to merge directly into the northbound through movement, travelling at 50km/h.

5.5 Cullen Bullen Town Centre to Blackmans Flat

5.5.1 Risk of head-on collision with overtaking vehicles in the opposed traffic lane

(Approximately 1km south of the start of 100km/h zone (CH 6.2km)

Overtaking in the opposed carriageway is permitted for a section of Castlereagh Highway with restricted visibility on an upgrade. The changing vertical alignment of Castlereagh Highway contains a series of upgrade and downgrades along the corridor, in some instances the uphill gradient is in the order of 8 per cent.

Southbound fully laden trucks decelerate dramatically in these upgrade conditions, with vehicles reducing to 30km/h in some instances. It follows that the temptation to overtake slow moving vehicles increases as the vehicle continues to decelerate.

Areas on an upgrade with a broken line permitting overtaking introduce a risk of head on collisions with high speed vehicles travelling in the downhill direction on the opposed traffic lane. In the uphill direction, driver appreciation is limited due to restricted visibility associated with an approaching a crest and particularly if the driver is following a large heavy vehicle (**Figure 15**). The driver may also not appreciate the length of the vehicle, and distance required in the opposed traffic lane.

Frequency: Occasional
Severity: Major
Level of Risk: High

Figure 15 Overtaking permitted on upgrade with reduced visibility



5.5.2 Risk of rear end and cross movement collisions as vehicles enter and exit the rest area

(Rest Area, CH 8.3km to 8.7km southbound)

No formal acceleration or deceleration lanes are available for entry to or egress from the rest area. Vehicles approaching the rest area are required to decelerate on the single lane carriageway, which could result in rear end (shunt type) collisions if the following driver does not anticipate this manoeuvre.

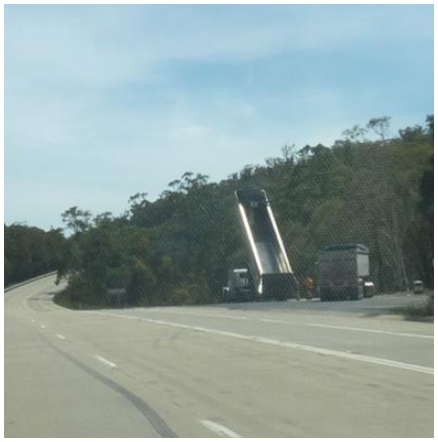
Similarly, vehicles exiting the rest area are required to merge into the 100km/h highway and find gaps within the main traffic stream. This may be an issue for fully laden large vehicles with increased time required to reach the 100km/h speed.

It is noted skid marks observed adjacent to the rest area may indicate drivers having to react quickly to vehicles entering and exiting the rest area.

Figure 16 Rest Stop entry (facing southbound)



Figure 17 Rest Stop exit (facing northbound)



Frequency: Occasional
Severity: Major
Level of Risk: High

5.5.3 Risk of errant vehicles leaving the southbound carriageway

(Southbound approach to the intersection of Boulder Road / Castlereagh Highway, CH 9.5)

There is an approximately 20m gap before wire rope (Brifen) fencing starts after the guard (W-beam) railing ends, located at the top of a crest (**Figure 17**, **Figure 18**). Should an errant vehicle collide with the roped fencing, there would be no protection against drop off.

Figure 18 SB approach to Boulder Road / Castlereagh Highway



Figure 19 Guard rail and wire rope fencing



Frequency: Improbable
Severity: Major
Level of Risk: Medium

5.5.4 Rear end collisions between right turning heavy vehicles and continuing southbound vehicles (Southbound approach to the intersection of Boulder Road / Castlereagh Highway, CH 9.5)

There is no advance signage warning drivers of decelerating trucks and right turning trucks. With trucks slowing down there is a possibility for rear end (shunt type) collisions prior to start of the right turn taper (over taking).

The right turn movement is located at the end of a downgrade movement, heavy vehicles are required to undertake a sharp 90 degree turning manoeuvre (with adverse camber, refer to **Figure 20**) from a high speed environment. During the site inspection, vehicles were observed undertaking the manoeuvre at high speeds and protruding into the kerbside lane.

Figure 20 Southbound visibility from Boulder Road / Castlereagh Highway



Figure 21 Truck undertaking 90 degree right turn



The wire rope fencing on the southbound carriageway has been damaged (refer to **Figure 22**) and indicated a collision has occurred at this location. It is noted that a change is observed in road characteristics once drivers leave Castlereagh Highway and enter deteriorated road conditions on Boulder Road.

Figure 22 Damaged Wire-rope fencing



Frequency: Occasional
Severity: Major
Level of Risk: High

5.5.5 Driver appreciation of degraded road conditions may introduce poor lane discipline or errant vehicles

(Boulder Road to Mount Piper Power Station Entry)

Once drivers leave the high speed carriageway and enter Boulder Road, there may be limited appreciation of the degrade road conditions. Edge line and chevron marking is substandard, with skid markings prevalent on the carriageway.

Figure 23 Mount Piper Power Station Coal Truck Entry



Figure 24 Skid Marking



Frequency: Improbable
Severity: Moderate
Level of Risk: Low

5.6 Blackmans Flat to Wallerawang Power Station

5.6.1 Potential conflict between northbound vehicles on Castlereagh Highway and exiting northbound trucks from Main Street

(Intersection of Castlereagh Highway / Main Street, to Wallerawang Power Station Coal Main Entrance)

Northbound exiting trucks from Main Street are required to merge into the 80km/h main traffic stream on a single lane carriageway, with no acceleration lane provided. This introduces potential rear end conflict due to the differential speed while a truck accelerates to the road speed limit.

In addition, rumble strip treatments within the hard shoulder are worn and are a potential hazard when torn from the carriageway.

Figure 25 Castlereagh Highway / Main Street (south facing)



Frequency: Occasional
Severity: Moderate
Level of Risk: Medium

5.6.2 Risk of vehicle-cycle impact due to conflicting priority

(Intersection of Castlereagh Highway / Wallerawang Power Station Coal Handling Area, CH 18km)

There is a cycleway on the western side of the carriageway to the north and south of the Wallerawang Power Station Coal Handling Area, however no provision for cyclists within the intersection. This potentially creates conflicting priority between vehicles utilising the access and northbound and southbound cyclists on the cycleway.

The level of cyclist activity is understood to be low along Castlereagh Highway.

Frequency: Improbable
Severity: Major
Level of Risk: Medium

5.6.3 Potential conflict between vehicles on Castlereagh Highway and entering and exiting vehicles from Wallerawang

(Intersection of Castlereagh Highway / Wallerawang Power Station Coal Handling Area, CH 18km)

No acceleration lane or deceleration lanes are provided for entry or egress from the Wallerawang Power Station Coal Handling area.

Vehicles entering from the north and south are required to decelerate within the main 80km/h carriageway for entry to the site; this could lead to potential rear end collisions if the driver following is unaware of the decelerating vehicle.

Similarly, heavy trucks exiting the site are required to merge directly into the single lane 80km/h carriageway for both the northbound and southbound directions. Heavy trucks are then required to accelerate to the 80km/h while in the single lane carriageway with surrounding vehicles required to decelerate in order to avoid a collision.

Signage was not available to notify drivers of the entering and exiting truck movements, this may contribute to limited driver appreciation in the event that increased truck movement occur at this access.

Figure 26 Northbound Intersection Approach



Figure 27 Southbound Intersection Approach



Frequency: Occasional
Severity: Major
Level of Risk: High

5.6.4 Poor lane discipline and potential for errant vehicles due to poor delineation and aquaplaning (Intersection of Castlereagh Highway / Wallerawang Power Station Coal Handling Area, CH 18km)

Limited lighting, narrow lanes and deteriorating pavement conditions may contribute to poor lane discipline and potentially conflicting priority. Previous lane marking can be identified (see above **Figure 25**, **Figure 26**), and potentially mistaken as the current intersection layout.

No formal drainage system was identified, with the potential for water build up during raining conditions.

Figure 28 Poor pavement quality



Figure 29 Shoulder



Frequency: Occasional
Severity: Moderate
Level of Risk: Medium

6.0 Summary

A road assessment has been undertaken for the road corridor from Baal Bone Colliery, south to Mount Piper Station coal receival entrance on Boulder Road and from Baal Bone Colliery to Wallerawang Power Station coal receival entry. The purpose of the assessment is to identify potential safety risks associated with transportation of coal from Baal Bone Colliery to the power stations.

School routes identified along the corridor include Routes 1014 and 1015, and would be exposed to issues identified for general traffic.

Issues were identified within the study area, a number of these are independent of the Baal Bone Colliery operations. These issues include accesses to private properties, collieries and the Mount Piper and Wallerawang Power Stations and within Cullen Bullen.

To understand the implication of the increased coal haulage by road, historical crash data was reviewed within study area. The analysis indicated crash cluster areas within the corridor and overall crash rates are below that of the state average for the road class.

Consideration of the crash cluster location and characteristics, together with safety issues identified in Chapter 5, indicates that a decrease in the likelihood of vehicle conflict could be achieved by increasing driver awareness of issues such as:

- the road environment and characteristics;
- trucks exiting and decelerating to enter the colliery;
- required speed reductions; and
- potential for over tipping (adverse camber at sharp corners),

It is anticipated that increased driver awareness could be achieved by installation of for example, increased signage. Monitoring could be undertaken to determine the effectiveness of signage, with review of other mitigation measures as appropriate. Provided appropriate mitigation measures are implemented, the level of impact on road safety generated by resumption of haulage from Baal Bone Colliery is not anticipated to be significant.

The assessment also identified a number of general issues along the corridor such as deteriorating road conditions, hazards within the clear zone, surrounding access and egress points and limited visibility. These issues relate to the road environment as a whole and are not specific to resumption of coal haulage operation from Baal Bone Colliery.



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